

PREDIX

The Industrial Internet Platform



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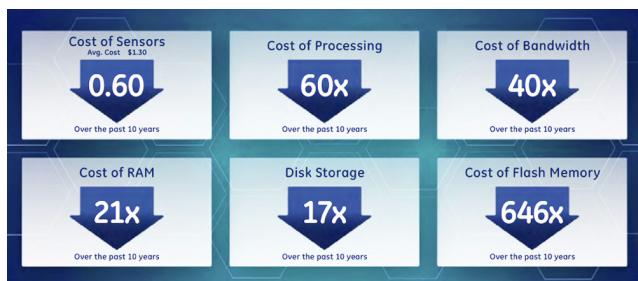
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The Industrial Internet of Things Opportunity

By 2020, over 50 billion assets will connect to the Internet.¹

Companies old and new are transforming themselves to extract value from traditional industrial sectors by delivering digital, data-rich services. By taking advantage of the rapid explosion of sensors, ultra-low cost connectivity, and data storage together with powerful analytics (commonly referred to as IIoT – or the Industrial Internet-of-Things,) these value-added services can produce business outcomes for customers and produce incremental revenue for the company. Indeed, customers are coming to expect not only best-in-class physical products from manufacturers but also new ways that they can drive increased levels of productivity and business impact.



Source: Goldman Sachs Global Investment Research, John C. McCallum Research, TCG Advisors

Challenges

But even the most established and well-run companies often underestimate the challenges in making an important ‘data driven’ transition in technology and business model. This transition will require new capabilities in software development and analytics. It will motivate the adoption—and nurturing—of new types of partners. It will lead

The rapid explosion of sensors, ultra-low cost connectivity, and data storage, together with powerful analytics is transforming services and business models in the industrial sector.

towards new sales models and opportunities. And it will change pricing schemes and approaches.

Ultimately however, most transitions fail because they underestimate the complexity, pervasiveness, and organizational impact of the challenge as well as the technology needed to underpin that shift.

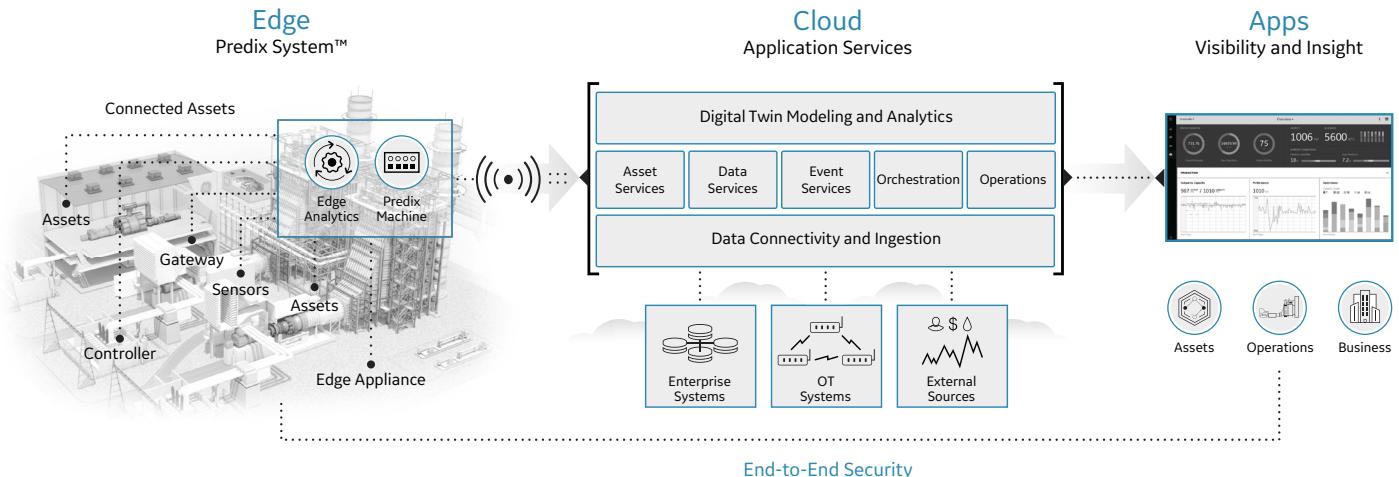
- Industrial data is growing twice as fast as any other sector. Yet today, less than 3% of that data is tagged and used in a meaningful fashion.²
- Datasets can be fragmented and siloed such that they can't be used elsewhere in the business.
- Operational technology (OT) and information technology (IT) systems often operate separately, leading to duplication as the roles these functions play in organizations converge.
- Edge devices are not always connected, may be air-gapped due to privacy/regulatory/security implications, or may need to continue operating when the connection is temporarily unavailable.

1 IDC report: December 2012 - THE DIGITAL UNIVERSE IN 2020: Big Data, Bigger Digital Shadows, and Biggest Growth in the Far East—<https://www.emc.com/collateral/analyst-reports/idc-the-digital-universe-in-2020.pdf>

2 Cisco report: The Internet of Things. How the Next Evolution of the Internet Is Changing Everything—http://www.cisco.com/web/about/ac79/docs/innov/IoT_IBSG_0411FINAL.pdf



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- Applications may need to adapt to local conditions at the edge in real-time and so won't be able to wait for the data to get to the cloud, be analyzed, and be able to send back insights.
- Diverse practices lead to performance variability as many of the best practices are used in some but not all parts of an organization.
- And, even though there are islands of excellence that meet various key performance indicators (KPIs), opportunities may be missed if those KPIs are not standardized across the business.

Consider also how decision makers may be struggling to answer questions such as:

- How do I allocate budgets strategically?
- Is my facility performing optimally?
- Are current security policies putting us at risk?
- How could data at the edge enhance our customer experience?

Tapping into the power of an Industrial Internet platform can help companies get the answers to the questions above that they need. The platform should:

- Be machine-centric
- Support heterogeneous data acquisition, storage, management, integration, and access

- Provide advanced predictive analytics
- Guide personnel with intuitive user experiences on their device of choice
- Be delivered securely in the cloud and at the edge

Predix

That's why GE built Predix – the Industrial Internet platform. By packaging its own capabilities and transformation experience, GE created Predix to guide industrial companies through this complex technology and business transition, putting them in charge of their IIoT journey. By using this comprehensive platform, businesses can create innovative apps on Predix that turn real-time operational data into actionable insights. Predix equips them with everything they need to rapidly build, securely deploy, and effectively operate industrial apps.

GE has the industrial know-how to help companies transform themselves because it has had to transform itself. GE is actively deploying Predix across its own business, IT, and manufacturing operations. GE also offers discrete SaaS solutions in such areas as asset performance management (APM). These solutions are built on Predix and are 'ready to go' so customers can get started today ([See Spotlight APM section](#)) but can also allow them to add their own capabilities to meet future needs.



WHY A SOFTWARE PLATFORM?

A platform offers a standardized way to enable an entire business to quickly take advantage of operational and business innovations. By using a platform that is designed around a reusable building block approach, a business can:

- Build apps quickly
- Leverage work elsewhere
- Reduce sources of error
- Develop and share best practices
- Lower risk of cost and time overruns
- Future-proof their initial investments

Independent third parties can also build apps and services on the platform, allowing businesses to extend their capabilities easily by tapping into the industrial app ecosystem.

WHY IN THE CLOUD?

The cloud model allows businesses to take advantage of key capabilities, including:

- Lower costs based on the economics of a centrally managed and shared infrastructure in a pay-as-you-go subscription model
- Scale to meet different business and application workloads by easily adjusting capacity on-demand
- Generate actionable insights with assets that can be modeled across the business
- Deliver insights from analytics that can be developed and run at all levels of the organization

A common cloud architecture also enables improved system governance, standardized security vulnerability assessments, and release management control and consistency.

WHY AT THE EDGE?

There are various use cases where a cloud-only model is effective and efficient. However, edge and cloud deployment architectures are complementary and can support use cases, including:

- Reduce latency for mission-control for safety-critical features
- Adhere to SLAs and regulatory compliance
- Avoid unnecessary exposure of data
- Offload compute-intensive tasks – such as analytics - from resource-constrained devices

An edge-to-cloud deployment model can help the majority of industrial applications, removing many of the limitations of a cloud-only strategy.

WHY MOVE TODAY?

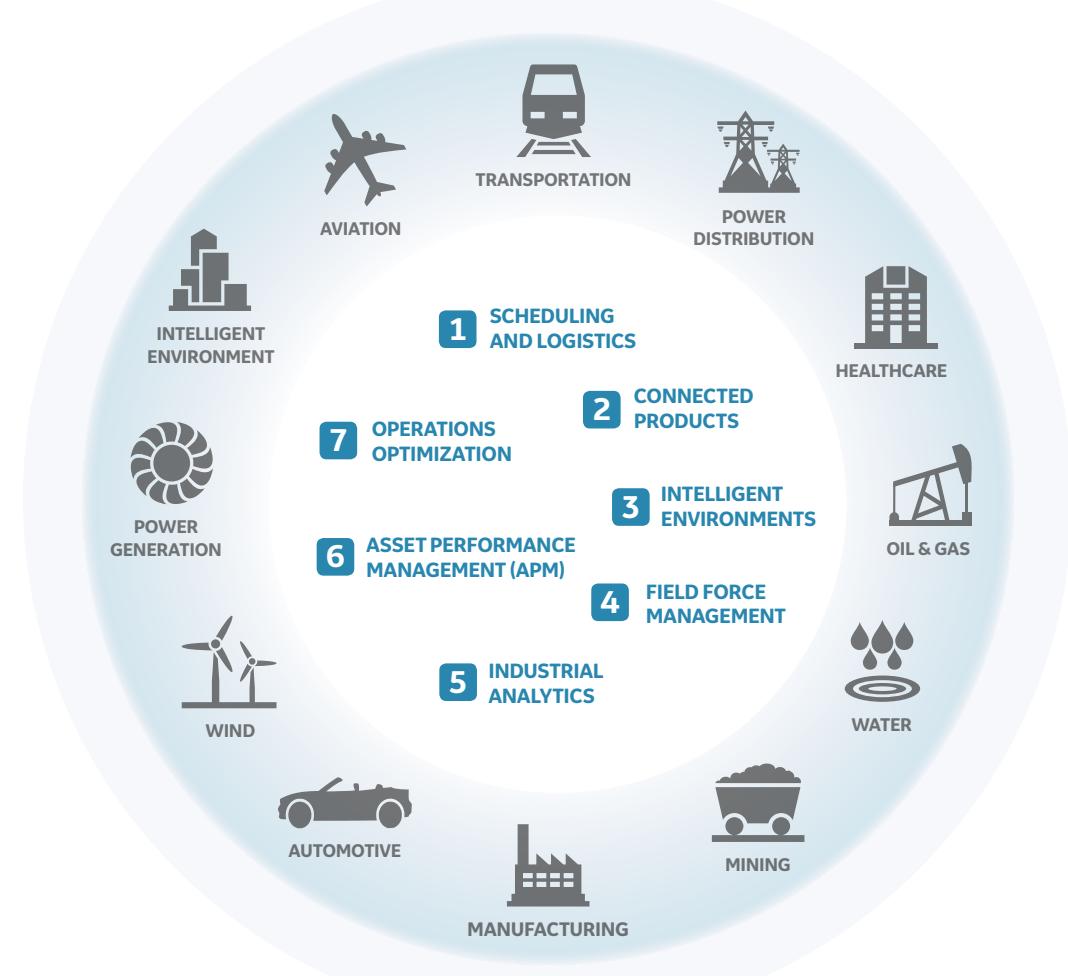
There is no time like the present to decrease unplanned downtime, increase productivity, and minimize missed opportunities. By getting started with an industrial edge-to-cloud platform today, businesses address an immediate need, knowing that an extensible architecture is there to help them grow to meet future requirements.



DELIVERING OUTCOMES THAT MATTER

Predix empowers organizations to develop, deploy, and operate industrial apps at the edge and in the cloud by securely connecting machines, data, and analytics to people. GE has invested in building capabilities that can deliver outcomes across many

different industries. These outcomes range from the reduction of unplanned downtime to improved asset output and operational efficiency. Companies can also create differentiated services that generate new sources of revenue.



1 Scheduling & Logistics

Increase asset utilization with predictive analytics, improving performance, and efficiency that can result in lower repair costs.

2 Connected Products

Replace the current “break-fix” model with a “predict-and-prevent” services approach by making machines software defined.

3 Intelligent Environments

Tap into LED solutions and sensors in cities and buildings to collect and analyze data and enhance everyone’s experience.

4 Field Force Management

Give workers the machine data, expertise, and processes they need to make repairs and upgrades more effective.

5 Industrial Analytics

Monitor asset health to identify problems, then use predictive and prescriptive analytics to boost productivity.

6 Asset Performance Management (APM)

Achieve new levels of performance, reliability, and availability throughout the life cycle of all assets ([See Spotlight](#) section for more on APM).

7 Operations Optimization

Use key insights on an enterprise-wide scale to resolve operational issues, drive productivity, and increase efficiencies.



A Comprehensive, Edge-to-Cloud Platform

Predix is a comprehensive, purpose-built industrial platform that can be deployed from the edge to the cloud. Edge and cloud deployment models are complementary and typical industrial applications need both. However, public clouds do not support the unique and demanding requirements of industry.

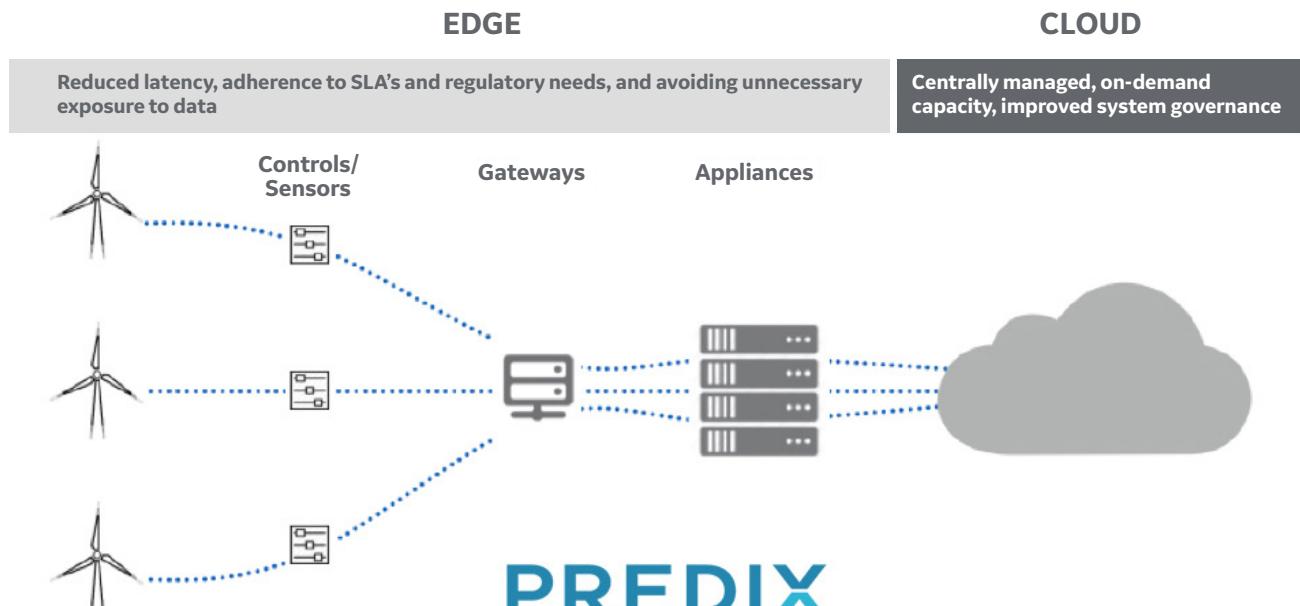
For example:

- Public clouds are developed to support IT data (such as ERP or CRM). Industrial data exists as multi-terabyte structured streams sampled continuously, resulting in unprecedented volumes of data (one plane flight, for example, can generate 1 TB of data).
- Public clouds also do not integrate edge services and intelligence. Instead, customers need to

consider third-party ‘add-ons’ that are not integrated into the platform (and thereby suffer the cost and integration challenges that come with that). Without an integrated edge, data MUST be centralized – which may be impractical from a cost and privacy perspective. Intelligence at the edge also allows the business to meet rigorous performance, efficiency, SLA, and regulatory compliance needs with real-time decision-making that can dramatically affect the way assets behave.

Edge – Distribute and run analytics to maximize outcomes

Predix Edge includes a range of integrated technologies that include; Predix Machine, Predix Connectivity, and Predix EdgeManager.



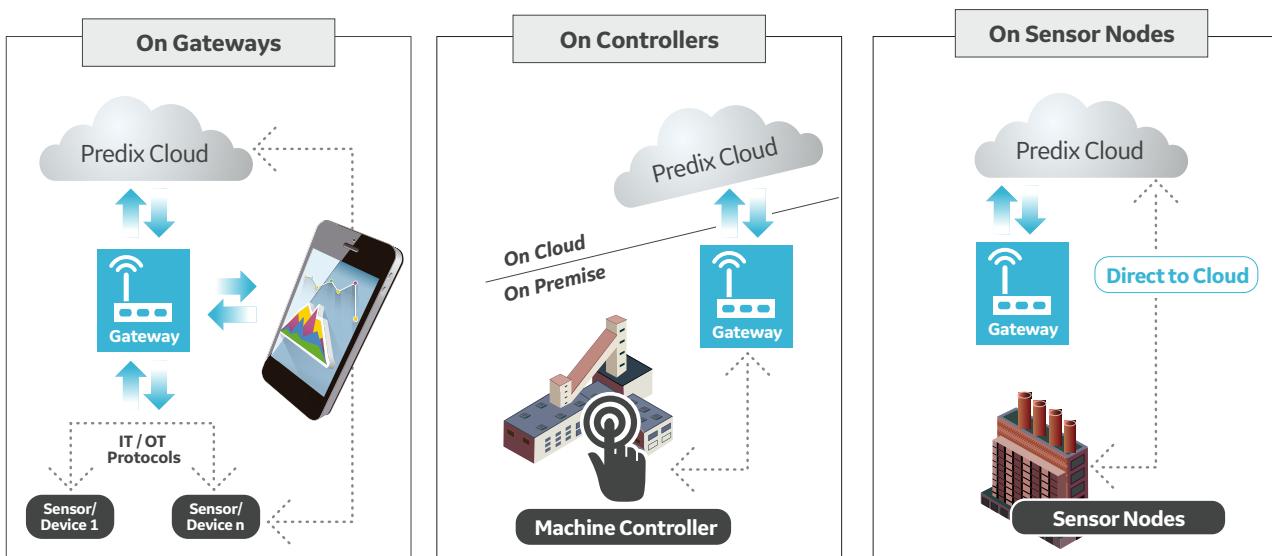
Securely manage devices, data, and app logic from the edge equipment to the plant or field, and all the way to the cloud.



PREDIX MACHINE

GE and non-GE devices use edge-based Predix Machine for device provisioning, management, monitoring, data collection, and edge analysis. Predix Machine is software that provides a standard way to develop and deploy machine apps, and can make a capable device, machine, or equipment a “software-defined machine,” enabling a new generation of social and interoperable products.

Predix Machine runs on a wide variety of hardware platforms from sensors, controllers, gateways, to on-premise appliances. The software also provides security, authentication, and governance services for endpoint devices. This allows security profiles to be audited and managed centrally across devices, ensuring that assets are connected, controlled, and managed in a safe and secure manner, and that critical data is protected. Predix EdgeManager is used to manage the Predix Machine software running on the hardware (see examples below).



The gateway acts as a smart conduit between the cloud and the machines - providing connectivity to assets via a variety of IT or OT protocols.

By using existing controllers, industrial and commercial assets that previously operated stand-alone can be connected to the cloud for data collection and analytics.

Leveraging low-cost intelligent sensors deployed on or near the assets allows data to be transmitted directly or through a gateway to Predix.

In order to support edge analytics, Predix Machine provides advanced edge analytics such as in-motion data analytics, machine learning capabilities with zero-touch application, and analytics deployment at the edge.



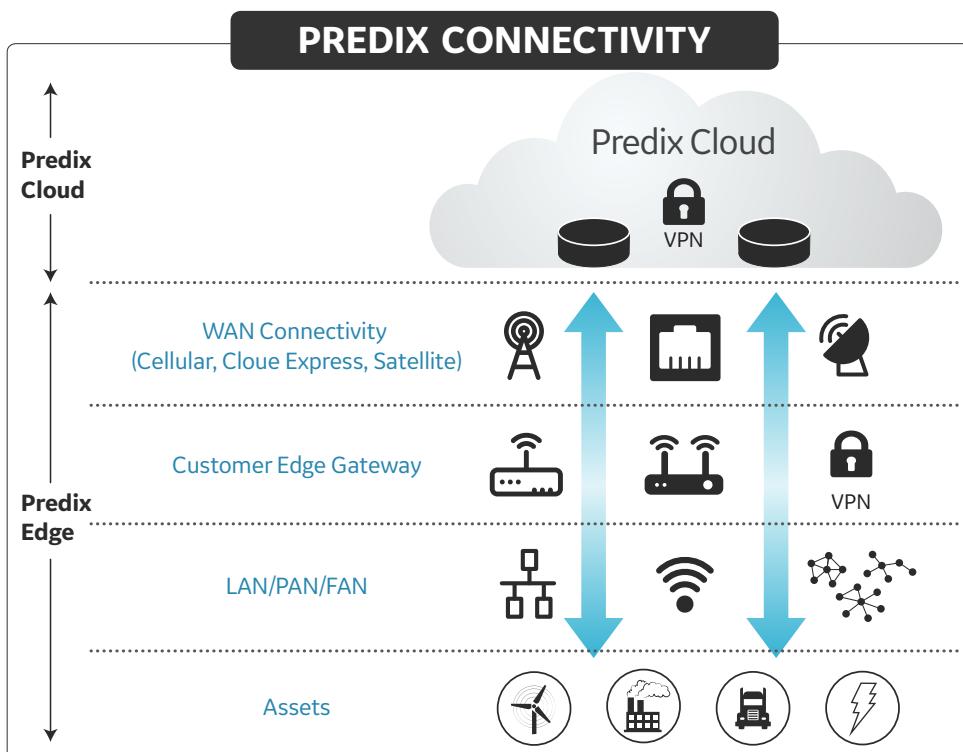
PREDIX CONNECTIVITY

The design and initial deployment of connectivity services can typically take 6-12 months. Predix connectivity services can eliminate the long lead times and expense of designing and operating a custom and sub-optimal connectivity infrastructure.

Predix Connectivity offers seamless, secure, and reliable end-to-end communication between Predix Edge gateway and controller devices and Predix Cloud over various access networks, including fixed line, cellular, and satellite communication. Customers can securely connect existing infrastructure and new deployments to the cloud for data ingestion, analytics, remote device management, and monitoring. Additionally, there is a unified portal that allows for ordering new services, managing existing endpoints, invoicing, and visibility into charges.

Combined with proactive monitoring support, troubleshooting, and automatic alerts, these services deliver a managed, secure, end-to-end connectivity solution from the edge of a customer's network to Predix. These services are available today through several partners and are offered worldwide, providing:

- End-to-end route and flow management between edge and cloud without multiple carrier arrangements
- Protocol-agnostic network configuration and management for M2M (Machine-to-Machine) and M2C (Machine-to-Cloud) connectivity
- Centrally managed policies driving QoS and bandwidth optimization
- Policy-driven data forwarding between multiple cloud and on-premises destinations
- Physical connectivity globally via cellular, fixed or satellite networks through partnerships with communication service providers
- Secure virtual private network (VPN) between the edge and cloud, ensuring data privacy and asset protection
- Ability to manage and control the edge assets by providing remote access via VNC, RDP, SSH, and HTTP
- End-to-end monitoring and notifications about the connectivity between Predix cloud and edge assets
- One-stop-shop billing and reporting for all connectivity and IP services
- Zero touch provisioning with a self-management portal

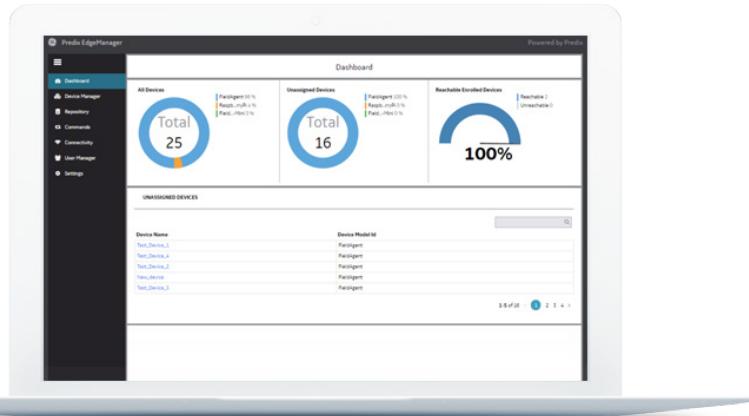


A truly global industrial platform needs to consume and analyze massive volumes of data by connecting to a wide variety of machines, sensors, control systems, data sources, and devices.



PREDIX EDGE MANAGER

Predix EdgeManager provides a comprehensive and centralized view of edge devices that are running Predix Machine. It significantly eases the management, configuration, and administration of edge devices (such as controllers and gateways), apps, and users. Administrators can quickly determine device condition and connectivity health - in addition to managing apps and configuration files - both at a device and fleet level. Devices can be auto-enrolled and decommissioned, technicians can connect and execute commands, and configuration files can be scheduled for deployment.



Cloud—Run industrial workloads in a managed, gated community

As a leader in the industrial world, GE built an edge-to-cloud platform purpose-built to meet the needs of industrial companies that require scale, security, and regulatory compliance. Predix can handle vast amounts of Industrial Internet information, while also managing customer SLAs, security, support, governance, compliance, and export controls.

GATED INDUSTRIAL COMMUNITY

Predix is based on a multi-tenant “gated community” model to ensure that tenants belong to the industrial ecosystem. This reduces the risk of bad actors entering the community, and enables GE to account for stringent regulatory requirements in ways that IT-focused public clouds cannot. Support for various data governance, federation, and privacy needs are included, as well as stringent security requirements, such as perimeter security, data security, access control, and data visibility.

BUILT ON CLOUD FOUNDRY

Predix is built on Pivotal’s Cloud Foundry, an open source Platform-as-a-Service (PaaS). By using Cloud Foundry’s unique microservices architecture, its support for existing languages and programming tools, together with its modern development and operations (DevOps) environment, app developers can quickly build, test, deploy, and—most importantly—scale applications in hours or days instead of weeks or months. Developers also gain access to the Cloud Foundry ecosystem and an ever-growing library of services that are continually being contributed by industry.

GE MANAGED POINTS-OF-PRESENCE

GE will make Predix available to customers in the Americas, Europe, Africa, Middle East, and Asia. These Points-of-Presence (PoPs) are to be selected based on provider diversity, network peering, technology capabilities, regional data privacy considerations, customer needs, and security considerations. All locations will be ISO27002/01, SSAE16 SOC 2 compliant and operate at either Tier III (Concurrently Maintainable) or Tier IV (Fault Tolerance) levels, based on the Uptime Institute Standards.

CAPACITY ON-DEMAND

Predix uses software-defined infrastructure (SDI) as an abstraction layer above the hardware, allowing services to evolve over time, with minimal disruption to the applications. This SDI is especially useful when an application dictates that a change to the underlying hardware configuration is needed to ensure that demand is met. 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.

ENHANCED SECURITY CONTROLS

Security is embedded at every level of the cloud stack. This specialized approach offers industrial-grade security, as every layer is monitored and scanned for vulnerabilities. Capabilities include encryption, key management, incident response services, logging, network-level security, support for end-to-end chain of custody reporting for code and data, and 24x7 security and network operations centers. [See Appendix A](#) for additional infrastructure security details.



Essential Industrial Services That Support The Unique Needs of Industry

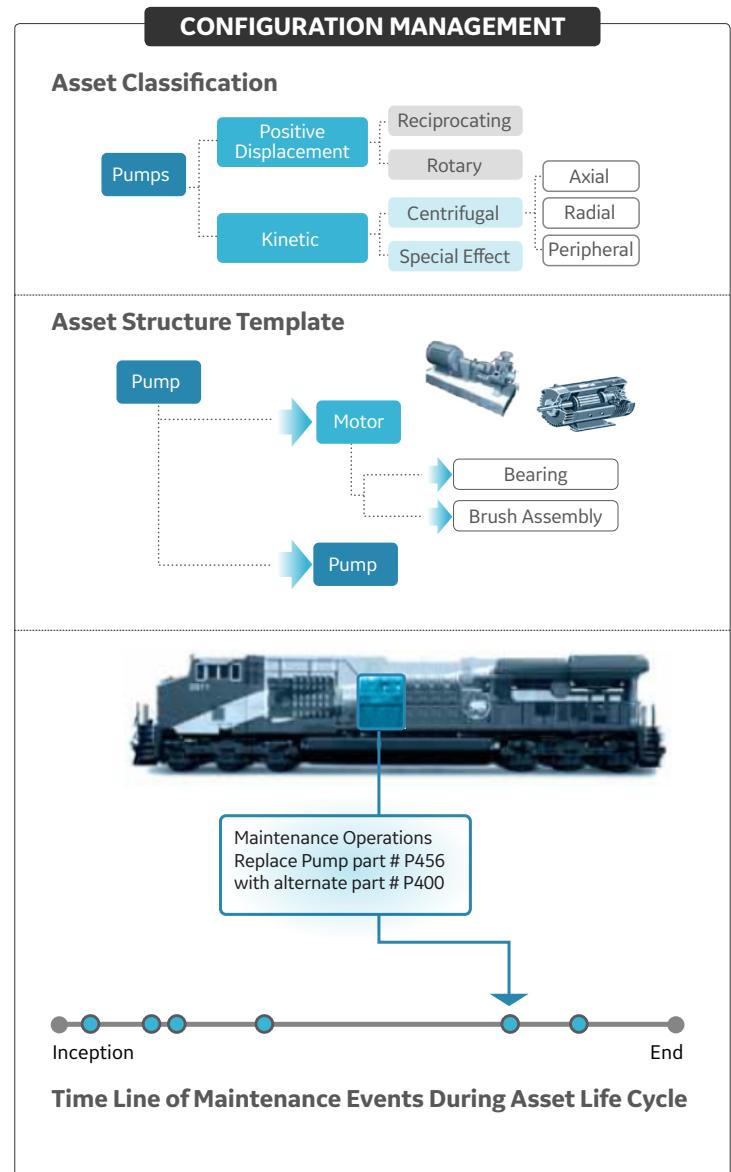
A truly global industrial platform needs to consume and analyze massive volumes of data by connecting to a wide variety of machines, sensors, control systems, data sources, and devices. Predix can securely connect with machines—old and new, GE and non-GE. Once connected, data is captured, stored, analyzed, and made available to the right people at the right time to enable the right decisions.

Modeling assets

Asset models are central to Predix. It is how data can be organized to understand context and to perform further analysis. [See the APM Spotlight section for how an asset model improves asset performance.](#)

The Predix asset service enables developers to create, store, and manage asset models that define asset properties, as well as hierarchical and network relationships (parent, child, peer, etc.) between assets and other modeling elements. Asset models are useful as they are the digital representation of its structure. Asset models typically employ common elements. For example, classifications support different ways to identify and search for assets, which can provide a richer view of the asset lifecycle within the business and who needs access. Templates can be used to create the structures that define the components that make up a complex asset. The Predix asset model is extensible, which allows developers to create custom modeling objects that meet their own unique domain needs—for example, to support non-GE assets.

To understand how this works, take a configuration management example. An application developer can create an asset model that describes the logical component structure of all locomotives in a fleet, and then create instances of that model to represent each individual locomotive. As a locomotive's

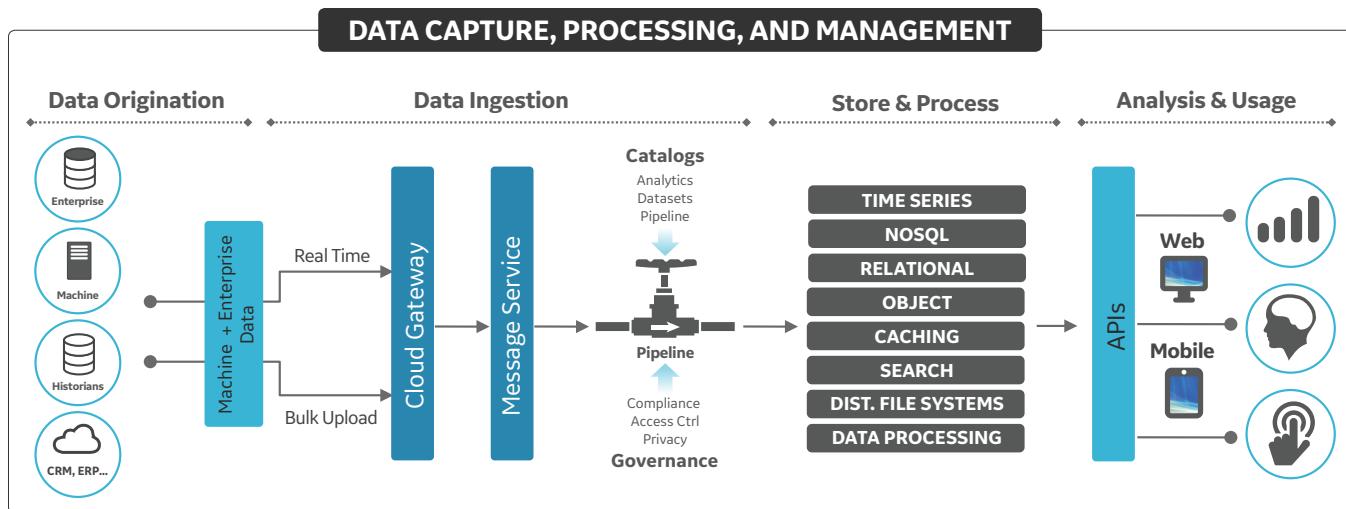


configuration changes over its lifespan, the changes are recorded in the system (for example, where the pumps are manufactured or who the suppliers are). This history then allows for a snapshot of that locomotive's state (operating, retired, etc.) at a particular date and time. It also allows for displaying timelines of change events that have occurred to the asset over its lifespan.



Data capture, processing, and management

Predix data services provide rapid access to data and timely analytics while minimizing storage and compute costs. It offers a secure, multi-tenancy model that includes network-level data isolation and encrypted key-management capabilities. It also supports the ability to plug in analytic engines and languages to interact and process the data. There are four key components:



- Connection to the source:** Connections are established with GE and non-GE machine sensors, controllers, gateways, enterprise databases, and historians.
- Data ingestion:** Data is ingested from the source in real time, and bulk upload tools allow the user to identify specific sources and to create default data flows for all data sets and data types, including unstructured, semi-structured, and structured. These tools speed the design, testing, and generation of code, making it easier to manage and monitor simple, onetime projects to complex, ongoing data synchronization projects.
- Pipeline processing:** The ingestion pipeline can efficiently ingest massive amounts of data from millions of assets. However, data can be messy, arrive in different formats, and come from multiple sources, all of which make running predictive analytics difficult. Pipeline processing allows the data to be converted to the correct format so that predictive analysis and data modeling can be done in real time. The pipeline policy framework provides governance and cataloging services, allowing users

to perform data cleansing, increase data quality, data enrichment (for example, merging with location or weather data), data tagging, and real-time data processing.

- Data management:** Data needs to be stored in the appropriate data store, whether it be time series for machine sensor data, Binary Large Object (BLOB) (for example, MRI images), or an RDBMS. This allows use of the data for both operational and analytical purposes. It also provides data blending capabilities, where users can deploy tools to extract value from these data sources to find patterns and process complex events (i.e. look for a combination of certain types of events to create a higher level business event).

Turning insights into outcomes with analytics

Predix offers a scalable, reusable framework for industrial analytics. This enables a business to be more data driven—analyzing data using targeted analyses that create insights leading to better business outcomes. Analytic services abstract the intellectual property of a business's advanced analyses to reusable components that can be



cataloged, shared, and reused across different business solutions, saving time and extending the investment elsewhere. Deploying analytics in the cloud — and at the edge — also ensures that analytics are distributed across the business to increase effectiveness of the proximity.

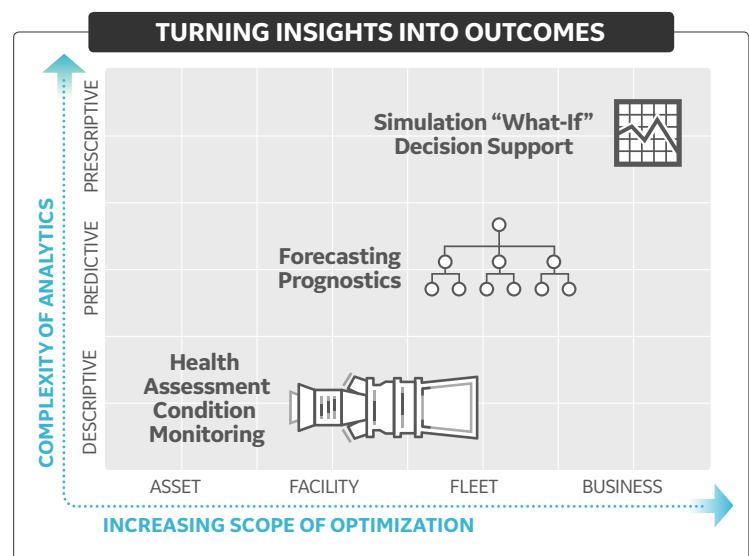
Operational analytics at the edge ensure the efficient operation of assets, but those analytics can be improved over time based on historical analysis.

Predix supports two types of data analyses: operational and historical.

- **Operational analytics:** Data is analyzed in real time at the edge — an aircraft engine, wind turbine, MRI machine, etc. — to detect problems so that split-second changes can be made in the operation of the asset to prevent damage or to optimize performance.
- **Historical analytics:** This is the collection and analysis of petabytes of historical operational data. From this analysis, it is possible to build a large-scale predictive model that can be used to more efficiently operate entire manufacturing plants or fleets of equipment.

Predix analytics enable a feedback loop between operational and historical analytics. Operational analytics at the edge ensure the efficient operation of assets, but those analytics can be improved over time based on historical analysis. Data scientists are able to publish analytics using programming languages Python, Java, and Matlab.

Predix also offers descriptive, predictive, and prescriptive analytics, providing a comprehensive approach to uncovering relationships in data. Each group of analytics has its own use, and can be used in sequence. However, companies can start small by identifying a workable problem, and use descriptive analytics as even small insights can generate big outcomes.



- **Descriptive analytics:** help determine what happened and why. Descriptive analytics summarize data to gain insights from the past and determine how the past might influence the future. For example, an airline might assess the health of an engine over six months to determine if preventative maintenance is required.
- **Predictive analytics:** help determine what might happen next by forecasting based on a model. For example, an oil company might look at how specific oil wells can be combined to increase the overall production of the entire field.
- **Prescriptive analytics:** help improve the decision-making process. Prescriptive analytics determine possible actions towards a solution that has the largest impact on a company's bottom line. For example, hospitals might look at what new opportunities exist to maximize physician throughput based on the mix of physicians, technicians, and operating rooms.

Predix also offers descriptive, predictive, and prescriptive analytics, providing a comprehensive approach to uncovering relationships in data.



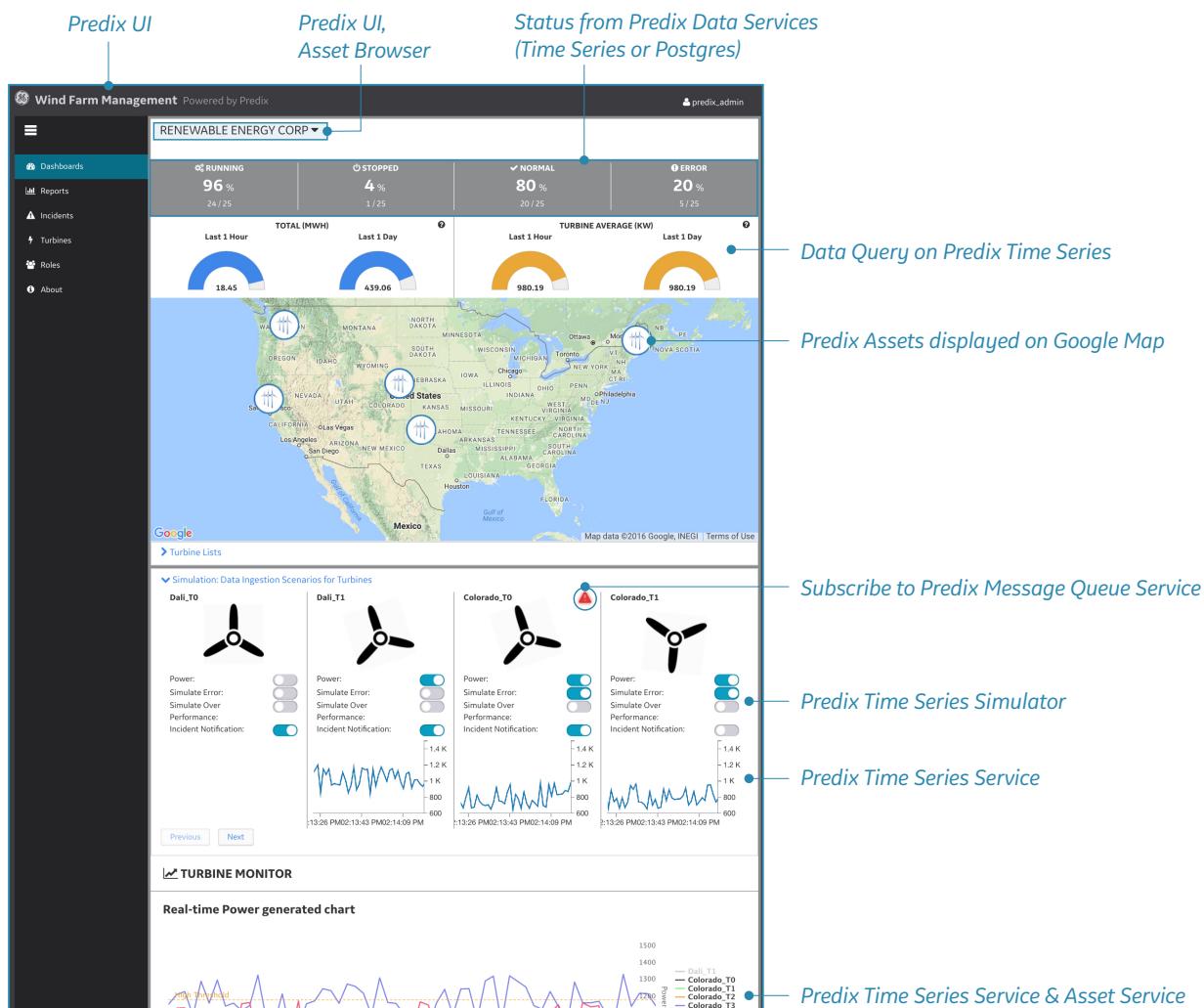
Building contextually relevant user experiences

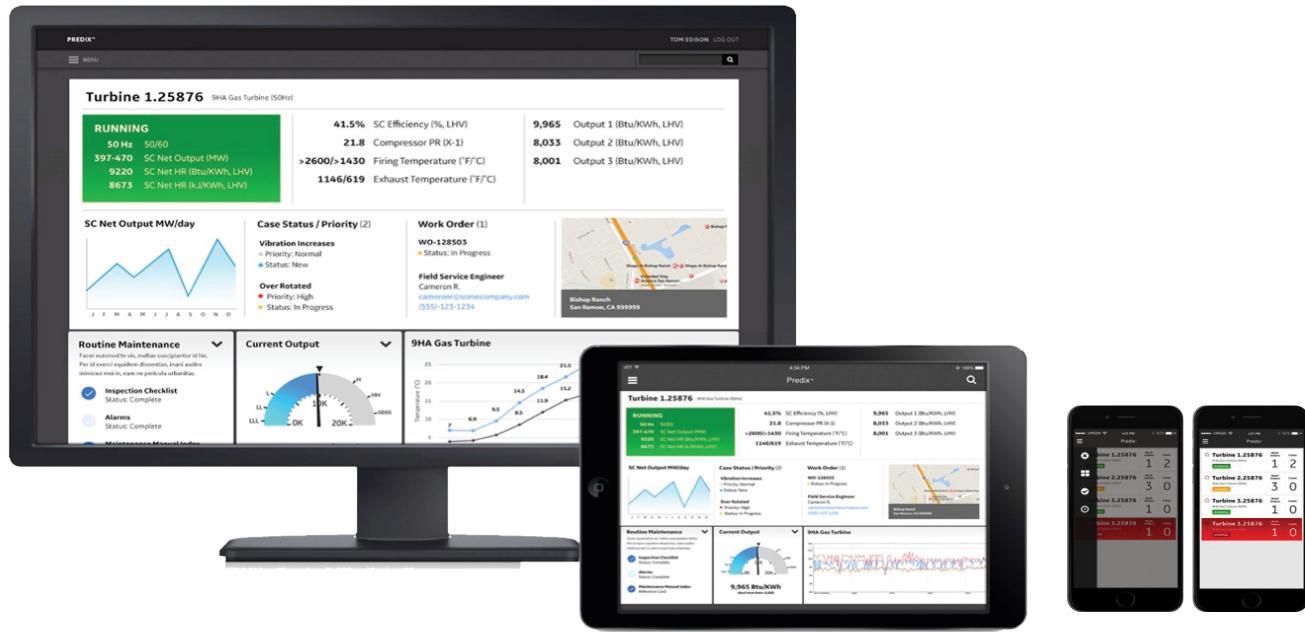
Predix supports the building of responsive web, mobile, and embedded applications that scale gracefully from smart phone to desktop. The Predix user experience (UX) system provides developers and designers with simple, modular, and cohesive solutions for theming, layout, and UI components with tailored integration points into the rest of the Predix platform stack.

Internationalization, localization, and compliance are taken care of within the system. Applications are not only context-aware, but also context-adaptive—meaning they will change according to the context - so users can visualize and interact with the application in a way that is relevant to them. This paradigm removes the need for multiple applications and context switching by users.

The result? Mobile staff, field operators, plant managers, business analysts, and data scientists can visualize data in the right context, build their own data models, answer key questions, and deliver on business outcomes.

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Mobility for always-on

Industrial mobile applications can suffer from connection issues based on geographical location or connectivity limitations. However, the user experience should continue to be seamless and consistent irrespective of the challenges and the device used.

Predix simplifies building of always-on mobile industrial applications. Predix Mobility provides an software developer kit (SDK) and a rich set of cross-platform responsive components that provide a consistent look and feel and work across multiple mobile devices, laptops, desktops, and browsers. Developers can build mobile apps rapidly by using a common approach for both front-end devices and back-end services that connect with other Predix

services – such as Predix Machine – as well as with other enterprise systems. This will allow developers to synchronize data between mobile devices and enterprise data domains.

Predix Mobility is a flexible and layered component system, with extensible services that support advanced application behaviors, including remote workflow and analytics. Designed to work everywhere, the responsive design includes web components for online scenarios, in addition to supporting a native experience using native controls with off-line capabilities for optimal performance. Predix Mobile applications also support a web view, giving the developer the ability to create truly cross-platform applications that will work on a small phone or a large-screen web browser.



Geospatial intelligence for enhanced insights

With geospatial intelligence, companies have a deeper understanding of the context behind asset performance, which can be critical in areas such as field-service, transportation logistics, supply chain inventory management, and risk management.

Predix location and mapping services provides precise, location-based information, unlocking deeper insights from any data set and any asset that has a location. Based on an address or a latitude and longitude data pair, everything from the local time to extensive location demographics can be discovered. By combining geospatial with Predix asset and analytics services, businesses can gain a deeper understanding of the context behind asset performance by locating the asset, which can lead to a reduction in downtime, a more accurate estimation of resolution time, and the ability to assess impact based on weather conditions.

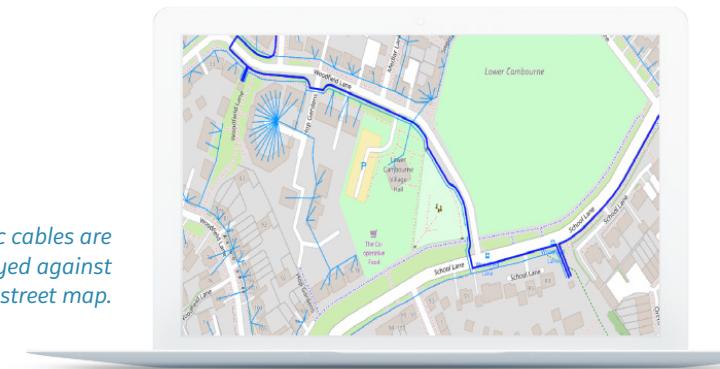
Additional services:

- Use enhanced location data for more than 120 countries
 - Add lifestyle and demographic insights to your local search
 - Integrate administrative call-routing information into 911 processes and workflows
 - Incorporate local tax rates into your billing, commerce, payments and payroll applications, processes, or workflows.

Brownfield integration

To take advantage of the Industrial Internet, integration with existing—and future—equipment, data and analytics are critical, especially in brownfield sites. Predix achieves this at a number of levels:

- **Machines:** Connect machines of any vendor or vintage. Predix machine supports a number of protocols, including OPC-UA, DDS, and MODBUS, as well as TCP-based sockets communication.
 - **Data:** Use connectors are included for time series, location, ERP, and CRM systems. Custom connectors can also be built to incorporate proprietary data schemas.
 - **Programming languages/tools:** Support is provided for Java, Node.js, Python, Artifactory, GitHub, JaCoCo, and Ruby on Rails.
 - **Analytics:** Support is provided for Java, Matlab, and Python.
 - **Mobile devices:** Support for HTML5, existing desktop browsers, smartphones, and tablets can be used across the business.



Developing Smarter to Innovate Faster

Building Industrial Internet apps comes with some unique requirements and needs that separate them from traditional IT apps. Typically developers can spend up to 80% of their time integrating and upgrading systems and technologies, versus only 20% of time spent on innovation⁴. GE has years of experience building software apps for industry, and the design of Predix incorporates those learnings with tools and services that decrease the amount of time spent on integration. Development teams are relieved from time-consuming integration tasks, such as building software server stacks, integrating and configuring products, systems and ‘things’, managing SLAs (service level agreements), and scaling and securing infrastructure.



Microservices as building blocks

Predix microservices are reusable software modules that can be leveraged as building blocks to rapidly create applications. Because they are developed and delivered as discrete services, these microservices can be loosely coupled into apps without the complexity and dependencies of traditional, monolithic app

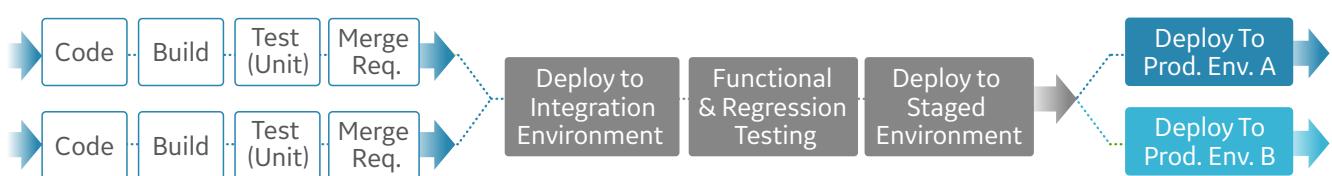
architectures. Additionally, because microservices can be developed as separate, stand-alone components, developers can use their favorite language and tools.

The microservices architecture provides a level of isolation, enabling small teams of developers to deliver new capabilities and to version existing services, such as Connectivity, Asset, Field Agent, and Time Series, incrementally. Microservices are also great enablers for continuous delivery, allowing frequent releases for users while keeping the rest of the system available and stable. Additionally, they are easy to maintain, so once solutions are deployed, updates are much simpler and more efficient, eliminating code recompilation and streamlining operations.

Continuous development using DevOps

Predix supports a set of development and operations (DevOps) tools that provide tight integration between functions that have traditionally been siloed, including development, quality assurance, and IT, enabling a more integrated and iterative environment from build to release to deployment operations. By tightly integrating these functions in a single environment, teams shorten their development cycles significantly and make the agile vision of incorporating frequent user feedback simple.

DevOps provides the software environment to make agile a reality. It also enables continuous development, where a new module or feature set can be automatically rolled into production as soon as it is completed. This results in building new capabilities faster and at a lower cost.



⁴ GE Sponsored report - The State of Industrial Internet Application Development – January 2016: <http://predix-io-assets.s3.amazonaws.com/2016%20State%20of%20Industrial%20Internet%20Application%20Development.pdf>



DevOps features supported include:

- Agile planning through the Track & Plan service
- Source control management (SCM) through GitHub service
- Automated build and deploy with the Delivery Pipeline service
- Load testing tools

Operating an applications business

Building applications is one thing; ensuring that they are actually being used and can be profited from (when desired in the future) is another. For any successful application strategy, placing the user at the center of that strategy is critical. Predix offers a rich development environment that allows developers to rapidly build, test, and deploy applications. Together with its user experience (UX) framework, Predix also helps users visualize data in a way that is contextually relevant and useful to them no matter the device they use. It also helps answer the nagging questions related to application commercialization such as:

- What is an application's adoption rate?
- How are users using it?
- What features or services are not being used and why?
- And, based on those factors, what is the best subscription strategy?

The Predix Business Operations service enables a data-driven decision-making process for businesses wishing to maximize their application efforts and speed time to usage or market.

UNDERSTANDING USAGE FOR DEVELOPERS

Business Operations service helps an organization roll out applications across different parts of its business. By placing the user at the center of every business operation, development teams can iteratively build, split-test, and launch components of their apps across different users. Now they have complete visibility into how each component is used, identifying the best and worst performing products, packages, user groups, and distribution channels. This offers invaluable insights for developers, as they can uncover the real impact of the way they package their application to drive long-term user engagement.

BUILDING A SUBSCRIPTION BUSINESS

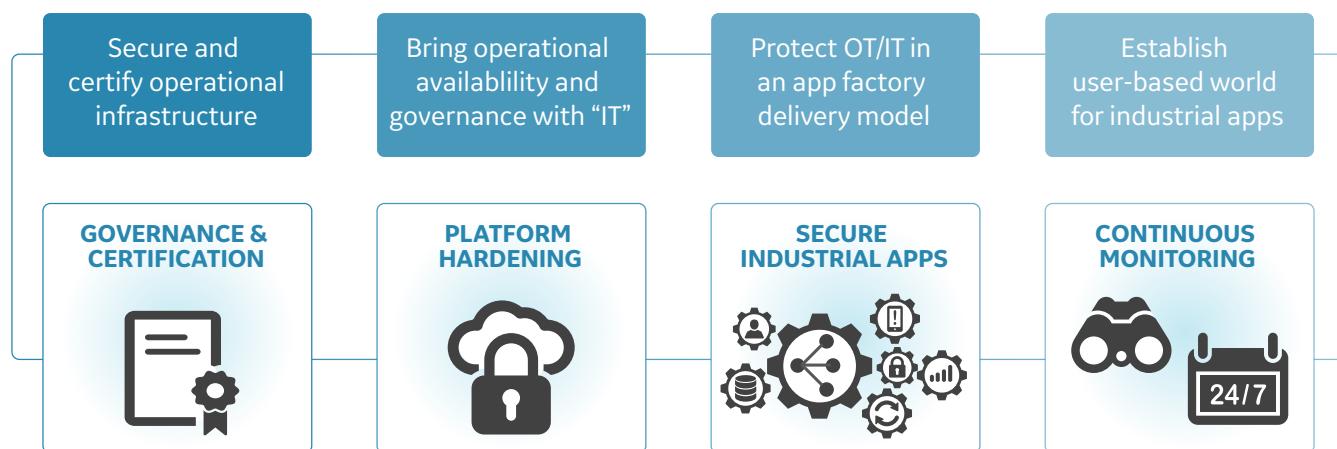
Business Operations services considers the lifetime value of each individual subscriber. It does so through advanced segmentation capabilities that enable applications to iteratively create pricing plans for each segment and to meter the service so that the cost-to-serve model is transparent. By understanding the cost dynamics of a service provided, and effectively segmenting the market to create appropriate subscription pricing models and terms, businesses can have complete visibility into the revenue and cost dynamics of the service they are offering to maximize subscriber revenues.

The Predix Business Operations service enables a data-driven decision-making process for businesses wishing to maximize their application efforts and speed time to usage or market.



Industrial-Grade Security that Builds End-to-End Trust

Companies need a strategy for adopting security that better positions them to take advantage of the opportunities presented by the Industrial Internet. They need a way to effectively bridge the worlds of IT and OT in a manner that can establish end-to-end security and trust — from the factory floor to users on their devices. GE has developed a comprehensive security strategy that combines security certifications, hardware, software, expertise, and best practices to create an environment of trust for industrial companies. These ‘pillars of trust’ are represented below.



Governance and certification

Governance and certification are essential components of an Industrial Internet platform that deals with sensitive information. Predix builds in governance end-to-end—from the end-user right through to the operational infrastructure. Instead of layering governance and certification onto existing IT data workflows, Predix integrates them directly into its architecture. Predix is built on a common infrastructure governance model based on ISO 27001/2, NIST 800-53, and FIPS 140-2 to manage the availability, integrity, and security of the data of each end-user enterprise. Predix leverages common controls that enables support compliance with over 60 national and international governing body regulations, meeting or exceeding the requirements of customers from a very broad range of industry sectors.

Platform hardening

When evaluating cloud technology, industrial companies are frequently concerned about levels of accountability and visibility into the proper functioning of the system. If a problem occurs, it is essential to have clarity on what went wrong, where it went wrong, and how to fix it. To that end, GE has implemented platform hardening at every layer and connection to remove unnecessary services, applications, and network protocols, as well as configured OS user authentication and 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. This results in unified and clean run-time environments.



Secure industrial apps

Establishing a secure software development environment is critical. Security, governance, and privacy cyber protections are automatically built into Predix, without impacting the developer or the application itself. The Predix infrastructure team follows a complete “DevOpsSec” (Development Operations-Security) process for all apps and microservices. As part of DevOpsSec, Predix makes tools available to help developers create secure workflows, handle data properly, evaluate app users, and dynamically test applications and APIs throughout the development process. This includes the ability to establish a baseline and highlight potential security concerns prior to deployment.

By combining DevOpsSec with static and dynamic automated testing, Predix helps keep new code as clean as possible. Predix can also survey new microservices arriving into the development area to detect any abnormal or suspicious behavior. This approach greatly reduces the possibility of malware making its way into the run-time environment.

Continuous monitoring

Maintaining security requires comprehensive visibility. Predix achieves this through continuous monitoring at every layer, with data loss protection and malware detection from the external networks all the way through to the application or microservice. This visibility extends into the exchanges to and from the OT environment, and creates a “heat-map” dashboard for the Predix Security Operations team to protect customers served by Predix. The Predix team also provides guidance for the shared responsibility of the user organization to implement controls at the application and data layers.

Additional capabilities include:

- Full Security Operations Center (SOC) and tooling
- Automated isolation and monitoring of incidents
- App-to-app behavioral evaluation
- Chain of custody for data communities maintained

Meet the Digital Twin— Digital representation of the physical world

A key innovation in delivering a radically new approach to industrial systems in a digital world is the Digital Twin. The Digital Twin provides knowledge, insights, and outcomes about its physical twin performance and operation (past and present), and allows for predictions and simulation of future operation.

Digital Twins consist of aggregated data from asset model, asset data, contextual data (such as environmental measurements), and reference data together with intelligence built using a variety of analytics and models. Advanced techniques such as AI or machine learning can also be added to the picture. In a nutshell, the Digital Twin is a container for all knowledge and expertise about a specific asset class, designed to deliver insights and outcomes that are essential to build apps about performance, optimization, and business transformation.

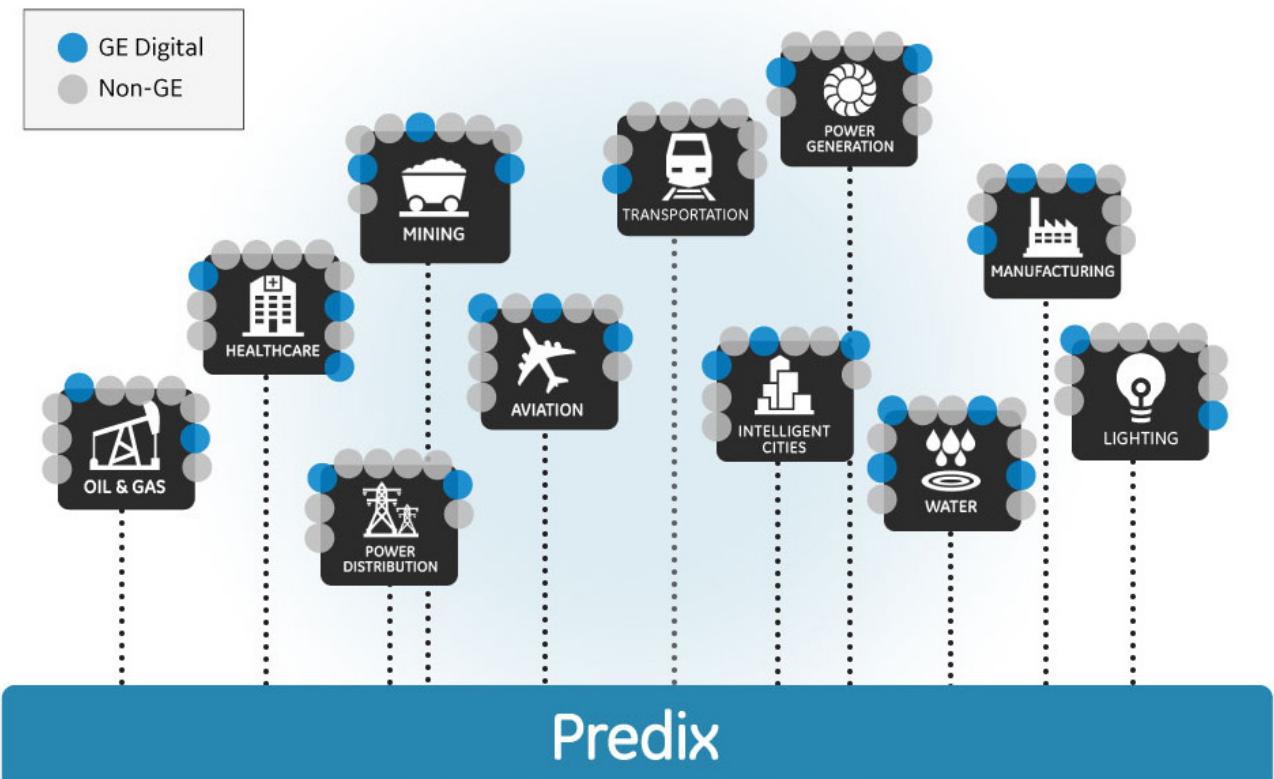


Growing the Ecosystem Together

With Predix, GE is transforming the industry. However the vision is bigger than just one company. Through partnerships with other technology companies, academia, consultants, and systems integrators, GE is sharing its expertise and know-how and co-innovating to drive important advances in functionality—harnessing the potential of the Industrial Internet to deliver powerful customer outcomes.

The result is a growing Predix marketplace: <https://www.ge.com/digital/content/meet-our-ecosystem>

GE is also a founding member of the Industrial Internet Consortium (IIC), an open membership, not-for-profit group of public and private institutions that focuses on developing use cases and test beds; sharing best practices, reference architectures, and case studies; and influencing global standards development to ensure interoperability.

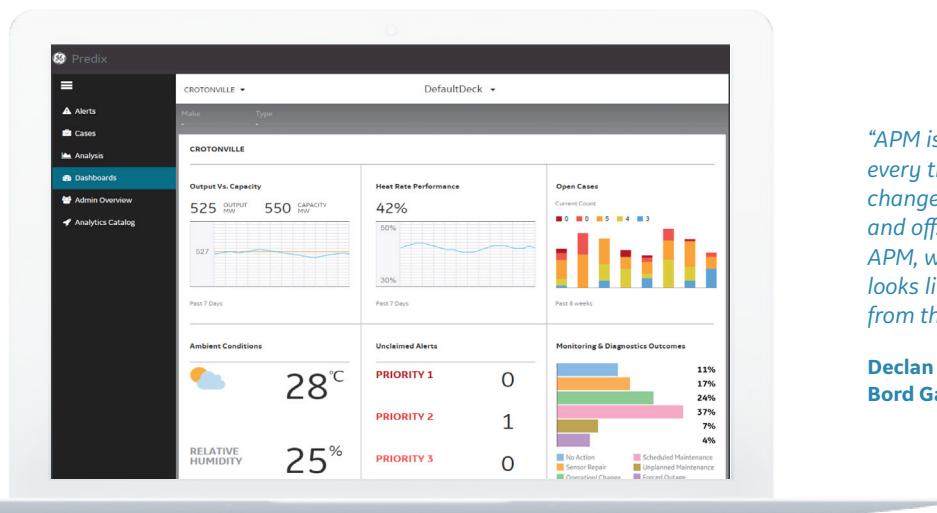


Spotlight: Asset Performance Management—Powered by Predix

GE Digital's Asset Performance Management (APM) suite is comprised of Predix-powered SaaS (Software-as-a-Service) apps. These apps use data and analytics to reduce unplanned asset downtime, improve reliability and availability, minimize costs, and reduce operational risks.

APM works across all equipment—regardless of manufacturer—in all industries, across plants and the entire fleet. APM covers the full range of industrial asset needs: Machine & Equipment Health, Reliability Management, and Maintenance Optimization.

[Learn more about GE Digital APM solutions.](#)



"APM is learning every time we start the plant, every time we stop the plant, every time we change load, every time we change a fan on and off. Our entire plant is being monitored by APM, which is learning what a healthy system looks like, and warning us when we deviate from that healthy system status."

**Declan Lynch | Deputy Project Manager,
Bord Gáis Energy**

| GET CONNECTED | GET INSIGHTS | GET OPTIMIZED |
|---|--|---|
| <p>APM gives you a single, secure way to gather data from a wide variety of assets and systems, creating a comprehensive and validated data repository. APM applications provide you a unified, complete, and accurate view of your operations – at the asset, plant, and enterprise levels – anytime and anywhere.</p> | <p>Once your equipment is connected, APM applications go to work monitoring your assets and alerting you about behavioral anomalies. APM predicts equipment problems before they happen so you can focus resources where they are needed. And when issues do arise, APM provides comprehensive case and knowledge management to ensure that your best practices are captured and available for future use.</p> | <p>The ultimate goal of APM is to identify maintenance strategies that balance reliability, performance and costs. APM allows you to replace scheduled maintenance with just-in-time, predictive maintenance. APM takes optimization to an entirely new level, providing you the quantitative foundation to implement a comprehensive, financially optimized asset management strategy.</p> |



Why GE?

GE uses Predix to transform itself.

GE saw a tremendous opportunity to transform the company to drive revenue and services growth, and reduce cost. To do that, it had to do things differently. However, the software and tools required didn't exist in the market. So GE built Predix for industry, which it now actively deploys in its own business, IT, and manufacturing operations.

Rather than taking on the entire burden, customers can now use Predix to build on its sophisticated infrastructure, and draw from its capabilities and the lessons learned from its industrial experts.

- **GE's billion+ dollar investment** in its own digital industrial transformation resulted in Predix.
- **GE knows industry. Decades of experience in industries** from power generation to manufacturing to healthcare have enabled GE to create a platform that meets the unique needs of industry.

- **GE secures and monitors 50 million data elements of its customers' industrial assets every day**, all in an effort to prevent unplanned downtime for its customers.
- Predix leverages common controls that **enable support compliance with over 60 national and international governing body regulations** (see Appendix A for more details).
- **GE is able to securely connect industrial assets at the edge from any vendor or vintage anywhere** with broad connectivity and security capabilities that allow for the management of complex asset data models.
- **GE manages data at an industrial scale** to meet the high velocity, high volume, and high variety of data from industrial machines.
- **Only GE can enable industrial data science** by leveraging its physics and engineering-based models, and its statistical and heuristics models. And only GE can incorporate learnings from industrial business processes.

To Learn More

Learn more

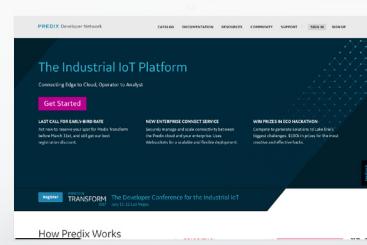
About Predix

predix.com



To start developing on Predix

predix.io



To learn more about GE Digital's services and products—www.ge.com/digital



Predix: The Industrial Internet Platform

Appendix A

Predix Cloud Infrastructure Security

The table below lists additional security in place to protect the Predix infrastructure.

| | |
|---|---|
| Isolated customer environments | Enable multi-tenancy to ensure that a customer's business environment and data are hidden from others as needed to ensure privacy. |
| OS security | Harden and maintain base OS images for provisioned virtual machines based on Predix hardening standards and related guidelines developed to comply with ISO27002/01 and SSAE16 SOC 2 standards and industry best practices. |
| Hardware security | Architect and securely deploy hardware for the infrastructure based on Predix hardening standards and related guidelines developed to comply with ISO27002/01 and SSAE16 SOC 2 standards and industry best practices. |
| Secured storage | Provide encrypted block and object storage with associated services. |
| Secured data in transit within the cloud network | Secure the network (using IPSec and SSL/TLS protocols) based on controls defined in Predix hardening standards and related guidelines. |
| Federated identity management | Use tools that leverage the existing identity stores and remove the burden of identity management. Secure single sign-on (SSO) services for access Predix. |
| Vulnerability and patch management | Test and update software and hardware based on security advisories and regular vendor patch releases utilizing proper change management procedures. |
| Monitoring and logging | Actively search for network intrusion, malicious activities, and compliance policy violations that are a threat to the infrastructure; communicate and remediate 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 Security Governance and Certification

Predix has adopted the ISO 27001/27002-based Information Security Management System and the Cloud Security Alliance-based Common Controls Matrix (CSA-CCM) for building its security governance and controls framework. Through these processes, Predix enables support for more than 60 regulatory and compliance frameworks, including the following:

CSA/CCM 3.01: The Cloud Security Alliance Cloud Controls Matrix (CCM) is specifically designed to provide fundamental security principles to guide cloud vendors (and to assist prospective cloud customers) in assessing the overall security risk of a cloud provider. The CCM provides a control framework for understanding security concepts and principles that are aligned with the Cloud Security Alliance guidance in 16 domains. CCM also provides a customized relationship to other industry-accepted security standards, regulations, and controls frameworks such as: ISO 27001/27002, ISACA COBIT, PCI, NIST, PCI, and NERC CIP.

ISO 27001/27002: Developed by the International Service Organization for Standards (ISO), these standards specify the requirements for establishing, implementing, maintaining, and continually improving information security within the organization. Once certification is attained, users are comforted knowing that security standards are being followed, thereby reducing time and resources needed to address customer-mandated audits and reviews.

SOC 2 Type 1: Developed by The American Institute of Certified Public Accountants (AICPA), a Service Organization Controls (SOC) report provides insight on internal controls and risks to users and companies regarding services provided by a third-party service organization (e.g., GE Digital–Predix PaaS). SOC Type 1 reports generate a point-in-time assessment reporting on the fairness of management's description of the processes as well as advising on the design of the controls.

SOC 2 Type 2: Developed by AICPA, a SOC report provides insight on internal controls and risks to users/companies on services provided by a third party service organization (e.g., GE Digital–Predix PaaS). SOC Type 2 reports on fairness of management's description on the processes and design of the controls (tests of effectiveness of controls), throughout a specified period.

HIPAA (protects): The Health Insurance Portability and Accountability Act (HIPAA) protects the privacy of individually identifiable health information. HIPAA compliance provides greater confidence to customers that stored and managed patient health information will be protected.

Export Controls/ITAR: The U.S. government regulates the transfer of information, commodities, technology, and software considered to be strategically important to the U.S., in the interest of national security, economic, and/or foreign policy concerns. Non-compliance with export controls can result in penalties, including the loss of government contracts and ability to export goods.



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Predix: The Platform for the Industrial Internet