Full-Stack Development Platform for the Internet of Things
Introduction

C3 IoT™ offers the world’s first full-stack development platform for next-generation enterprise Internet of Things (IoT) applications and business processes.

The C3 IoT Platform™—seven years in development—is platform as a service (PaaS) for the design, development, deployment, and operation of next-generation applications and business processes. The applications apply advanced machine learning to recommend actions based on real-time analysis of petabyte-scale data sets, dozens of enterprise and extraprise data sources, and telemetry data from tens of millions of endpoints.

The C3 IoT Platform is currently in large-scale production at 20 leading enterprises in North America and Europe. Customer successes include saving tens of millions of dollars annually from improved fraud detection and reduced equipment failure; increasing customer engagement by 30 percent through real-time segmentation; and significantly lowering energy costs and greenhouse gas emissions.

Initially focused on the energy industry, C3 IoT now provides a suite of pre-built, cross-industry applications, developed on its platform, that facilitate IoT business transformation for organizations in energy, manufacturing, aerospace, automotive, chemical, pharmaceutical, telecommunications, retail, insurance, healthcare, financial services and the public sector. C3 IoT cross-industry applications are highly customizable and extensible.

Prebuilt applications are available for predictive maintenance, sensor health, enterprise energy management, capital asset planning, fraud detection, CRM, and supply network optimization. Customers can also use the C3 IoT Platform to build and deploy custom applications.

C3 IoT plays an important role at the forefront of enabling some of the world’s largest enterprises, across all verticals, to realize the immediate business benefits of elastic cloud computing in ways that were unimaginable even a few years ago. C3’s work ensures their customers can focus their valuable resources on delivering innovative IoT solutions to their end users, instead of managing the heavy lifting of the underlying IT infrastructure platform needed to support it.”

— Mike Clayville, Vice President Worldwide Commercial Sales, Amazon Web Services, Inc.
The Fourth IT Revolution is Underway

New technologies are shifting the platform of computing. The shift this time is to scale-out architecture on distributed computing platforms such as Amazon Web Services (AWS), which can accommodate big data from connected devices and other sources.

To make sense of and act on an unprecedented volume, velocity, and variety of data in real time, companies are applying the sciences of big data, advanced analytics, machine learning, and cloud computing. Products themselves are being redesigned to accommodate connectivity and low-cost sensors, creating a market opportunity for adaptive systems, a new generation of smart applications, and a renaissance of business process reengineering.

The new IT paradigm will reshape the value chain by transforming product design, marketing, manufacturing, and after-sale services. The McKinsey Global Institute estimates the potential economic impact of new IoT applications and products to be as much as US$3.9–$11.1 trillion by 2025. Other industry researchers project that 50 billion devices will connect to the Internet by 2020.

C3 IoT™ offers a new generation of smart, real-time applications, overcoming the development challenges that have blocked companies from realizing that potential. Proven in more than 20 enterprise-scale production environments, the C3 IoT Platform™ is PaaS for the design, development, deployment, and operation of next-generation IoT applications and business processes.

The Convergence of New Technologies Enables a New Generation of Business Processes and Applications

Multiple technologies are converging to enable a new generation of smart business processes and applications—and ultimately replace the current enterprise software applications stack. The number of emerging processes addressed will likely exceed by at least an order of magnitude the number of business processes that have been automated to date in client-server enterprise software and modern software-as-a-service (SaaS) applications.

The component technologies include:

- Nearly free and unlimited compute capacity and storage in scale-out cloud environments such as AWS
- Big data and real-time streaming
- IoT devices with low-cost sensors
- Smart connected devices
- Mobile computing
- Data science: big-data analytics and machine learning to process the volume, velocity, and variety of big-data streams.

This new computing platform will enable capabilities and applications not previously possible, including precise predictive analytics, massively parallel computing at the edge of the network, and fully connected sensor networks at the core of the business value chain. The number of addressable business processes will grow exponentially and require a new platform for the design, development, deployment, and operation of new generation, real-time, smart and connected applications.

Data are strategic resources at the heart of the emerging digital enterprise. The new IoT infrastructure software stack will be the nerve center that connects and enables collaboration among previously separate business functions, including product development, market, sales, service support, manufacturing, finance, and human capital management.

C3 IoT is unique in the IoT market as it has developed a full-stack IoT platform that enables the design, development, provisioning, and operation of large-scale enterprise applications. C3 IoT is distinguished from the myriad of IoT market offerings that address a small subset of the solution requirement – for example, device connection, data persistence, or SQL-like access – by addressing the full problem with a comprehensive, cohesive, end-to-end IoT platform.”

— K.R. Sridhar, CEO, Bloom Energy

The new infrastructure software stack will be the nerve center that connects and enables collaboration among previously separate business functions, including product development, market, sales, service support, manufacturing, finance, and human capital management.

Fourth IT Wave Is Underway
The emerging market opportunity is broad. At one end are targeted applications that address the fragmented needs of specific micro-vertical markets—for example, applying machine learning to sensor data for predictive maintenance that reduces expensive unscheduled down time. At the other end are a new generation of core ERP, CRM, and human capital management (HCM) applications and a new generation of current SaaS applications.

These smart and real-time applications will be adaptive, continually evolving based on knowledge gained from machine learning. The integration of big data from IoT sensors, operational machine learning, and analytics can be used in a closed loop to control the devices being monitored. Real-time streaming with in-line or operationalized analytics and machine learning will enhance business operations and enable near-real-time decision making not possible by applying traditional business intelligence against batch-oriented data warehouses.

Smart, connected products will disrupt and transform the value chain. They require a new class of enterprise applications that correlate, aggregate, and apply advanced machine learning to perform real-time analysis of data from their own sensors, extraprise data (such as weather, traffic, and commodity prices), and all available operational and enterprise data across supplier networks, logistics, manufacturing, dealers, and customers. These new IoT applications will deliver a step-function improvement in operational efficiencies and customer engagement, and enable new revenue-generation opportunities.

IoT applications differ from traditional enterprise applications both by their use of real-time telemetry data from smart connected products and devices but also by operating against all available data across a company’s business value chain and applying machine learning to continuously deliver highly accurate and actionable predictions and optimizations. Think Google Now for the enterprise.

These real-time, anticipatory, and adaptive-learning applications apply across industries, whether to predict heart attacks; tune insurance rates to customer behavior; anticipate the next crime location, terrorist attack, or civil unrest; anticipate customer churn or promote a customer-specific wireless data plan; or optimize distributed energy resources in smart grids, micro-grids, and buildings.
Operationalizing IoT, Big Data Analytics, and Machine Learning: Harder than it Looks

The IoT and related big data analytics have received much attention, with large enterprises making claims to stake out their market position—examples include Amazon, Cisco, GE, Microsoft, Salesforce, and SAP. Recognizing the importance of this business opportunity, investors have assigned outsized valuations to market entrants that promise solutions to take advantage of the IoT. Recent examples include Cloudera, MapR, Palantir, Pivotal, and Uptake, each valued at well over $1 billion. Large corporations also recognize the opportunity and have been investing heavily in development of IoT capabilities. In 2011 GE Digital, for example, invested more than $1 billion to build a “Center of Excellence” in San Ramon, California, and has been working hard on development of an industrial internet IoT platform, Predix. GE invested approximately $100 million in data-analytics company Pivotal to help with Predix development, and reportedly is spending over $1 billion per year to develop its IoT capabilities by hiring 1,000 additional software engineers and data scientists. Cisco’s recently announced $1.4 billion purchase of Jasper is yet another indication of IoT interest by large corporations.

The market growth and size projections for IoT applications and services are staggering. Many thought leaders, including Harvard Business School’s Michael E. Porter, have concluded that IoT is essentially an entire replacement market in global IT. However, virtually all IoT platform development efforts to date—internal development projects as well as industry-giant development projects such as GE’s Predix and Pivotal—are attempts to develop a solution from the many independent software components that are collectively known as the open-source Apache Hadoop stack. It is clear that these efforts are more difficult than they appear. The many market claims aside, a close examination suggests that there are few examples, if any, of enterprise production-scale, elastic cloud, big data, and machine learning IoT applications that have been successfully deployed in any vertical market except for energy applications addressed with the C3 IoT Platform™.
The remarkable lack of success results from the lack of a complete IoT application development platform. Companies typically look to the Apache Hadoop Open Source Foundation and are initially encouraged that they can install the Hadoop open-source stack to establish a “data lake” and build from there. However, the investment and skill level required to deliver business value quickly escalates when developers face hundreds of disparate software components in various stages of maturity, designed and developed by over 350 different contributors using different programming languages while providing incompatible software interfaces. A loose collection of independent, open source projects is not a true platform, but rather a set of independent technologies that need to be somehow integrated and maintained by developers.

— Michael E. Porter, Harvard Business School Institute for Strategy and Competitiveness

Apache Hadoop repackagers, including Cloudera and Hortonworks, provide technical support but have failed to integrate their Hadoop components into a cohesive software development environment. To date, there is no successful large-scale enterprise IoT application deployments using the Apache Hadoop technology stack. Adoption is further hampered by complexity and a lack of qualified software engineers and data scientists. Gartner Research concludes that Hadoop adoption remains low as firms struggle to articulate Hadoop’s business value and overcome a shortage of workers who have the skills to use it. A survey of 284 global IT and business leaders in May 2015 found that, “The lack of near-term plans for Hadoop adoption suggests that despite continuing enthusiasm for the big data phenomenon, specific demand for Hadoop is not accelerating.”

Developing next-generation applications with measurable value to the business requires a scalable, real-time platform that works with traditional systems of record and augments them with sophisticated analytics and machine learning. But the risk of failure is high. You don’t know what you don’t know. IoT is new technology to most enterprise IT-oriented development organizations, and expertise may be difficult to acquire. Time to market is measured in years. Costs are typically higher than anticipated, often hundreds of millions of dollars. The cost of GE Predix, for example, is measured in billions.

— Dr. Michael Stonebraker, Professor, MIT, and 2014 Turing Award Winner

If you just dump data into a lake, what you get is an uncurated data swamp. That essentially has no value. Curation is where all the action is going to be, and it’s hard and costly... data curation is a huge, huge deal...

— Dr. Michael Stonebraker, Professor, MIT, and 2014 Turing Award Winner

Only about 5% of the problems that anybody’s interested in are embarrassingly parallel. So basically, MapReduce is this insignificant little corner case and is a terrible internal interface for a higher-level system...

— Dr. Michael Stonebraker, Professor, MIT, and 2014 Turing Award Winner


Next-generation IoT applications require a new enterprise software platform. Requirements extend well beyond relatively small-scale (by Internet standards) business-activity tracking using transactional/relational databases, division-level process optimization using limited data and linear algorithms, and reporting using mostly offline data warehouses. Next-gen IoT applications manage dynamic, petabyte-size datasets consisting of unified data images of all relevant data across a company’s value chain, and apply machine learning to make predictions in real time as those data change. These applications require cost-effective Internet/cloud-scale distributed computing architectures and infrastructures such as those from AWS, Microsoft, and Google. These public clouds are designed to scale out—not up, like traditional compute infrastructures—by taking advantage of millions of fast, inexpensive commodity processors. Google, for example, uses a distributed computing infrastructure to process over 26PB per day at rates of one billion data points per second.

Distributed infrastructure requires new distributed software architectures and applications. Writing application software to take advantage of these distributed architectures is non-trivial. Without a cohesive application development platform, most enterprise-caliber IT teams and system integrators do not have the qualifications or experience to succeed.

### IoT Platform Requirements

<table>
<thead>
<tr>
<th>Capabilities</th>
<th>Function</th>
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<tbody>
<tr>
<td><strong>Real-time communication and control of sensor networks</strong></td>
<td>Bi-directional communication and control of sensor networks and over-the-air delivery of commands to remotely:</td>
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<tr>
<td></td>
<td>• Connect and disconnect</td>
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<td></td>
<td>• Upgrade firmware/software</td>
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<td>• Adaptively switch devices on and off</td>
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<td></td>
<td>• Ensure the health and proper functioning of sensors, devices, and supporting network equipment.</td>
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<td><strong>“System of systems,” or unified cloud data image</strong></td>
<td>Sensing and tracking the state of the end-to-end company value chain by generating a unified, federated cloud data image and keeping it current in near real-time. This requires integrating a multitude of disparate extraprise, enterprise, and operational systems, and sensor network data.</td>
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<td><strong>Elastic cloud computing</strong></td>
<td>Cost-effective storage and real-time processing of petabyte-scale dynamic data sets growing at tens or hundreds of terabytes per day and bursting at millions of messages per second.</td>
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<td><strong>Cloud-scale real-time and iterative data analysis</strong></td>
<td>Analysis of all data, including telemetry data with sampling frequencies ranging from minutes to kilohertz and enterprise and operational data. Requires a combination of:</td>
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<td>• Real-time stream processing</td>
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<td>• Near-real-time contextualized data analysis</td>
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<td>• Batch data analysis</td>
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<td>• Fast, iterative data processing to support machine-learning data exploration.</td>
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<td><strong>Anticipatory and adaptive applications</strong></td>
<td>Integrated machine learning to analyze data across the value chain by interpreting changes to the unified data image in real-time, identifying anomalies, and updating predictions and optimizations accordingly. Self-tuning algorithms continuously adapt predictions and optimizations based on feedback from customer, distributor, manufacturer, and supplier interactions and data from connected products and sensor networks.</td>
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</table>
What Companies Need For Next-Gen IoT

For an innovative company willing to invest in the development of a new generation of mission-critical enterprise applications, the first requirement is a comprehensive and integrated infrastructure stack. The goal is PaaS: a modern scale-out architecture leveraging big data, open-source technologies, and data science.

Vendors of existing enterprise and SaaS applications face the risk that these disruptive technologies will create a market discontinuity—a shift in market forces that undermines the market for existing systems. It should be anticipated that emerging SaaS vendors will indeed disrupt the market. However, there is also a high potential to address the emerging market opportunities with an architecture that can link the two platforms together—traditional systems and modern big data/scale-out architecture—in a complementary and non-disruptive fashion.

Market incumbents, legacy application vendors and SaaS vendors have an advantage because of their enterprise application development expertise, business process domain expertise, established customer base, and existing distribution channels.

Application and SaaS vendors can increase the value of their systems of record by complementing them with a new IoT/big data and machine learning PaaS infrastructure stack, unifying the two stacks into a comprehensive and integrated platform for the development and deployment of next-generation business processes. This approach extends existing applications at the same time it allows for the development of entirely new applications that are highly targeted and responsive to the explosion of new business process requirements.

Given the complexity of the platform for next-generation application design, development, provisioning, and operations, it’s important to understand the effects of the build-versus-buy decision on costs and time to market.

Avoid Market Discontinuity By Linking Traditional and Modern Infrastructure Stacks

Cohesive integrated platform for rapid development of anticipatory and adaptive applications

- Design
- Development
- Provisioning
- Deployment

PROVEN RESULTS IN WEEKS, NOT YEARS

Complete a low-cost, low-risk production trial of the C3 IoT Platform™ in just 4-16 weeks. Validate the economic value and other benefits to your organization before expanding into full production use. For more details, visit www.C3IoT.com/products/trial-offers/.
C3 IoT Platform: Proven Enterprise IoT Application Development and Deployment Platform

Over the past seven years, C3 IoT™ has designed, developed, and brought to market the C3 IoT Platform™, a cohesive application development PaaS that enables IT teams to rapidly design, develop, and deploy enterprise-scale applications. These applications exploit the capabilities of streaming analytics, IoT, elastic cloud computing, machine learning, and mobile computing—integrating dynamic, rapidly growing petabyte-scale data sets, scores of enterprise and extraprise data sources, and complex sensor networks with tens of millions of endpoints.

The C3 IoT Platform is deployed at 20 endpoints. Networks with tens of millions of smart meters and sensors throughout the value chain—from power generation to distribution to the home or building—applying machine learning to loop back and control devices in real time and integrating with legacy systems of record.

Production use cases at enterprise scale include Enel, Exelon, Eversource, AEP, and others. One customer credits C3 IoT applications with $20 million in annual savings from smarter fraud detection. Another company reduced equipment failures between scheduled maintenance by 50 percent, lowering costs and downtime. One large enterprise lowered energy costs by 10 percent and another reduced greenhouse gas emissions by 14 percent.

Since its beginnings in the energy industry, C3 IoT has broadened its focus by developing a range of next-generation applications for horizontal markets such as CRM, predictive maintenance, and sensor health, and verticals including manufacturing, oil and gas, retail, computer software, discrete manufacturing, aerospace, and telecommunications.

Enterprises can also use the C3 IoT Platform and its enhanced application tooling to build and deploy custom applications and business processes. Systems integrators can use C3 IoT to build out a partner ecosystem and drive early network-effect benefits. New applications made possible by C3 IoT and other big data sources will likely drive a renaissance of business process reengineering.

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### C3 IoT Platform

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<tr>
<th>C3 Tools™ &amp; Application Management</th>
<th>C3 Type System</th>
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<tr>
<td>C3 Integration Designer™</td>
<td>C3 Type Designer™</td>
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<tr>
<td>C3 Type System</td>
<td>C3 Application Logic™</td>
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<td>C3 Data Explorer™</td>
<td>C3 Analytic Designer™</td>
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<tr>
<td>C3 Ex Machine™</td>
<td>C3 UI Designer™</td>
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<tr>
<td>C3 Provisioner™</td>
<td>C3 IoT Platform™</td>
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</table>

#### MACHINE LEARNING / PREDICTIONS

- Data Statistics
- Classification & Regression
- Dimensionality Reduction
- Feature Selection

#### CONTINUOUS DATA PROCESSING

- Batch Services
- Continuous Analytics Processing
- Iterative Processing

#### PLATFORM SERVICES

- Analytic Application Logic
- Authentication
- Data Deployment
- Monitoring
- System Management

#### CUSTOM IoT APPLICATIONS

- IoT
- Supply Chain
- Human Capital

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Time to market is critical as new generation computing platforms emerge. C3 IoT™ is a proven, scalable, production and development environment that provides what others have so far failed to deliver. Other than C3 IoT, there are no large scale IoT applications deployed in the market, managing tens of millions of smart, sensor enabled devices. The time to market advantage of a proven, scalable architecture can be leveraged to gain early network effects and competitive differentiation in the next big wave of computing and industrial automation.

C3 IoT has assembled an unusually experienced and successful management, engineering, and data science team who have dedicated seven years to tackling the IoT market. With the exception of C3 IoT, I am unaware of any cloud-based IoT enterprise application development platform available in the market with proven scalability supporting tens of millions of devices.”
— Rick Sherlund, Chairman, Software Investment Banking, Barclays

### C3 IoT: The Only Proven IoT Application Development Platform Available Today

| Open Platform | • Standard based APIs (REST, JSON etc.) allow users to integrate third-party software |
| Complete, cohesive IoT application software services | • Uniform programming language, complete set of data processing services for real-time, batch, iterative processing and machine learning |
| | • Consistent, integrated platform services accessed using a uniform, standard development language |
| | • Distributed, scalable architecture leveraging Infrastructures such as AWS; demonstrated over 1.5 million transactions per second |
| Highly-productive application development platform | • Integrated development environment and visual application development tools (C3 Tools) |
| Scalable | • Demonstrated steady-state processing over 650,000 sensor messages per second (1.5 million writes per second) |
| Proven | • Over 20 large scale production deployments |
| C3 IoT Platform future proofs investment in applications | • Software services abstract technology components, allowing components to be substituted over time |
| | • Standard based APIs (REST, JSON, etc.) allows users to integrate third-party software |
| Rapid application development, resulting in production pilots in 4 - 16 weeks | • Meta data driven application configuration with visual development tools (C3 Tools) |
| | • Less code to develop and debug to express application business logic, less code to maintain over time |
| Fully-integrated machine learning environment allows data scientists to quickly develop, test and deploy models into production | • Enables data scientists and app developers to work with same software services and operate against all relevant data (through a distributed in-memory data store) |
| | • Removes necessity for data scientists to establish and maintain their own redundant compute infrastructure, ETLs, and data cleansing and preparation routines |
From C3 Energy to C3 IoT

Formerly known as C3 Energy, C3 IoT™ rebranded itself to reflect its expansion into the broader IoT application software and development platform markets. Initially targeting electric utility IoT use cases, C3 IoT has since demonstrated the value of its application platform and framework across multiple industries, including manufacturing, oil and gas, retail, computer software, discrete manufacturing, aerospace, and telecommunications.

Led by veterans in enterprise software management, software engineering, and data science, C3 IoT has also assembled a deep bench of experts in distributed computing, user interface design, and enterprise systems architecture.

The C3 IoT Platform™ is designed for industrial leaders, infrastructure as a service providers, software platform players, software application companies, and systems integrators. Industrial leaders see a comprehensive IoT platform as a means of establishing an early market lead, building network effects, and maintaining a strategic competitive advantage in the coming Industry 4.0 world.

C3 IoT is currently engaged with manufacturing companies to license the platform for predictive maintenance and supply chain management; enterprise software vendors interested in building their own next-generation applications on the C3 IoT Platform; and telco and healthcare companies and others that require next-generation applications to address new market opportunities and rapid time-to-market for competitive differentiation.

"C3 Energy was ahead of its time in recognizing the inevitable convergence of IoT with energy markets. The C3 IoT platform has changed the way energy producers think about the future of the smart grid infrastructure. The C3 platform appears well positioned to have a similar impact upon government, intelligence, and commercial markets."

— Hon. Spencer Abraham, Former U.S. Secretary of Energy
Conclusion

The Internet of Things and advanced data science are rewriting the rules of competition. The advantage goes to organizations that can convert petabytes of freshly arrived and historical data to predictions—more quickly and more accurately than their competitors. Payoffs include better product and service design, promotion, and pricing; optimized supply chains that avoid delays and increase output; reduced churn; higher average revenue per customer; and predictive maintenance that avoids downtime for vehicle fleets and manufacturing systems while lowering service costs.

Capitalizing on the potential of the IoT requires a new kind of technology stack that can handle the volume, velocity, and variety of big data and apply operational machine learning at scale. Existing attempts to build an IoT technology stack from open-source components have failed—frustrated by the complexity of integrating hundreds of software components developed with disparate programming languages and incompatible software interfaces.

C3 IoT has successfully developed a comprehensive technology stack from scratch for the design, development, deployment, and operation of next-generation applications and business processes. The C3 IoT Platform is the result of a 7-year development effort from a seasoned management team with leading data scientists and software developers.

The C3 IoT Platform is the world’s only IoT platform proven in full-scale production. More than 20 enterprise customers report measurable ROI, including improved fraud detection, increased uptime as a result of predictive maintenance, improved energy efficiency, and stronger customer engagement. Customers can use prebuilt C3 IoT Applications, adapt those applications using the platform’s toolset, or build custom applications using C3 IoT’s platform as a service. C3 IoT supplies the technology; you bring the vision.

Energy Industry as Testing Grounds for IoT Platform

Amazon.com processes 426 transactions per second during its busiest periods. By contrast, an energy company with millions of smart meters processes hundreds of thousands of messages per second. The C3 IoT Platform™ is proven in this high-volume environment.

A large utility in Europe, for example, uses C3 IoT™ applications for predictive grid maintenance and advanced power fraud detection. The first phase of C3 IoT’s rollout established one of the largest and most productive enterprise analytic IoT system deployments to date. In the first eight months, achievements included:

- 13 unique data source systems integrated
- 1.5 million writes per second
- 8+ million predictions per day
- >99.99% uptime
- 550+ billion sensor and device reads
- 2,500 analytics processing in near real-time

Baltimore Gas & Electric (BGE), a subsidiary of Exelon, uses C3 IoT applications to monitor network health and detect fraud across its two million smart meters with up to 99 percent accuracy. Since deployment, the solutions have met or exceeded all business performance targets. Improved fraud detection and sensor health monitoring are on target to save more than $20 million annually for BGE and its customers.

“We are already experiencing the enormous business value we can get from the data we collect.”

— Michael Butts, Director of Smart Grid, BGE

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