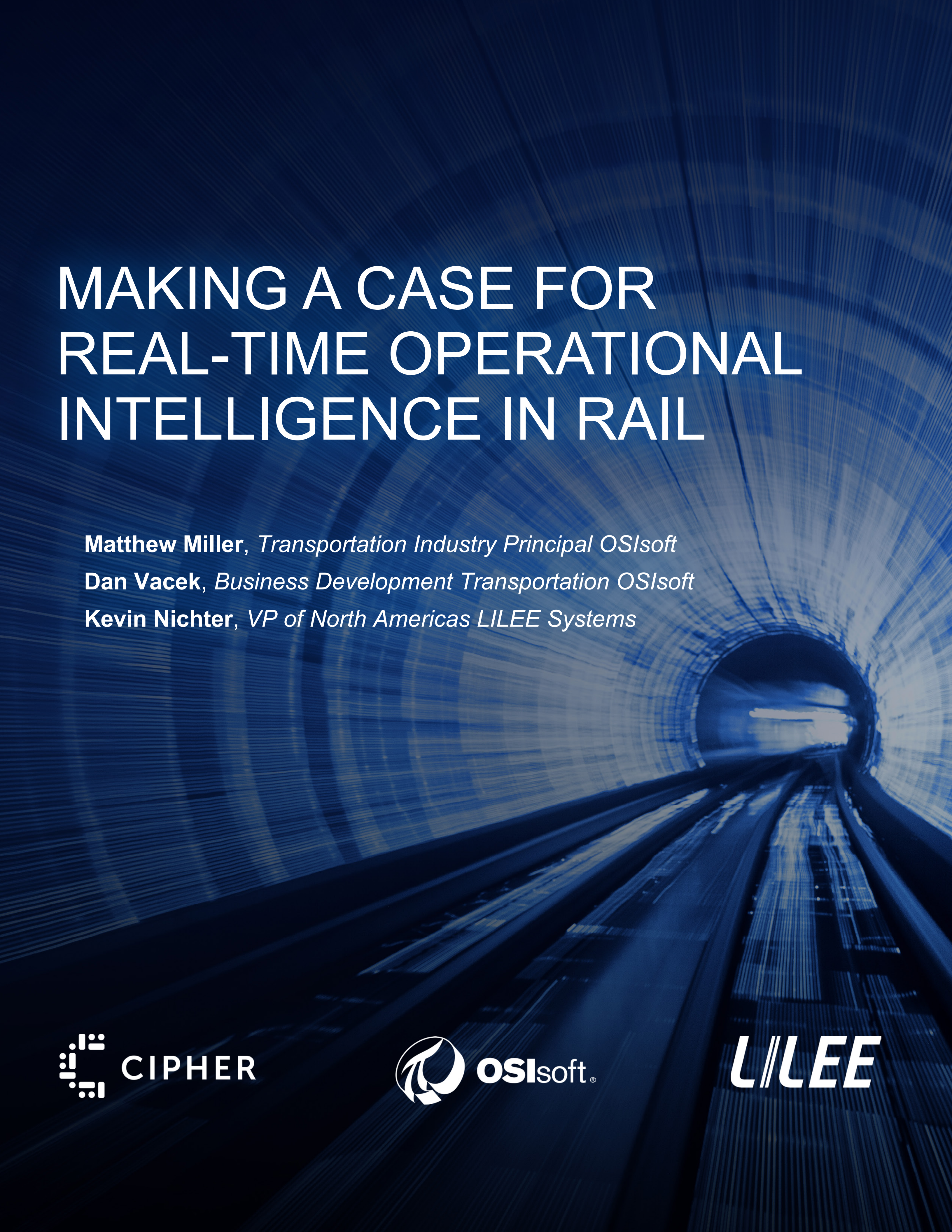

MAKING A CASE FOR REAL-TIME OPERATIONAL INTELLIGENCE IN RAIL

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INTRODUCTION

Railways are maturing in their use of data and can leverage the investments in Positive Train Control (PTC) to drive operational intelligence and create compelling business advantages. The ability to empower stakeholders and manage these new capabilities will determine relative success against other operators and model alternatives. The case will be made for leveraging commercial-off-the-shelf (COTS) tool sets like those used in other critical infrastructures to quickly meet these challenges and provide faster payback on investments.

OSISOFT AND ITS PARTNERS ARE ACCELERATING THE U.S. RAIL DIGITAL TRANSFORMATION USING HIGH-FIDELITY DATA TO:

1. Bring together information from disparate railway data sources to create an operational System of Record (SOR).
2. Improve situational awareness and operational forensics with real-time, trusted data that helps staff quickly identify and address issues.
3. Create a unified operation model that helps focus on ideal outcomes over which data supports which opinions, thus improving response times.
4. Remotely monitor and proactively diagnose field events before “rolling trucks” to ensure the right resources arrive at the right location at the right time.
5. Reduce the time to value and the total cost of ownership with configurable, commercial-off-the-shelf technology.

DIGITALIZATION OF RAIL

The shift to a digital world has been underway for nearly three decades and accelerated by ubiquitous networks, edge computing and better ways to centrally manage large numbers of devices and massive data sets. As computers have taken over many repetitive and mundane tasks to which they are far better at serving, our attention has turned to dealing with higher value tasks such as taking action to improve operations and innovation - something we have not yet been able to completely automate.

Although not always recognized as digital leaders, many industrial companies are building a solid data infrastructure to manage the rapidly expanding data, engage stakeholders, and deliver significant competitive advantages.

Many of these industrial digital leaders are in the Oil and Gas, Petrochemical, Power and Utilities and Metals, Mining and Metallurgy sectors, and are driven both by fiscal and operating performance as well as political and social pressure to continuously improve service value. Similarly, the railways are always working to adopt new technologies and drive continuous improvement. With the profound challenges in creating a robust communications infrastructure that span the geographical reach of operating assets, digital innovations like ERTMS/ETCS from European and Asian passenger rail have not translated well to North American freight rail.

CHALLENGES IN DIGITIZING RAIL

Railways have many of the same needs and pressures as other critical infrastructures such as electrical, water and gas utilities. They manage billions of dollars of heterogeneous assets that are geographically dispersed, exposed to a wide range of environments and are often targets of interference and tampering (both physical and cyber). These assets are also energy intensive, each year consuming over 3.5 billion gallons of diesel fuel annually and representing a significant potential operating risk to both people and the environment reporting over 4,400 accidents and incidents with 341 fatalities and 662 collisions (*source: FRA*). More importantly, they represent a significant economic impact to the regions they serve, moving nearly 2 trillion ton-miles (*source: AAR*) of commodities and trade goods last year to and from intermodal hubs.

Most organizations see significant operating performance improvements after moving to digital. Data driven companies statistically are more agile, focused, profitable, have better corporate cultures, outperform competitors, and have happier customers.

According to the McKinsey Global Institute 2015 Digital America Report:

"At a broad level, the industries with the fastest profit margin growth tend to be those with the fastest growth in software intensity. And within these sectors, the margin spreads between the top-performing companies and the lowest performers are two to four times those in other sectors. In other words, the most digitized industries are developing a winner-take-all dynamic."

NOT SO "DARK" TERRITORY

Unlike these other critical infrastructure industries, railways have been slower to modernize and connect their assets, leaning on physical process and safety traditions and the inherent relative cost efficiencies of bulk material that date back to the turn of the century. Centralized dispatch, geospatial information systems, and logistics tracking through RFID helped the industry keep relevance against pressures from the trucking and marine segments. But the just-in-time supply chain needs continue to push railways to deliver more accurate delivery times and location data. With the U.S. Federal mandate to install Positive Train Control (PTC) sometime referred to generally as Automatic Train Control (ATC) the industry will take a step forward in digitalization. Globally, the ETCS level 3 initiative of the European Rail Administration has a similar goal in addition to unifying operating processes (ERTMS). The rollout of PTC across North America will enable large sections of railway previously considered "dark" to centralized dispatch systems to now stream large amounts of data, making it available to numerous supply and value chains. This will light up the otherwise dark territory, but this is just the start of a much larger trend toward more data. To leverage their investment in PTC, operators must match this investment with the operational intelligence tools needed to make the information actionable so it can create a monetary benefit thus driving PTC Operational Excellence across the rail enterprise.

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PTC/ATC OVERVIEW

GOALS

In 2008, Congress passed a law requiring all Class I railroad main lines handling poisonous-inhalation-hazard materials and any railroad main lines with regularly scheduled intercity and commuter rail passenger service to fully implement PTC as a safety system to prevent human error based accidents. The industry created the Interoperable Train Control (ITC) Committee to create standards and facilitate supplier support to meet the implementation challenges.

COMPONENTS

There are three major components of an ITC communications network for PTC:

1. A data radio network provided by Interoperable Train Control Radio (ITCR).
2. The messaging system provided by Interoperable Train Control Messaging (ITCM) for both locomotive and wayside equipment.
3. Systems management and supporting information systems.

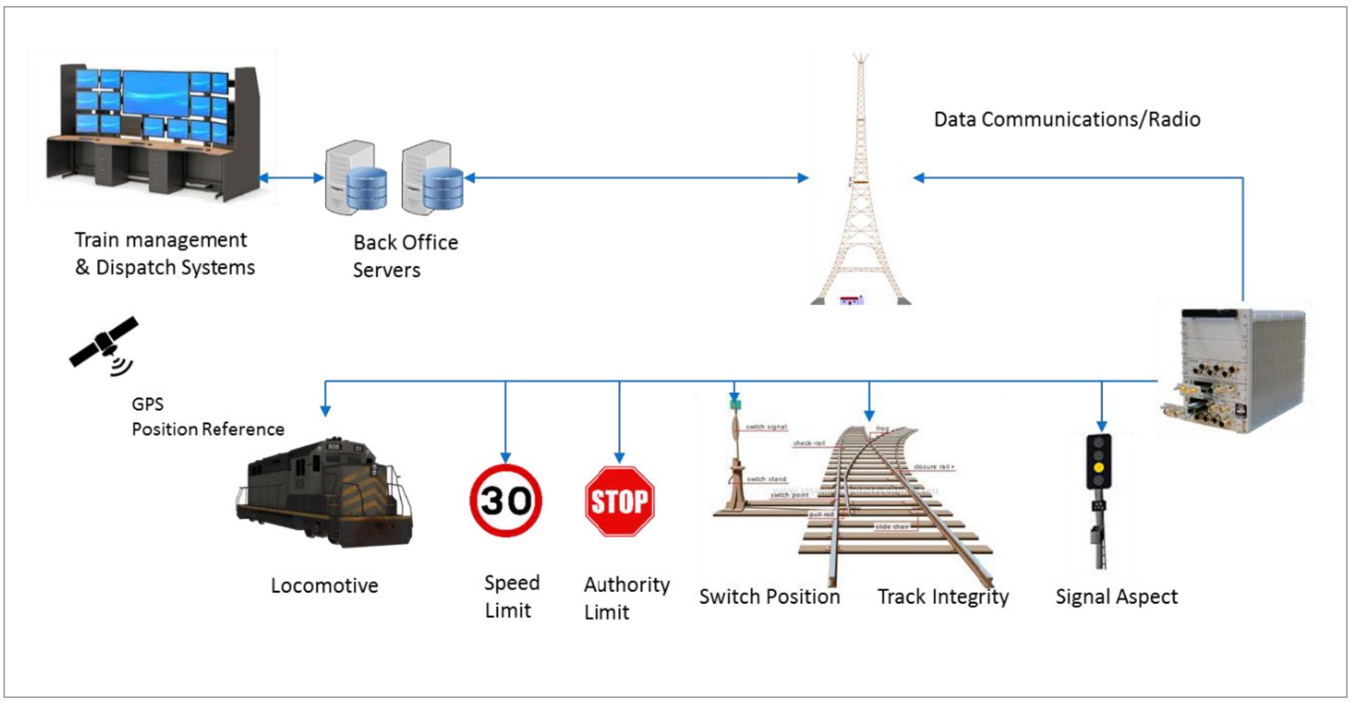

Figure 1: PTC Operation Diagram

1. INTEROPERABLE TRAIN CONTROL RADIO (ITCR)

The data radio network is comprised of both narrow band and broadband networks. In the case of the narrow band network, an interoperable radio link is provided through a radio operating in the 220 MHz spectrum based on an MCC reference design. Broadband networks (such 802.11 Wi-Fi, satellite, fiber, copper, and cellular / LTE) are also utilized within PTC for functions such as distributing large data downloads needed for train initialization and providing image and firmware updates to components on the network. Other wireless communications mediums may be utilized as alternate paths for redundant communications, to augment coverage issues, or optimize large file transfers. Operational data from these systems can be collected over time to troubleshoot issues. For example, input power, signal strength and status can help identify brown-out conditions from initialization problems.

2. INTEROPERABLE TRAIN CONTROL MESSAGING (ITCM)

The ITCM is a suite of software that is deployed in both the back office and remote environments (typically wayside and locomotive areas). It is a store-and-forward system which utilizes no guaranteed method of delivery. This allows the system to operate more efficiently, but places an onus on the sender and receiver to detect lost messages and take appropriate actions to retransmit automatically. ITCM is designed to run on SBCs (single board computers) currently based on x86 architectures. These SBCs are coupled with other devices (such as Ethernet switches) within a ruggedized enclosure to operate as a Wayside Messaging Server (WMS) operating at PTC-equipped wayside locations. In the locomotive, a Locomotive Messaging Server (LMS) performs a similar function as the WMS – both the WMS and LMS are responsible for running the ITCM at their respective locations.

The locomotive and wayside installations of ITCM, also known as Remote Areas, connect to the back office using ITCM through any available transport (such as the 220 MHz radio, satellite, fiber, copper, cellular, or Wi-Fi paths).

These Remote Areas connect to the back office through an ITCM Application Gateway and provides valuable information about the wayside equipment and locomotives. Quickly correlating issues with specific equipment can lead to faster root cause diagnosis, eliminate false positives and start building data sets for a shift to equipment condition-based maintenance.

3. SYSTEMS MANAGEMENT AND SUPPORTING INFORMATION SYSTEMS (ITCSM)

The third component of an ITC communications network is ITCSM, which is designed to pass information concerning asset health, configuration, alarms, and other data over the network. ITCSM also enables remote log retrieval and over-the-air software update capability. It provides the necessary framework for over-the-air software downloads, remote command execution, and kits.

ITCSM can be broken down into two additional sub-components. The first is the ITC SMG (Systems Management Gateway), which provides services such as orchestration authorization, and security for the railroad back office applications as well as ITC SMGs located on other railways. ITCSM uses the ITCM for transport across the network and utilizes a standard protocol known as ISMP, or Interoperable Systems Management Protocol. ISMP is embedded within an Edge Message Protocol (EMP) message, enabling it to be transported across the ITCM in the same manner as other PTC messages.

The second sub component is the SMA, or Systems Management Agents, which are software modules installed in back office locations or directly on assets. SMAs enable wayside and locomotive devices to utilize ITCSM infrastructure to report health status and other information about the asset to interfaces and users in a centralized location such as a back office. An asset may be any device the railroad desires to manage – a WIU, TMC, or WMS for example. Each asset to be managed via ITCSM has a respective SMA. These agents are embedded or remote software agents and differ depending on the architecture deployed for PTC as well as the hardware that is utilized in the field. In the case of an embedded agent, the asset will provide support for communicating directly with ITCSM via API calls embedded in the asset’s software without the need for external software. This external software would have been necessary to provide protocol conversion support to the ITCSM-required format of ISMP. Such remote agents provide translation services to remote assets which support a non-ISMP form of management such as SNMP.

PTC CHALLENGES

While a great deal of time and effort has been expended to develop the standards for interoperable PTC, several challenges remain to fully deliver an interoperable systems management solution.

First and foremost, interoperable PTC has no precedent. While the industry as a whole has worked to leverage commercially available solutions and standards wherever possible to achieve their respective goals, a significant number of specifications and requirements not only needed to be defined by the industry committees and other stakeholders, but conforming solutions must also be built, tested, delivered, and evaluated. The testing and the evaluation of the success metrics may be more complex because requirements may be implemented differently, and discrepancies must be worked out and potentially refined with the various industry bodies involved with implementation. Moreover, it is possible that the specifications will evolve over time to accommodate for "lessons learned" and other advancements by the underlying technology in PTC as it is deployed. This implies that standards bodies such as the FRA or NTSB will have a continuing role to play in the evolution of PTC as it becomes part of daily operations.

The second issue potentially impacts the incorporation of systems management in the broader discussion of delivery of a PTC system that is compliant with ITC specifications. In particular, for those commuter railways who rely on systems integrators, is the method for managing the potentially evolutionary aspects of PTC. When a specific scope of work is committed to by a third party to deliver an interoperable PTC solution, and it is understood that many aspects of systems management (and PTC in general) may evolve over time, the potential impact to schedules and budgets must also be accounted for as well.

Also, the processing capabilities of the software and technologies applied for systems management also may present constraints. For example, a railroad may wish to access and report signal aspect information from their wayside locations for trending or other diagnostic purposes. Wayside status messages (WSM) may be transmitted from each wayside location at a rate of approximately once every three seconds. For a railroad with 1000 wayside locations, and WSMs being delivered asynchronously, it would be expected to receive 500 or more messages from the field at any given second. However, a single wayside may be heard by more than one base radio, and base radios may hear other base radios as well. This generates duplicate messages which can be filtered in the back office before processing and forwarding, but this still diverts processing capability and takes time. Assuming a multiple of five due to this duplication, such an application may need to process up to 2500 messages per second. While modern computing is capable of meeting this level of processing capability, this assessment is also based on estimated loads which should be reevaluated as more railroads extend their PTC deployments.

There are also technological limitations which may present unique challenges to deployment of systems management. The wired and wireless mediums used to access locomotive and wayside areas may present constraints as to the amount of information that the railroads may be able to access without overloading the network.

If a narrow band 220 MHz radio is the sole connection to a remote asset, the amount of systems management traffic that can be supported is partly a function of the amount of train control traffic which takes priority over all other traffic. Retransmissions of missed data, duplicated data received from other base stations, and other events further limit the amount of bandwidth available for other purposes.

A final challenge involves the decision to implement remote or embedded agents into the hardware necessary for PTC. As stated above, ITCM is designed to run on SBCs based on x86 architectures. In the ITC architecture, the WMS and LMS are designated to run the ITCM in the wayside and locomotive environments, respectively. For a variety of technology reasons, other devices on the PTC system may not offer a readily available ITCSM agent (ITCSM can be implemented on any processor).

For a railroad looking to leverage the information available from devices that do not support an ITCSM embedded agent, a remote agent running on an x86 device is utilized to function as a protocol converter between ISMP and the other chosen protocol (e.g. SNMP). In an IP connected wayside environment, the remote agent could be implemented on a server located in the back office or elsewhere on the network. For wayside installations which include a WMS, the remote agent can be implemented directly on the WMS itself. This offers the additional benefit of hosting remote agents for other devices – especially COTS devices - that may have information useful for management purposes.

PTC OPPORTUNITIES

According to the FRA, the North American rail industry has spent more than $8B implementing PTC to date as they complete half of the required segments. As a cornerstone innovation to improve safety the initial implementation phase will certainly impact operational performance until the systems are operationalized and reliability equilibrium is reached. The investment can be leveraged by using it as a network infrastructure for operational data to drive visibility and improvements beyond the pre-PTC levels.

One of the benefits of PTC will be to improve the real-time awareness of the network. Incidents and events will be triggered automatically and teams can draw attention to those areas, hopefully before they become serious. This approach is part of what is referred to as operational intelligence and usually linked to physical security and safety aspects. Once these events are identified they can be operationalized and used to predict when they are likely to occur and take corrective action.

Another important opportunity is the ability to increase train headway. By reducing the operating complexity for operators, trains could safely run closer together, increasing the capacity of the existing network. To accomplish this the system needs to demonstrate reliable operations with reliable and credible systems that detect problems before they lead to incidents and emergencies.

Once these optimized systems are fully operational and free of false positives, the opportunity to build autonomous behaviors will increase, by continuing to limit the operating complexity and risk to human life due to human error.

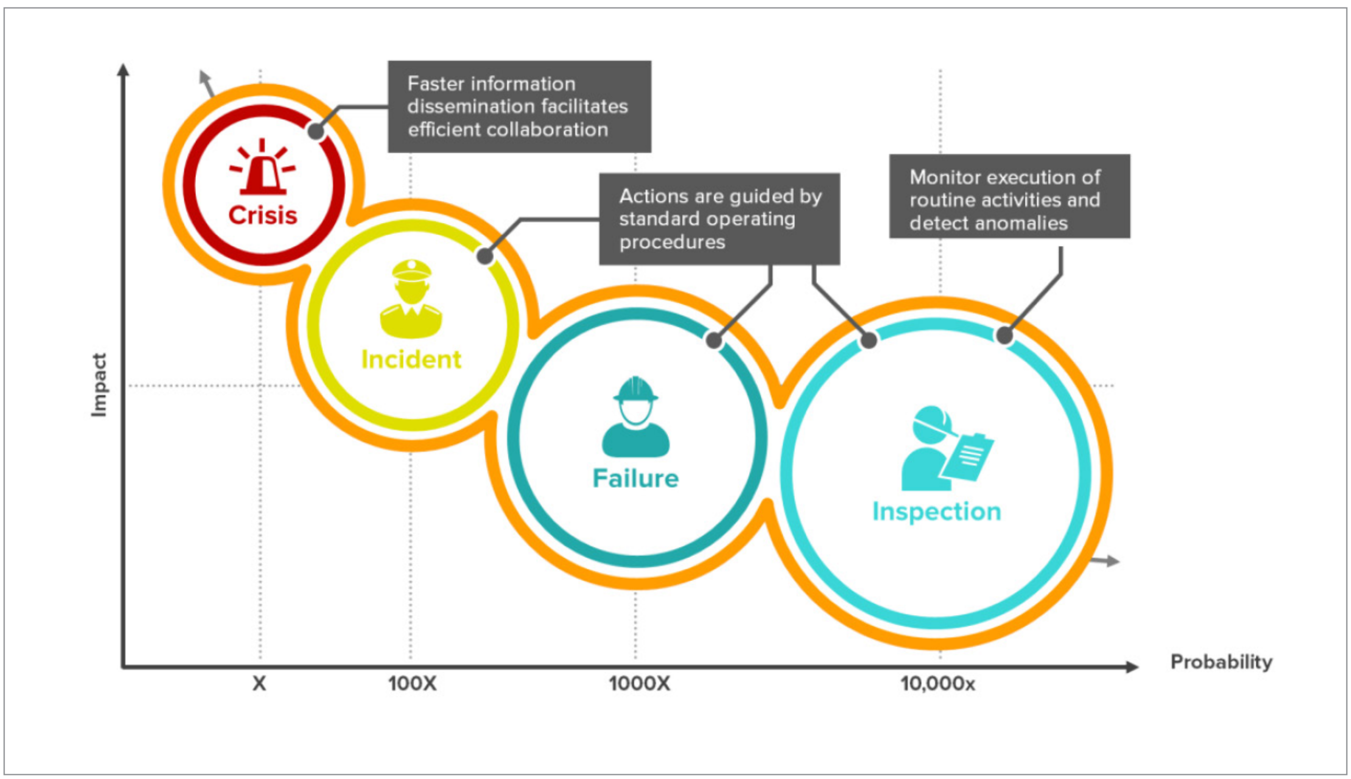

Figure 2: Using operational intelligence to avoid emergencies by responding before events escalate.

REAL-TIME OPERATIONAL INTELLIGENCE

Rail companies are starting to design and build real-time information infrastructures like those in other critical infrastructure industries to meet their data challenges. Looking to consultants, new technology providers and legacy service providers, who are themselves are often digitally immature, instead of more digitally mature industries to help save time, effort and money by not making the same mistakes that has taken years for others to learn.

Hard lessons other industries have learned:

- Invest in an enterprise scalable data infrastructure before applications – Create one version of the truth and avoid the impossible task of integrating dynamically changing business applications together.
- Bring Operations and IT together – Tightly integrate people and processes with the data, feed favorite user tools and standardize across groups wherever possible.
- Enable decision making in business real-time – as data shifts to real-time you won't need to change your architecture.
- Steer clear of custom solutions – Use a COTS solution wherever possible and fill whitespace as needed.
- Follow Critical Infrastructure Protection (CIP) security best practices – Leverage the edge with secure zones (DMZ's) creating cyber and physical barriers. Not currently required by DHS, but the need is there and will be if steps are not taken.
- Promote and leverage partnerships and ecosystems to fill white space and limit integration investments.

There are six main business challenges addressed by an operational system of record (SOR) needed to achieve operational excellence. Each of these are moving to advanced analytical methods to achieve more predictable outcomes:

1. Performance Optimization
2. Service Quality – On-time Performance
3. Asset Condition and Health
4. Environmental Resilience and Compliance
5. Energy Utilization and Management
6. Safety and Security

In the 1990's, electric transmission companies found ways to increase the capacity of the existing infrastructure using asset time-series data to mitigate on-line failures and identify increased capacity. The resulting mitigation & increase allowed them to put off massive capital investments to increase capacity to this day. The same technology provided a digital barrier for cyber security threats and their ability to meet the NERC/FERC requirements mandated in the early 2000's and the agility to deploy smart metering, enabling them to balance the "smart grid" in real-time today. The same infrastructure is poised to incorporate dynamic renewable energy to meet the environmental challenges of the future with demand response approach to grid balance.

ENTERPRISE OPERATIONAL DATA INFRASTRUCTURE

Digital systems have a unique paradox, some parts change very quickly and others change very slowly, based on their life cycle. This creates a unique challenge for technologists. How can assets and systems with long life cycles (sometime 40+ years) be supported with technology that has a very short life-cycle (6-12 months)?

The logical approach is to create abstraction layers in the information infrastructure that allow component on either side to change without having to change the architecture and re-integrate each time it does. This allows agility in the system so that a new signaling system, an Industrial Internet of Things (IIoT) platform, Enterprise Asset Management or a new Enterprise Resource Planning (ERP) systems can be deployed without a major change to the enterprise architecture. This is also true for operating processes, which often are constrained by rigid GAP compliance. The resulting agility also builds digital engagement with operational stakeholders who are empowered by data to evolve their operating models.

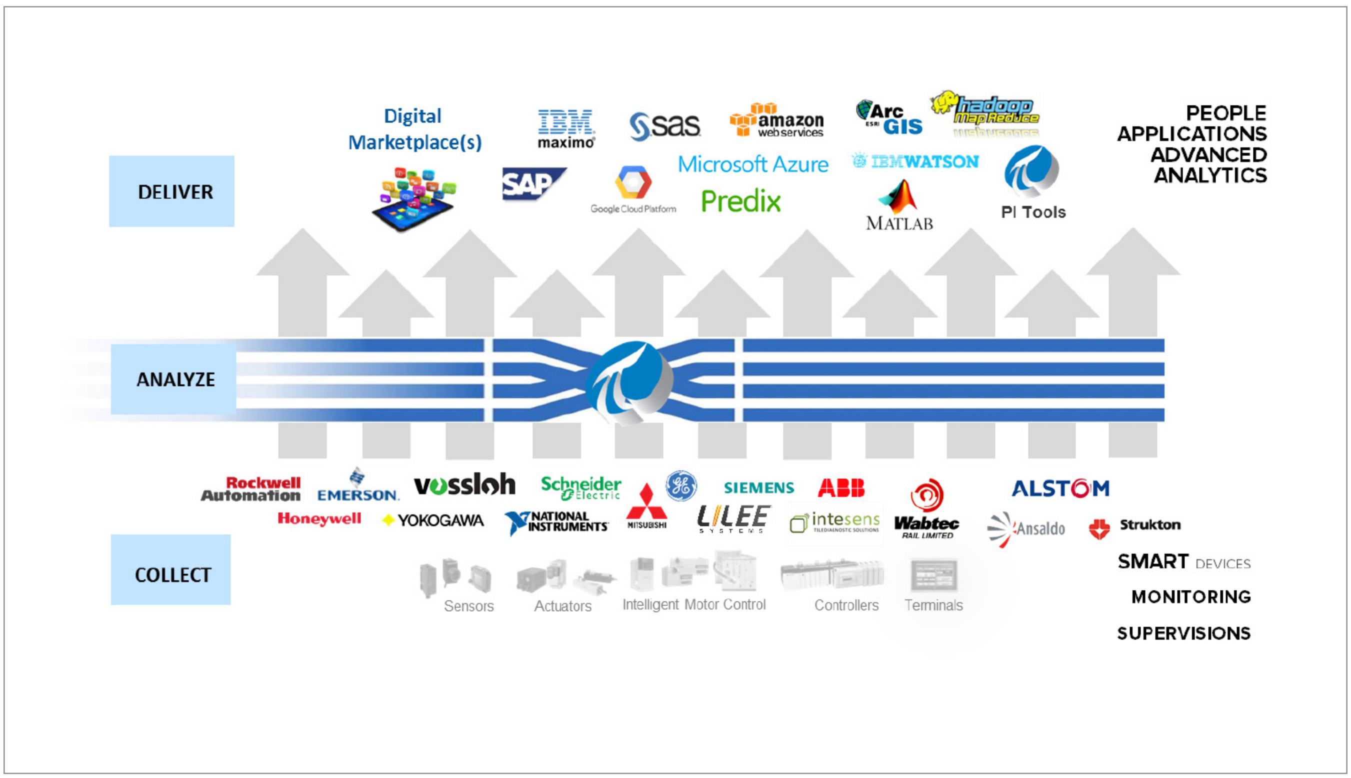

Figure 3: Operational Data Infrastructure – Bringing desperate data sources into applications.

Today there is no shortage of applications, technologies and tools aimed at this challenge. Each has its own approach to the problem with the promise of operational intelligence with big data.

Most require an IT project to deploy with little opportunity for the user's ability to manage the information system and service their own information, data mining and reporting needs. Other COTS technology for device management, BI, and other big data tools are being used to address the challenges of PTC. Still others such as BI (Microsoft, SAS, IBM etc.) and Predictive Analytic Tools (Falkonry, Element Analytics, Spark Cognition, Seeq, Predicts, Pattern Discovery, Predickto, Watson etc.) are already being used by business units to deal with the data they already have. They will want to use them against additional operations data whenever practice as well.

Complex data sets from track inspection, wayside and rollingstock equipment (LIDAR, Vibration, Acoustics, X-Ray, Video etc.) can also be used with the use of more elaborate analytics, by extracting digital signatures and features into streaming data that can be managed as virtual sensors with indexes back into it original data sets. This approach can be used at the edge or centrally based on the edge computing requirements and long-term archiving of the raw data set.

BRINGING IT ALL TOGETHER

OSIsoft has been a trusted partner in delivering Real-time Operational Intelligence to 65% of the Global Fortune 500 operating companies. Considered the gold standard in Critical Infrastructure Protection (CIP) applications such as power, water and gas utilities as well as chemicals, pharmaceuticals and data centers. Enterprise historian technology has been successfully delivering operational intelligence for over 30 years, by creating a detailed (signature) record of sensor-based data and events that create an operational system of record (SOR), driving continuous improvements and providing robust, secure, scalable real-time information systems.

Our COTS software called the PI System has been installed at over 20,000 operations centers supporting half a million users across more than a dozen industries in 127 countries. Currently being deployed network-wide at one NA Class 1, one SA Class 1, two EU national systems and one Japanese Railway to deliver on operational intelligence for real-time asset condition monitoring and environmental compliance.

The PI System collects data from a wide range of data sources and normalizes them into a unified metadata layer that matches the operating model. Raw data can be enriched with analytics using combinations of sources to extract more actionable information.

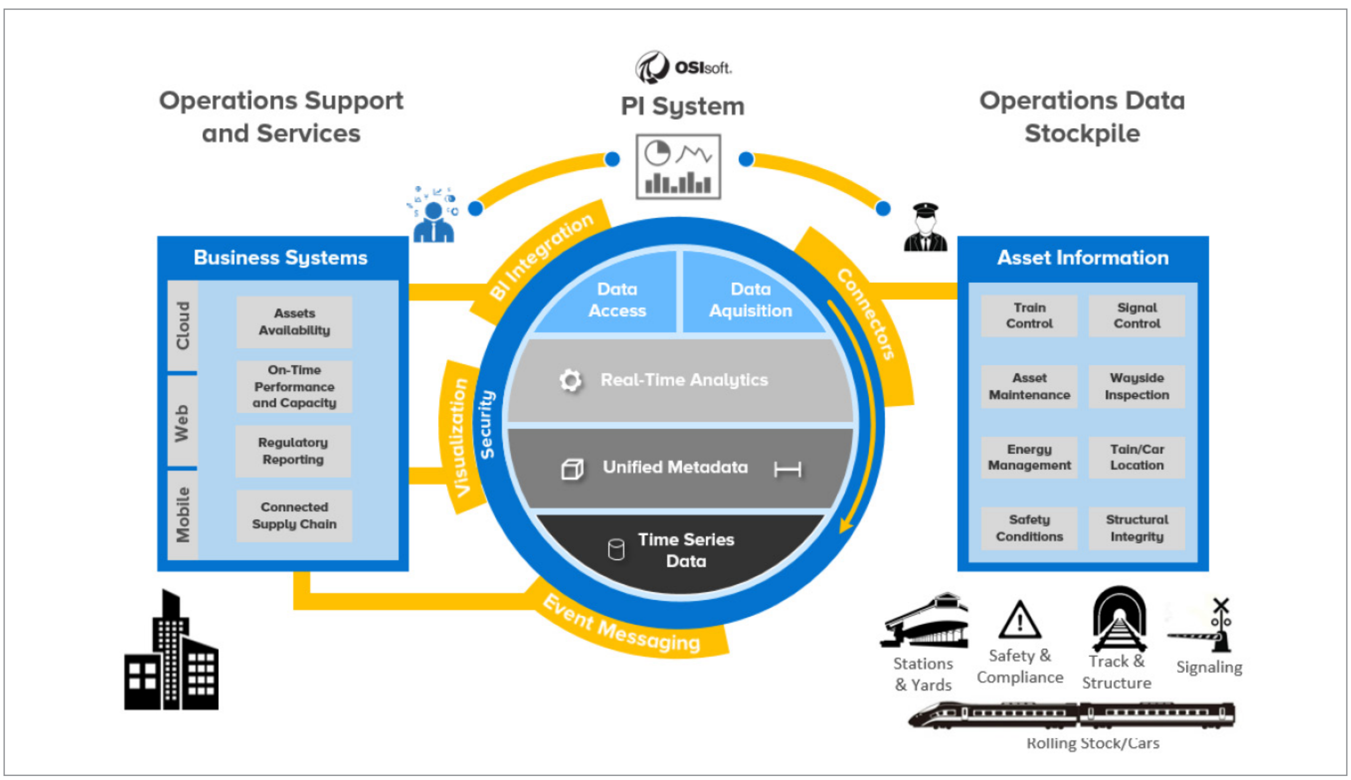

Figure 4: High level architecture of the PI System in Railways

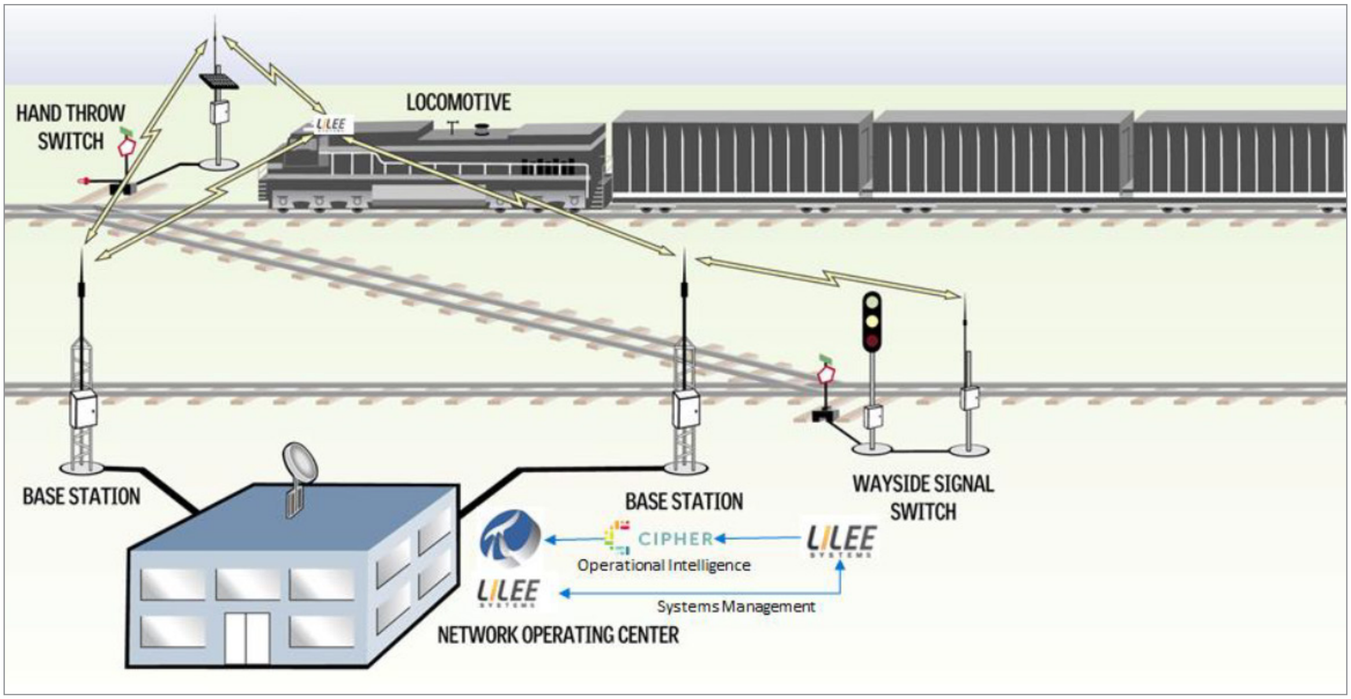

Figure 5: Diagram of PTC Operational System with Systems Management and Forensics

For PTC and ATC systems this means more than just the control systems and essential radio gear — it needs to have this data in conjunction with supporting information to get a full digital picture. Data from power sources, weather, satellite and terrestrial networks, locomotive and wayside equipment information combined with the device and network management tools to ensure reliable operations.

*Working with **LILEE Systems** and **RtTech**, we have demonstrated how these systems would work with COTS technology like the PI System to deliver PTC Forensics and unlock the potential for operational excellence and predictive analytics.*

The PI System can be deployed out of the box as an operational technology (OT) implementation for use by rail line of business owners. The PI System software components will allow a railroad to deploy an agile solution in a manner that best suits roadmaps, schedules, and needs. For example, it may be preferred to start with a proof of concept or with one or more projects and build out from there.

Figure 6: Example of PTC data viewed through PI System Client PI Vision

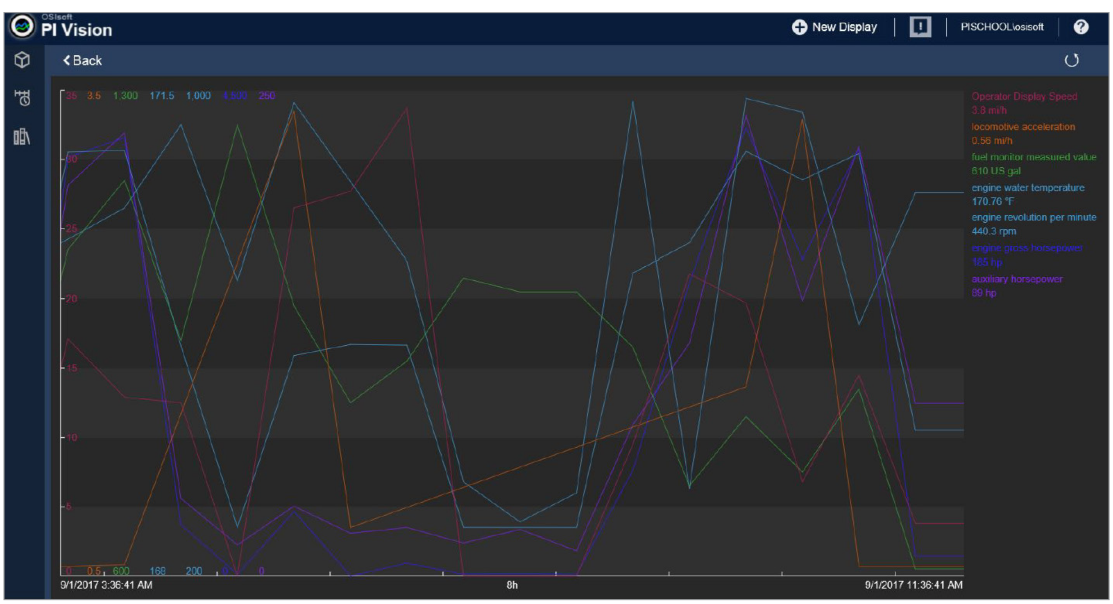

Figure 7: Trend of key parameters around a PTC event

Perhaps an approach is to correct currently deployed traditional IT tools/architecture, thus mitigating some risk while meeting the short-term objectives. Then, the system can be scaled out in both size and functionality with an enterprise deployment of the PI System to truly achieve PTC Operational Excellence. After PTC commissioning and refinement, the enterprise data infrastructure deployment can be built out of the PI System with the addition of real time condition-based maintenance and enterprise asset management programs across all PTC and non-PTC rolling stock and infrastructure assets. Finally using information to build a data-driven ecosystem for intermodal and railway-to-railway data sharing via connected services deployment(s).

Proving this technology can deliver needed operational intelligence for PTC and non-PTC assets will provide the fuel to increase safety and capacity in the next generation of rail operations. OSIsoft and our partners are demonstrating the ability of the PI System to provide this capability and many others as a powerful enabler to the digitalization of rail.

If you are interested to find out how this approach can help your organization, please email us for a demonstration or a digitalization workshop to better access the ability of your organization to get value from the data you have.

MORE INFORMATION IS AVAILABLE FROM THE FOLLOWING WEBSITES:

www.osisoft.com/transportation/rail/

www.lileesystems.com/ptc

www.rttechsoftware.com/en/cipher

ABOUT OSISOFT

With the belief that people can improve process efficiency, manage assets and mitigate risk if they have access to the data they need, OSIsoft created the PI System as a common data infrastructure to capture and store real-time data and make it available however and wherever needed. For over 30 years, OSIsoft has delivered the PI System with the singular goal of creating a common data source to connect enterprise data with people making decisions and solving problems.

Today, the PI System is trusted to do just that. Processing over 1.5 billion data streams across 19,000 sites, the PI System is embedded in operations and critical infrastructure in over 125 countries. Our customer base includes Fortune 100 and Fortune 500 companies in power generation, oil and gas, utilities, metals and mining, transportation, critical facilities and other industries.

To see any of the 1100+ customer success stories, product descriptions or global initiatives, please visit www.osisoft.com.

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