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## Things making things

How equipment manufacturers can use MindSphere to unleash new business models

### Executive summary

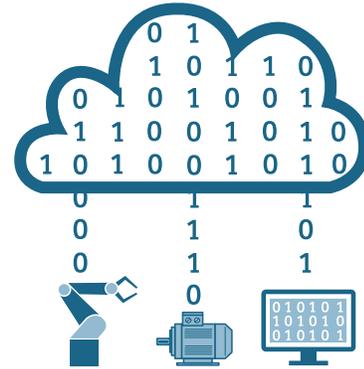
MindSphere, the cloud-based, open Internet of Things (IOT) operating system from Siemens, enables industrial manufacturers to link their machines and physical infrastructure to the digital world easily, quickly and economically. They can harness data from virtually any number of intelligent connected devices, enterprise systems and databases to analyze and uncover transformational insights, enhance their offerings and launch new business models.

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# Abstract

By 2025, experts expect that the Industrial Internet of Things (IIoT) will provide a \$4.6 trillion opportunity for the world's industrial operations to upgrade and add value to the global economy. This reflects the trend toward digitalization just about everywhere, thanks to technology advancements. For original equipment manufacturers (OEMs), the digitalization trend coincides with industry's need to generate value from infrastructure – even aging ones – by making it data- and connectivity-ready. This paper describes how OEMs can align these trends and capitalize on them using MindSphere, the cloud-based, open IoT operating system from Siemens. Capable of being rapidly deployed, MindSphere provides users with powerful analytics and fleet management tools, with access to a fast-growing number of MindSphere application programming interfaces (APIs) and applications to boost the performance and optimization of their machines, create new revenue streams, enhance their company profitability and extend their competitive market advantages.

This white paper explains how OEMs can think expansively about building innovative solutions, even new services-led business models, to take advantage of cloud-based technologies. It then provides an overview of Siemens' MindSphere, the cloud-based, open IoT operating system that enables OEMs to make their vision a reality.



# Moving toward a dynamic, forward-looking vision

More and more, OEMs are starting to face a fundamental and growing challenge to their business models: Equipment lifecycles are becoming increasingly compressed, resulting in shorter timeframes to capitalize on and profit from their products. Compounding that challenge is the task of keeping machine firmware and software fresh and secure to help ensure their customers can utilize their equipment assets to the fullest extent possible. Figure 1 illustrates this phenomenon.

Most OEMs understand that their customers buy machines to accomplish a task. Draw oil from the ground. Drop an engine into a truck. Put soda in a bottle. And so on. What many don't realize is the extent to which higher-level, data-driven software applications are – or could be – driving that task. Understanding this phenomenon is important to imagining how autonomous manufacturing will work.

For example, in an IIoT setting, manufacturing execution systems (MES) may be getting their commands from enterprise resource planning (ERP) systems. These, in turn, could be receiving preset demand signals via an electronic data interchange (or a web app) that is tied into a retail chain's ERP. The latter monitors unit sales at cash registers to know when more product will be needed on a particular store's shelves.

This kind of demand-driven manufacturing can also be combined with mass customization scenarios. Consider how a truck might move down the assembly line, being built for a particular customer, perhaps an individual or a fleet owner. The robotic machine dropping in the engine can know whether that truck needs a six- or eight-cylinder motor under the hood, and pull the right one from an automated guided vehicle that brought it from stock.

Point is, conventional OEM thinking sees a piece of equipment, even one as sophisticated as a multi-axis computer numerical control (CNC) machine, as a stand-alone part of the industrial customer's production landscape with its inputs and outputs as part of a factory's production flow.

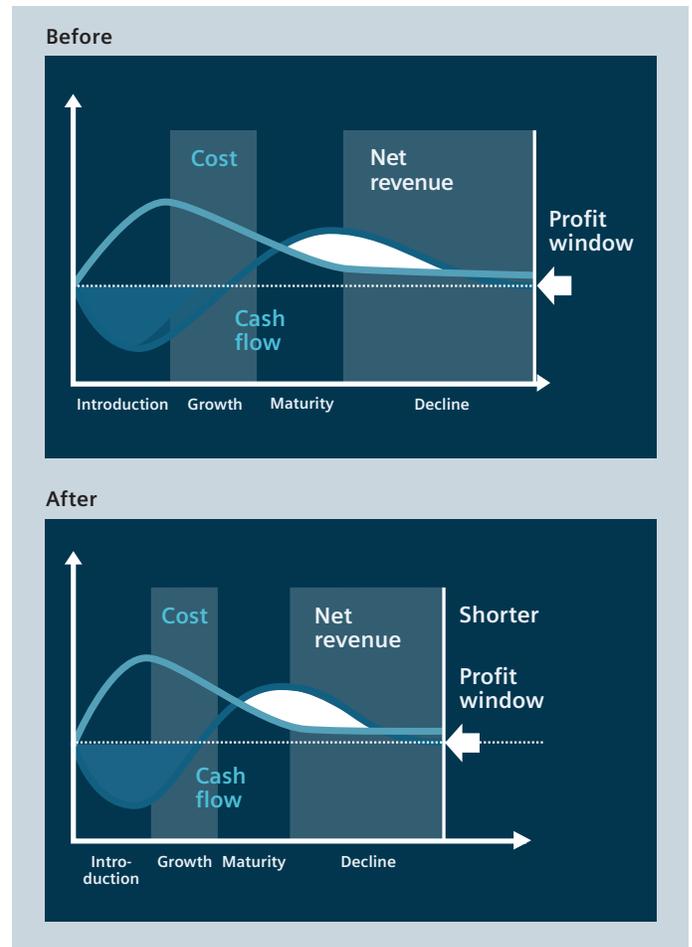


Figure 1: As equipment lifecycles shorten, so do their profit windows, requiring OEMs to minimize service and warranty costs while maximizing profitability.

In contrast, a forward-thinking OEM sees it as a means of providing outcomes that industrial operators use in their value-adding missions to serve customers better than their competition. After all, someone walking into a hardware store looking for a one-quarter-inch drill bit isn't really looking for a one-quarter-inch diameter metal rod machined with a sharp, spiraled edge; they're looking for the outcome of operating that drill bit: a

one-quarter-inch hole in whatever material they're working with.

To succeed in a world heading toward autonomous manufacturing, OEMs must think differently, turning from a product-focused mindset to a user-centric one. As users, OEM customers prefer to minimize capital expenses in favor of operating expenses. They don't want an air compressor; they want compressed air. Again, it's the outcomes they want, not necessarily the means. That's why forward thinkers will next consider how they can build more capability into their machines to support this user-centric perspective, and it usually involves taking advantage of the data that those machines generate.

How can OEMs do this? Through advanced analytics at the edge and in the cloud to help plant operators better manage variability – especially in mass customization scenarios. Here are other ways that OEMs can use MindSphere to benefit both their own operations and those of their industrial customers:

- **Increased service efficiencies**, while lowering warranty costs with condition-based, predictive maintenance and cloud-enabled remote diagnostics that can reduce or eliminate technician visits
- **Enhanced product features and capabilities** through real-time performance data feedback to OEM R&D groups as actionable intelligence to better align product design and virtual digital twin models with actual product performance
- **Added services**, such as monitoring performance and tooling wear with fleet management solutions, to generate incremental, high-margin service revenues to build the OEM's bottom-line profitability
- **Innovative business models**, such as offering a machine's operating services on a time-metered basis, enabling OEMs to capture asset depreciation for their own balance sheet and tax-accounting purposes

OEMs can use MindSphere to invigorate their value propositions with innovative data-driven features, capabilities and services that may not have been possible before – or were cost-prohibitive, if they were. Microsoft founder Bill Gates started his \$90 billion fortune on the simple but profound realization that the real value of PCs wasn't in the hardware, but in the software. The good news for today's OEMs, no matter what their size, is that Siemens' MindSphere can provide them with the ability to make good on this same insight for their businesses.

### Modernizing decades-old industrial infrastructure – today's imperative

While McKinsey suggests the OEM IIoT opportunity is huge, Siemens' own research echoes that notion with an estimate that only three percent of the world's plant machines are monitored. That's because so much of the world's industrial capacity involves outdated infrastructure, much of it decades old with limited digital electronics or communications features, if any.

In the years since so much of that legacy equipment was installed, technology advanced by one measure more than 1,000-fold. In 2016, for example, Intel released its 22-core Intel Xeon Broadwell-E5 chip with 7.5 billion circuits, while 20 years previously, its flagship Pentium II chip carried "only" 7.5 million circuits. And costs have fallen by just about as much or more.

Taken together, technology advancements have spurred other innovations. Circuit densities have enabled smart sensors to pack a lunar lander's worth of processing power and capabilities in tiny form factors. Programmable logic controllers (PLCs) can do more work than ever, including integrating safety features that once required their own plant networks. Advanced analytics can process not only structured data in databases, but also unstructured data from text and video inputs. In fact, supercomputer-scale parallel processing can now analyze unstructured data sets that are terabytes in size.

In software, similar innovations have taken place. Developers have enabled machine learning – the ability for machines to learn without being explicitly programmed – and artificial intelligence (AI), which imbues computers with human-like behaviors. Machine learning algorithms, for example, are designed to improve their performance iteratively in milliseconds. This can help operators of plant equipment optimize cycle times and material use in minutes instead of requiring months of manual fine-tuning. In turn, it can lead to greater efficiencies with savings in production time and cost that can potentially be game-changing – delivering higher margins for greater pricing latitude or bottom-line profitability.

### Opening doors to new opportunities via the cloud

For OEMs, all these technology performance enhancements may or may not yet have found their way into their industrial equipment. To be sure, many machines don't need all this speed, processing power, storage and communications. If unconnected, embedding advanced software capabilities can make OEM machine products much more challenging to update, upgrade and support, especially from a distance. However, connecting

machines to networks can expose them to cybersecurity risks. While advanced capabilities might make machines more attractive to customers, doing so might make them less cost competitive.

So, what are OEMs to do? Standing still isn't an option. They should consider the cloud, especially one designed not for office, business and web applications, but for the world of industrial IoT: Siemens' MindSphere. With it, they can begin to help their customers' own digital transformations in these ways:

- **Optimize asset utilization** to deliver maximum uptime and availability
- **Increase maintenance efficiencies**, implementing predictive maintenance practices
- **Boost operational visibility** with condition-based monitoring
- **Leverage data transparency and centralized key performance indicators (KPIs)** for greater operational insights and accountability
- **Make possible new machine capabilities**, combining data analytics and asset fleet monitoring

By connecting industrial assets to MindSphere, OEMs can take advantage of how data drawn from the IoT is foundational to the transformation of manufacturing.

Consider the example of a wind turbine designed with Siemens PLM Software solutions. After the turbine is deployed, Siemens' software can be used to monitor and detect vibrations in its physical performance, then compare this operating profile to the simulations that were run during the turbine's design phase. Using this digital twin concept, the operational characteristics of the turbine in the real world can be compared against what the software says it should be doing, so adjustments can be made long before maintenance or repair issues might arise.

MindSphere can help OEMs extend this concept to their machines, improving performance, reliability and serviceability, while gaining a significant competitive edge over other OEMs that are not using the concept in their equipment offerings. Companies can now leverage MindSphere to close the loop through product ideation, realization and utilization to seamlessly integrate operational data throughout the value chain – not only driving operational efficiency, but also comparing simulation and test results with real-world observations.

### Expanding performance, scalability, visibility and insights with MindSphere

As a cloud-based, open IoT operating system, MindSphere offers OEMs market-specific applications and solutions. These are designed to eliminate much of the effort, time and expense of building sophisticated features and capabilities into their machines, such as turnkey analytics and fleet management tools that come standard with MindSphere. The cloud computing that MindSphere provides is already embraced by information technology (IT) groups in companies worldwide for digitally transforming many of their front-office and customer-facing business functions. That's because the cloud model offers:

- **On-demand IT infrastructure**, always updated and highly secure with virtually limitless scale and no bother with maintenance, patches, updates, security and other ownership chores
- **Capital expense savings**, plus savings in time, effort and skills to acquire, deploy, commission and maintain needed hardware
- **Flexible pay-as-you-go cost models** via consumption-based pricing helps OEMs to avoid up-front capital costs of hardware, while aligning costs with usage – a model that OEMs can pass through to their customers, too, as both a benefit and a competitive differentiator
- **Cost-effective access** to platform-as-a-service (PaaS) functions, such as high-performance computing, and software-as-a-service (SaaS) applications, such as advanced data analytics built on MindSphere

With the open standards and interfaces of MindSphere, OEMs have the flexibility to gather data and match their solutions with their customers' infrastructure regardless of whether the equipment was manufactured by Siemens or third parties.

# How MindSphere works

Siemens' MindSphere has a simple, three-tiered architecture:

**1. MindConnect, the connectivity layer** This secure layer – with both software and hardware options – links OEM machines to MindSphere. It enables programming of specific customer or use-case connectivity agents by interacting with MindSphere standardized APIs via the MindConnect LIB software development kit (SDK). These APIs facilitate data transmission from equipment assets to MindSphere while expanding protocol support.

In addition, MindConnect IoT Extension is an additional connectivity layer option that enables dozens of new IoT protocols to communicate with MindSphere. Examples include OPC Unified Architecture (OPC UA), S7, ModBus/RTU and ModBus/TCP, REST, MQTT and CANBus. By using a complete environment, OEMs can manage devices and further develop assets to interact with numerous supported field protocols, along with a wide range of hardware connectivity agents to bridge the gap for other protocols.

Alongside software, MindConnect solutions, the MindConnect Nano and MindConnect IoT2040 devices, are hardware connectivity solutions. These support industry standard protocols to facilitate data collection and transfer through interaction with PLCs and other sensors.

The Siemens S7 protocol, used for collecting data from S7-3xx, S7-4xx and ET-200 PLC models, is supported. In addition, OPC UA is supported for collecting data from all sources able to provide data via an OPC UA server that uses Part 8 of the OPC UA specification. Also, OEMs can leverage existing Siemens S7-1500 PLCs to connect directly to MindSphere and the digital world using a Totally Integrated Automation (TIA) Portal STEP 7 library. The TIA Portal STEP 7 library extends the function of the S7-1500 PLC to transmit PLC data to MindSphere.

Using Manage MyMachines, a MindApp, computer numerical controls (CNCs) such as Sinumerik 840D sl and 828D can be seamlessly connected to MindSphere by means of encrypted communication

over the internet. This provides shop-floor managers, machine-tool operators and maintenance personnel a cloud-based overview of key data and operating status across all connected CNC machines.

In addition to asset connectivity, MindConnect Integration offers a secure way to connect multiple data systems to MindSphere, such as enterprise solutions, ERP and MES systems, legacy applications and supervisory control and data acquisition (SCADA) systems. Browser-based tools can be used to graphically configure data value mapping, helping OEMs to build flexible integrations that bring enterprise systems, whether residing in a cloud or on premise, into context with MindSphere.

**2. MindSphere, the operating system** MindSphere is hosted in highly secure cloud provider data centers, namely Amazon Web Services (AWS). It enables OEMs and their customers to develop, run and manage applications without the expense, effort or complexity of building infrastructure or managing complicated software stacks.

MindSphere is designed so that OEMs and their customers can choose cloud deployment strategies that best suit their needs based on cost, configurability, scalability, location and security.

With Siemens having deep domain expertise across most of the world's industries, and the global scale of AWS public cloud, OEMs can accelerate the IoT solution development dramatically. By accessing the MindSphere open lot APIs, partners can develop high-value applications and deliver digital services in collaboration with Siemens and AWS. Given open APIs, partners can develop, deploy and sell their own MindSphere solutions.

**3. MindApps, the application layer** MindSphere comes with a ready-to-use application as part of the core MindSphere offering: fleet manager. It provides an overview of assets configured in MindSphere so users can quickly search for all assets and focus on relevant issues based on user-defined parameters configured within fleet manager. Users are also able to configure rules to automatically monitor machines and create

follow-up requests, such as email notifications, when the operating parameters of a machine or fleet of machines reach a predefined state.

Fleet manager displays these notifications to users in intuitive ways. For example, a map view shows the geographic location of connected assets. In the detail view, users see the recorded data shown in different diagrams. Users can also define the timeframe for which the data is displayed and drill down deep into their data. To complement the fleet manager application, Siemens offers the visual analyzer as an option to provide rich data visualizations and complex algorithmic applications integrated in one user interface.

In addition, MindSphere provides additional tools to streamline data analysis and application development. For example, OEMs can design their own workflows for visualization, create rules and define trigger actions using a web-based editor. Using configuration-only mode, they can prepare data for further visualizations, including normalize, convert, change, aggregate, add variables and modify the data model. Following data preparation, they can define the KPIs, calculate and store the data.

MindSphere also provides open APIs and services to enable OEMs to develop and deploy software applications in an accelerated timeframe. MindSphere APIs draw upon Siemens' industry knowledge and the IoT to support the key business drivers for moving to an IoT solution. It supports integrated development environments, too, such as IntelliJ and Eclipse as well as integration with AWS native services. Over time, new functionality in APIs, analytics and tools will help OEMs enhance and expand the capabilities of their machines.

In addition, Siemens will use its broad domain expertise to continuously launch new MindApps across a range of industries. These MindSphere applications will be developed by Siemens and our partners. All MindSphere applications are available in the MindSphere Store where OEMs can choose from Siemens' applications or those developed from a broad and ever-growing MindSphere ecosystem of qualified, third-party software partners.

### Six ways MindSphere differs from other clouds for OEMs

1. Siemens is the only company to offer a total IoT to a complete end-to-end cloud operating system, from connectivity to the PaaS to applications and digital services.
2. Siemens' knowledge of manufacturing processes and automation technology informed the development of the MindSphere IoT operating system right from the start.
3. Plant operators know their own plants and machines better than anyone, so Siemens designed MindSphere as an open operating system for industrial IoT, enabling a choice in using other clouds and tools.
4. Users can quickly and efficiently analyze huge data volumes their plants generate, identify weak points, and achieve big improvements in production performance and availability.
5. MindSphere tailors connectivity for OEMs and their customers via built-in MindSphere ready software agents that can be installed on OEM machines as connectivity layers to expand protocol support, integration with multiple data systems, MindConnect devices and existing Siemens legacy hardware.
6. Following data ingest and analysis, OEMs can offer their end customers innovative digital services along with access to MindSphere applications to support these new business offerings.

## Securing data and connectivity from even the most advanced threats

Yet another MindSphere difference from other cloud-based solutions is industrial-grade cybersecurity, which is focused on operational technology. It's based on industry standards, such as International Organization of Standardization (ISO) 27001, International Electrotechnical Commission (IEC) 62443 and BSI, the German Federal Office for Information Security. Data at rest is stored on high-performance servers at AWS data centers. All meet the highest standards for data security, safeguarded against both cyber threats and natural disasters. Data in motion is always encrypted using 256-bit Secure Sockets Layer (SSL)/Transport Layer Security (TLS) encryption or better.

OEMs can use these rigorous security standards to help sell their solutions to industrial customers concerned about cyber threats, as all industrial operators should be. At the same time, OEMs and their customers need to ensure their own security measures, too, such as enacting defense-in-depth best practices. And both OEMs and customers can be assured that they own their respective data.

The MindConnect Nano, an example of a MindSphere hardware connectivity option, employs security mechanisms to connect and send data only to the MindSphere platform. It identifies MindSphere by validating its security certificate. Certificate and key management measures are applied to handle the certificates and keys used by the device. Importantly, the MindConnect Nano has no open inbound ports, which can keep out attacks from internal adversaries.

During the onboarding process, the MindConnect Nano must go through an authentication process with MindSphere. Once this is accomplished, the two entities agree on cryptographic keys for use in later communications. As a result, MindSphere is designed to receive data only from valid MindConnect Nanos, which have successfully completed the authentication procedures.

All communications between the MindConnect Nano and MindSphere are encrypted via the TLS 1.2 standard with an encryption key length of 256 bits. The TLS configuration is regularly checked to comply with the applicable Siemens information security guidelines. This helps guard against man-in-the-middle attacks or any manipulation of communication between the MindConnect Nano and MindSphere.

What's more, the MindConnect Nano has the following features to protect the integrity of the automation networks of OEM customers:

- **Only outbound HTTPS connections from the MindConnect Nano:** Only outbound HTTPS connections are established from the MindConnect Nano device to the MindSphere platform. The connection is always initiated by MindConnect Nano (and never by the MindSphere platform). The "outbound only" rule is followed even for firmware updates on the MindConnect Nano device
- **Separate physical interfaces:** The MindConnect Nano uses two separate network interfaces for connecting to the automation network and the external network. In addition, it also has an internal firewall to reduce the exposure of the automation network to the external network. The internal firewall is specific to the MindConnect Nano use case and cannot be configured by customers
- **Read-only access to automation systems:** All data acquisition drivers in MindConnect Nano have read-only access to the data sources. The device is not designed to modify any data or send any control signals to the data source
- **Security-hardened software:** MindConnect Nano software is based on a customized Linux operating system that is limited only to a set of components and services as required by the OEM's customer
- **Firewall-friendly connectivity:** The MindConnect Nano communicates via firewall-friendly outbound internet traffic over HTTPS. Only a single outbound port (HTTPS port 443) and a fixed URL need to be open at the firewall. No inbound port is required to be open
- **Proxy support:** The MindConnect Nano supports proxies for outbound traffic to the MindSphere platform. The proxy settings can be configured with the asset configuration tool in MindSphere
- **Off-boarding:** Off-boarding a MindConnect Nano stops data collection and detaches it from MindSphere

# Taking the next step toward achieving a digital transformation

The trend toward digitalization of the world's industrial plant facilities is unstoppable. First, operators simply have no choice but to modernize rapidly aging infrastructure if they are to stay profitable and competitive. Not only are the operational costs of outdated machinery mounting in terms of more frequent maintenance, repairs, onsite replacements and hard-to-find spares, but also the engineering and maintenance know-how is quickly retiring – the “grey tsunami,” as it's called. What's more, there are opportunity costs associated with using old machines when newer ones can do the work faster, better, cheaper and, in many cases, with a smaller footprint.

Second, the ability to mine data from the IIoT for quantum gains in operational transparency and productivity is now practical and economical for all sizes of plant operators. That's especially true given a quick and easy, pay-as-you-go cloud model, such as what the Siemens' MindSphere cloud-based, open IoT operating system offers. And, with this model, they can gain IIoT capabilities, while eliminating the capital and maintenance expenses that hardware infrastructures require, making sure security and upgrades are always done, and gaining a flexible, usage-based cost model.

For OEMs, the digitalization trend promises huge potential paydays. And Siemens' MindSphere can help them capitalize on it, no matter their size. It can help open doors to new markets they might not have been able to afford to consider before, including international ones, thanks to the global reach of the cloud. And MindSphere is backed by Siemens' sales and professional service footprint as well as a world-class global partner ecosystem in nearly every country in the world.

If you are among those OEMs who could benefit from incorporating Siemens' MindSphere (the cloud-based, open IoT operating system) in your machines, we invite you to contact your local Siemens representative or global partner, or visit the MindSphere website to learn more. It's designed and built for industry and OEMs.



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