SAP Leonardo Internet of Things

SAP® Leonardo Internet of Things: Business Outcomes in a Connected World

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From the Internet of Things to Digital Transformation

The Internet of Things (IoT) is often mentioned as a **key enabler of digital transformation**. The notion of embedding sensors in machines with connectivity to transmit data has evolved over the past decades. More recently, the costs of sensors and power consumption have dropped, while connectivity has grown ubiquitous and Internet protocols have proliferated. The result is that every "thing" – from industrial equipment to every imaginable consumer product – is now connected and sharing data.

At the same time, cloud and Big Data technologies help efficiently ingest, store, process, and analyze large volumes of data. The most obvious approach is to send all or a relevant subset of IoT data to the cloud and apply sophisticated analytics, data science, and machine learning to help detect anomalies, identify issues early, predict failure, and optimize machine operations. "Intelligent edge solutions" keep data processing at the edge of the network while addressing latency, relevance, and security.

Business value beyond connectivity and IoT data insights requires integration between the IoT and the business. Remaining lifetime calculations create a dynamic maintenance scheduling process, which includes time-of-arrival forecasts to improve logistics operations and early detection of product issues to increase service delivery effectiveness and customer satisfaction. In most scenarios, IoT data is made available to different departments within a company for a variety of decision needs. Information on product usage and quality can be used by engineering, manufacturing, field services, maintenance, and sales teams. At this stage, IoT projects focus less on technology and more on better ways to enable desired outcomes. Organizations are beginning to rethink their business model – from selling products and after-sales services to providing entire products as a service. In the long term, this exercise will fundamentally affect asset operations and management accounting.

In today's networked economy, stakeholders for IoT data no longer sit within corporate or industry boundaries. Third-party service technicians and asset operators, insurance and financial services providers, regulators, customers, and suppliers jointly deliver value within the business network. Data usage and sharing rights will be governed by corporate contracts; however, data access authorizations need to be derived automatically from underlying systems. Live representation of the physical object or a digital twin can be valuable concepts when abstracting operational technology and building applications on top of a digital platform. In this scenario, the IoT opens the door to new data-driven business models that connect digital twin providers and consumers.

The use of machine learning in the cloud has quickly evolved to detect and identify anomalies, automate processes, and provide prescriptive problem resolution. At the same time, devices at the edge will become increasingly intelligent and interact with users and other devices such as autonomous vehicles, robots, or drones.

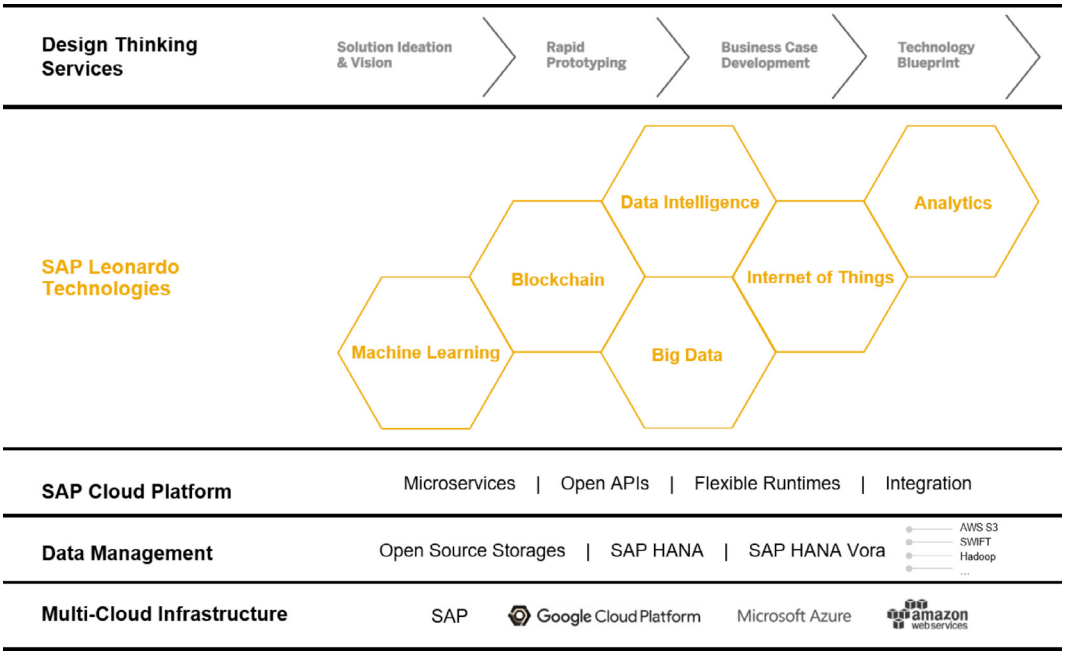
Furthermore, successful transformation requires collaboration and an ecosystem of partnerships at various levels. This closes the loop from connecting things to processes and people and lays the foundation for digital transformation.

SAP has launched the SAP® Leonardo digital innovation system to deliver innovation at scale and help organizations transform themselves to unleash sustainable value in a connected, digital, intelligent, and networked environment. Figure 1 shows how we combine IoT technology with processes to take advantage of digital transformation and increase business value. SAP Leonardo Internet of Things (IoT) capabilities connect things to people and processes, allowing you to transform your processes and business models to a digital environment.

Designed to securely ingest large volumes of data and to provide visibility and insights using data science and machine learning, SAP Leonardo IoT capabilities are integrated in SAP Business Suite software and SAP S/4HANA®. In addition, SAP Leonardo IoT is open to other business and operational systems through standards-based APIs.

SAP Leonardo IoT capabilities are extensible for customers and partners through SAP Cloud Platform and scale according to the needs of customers. The following sections describe proven IoT-enabled use cases in detail, present the IoT solution portfolio from SAP, and demonstrate how SAP Leonardo accelerates time to value.

Figure 1: SAP Leonardo Digital Innovation System



Use Cases for the Internet of Things

The IoT provides the opportunity to deliver a large economic impact. Five use cases for intelligent products, digital assets, connected manufacturing (Industry 4.0), connected vehicles, and the "Internet of Everything" are commonly adopted by companies across different industries.

INTELLIGENT PRODUCTS

Consider a manufacturer of commercial or industrial goods that is building an established after-sales business with support, repair, and spare part services, accounting for 30% to 40% of total revenue. Through intelligent products, the company can realize additional value along the lifecycle of a product.

To get started, most manufacturers improve services efficiency. Intelligent products enable more proactive issue resolution with remote diagnostics. The right resources – from service technicians to tools and spare parts – are quickly dispatched and find the right solution by using historical and actual data recorded in the digital twin. A joint view of the digital twin for customers and staff is integrated with a field services solution, while remote support from manufacturers simplifies collaboration.

API-based access to IoT data helps create mobile apps and conversational interfaces for field services and remote support staff. Meanwhile, proper access rights to critical data are ensured. These experiences can be augmented with virtual reality, live video streaming, virtual repair and assembly views, or prescriptive instructions.

As manufacturers strive to differentiate themselves in the market with additional services, intelligent products allow the development of data-driven business models and the use of value-added services such as benchmarking, machine optimization, and prescriptive maintenance. New product-as-a-service business models based on actual product usage or consumption can be developed to drive revenue and margin.

Customer Story: Providing Air As a Service

A provider of a wide range of industrial equipment installed sensors in its compressors to collect data, analyze it in real time, and create a new revenue stream based on consumption. Instead of generating revenue by selling compressors, the company is using SAP® Leonardo Internet of Things capabilities to sell compressed air by the cubic meter through an air-as-a-service business model. At the same time, product development and services are aligned with customer needs as the company continuously analyzes data generated by its compressors.

Based on usage information and condition monitoring, the sales or service department of the manufacturer can take a proactive approach to fixing components before they reach the end of their life or break and to recommending the right replacement product.

While most manufacturers have digitalized design documents such as CAD and product lifecycle management and use CAE or CAM for engineering purposes, access to IoT data from the operations phase provides a different level of customer insight. Continuously ingesting and analyzing data not only allows improved product design based on actual usage but also delivers immediate feedback to gain insight into potential warranty issues. At the same time, engineering can evolve the edge capabilities of equipment by using embedded systems and systems engineering techniques to lay the foundation for additional value-added services or product-as-a-service business models.

HIGHLIGHTED SOLUTIONS

SAP Connected Goods software helps maximize the value of products – everything from raw materials to semifinished and finished products. It does this through insights derived from key indicators as to where, how, and how much the products are stored or used (for example, in containers, silos, coolers, or other receptacles). The solution combines sensor data with back-end systems and support for business processes to improve efficiency and automation as well as provide "insight to action." It digitalizes use and consumption insights and enables the creation of new product-as-a-service models.

DIGITAL ASSETS

An operator of an asset strives for overall equipment effectiveness and operational efficiency while improving asset performance and reducing maintenance cost. Managing risk and safety are equally important in many industries. Most industrial assets are built or assembled from individual products and require a holistic perspective.

With a strong focus on efficiency, condition monitoring provides real-time visibility into the state of an asset during operations and allows operations staff to react immediately to any anomaly, continuously improve, gain insight, and predict potential issues. For the maintenance crew, predictive maintenance delivers asset health scores and remaining lifetime information on a component level. However, most components are not inspected, maintained, and repaired individually. Instead, they are part of scheduled maintenance that includes resource allocation for people, tools, spare parts, and potentially workshop space. Moreover, maintenance windows need to be aligned with operations phases.

Customer Story: Reimagining Maintenance and Improving the Traveler's Experience

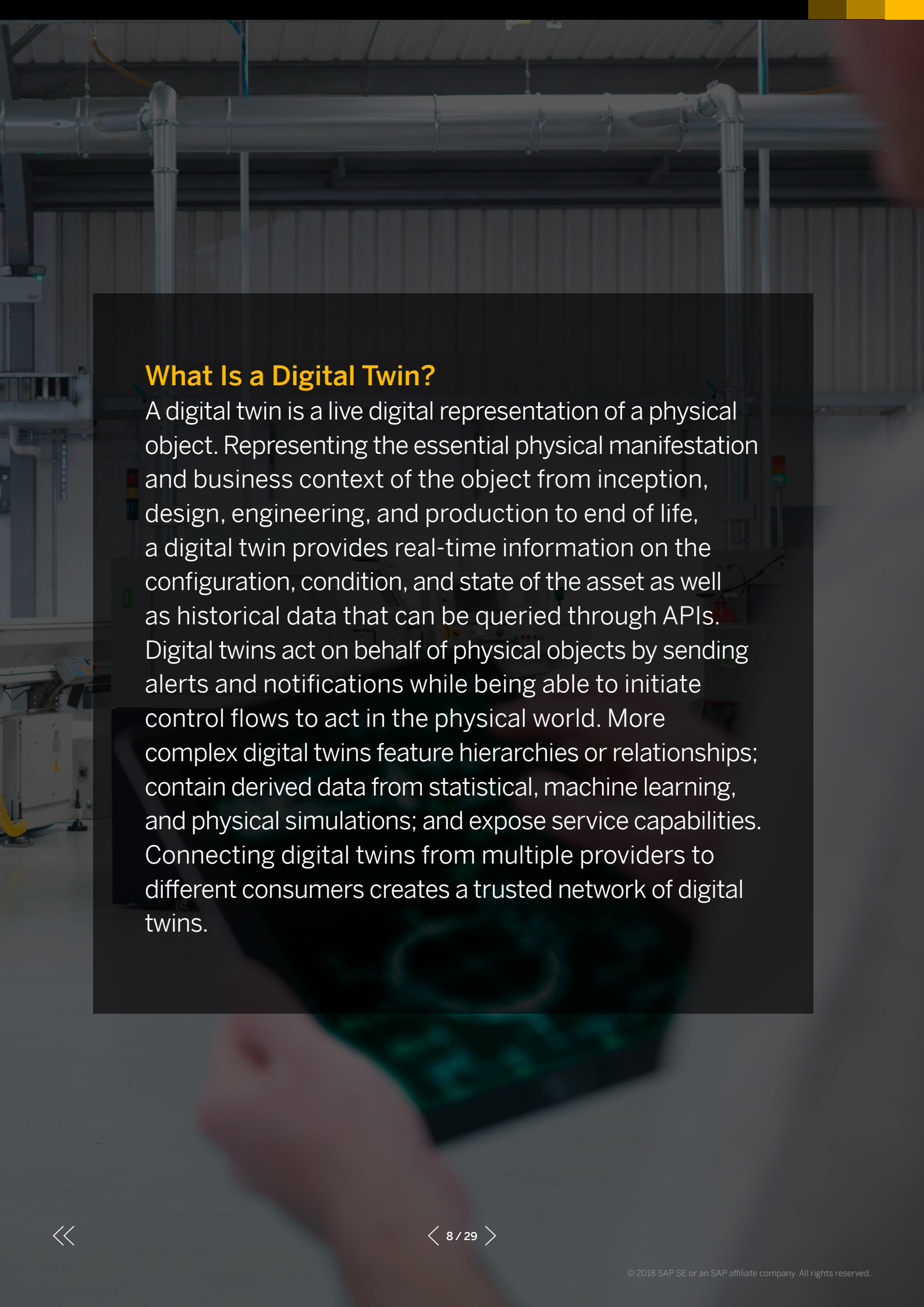
One of the main reasons for late trains is unplanned maintenance, which consumes significant costs, time, and labor. Serving more than 2 million passengers every day, one of the world's largest train operators decided to rethink how it manages train maintenance. Rather than fixing failures when they occur, the company favored a maintenance model with a more dynamic approach. By gathering information from sensors embedded in various areas of each train such as doors, motors, batteries, and brakes, the maintenance shop gathers and analyzes a huge amount of data to avoid downtime and predict train-machine failure before it happens. With SAP® Leonardo Internet of Things capabilities, the train operator lowered maintenance errors, increased train availability, improved customer service, and reduced expected maintenance costs by 8% to 10%.

"We strive to provide our customers with an enhanced travel experience by investing in high-tech solutions that enable a more efficient, sustainable, and fast journey. The cooperation with SAP is part of this strategy and helps us to provide better services, with a strong reduction of industrial costs."

– Barbara Morgante, CEO, Trenitalia

Using historical data, operators can take a data-driven approach to asset disposal or reuse. During the planning phase, data allows the simulation of asset performance and detailed assessment of risks, complementing and enhancing traditional reliability engineering methods. While emerging product-as-a-service models promise higher services share, operators adopting these models will need to access digital twins to define service definitions and service-level agreements.

The digital twin for digital assets also serves as the central integration point for various stakeholders working on or with the assets. This approach includes not only operations and maintenance staff from the owner and operator but also external service providers and contingent workers, insurers, and other financial service providers. In the case of asset-as-a-service business models, the digital twin becomes the handover point between data used to provide services and data used for managing end-to-end operations.



What Is a Digital Twin?

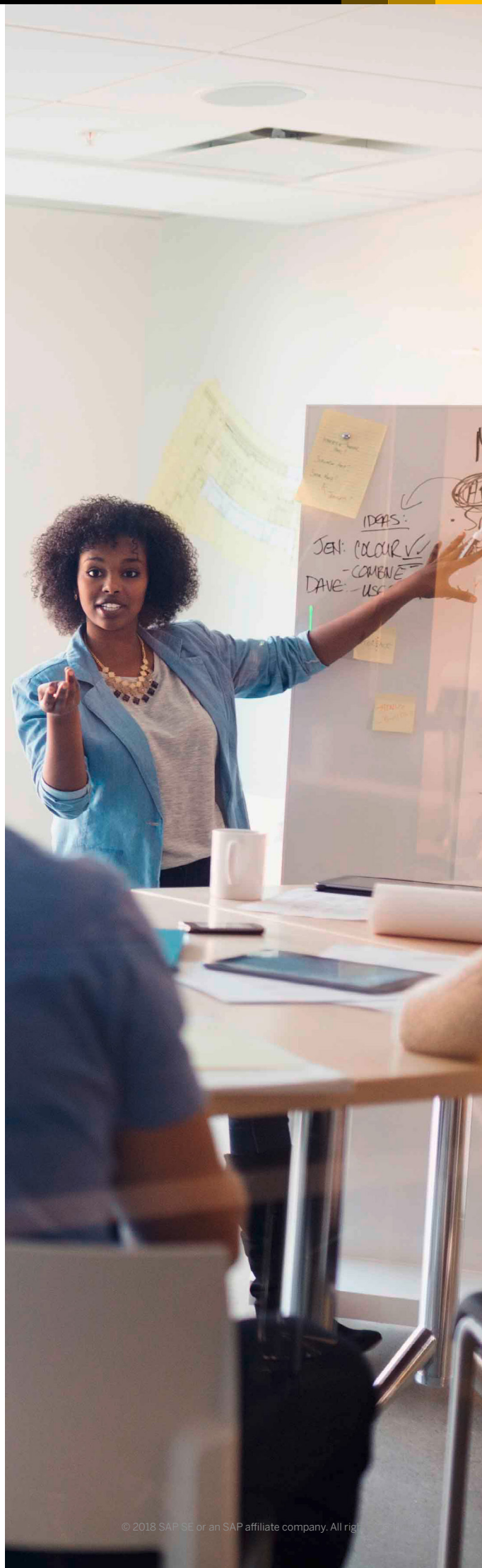
A digital twin is a live digital representation of a physical object. Representing the essential physical manifestation and business context of the object from inception, design, engineering, and production to end of life, a digital twin provides real-time information on the configuration, condition, and state of the asset as well as historical data that can be queried through APIs. Digital twins act on behalf of physical objects by sending alerts and notifications while being able to initiate control flows to act in the physical world. More complex digital twins feature hierarchies or relationships; contain derived data from statistical, machine learning, and physical simulations; and expose service capabilities. Connecting digital twins from multiple providers to different consumers creates a trusted network of digital twins.

HIGHLIGHTED SOLUTIONS

The SAP Predictive Maintenance and Service solution allows organizations to predict machine and equipment malfunctions before they happen. Integrating predictive models into digital twins helps detect anomalies by calculating asset health scores and remaining lifetimes to ultimately provide decision support for maintenance schedulers. The solution integrates with the digital core of SAP S/4HANA for plant maintenance. With real-time remote-machine sensors, businesses can monitor their equipment 24x7 to analyze large volumes of operational data and apply predictive insights in real time.

The SAP Predictive Engineering Insights solution for use in structural dynamics enables the monitoring and analysis of structure and mechanical system behavior, as well as the influence of complex and dynamic loads. The software allows businesses to perform real-time digital inspections of critical components running in the moment. Using the physical-based model, operators can continuously monitor and assess the structural integrity of critical components and simulate effects of events such as upcoming weather changes to avoid damages or serious accidents, which as a worst-case scenario could result in a blowout.

SAP Asset Intelligence Network brings your asset ecosystem partners – such as operators, dealers, engineering service providers, manufacturers – into a single cloud-based network platform to optimize asset performance throughout their entire lifecycle and build an asset network collaboration for better service and maintenance processes. In addition, it can be used as a shared repository and collaboration platform for assets, connecting authorized stakeholders to asset digital twins for scenario planning, data and analysis sharing, and value creation.



SAP Leonardo IoT intelligently connects things with people and processes across company boundaries through business network solutions to enable unparalleled collaboration and productivity. Companies can connect to their ecosystems to increase engagement and collaboration, improve transparency, and create more value for their customers. SAP Leonardo IoT capabilities support new networked business models, such as product-as-a-service offerings and value-added services. This approach allows collaborative resolution of business and operational issues by connecting the right people with the right training and supplies at the right time and place to solve problems in a safe and reliable manner.

CONNECTED MANUFACTURING: INDUSTRY 4.0

Under the notion of Industry 4.0, discrete and process manufacturing companies engage in vertical integration of an ERP solution with manufacturing execution systems and programmable logic controllers, as well as horizontally connected engineering and manufacturing systems, ERP production planning, and logistics systems. Creating a digital, paperless factory with real-time visibility across the entire supply chain process allows operations to become more responsive to increasing mass customization and individualization (known as a lot size of one) while improving overall equipment effectiveness.

Customer Story: Enabling a Live Factory at Caterpillar

Caterpillar, one of the world's leading manufacturers of construction and mining equipment, embarked on a digital transformation initiative called "Live Factory" to drive lean transformation and integrated value chains in manufacturing and intralogistics processes. By integrating several SAP® Leonardo Internet of Things capabilities, the company gathered data from the shop floor, optimizing material flows through Kanban vehicles, maximizing overall engine uptime, and increasing efficiency and safety. As part of its industrial retail, Caterpillar is engaging customers through its dealers and digital supply network to connect its manufacturing solution with the digital core.

"We automatically start driving that cognitive use of the data to solve issues in the moment — so we can produce better-quality processes and products."

– Marty Groover, Operational Technology Manager, Caterpillar

Customer Story: Realizing Industry 4.0 at ebm-papst

A leading manufacturer of energy-saving fans and motors, ebm-papst used SAP® Leonardo Internet of Things (IoT) capabilities to connect cross-company boundaries with its suppliers and customers while digitalizing the production process. The company's Industry 4.0 toolbox enabled components such as active process control, virtual packaging, traceability, and recording of machine states and various other functions. Using the company's production machines and SAP Leonardo IoT, ebm-papst evaluates data and initiates production steps. The entire production process is managed and checked in a central system that is integrated with core processes. Employees can keep track of production steps that are completed and the materials used, as well as any outstanding steps. Furthermore, the company traces back the production of every single product at any time.

"Everyone from the shop floor to the top floor should work with the same information base, so it made sense to use SAP software for production. We streamlined all organizational processes and increased first pass yield to 99.5%."

Thomas Wagner, Chief Operating Officer, ebm-papst Inc.

Manufacturing companies have started to move beyond traditional Industry 4.0 initiatives by combining data from connected machines and equipment during the production phase; connected products throughout customer use; connected logistics (such as forklifts, autonomous vehicles, and picking robots); and unstructured data (including oil samples or other quality analysis, video and image captures, and audio samples) into a holistic manufacturing data store. Typical examples of production optimization range from improving factory layouts, optimizing tool management, and reducing milk runs and inventory to shortening planned downtime and avoiding unplanned outages. This approach enables predictive quality management capabilities to prevent rework, minimize production waste, and lower warranty costs. The same IoT data can also be used to fulfill traceability and other regulatory compliance requirements.

HIGHLIGHTED SOLUTIONS

The SAP Manufacturing Execution application enables individualization and mass customization to deliver a lot size of one to meet growing demand for personalized products. The application is integrated with SAP S/4HANA for production planning, supported by analytics, artificial intelligence, and machine learning. The application enables businesses to push autonomous decision-making to the edge of the factory, so they can respond more effectively to customer needs. It facilitates end-to-end visibility into production and builds responsive manufacturing capabilities by connecting production systems to core processes.

CONNECTED VEHICLES

Moving objects – from cars, vans, buses, trucks, forklifts, and cranes to land machines, containers, and trains – are natural starting points for the IoT. With the proliferation of 3G and 4G mobile networks (including the NarrowBand IoT [NB-IoT] standard and upcoming 5G standards designed for the IoT) and the availability of unlicensed band solutions (such as Sigfox or LoRaWAN), location information on speed, direction, and acceleration as well as condition and consumption data can be simply collected to oversee fleets of moving assets. Furthermore, in delimited areas including harbors, mines, or construction sites, operators can optimize logistics and reduce consumption while increasing worker safety.

Routing that uses location data helps predict times of arrival in real time for dynamic inbound or outbound logistics planning, while geofencing and other geospatial capabilities track the desired and undesired crossing of boundaries by connected objects.

Customer Story: Reimagining Mobility Services at AMAG

As customers shift from owning cars to sharing mobility services, AMAG – one of the largest Swiss vehicle importers and dealers – sought to expand its business beyond importing, selling, and leasing cars. Live telematics data gathered from the vehicles enabled the company to reimagine new services such as offering mobility on demand and e-mobility. Furthermore, AMAG optimized the dealer network after insurance companies created a driver performance index to tailor their offerings. The strategic investment in scalable cloud solutions using the capabilities in SAP® Leonardo Internet of Things has lowered total cost of ownership, transformed the business model, and opened up new revenue streams.

Customer Story: Digitalizing the Farmer's Experience at Stara

Stara, the largest Brazilian manufacturer of agricultural machinery, digitalized the farming experience by analyzing sensor data from its land machinery, weather and soil readings, and drones. Now the company can connect farmers with the global value chain, allowing real-time monitoring of the amount of seed planted and volume of fertilizers used. As a result, farmers can diagnose pests and crop diseases, track fertilization and irrigation status, and automate crop protection tasks. Essentially, SAP® Leonardo Internet of Things capabilities created a connected ecosystem of farmers, plants, and machines.

"The Internet of Things revolutionized our business model. Previously, we viewed the machines and the farmers as separate entities. Now, we can connect machines to machines and people to machines. We can connect the customers to their business in real time on their handheld devices."

– Cristiano Buss, Director of Research and Development, Stara

HIGHLIGHTED SOLUTIONS

The SAP Vehicle Insights application allows companies to explore new business models (such as e-mobility services) by connecting any moving asset (such as vehicles, tractors, and land machines) and monitoring vehicle conditions remotely on a large scale to support issue resolution, usage-based services, and pay-as-you-drive contracting. The application enables these capabilities through the integration of telematics, enterprise and customer data, driver behavior analytics, and geo-based services that help improve services and execution of processes – from ordering and goods collection to delivery.

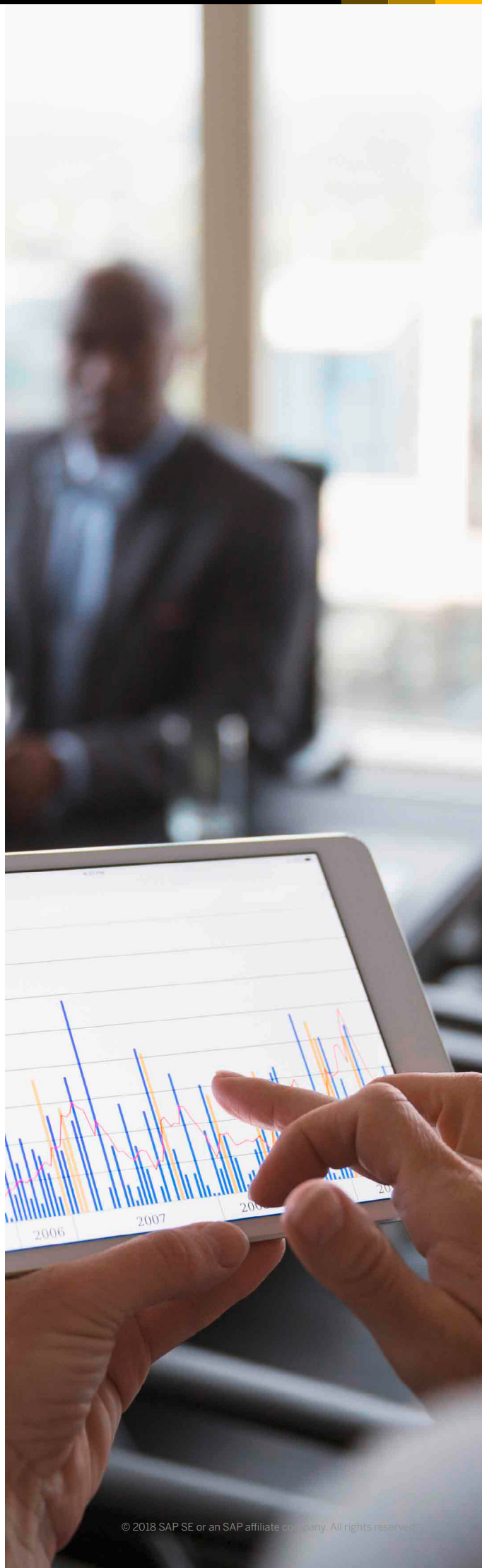
The SAP Global Track and Trace solution provides visibility across a supply chain network to engage end-to-end, global track and trace capabilities and cross-company boundaries through a cloud-based solution. The solution provides real-time situational insight across global sourcing, production, and fulfillment networks across industries. This approach enables businesses to monitor goods transport, shorten vehicle routes, and avoid collisions by collecting and analyzing all relevant vehicle data.

THE INTERNET OF EVERYTHING

Consumer- or citizen-focused scenarios are driving tremendous interest in the IoT. Consumer goods companies, fashion and food retailers, and cities can improve operations, provide new services, and innovate their business models.

Customer Story: Delivering the Best Customer Experience Possible

A leading beverage company wanted to ensure a high level of customer satisfaction by selling cold beverages under certain storage conditions. By installing sensors on its beverage coolers, it can connect, monitor, and control thousands of storage units with SAP® Leonardo Internet of Things capabilities, which has improved the performance of every cooler, increased sales, and boosted overall customer satisfaction and loyalty. Now the company can remotely control temperature settings, detect when a door is left open, and track coolers lost during an event. Plus, it can monitor product variety in the cooler to help ensure that customers always have access to the broadest range of products available.



The IoT is used to improve the experience and satisfaction of end users while driving loyalty and revenue. Innovative companies strive to build a business around software or a content platform based on IoT data collected from millions of consumers.

Customer Story: Digitalizing the Athlete's Experience

An innovative athletic undergarments and apparel company is changing the way athletes dress and perform. With sensors and wearable devices, its customers can monitor and manage their daily patterns such as sleep, fitness, activity, nutrition, weight, and overall health. Now athletes can compare themselves against others through a fitness tracking app. Thousands of customers are tracking their running shoes with SAP® Leonardo Internet of Things capabilities, helping them prevent injuries by receiving notifications from the company when the time to replace their shoes has arrived.

The digital transformation of cities into smart cities is a key differentiator in improving quality of life, reducing impacts on the environment, attracting digital-native talent, and fostering growth from new companies. IoT deployments in the public space range from parking, traffic management, waste management, energy management, and public safety to new tourist experiences.

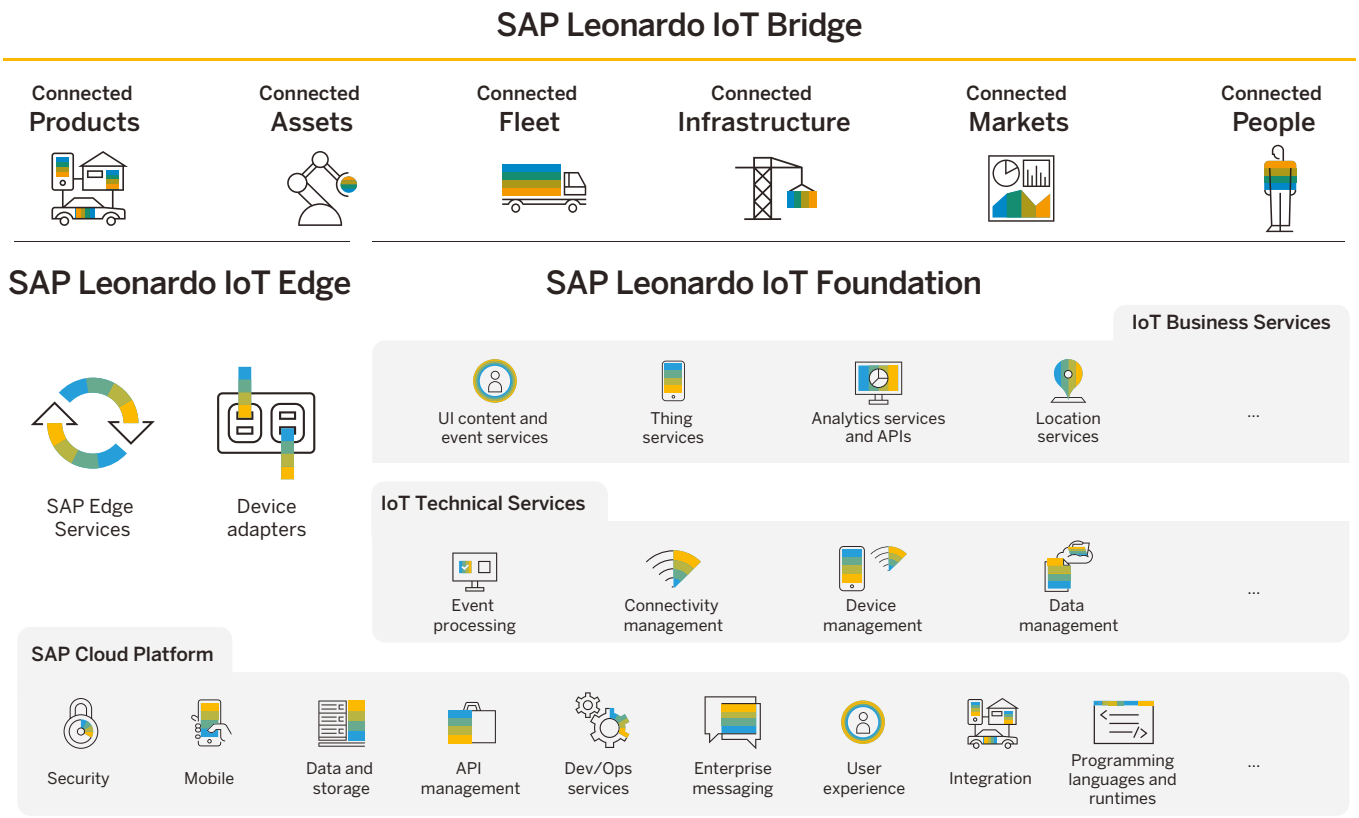
Customer Story: Improving People's Lives

Routinely impacted by the aftermath of rainstorms and floods, one city decided to take action. As the population grew, the city's infrastructure could not sustain the increased volume of water, leading to property damage and lower living standards. To prevent flooding and mitigate risks caused by heavy rains, the environment and public spaces ministry connected thousands of assets including roads, lighting, parks, bus stops, sewers, buildings, and bridges with the help of SAP Leonardo Internet of Things capabilities. The city can now maintain its infrastructure, maintain complex contractor and supplier relationships, elevate its services, and improve lives. More importantly, three days of heavy rain no longer result in widespread flooding.

SAP Leonardo: Digital Innovation at Scale

The SAP Leonardo digital innovation system helps our customers succeed in digital transformation. Running on SAP Cloud Platform, the SAP Leonardo system supports IoT, machine learning, Big Data, analytics, and blockchain, as well as design thinking services, to help our customers tackle the right digital transformation projects in the right way and maximize their success. SAP Leonardo can be implemented rapidly with proven accelerators used by an ecosystem of partners that understand how to deliver the business outcome. Figure 2 shows the various elements of SAP Leonardo IoT.

Figure 2: SAP Leonardo Internet of Things

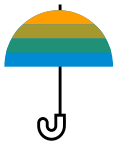


SAP LEONARDO IOT FOUNDATION

SAP Leonardo IoT Foundation is built on top of SAP Cloud Platform as a multicloud platform-as-a-service offering. It allows businesses to manage devices securely and connect to a wide variety of industry-standard protocols. Its flexible "thing" model enables organizations to build a digital representation of physical devices. By establishing a unified semantic layer through the SAP IoT Application Enablement toolkit, organizations can build IoT applications as well as maintain scale and consistency across all their IoT applications. Data is ingested into a managed IoT data solution with time-series storage, archiving, or any other data storage such as the SAP HANA® platform and the SAP Data Hub solution.

SAP Cloud Platform IoT service: This service provides device management capabilities to onboard, configure, manage, and decommission any remote device. The service supports security standards, including X.509 for public key certificates, to help ensure operational security and role-based access to meet privacy and data security requirements. The SAP Cloud Platform IoT service also provides decision-making tools at the edge, leading to significant process optimization at the core of the business. Companies can intelligently connect things, people, and processes to optimize IoT deployments, speed decision-making, and support the adaptability required to change quickly.

Device management: Onboard, configure, manage, and decommission any remote device. Businesses can benefit from the messaging functionality, remote device control, and scalability required to collect, preprocess, and handle high volumes of sensor data through the cloud or at the edge.



Compliance: Address regulatory, environmental, industrial, and safety compliance requirements for IoT devices and processes. Businesses can meet IoT-related guidelines and regulations for privacy and data security, product safety, and energy efficiency, as well as other legal, procedural, and documentation requirements.

Protocols: Deploy IoT applications and devices by using a wide array of IoT connectivity protocols such as message queue telemetry transport (MQTT), which is a lightweight messaging protocol that simplifies publishing and subscribing. An IoT gateway provides a wide array of connectivity protocols including MQTT and integration with connectivity platforms such as Sigfox.

Security: Manage operational security for IoT devices with support for security standards including X.509 for public key certificates. Enhance privacy with role-based information access and support for multitenancy for connected devices.

SAP IoT Application Enablement: In a model-driven approach supported by the SAP IoT Application Enablement toolkit, you can create a digital representation of a physical thing and build IoT applications, and the resulting service manages IoT data. This includes a time-series store, a configurable time-series archive, and an analytics service powered by SAP HANA for aggregates. SAP IoT Application Enablement supports:

- **Thing model:** The semantic and hierarchical thing model allows customers to create a digital representation of a physical thing. The offering comprises:
  - Thing registry, which contains and structures things
  - Thing shadow, which allows you to keep the physical and the digital world in sync
  - Event management, which is used to monitor and control changes in a thing's status as well as manage business partners
  - Thing authorization model, which is used to define business partners and grant role- and instance-specific access to data
- **Rapid application development:** Based on SAP Cloud Platform, templates from SAP Web IDE are provided to create IoT applications. You do this by selecting UI patterns, such as a map, a list of things, a thing info card, and so on, and connecting these UI elements with data sources using the SAP IoT Application Enablement toolkit. Additionally, a code-free development environment is available to let you freely define page layouts, with drag and drop of reusable UI controls, and define a live connection to data and a live preview. The generated code can be modified or enhanced to fit the customer use case. The integration with SAP Fiori® launchpad makes your application easily accessible to users.
- **Manage huge amounts of IoT data:** With SAP IoT Application Enablement, which provides automated, dynamic data tiering within its Big Data infrastructure, customers and partners can manage huge amounts of IoT data. A time-series store is provided as well as a configurable time-series archive.

SAP LEONARDO IOT EDGE

SAP Leonardo IoT Edge helps optimize business processes at the edge of the network, near the source of IoT data, to increase asset uptimes, operational efficiency, and worker productivity. IoT sensor data can be enriched with enterprise business context to enable real-time actions and outcomes, and provide continuity for critical business functions to help ensure uninterrupted business process flow, without reliance on network connectivity. By optimizing compute spend and transmitting only relevant data from the edge back to the enterprise, through the cloud, businesses can dramatically improve IoT efficiency and accelerate data processing speed, response time, and performance at the edge, reducing expensive communication costs.

A containerized IoT gateway, shipped as part of SAP Cloud Platform IoT, allows near-edge devices in an IoT network to connect to sensors through a variety of protocols. This gateway can help conserve bandwidth by running an algorithm to determine the business value of incoming sensor data and transmitting only essential business data and insights back to the enterprise. Latency issues are also addressed through the gateway, which accelerates communication with sensors through fast, low-energy protocols to enable ultra-low latency.

The gateway architecture provides a platform for additional SAP Edge Services, which can be deployed on edge computing devices. These include the persistence service, which persists IoT data for local data storage and computations, and the streaming service, which runs rules and streaming analytics algorithms to, for example, detect anomalies from different sensors during a specific time window. The business essential functions service provides business context from the SAP ERP application or SAP S/4HANA and executes this business logic at the edge, closer to the data and devices. This increases local autonomy and reduces latency, independent of connectivity. Predictive analytical models can also be deployed, executed, and updated at the edge. These different microservices are centrally defined, managed, and distributed from the cloud to local edge nodes.

Across industries, from off-shore oil rigs to retail outlets, military tanks, and manufacturing equipment, SAP Leonardo IoT Edge enables businesses to run live at the edge, bringing compute, storage, business semantics, and predictive analytics to the intelligent edge for deterministic performance and real-time action. SAP Leonardo IoT Edge allows business processes to run in offline mode while ensuring transactional integrity and synchronization with enterprise systems, even with intermittent connectivity.

SAP CLOUD PLATFORM

SAP Leonardo IoT is completely integrated into SAP Cloud Platform, providing a rich set of additional business and platform services. SAP Cloud Platform supports a multicloud architecture and is based on Cloud Foundry technology to deliver an open, robust, and flexible cloud-native enterprise platform to build, deploy, and manage innovative business applications.

Mobile: A full-featured mobile app development platform for native, hybrid, and micro mobile apps supports multiple authentication methods, offline synchronization, remote logging control and retrieval, automatic app updates for hybrid apps, and one-to-one and one-to-many push notifications. An SAP Cloud Platform software development kit (SDK) for iOS is delivered with SAP Cloud Platform.

User experience: The SAP Fiori user experience enhances cloud development and deployment in the cloud portal. Also, the SAP Build tool allows project teams to collaboratively develop prototypes, engage end users for feedback, and jump-start designs with one of many prototype examples from the gallery.

Cloud-based integration: Gain secure cloud-to-cloud and cloud-to-on-premise integration, connecting SAP and third-party software systems. SAP API Business Hub lists more than 500 predefined integration flows and value mappings for deployment. These include business-to-business and technical protocol connectors as well as an adapter SDK for custom-built integration.

Workflow and business rules: With Web-based tools, businesses can build and modify workflow applications. In addition, they can manage workflow tasks by using the "My Inbox" app in SAP Fiori. Web-based development and authoring environments for business rules help quickly translate decision logic into a natural language that is configurable by end users.

Enterprise messaging: A cloud-based messaging framework connects applications, services, and devices across various technologies, platforms, and clouds. Scaling to millions of messages per second in real time, users can send and receive messages reliably using open standards and protocols such as MQTT.

Programming languages and runtimes: From Java, JavaScript/HTML5, and node.js to SAP HANA extended application services and SAPUI5, businesses can use their own language with community-supported build packs such as PHP, Python, Ruby, and Go, as well as a Web-based development environment including SAP Cloud Platform and SAP Web IDE.

Data storage: Data can be stored and archived in SAP Data Hub, SAP HANA , Big Data services, PostgreSQL, MongoDB, SAP Adaptive Server® Enterprise in the cloud, object store for unstructured data, document service, or Redis in-memory caching.

API management: Simple, scalable, and secure access to applications through APIs enables sharing with business partners to create business networks. Companies can discover and consume digital content packages with APIs, prepackaged integrations, and sample applications from SAP and select partners on SAP API Business Hub.

SAP Leonardo Machine Learning Foundation: Advanced machine learning capabilities help applications recognize patterns and correlations in data. Image-processing services, natural language processing services, and tabular and time-series processing services are also available. In addition, you can deploy and publish TensorFlow models.

SAP Leonardo Blockchain: This set of capabilities enables blockchain as a service for distributed ledger implementations.

Analytics: The SAP Analytics Cloud solution provides cloud-based advanced analytics services for predictive, spatial, and text analytics. Streaming analytics processes streams of incoming event data in real time.

Dev/Ops services: To minimize development cycle times, continuous integration and continuous delivery are supported. A monitoring service provides the health status and metrics of Java applications, and the Java profiler helps you analyze resource-related problems.

Security: SAP Cloud Platform supports enterprise-grade cloud identity and access management; two-factor authentication; support for open standards such as SAML, open authorization, and SCIM; propagation of the logged-in user to SAP and third-party back-end systems (principal propagation); end-to-end encrypted data transfer and secure storage of confidential data in the cloud; and integration with a corporate user store (such as Microsoft Active Directory). In addition to these capabilities, SAP Cloud Platform also supports auditing and compliance with support for ISO 27001, SOC 1 (type 1 and 2), and SOC 2 (type 1 and 2). And to help meet objectives for high availability and disaster recovery, SAP Cloud Platform is designed from the ground up with redundant infrastructure. Available in many regions around the globe, SAP Cloud Platform offers a choice of infrastructure-as-a-service providers: SAP Data Center, Google Cloud Platform, Microsoft Azure, and Amazon AWS. At the same time, the unique approach with SAP Cloud Platform is designed to prevent provider lock-in with any specific provider of the infrastructure layer.

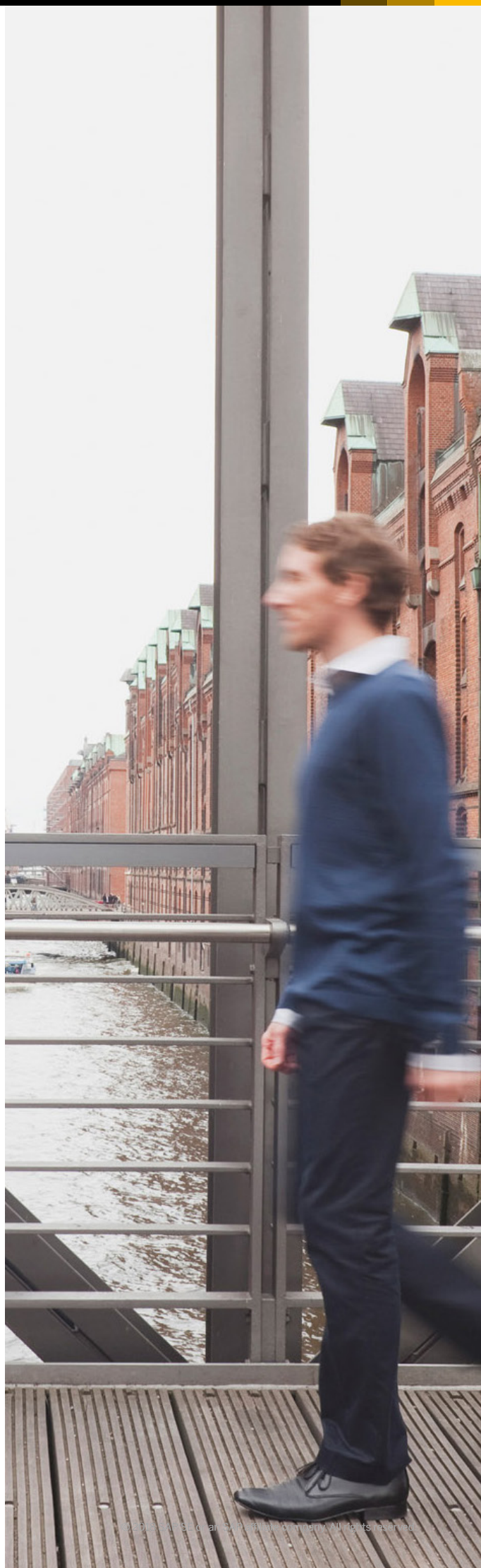
SAP LEONARDO IOT BRIDGE

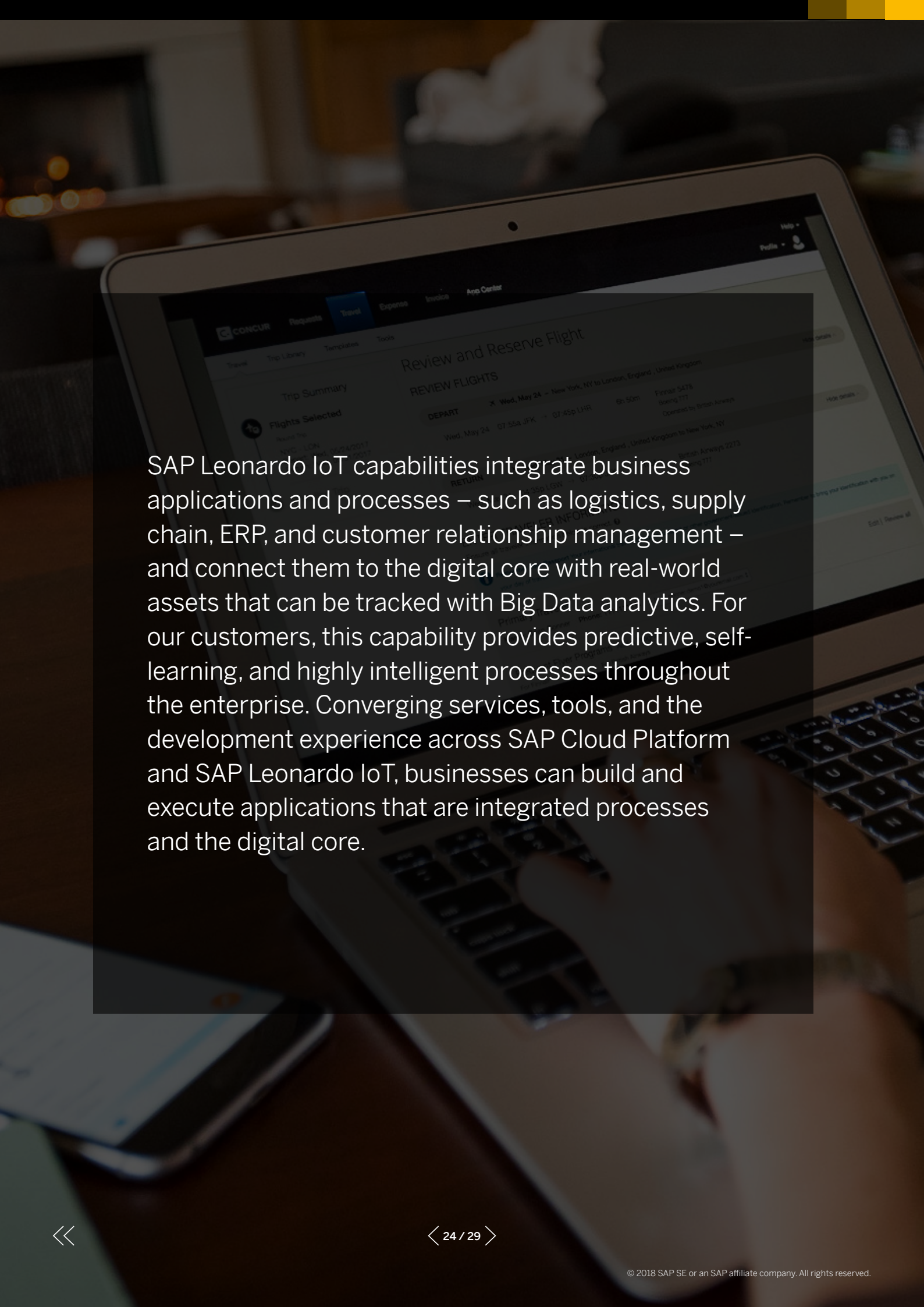
Digital transformation is not only about data-driven automation; it also empowers operational users with decision support by providing additional context to the issue at hand. End-to-end business process visibility in real time and across multiple lines of business is a pressing need for businesses in this digital economy. SAP Leonardo IoT Bridge closes the gap between these different sources of information (such as IoT data, line-of-business data, and other transactional data) into a unified command center, like the bridge of a ship.

For example, imagine a major manufacturing company working with a contract manufacturing organization (CMO) to supply its customers with specific products. The procurement manager needs to be able to create and submit sales orders to the manufacturer and therefore also needs visibility into production capacity information of the CMO, along with the ability to monitor the status of all the sales orders created. The customer care specialist at the manufacturer needs visibility into all incoming sales orders from customer accounts, along with the ability to create and submit purchase orders to the CMO. In contrast, the production operations manager at the CMO is tasked with managing incoming purchase orders and requires overall visibility into production operations for meeting demand.

At the same time, an outbound logistics manager at the manufacturer needs something completely different in the form of real-time visibility into all shipments and deliveries from the third-party logistics company employed. This includes information such as product quality during transit and data on order fulfillment. An account manager at the manufacturer, on the other hand, needs a holistic view of all this information such as sales orders, purchase orders, production data, and order fulfillment details from the third-party logistics provider.

These different roles have an underlying common thread in terms of their responsibilities within the larger digital supply chain framework of a company. But they each require completely different perspectives and information to execute their day-to-day tasks. SAP Leonardo IoT Bridge provides this level of role-based visibility by bringing together different sources of information, including sensor data and business process and operations data, in a unified, persona-centric way to help ensure a consistent experience for all.

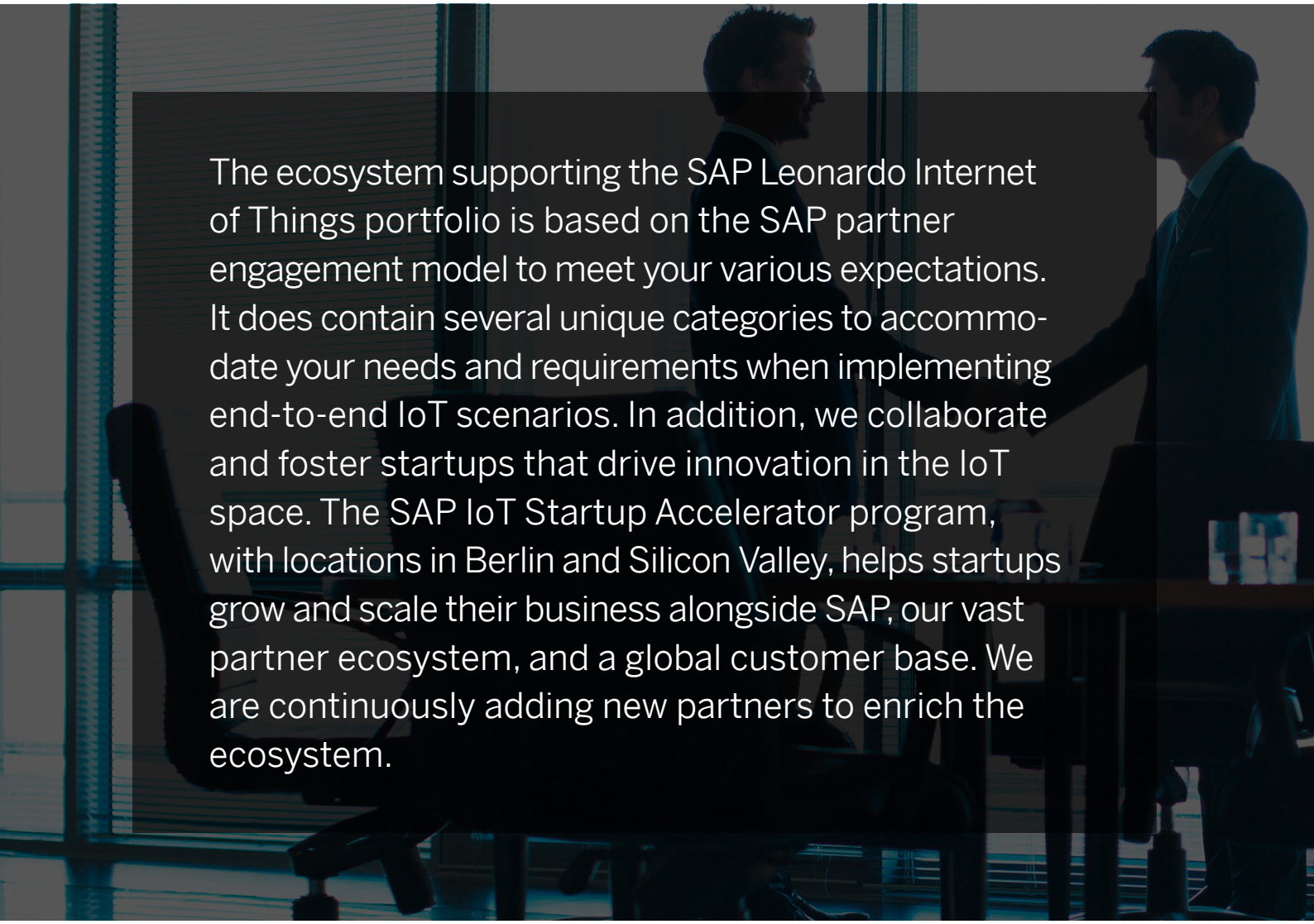




SAP Leonardo IoT capabilities integrate business applications and processes – such as logistics, supply chain, ERP, and customer relationship management – and connect them to the digital core with real-world assets that can be tracked with Big Data analytics. For our customers, this capability provides predictive, self-learning, and highly intelligent processes throughout the enterprise. Converging services, tools, and the development experience across SAP Cloud Platform and SAP Leonardo IoT, businesses can build and execute applications that are integrated processes and the digital core.

ECOSYSTEM OF PARTNERS

To move successful IoT solutions from things to outcomes, digital transformation projects require a well-established and knowledgeable partner ecosystem. SAP Leonardo IoT is built on proven and established partner engagement models from SAP and the award-winning SAP PartnerEdge® program to build, sell, service, and run SAP solutions.



The ecosystem supporting the SAP Leonardo Internet of Things portfolio is based on the SAP partner engagement model to meet your various expectations. It does contain several unique categories to accommodate your needs and requirements when implementing end-to-end IoT scenarios. In addition, we collaborate and foster startups that drive innovation in the IoT space. The SAP IoT Startup Accelerator program, with locations in Berlin and Silicon Valley, helps startups grow and scale their business alongside SAP, our vast partner ecosystem, and a global customer base. We are continuously adding new partners to enrich the ecosystem.

Independent software vendor partners can join the SAP PartnerEdge program to develop IoT applications with SAP Leonardo IoT capabilities. The IoT add-on pack for SAP Cloud Platform includes cloud resources and developer licenses with options for commercialization.

The Sell engagement model of SAP PartnerEdge provides **value-added resellers** with access to the SAP Leonardo portfolio to sell and implement SAP Leonardo capabilities, including IoT, managing the entire customer lifecycle.

System integrators: Implementing an end-to-end scenario requires secure integration and ongoing monitoring of connected things. Furthermore, the insight derived from the data that things generate requires the unique skills of data scientists, asset domain experts, application developers, and system integrators who are knowledgeable in the technical and business process integration of SAP Leonardo IoT in the cloud or on premise. This is the core skill of a trained and certified group of professionals residing within the competence centers of our system integrators – large and small – throughout the world.

SAP has extended its ecosystem to a variety of IoT domain partners to facilitate integration across a variety of devices, hardware and edge gateways, telecommunications and connectivity providers, and IoT-specific cloud integration.

Device management and connectivity partnerships: Depending on the scenario, enterprises will have different requirements concerning device management and connectivity. At SAP, the selection of partner offerings ranges from connectivity solutions using low-power, long-range technology including Sigfox and LoRa. Preintegrated offerings include partner device offerings such as SIM/e-SIM card–enabled cellular connectivity solutions that take advantage of the latest mobile communication networks such as Vodafone and Telus. Partnerships in this space will increasingly be subjected to standard integration models and associated certifications.

Edge and hardware partnerships: As explained earlier, a significant amount of IoT data will be processed at the edge of the network. Devices on the edge need to address security, identity, data protocols, communication modules, operating systems, firmware, and applications. To achieve this ambition, SAP is partnering with leading providers of edge hardware and device management capabilities that complement the SAP offering such as Hewlett-Packard Enterprise, Dell, Samsung, Intel, and VMWare. Using a certification process, we ensure that edge devices – particularly gateways and modules – from leading providers are compatible with SAP Leonardo IoT Edge and can be handled holistically.

Integration partnerships with the IoT cloud and SAP Leonardo: Businesses may have to deal with an environment that uses more than one IoT platform. Recognizing this reality, SAP is partnering, particularly in the heavy assets domain, with leading providers of vertically oriented offerings. SAP is working with several providers not only providing API-based technical integration but also enabling scenarios that require rules-based, bidirectional synchronization of master data that are structured, unstructured, contextual, or refined. The synchronization of digital twins with their related data patterns – including the ability to determine their relationships – will be a key achievement that SAP aims to address.

SAP IoT Startup Accelerator: Located in Berlin and Silicon Valley, the program helps startups grow and scale their business alongside SAP, our vast partner ecosystem, and a global customer base.

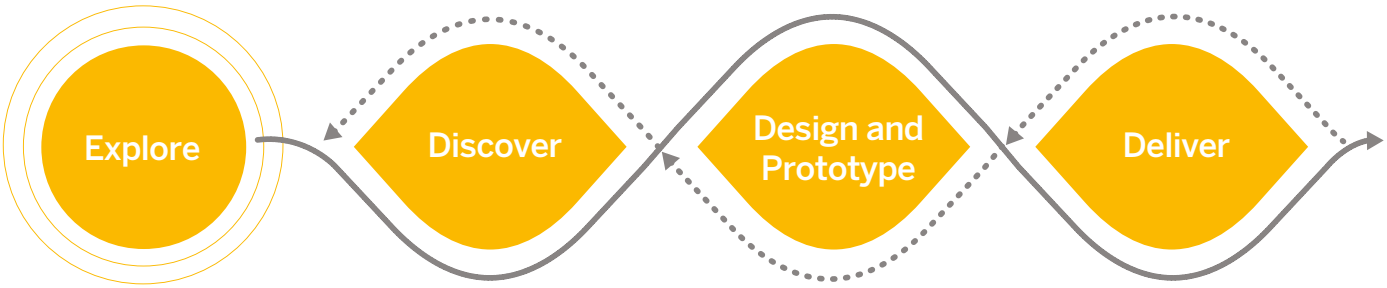
Getting Started with SAP Leonardo

To kick-start your digital transformation, the SAP Leonardo digital innovation system offers all technologies and services in one place. SAP Leonardo Innovation Services is a guided approach using design thinking methods and IoT accelerator packages to suit your specific industry needs. This is all delivered through the SAP global network of physical locations, SAP Leonardo Centers.

SAP LEONARDO INNOVATION SERVICES

SAP Leonardo Innovation Services helps deliver an IoT proof of concept supported by technologies such as machine learning, blockchain, Big Data, and analytics. Design thinking plays an important role when identifying the right business model with minimal up-front investment and lower risk to jump-start innovation (see Figure 3).

Figure 3: Processes Supported by SAP Leonardo Innovation Services



Businesses can choose from a selection of editions based on their specific needs.

SAP Leonardo Innovation Services, express edition, provides a fast implementation of predefined industry and IoT accelerators. This edition helps implement the solution and customize it to specific needs in less than eight weeks.

SAP Leonardo Innovation Services, open innovation edition, supports the creation of a new solution tailored to specific challenges. Within nine weeks, the innovation goes from concept to a workable prototype through Digital Design Zone, an agile design space that helps ensure that the business remains at the center of every innovation stage.

SAP Leonardo Innovation Services, enterprise edition, extends the scope of the open innovation edition to help create multiple solutions unique to specific business needs in parallel. In addition to Digital Design Zone, the enterprise edition provides empowerment sessions and access to the SAP Leonardo Innovation Services showroom.

IOT ACCELERATORS TO GET MOVING FIRST

We offer more than 20 SAP Leonardo IoT accelerator packages for specific industries and lines of business to meet specific needs. These packages provide industry knowledge, proven software, and design thinking services with an express methodology to help discover, rapidly pilot, and deliver the innovation within eight weeks.

Businesses receive a value assessment that identifies their priorities and details the implementation road map for moving forward. They also get a fully functional, productive pilot that is designed to scale rapidly while capitalizing on incremental opportunities where they exist. And with scenario design and architecture services built in, the initiative is aligned with the expected outcome. This approach minimizes risk while moving forward quickly to take advantage of the opportunities represented by the IoT and supported by the guided approach of SAP Leonardo Innovation Services.

SAP LEONARDO CENTERS FOR CO-INNOVATION AND A TRANSFORMATIONAL EXPERIENCE

As the delivery provider of SAP Leonardo Innovation Services, SAP Leonardo Centers are coming closer to your physical location for faster and more efficient co-innovation. SAP Leonardo Centers are a global network of connected, physical locations that inspire digital strategies and co-innovation through design thinking and the SAP Leonardo digital innovation system. In addition, the services connect businesses to a broader ecosystem including universities, startups, tech communities, and accelerators.

SAP Leonardo Centers are located across the globe in several locations including New York City, São Leopoldo, Paris, and Bangalore.

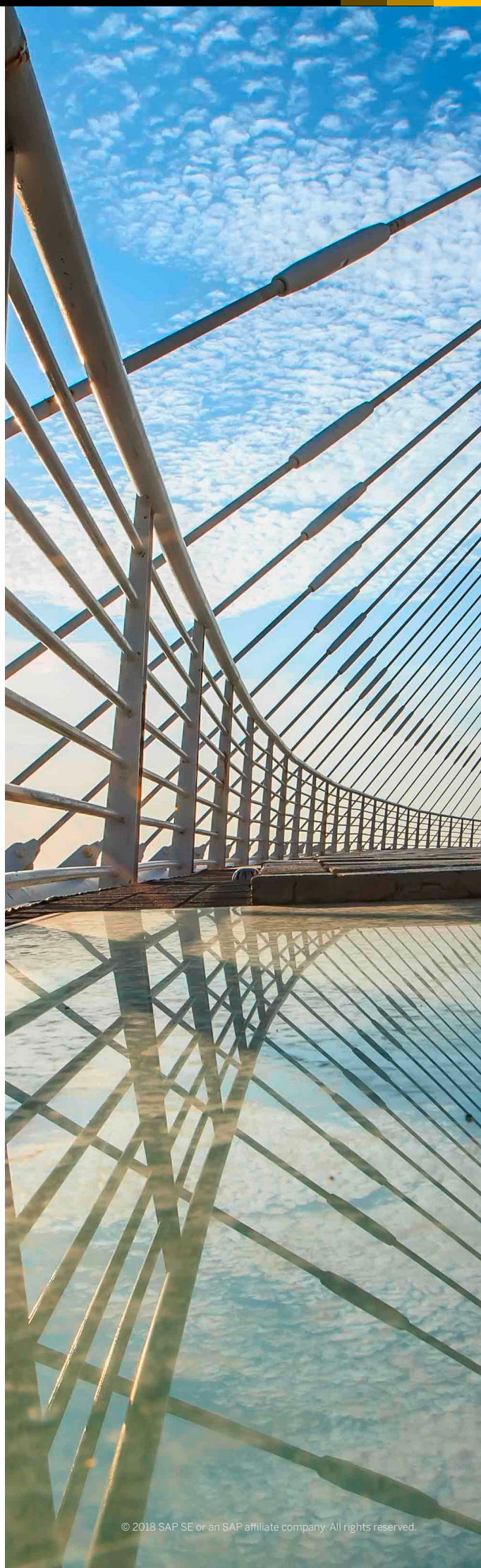
BENEFIT FROM SAP LEONARDO IOT CAPABILITIES

Designed with an emphasis on flexibility, scalability, and ease of use, SAP Leonardo IoT helps you connect assets, products, machines, fleets, and every other thing to generate valuable insights from large amounts of data. You can run business logic at the edge of the network, incorporate advanced capabilities such as machine learning into your IoT deployments, and integrate with new or existing business processes across industry scenarios and to the digital core.

The goal is to help you get your IoT project off the ground and deployed in weeks rather than months using proven, standardized technology – with the ability to customize your deployment to meet your innovation objectives. SAP Leonardo includes a proven methodology and service offering to accelerate the path to your first productive pilots, as well as an extensive partner ecosystem. Transformation of business processes, business models, and work environments in a digital, connected, intelligent, and networked world is a journey for every customer.

FOR MORE INFORMATION

For more information about how SAP Leonardo IoT capabilities can help your organization in its digital transformation, visit us **online**.



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