Hype Cycle for the Internet of Things, 2020

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As part of a digital business strategy, the Internet of Things blends the physical and digital worlds and is transforming the way we live and work. This Hype Cycle will help enterprises assess the level of maturity and hype associated with critical IoT building blocks.

Analysis

What You Need to Know

Application leaders must work with business leaders in selecting Internet of Things (IoT)-enabled business solutions to ensure business and IT alignment on business value. The IT organization must devise policies for data ownership, governance (including quality, security, privacy, and life cycle concerns), architecture, and digital ethics. Application leaders can use this Hype Cycle as a perspective on the maturity and penetration of evolving IoT technology and business elements.

The 2020 Gartner CIO Survey reveals that digital has become business as usual, with 40% of enterprises in the scaling and refining stages and they affirmed IoT remains a top-five most important game-changing technology (see “The 2020 CIO Agenda: Winning in the Turns”). Most enterprises are using IoT for cost and operations optimization/efficiencies or employee safety monitoring projects. In some cases, enterprises are accelerating their business journey to offer IoT-enabled products or services as part of a broader business transformation strategy.

The Hype Cycle

The 2020 Hype Cycle reflects the continued evolution of IoT, as it moves into the Trough of Disillusionment. More enterprises are driving IoT-enabled business solutions, focusing on key cost metrics or on launching new products. The transition to scaling IoT across the business is challenging leaders to clarify the near-term enterprise business goals, engage key stakeholders to change the culture, and drive technology plans (see “Toolkit: Enterprise Internet of Things Maturity”). Five specific innovation profiles encapsulate these challenges:

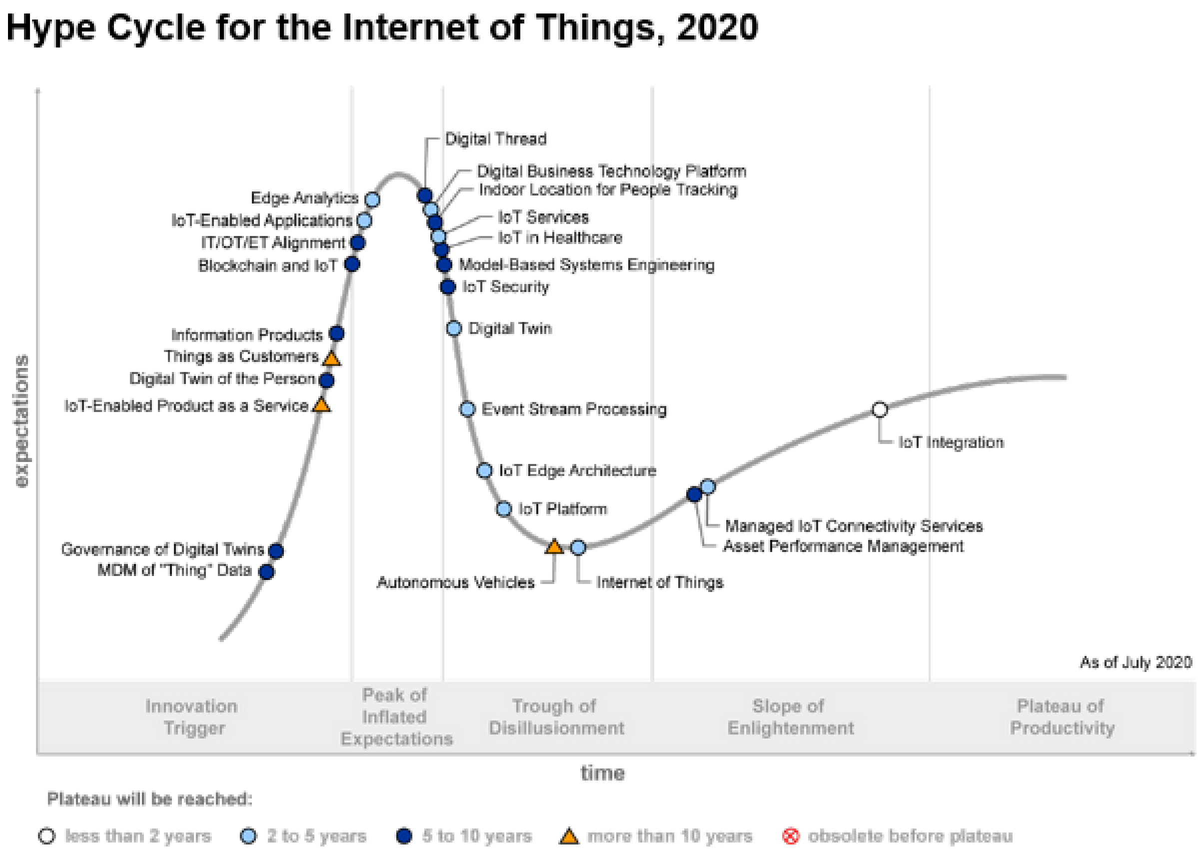
- The summary Internet of Things profile has migrated to the Trough of Disillusionment. Despite excess hype, integration, immature standards, cultural resistance, and other challenges, more enterprises are actively scaling up their initial deployments to make their technology and business approach better leverage the IoT benefits. This will begin to push IoT onto the Slope of Enlightenment in 2021.
- Indoor location for people tracking is at the Peak of Inflated Expectations, and digital twin of the person midway toward the peak, reflects the challenges that COVID-19 brings to enterprises.

Enterprises are increasingly being required to provide some level of monitoring on people's health. But this increased societal surveillance potentially diminishes privacy and exposes enterprises to risks about people's data.

- Digital twin moved significantly past the Peak of Inflated Expectations. Digital twins are being used to drive business models, such as superior asset utilization, and new ways to monetize data. Yet digital twins highlight the need for digital ethics and clear governance policies.
- IoT platform is sliding into the Trough of Disillusionment, driven by issues such as integrating securely into a broad range of assets and applications, unclear business sponsorship, and COVID-19-related delays.

Application leaders will be challenged to avoid the "hype trap" of technology projects that do not deliver business value, while helping accelerate digitalization initiatives. Application leaders can help build the IoT roadmap, protect the enterprise's data, and establish governance processes to support business transformation.

Figure 1. Hype Cycle for the Internet of Things, 2020



Source: Gartner
ID: 441743

The Priority Matrix

The Priority Matrix shows that many IoT technologies are still two to five years from mainstream adoption. Furthermore, IoT technologies generally have higher benefit levels. The adoption scope of relevant IoT technologies and IoT-enabled business models varies dramatically across different industries (separate Hype Cycle documents address some of these industry variations). Only one innovation profile will reach maturity in two years — IoT integration — showcasing IoT's journey from emerging to adolescent stages using a maturity model perspective.

IoT requires an array of horizontal technologies, most of which are over five years out from mainstream adoption. These address enterprises' challenges in connecting to their assets, starting with cost-effective development tools. This is complemented with a drive to develop an edge architecture and to position analytics at the network edge, an approach that drives better and lower-cost integration. Given the lack of standards and enterprises skills to implement IoT projects, enterprises will require service partners, raising project costs. Finally, the data generated by these assets provides input for artificial intelligence (AI) and machine learning techniques to help enterprises glean better insights and may become commercial information products.

Key two-to-five-year technologies for IoT include:

- Digital twin
- Edge analytics
- Event stream processing
- IoT edge architecture
- IoT platform
- Managed IoT connectivity services

Use cases for IoT that showcase the wide range of vertical markets and enterprise uses include:

- Autonomous vehicles
- IoT in healthcare
- Indoor location for people tracking
- IoT-enabled product as a service

Figure 2. Priority Matrix for the Internet of Things, 2020

Priority Matrix for the Internet of Things, 2020

benefit	years to mainstream adoption			
	less than two years	two to five years	five to 10 years	more than 10 years
transformational		Digital Business Technology Platform Digital Twin Event Stream Processing Internet of Things IoT-Enabled Applications	Blockchain and IoT Digital Twin of the Person IoT in Healthcare Model-Based Systems Engineering	Autonomous Vehicles IoT-Enabled Product as a Service
high	IoT Integration	Edge Analytics IoT Edge Architecture IoT Platform IoT Services Managed IoT Connectivity Services	Asset Performance Management Digital Thread Indoor Location for People Tracking Information Products IoT Security IT/OT/ET Alignment MDM of "Thing" Data	Things as Customers
moderate			Governance of Digital Twins	
low				

As of July 2020

Source: Gartner
ID: 441743

Off the Hype Cycle

For 2020, to provide readers with clearer, more focused research that supports their analysis and planning, authors included only those innovation profiles most strongly linked to the Hype Cycle and its theme. In many cases, selecting only the most salient profiles has reduced the number of innovation profiles on the Hype Cycle. We have added profiles for technologies of increasing interest to CIOs working on implementing and executing digital acceleration using IoT capabilities. This includes a focus on building-block technologies (such as IoT integration) and practical use cases (such as indoor location for people tracking). The following is a list of profiles that were removed in the 2020 analysis:

- Building information modeling
- Edge AI
- Event broker PaaS (ebPaaS)
- Indoor location for assets
- Infonomics

- Internet of meat
- IoT business solutions
- IT/OT alignment

On the Rise

MDM of "Thing" Data

Analysis By: Simon Walker

Definition: MDM of "thing" data is the application of master data management — the practice, discipline and enabling technology — in support of mastering entity-identifying data for IoT-enabled objects and their digital twins. It provides for semantically consistent representation of master thing data across distributed architectures — IoT, OT and IT. The result enables entity resolution of the object irrespective of application, system or platform.

Position and Adoption Speed Justification: The market is at the outset of recognizing and responding to the need of master data management (MDM) in support of IoT requirements on an end-to-end data value chain basis. In this context, the described data value chain would encompass the full spectrum of a distributed IoT architecture, spanning from thing(s) at the edge to OT and/or IT (enterprise application environment) in both directions of data travel.

Though packaged MDM solutions have been available within the market for several years, IoT data objects and the applications, systems and technologies emerging in direct support of IoT are "net new" to the experience of any MDM vendor.

User Advice: MDM for IoT is not for every IoT — only those for which there is both representation within OT and IT environments and for which semantically consistent representation of entity data is important, such as digital twins.

Some recommendations:

- Identify requirements for semantically consistent representation of IoT thing data across distributed IoT data architecture. This will be key for IoT or digital twin deployments where multiple applications are engaged.
- To the extent practicable, work to leverage existing effort, practices, disciplines and enabling technology in support of traditional MDM.
- Recognize that IoT presents as an entirely new data domain for MDM, across all dimensions and elements.
- When engaging with established MDM vendors, ensure to validate claimed capabilities and experience by means of detailed proofs of concept where possible and otherwise through detailed reference customers.

- Determine whether and to what extent eBOM data needs to be encompassed by thing master data. The more complex the thing — that is, a compound object composed of complex subcomponents also classified as things (e.g., aircraft turbine) — the greater the likelihood this will prove to be the case.

- For those organizations implementing digital twins, Gartner recommends incorporating MDM as an integral aspect of that effort.

Business Impact: Business impact will be greatest in areas and/or business processes where the generation of data by things contributes to the tracking and/or performance management within OT and/or IT enterprise applications that serve to control and manage physical assets.

Key scenarios in which MDM for IoT is envisioned to be critical are:

- Condition and predictive-based maintenance (asset performance management, enterprise asset management, ERP, field service management).

- Sharing of thing asset data across a partner ecosystem.

- Digital twins (whether intraenterprise or interenterprise).

Benefit Rating: High

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Sample Vendors: IBM (InfoSphere Master Data Management Advanced Edition); Informatica; SAP (Master Data Governance)

Recommended Reading: "Magic Quadrant for Master Data Management Solutions"

"Implementing the Technical Architecture for Master Data Management"

Governance of Digital Twins

Analysis By: Roger Williams; Alfonso Velosa; Marc Halpern

Definition: Governance of digital twins refers to the oversight and mechanisms required to ensure that digital twins deliver their intended business benefits at an acceptable level of organizational costs and enterprise risks over the life cycle of the twin's physical world counterpart.

Position and Adoption Speed Justification: Like many hyped technologies, far more interest is paid to the initial creation and development of digital twins than to governing, operating, continuously upgrading and supporting them:

- Digital twins are potentially a transformative technology for everything from devices to cities.

- No standards or common integration frameworks exist for digital twin data, models, analytics or security.
- Stakeholders from all business functions and across IT seek significant, yet varied benefits.
- The need for coordination between organizations on shared-data models adds another layer of complexity for composite and organizational digital twins.

The barriers threaten the scalability and value that organizations can realize from digital twins and related investments such as IoT. Thus, organizations must ensure that their governance approach incorporates digital twins and provides clear guidance to managers and staff to enable sustained value from these investments.

User Advice: Ensure that steering committees and other governing bodies provide adequate guidance for digital twins around four areas of decision making: accountability for outcomes, participation by appropriate stakeholders, predictability in how results are reported and acted upon, and transparency into digital twin performance and conformance:

- Accountability: Create a charter for governing digital twins that emphasizes three primary roles — the executive sponsor, the program lead and the owner(s) of digital twins.
- Participation: Define decision models that specify who participates in decision phases, including external partners. Pay particular attention to who provides initial input, since failure to include important perspectives increases the odds of poor digital twin performance due to missed requirements.
- Predictability: All stakeholders must know what is required of them regarding digital twin management activities, how they will be informed of outcomes and what actions will be taken. Set clear expectations for each stakeholder, communicate results on a timely cadence, and handle exceptions using specific thresholds and methods focused on learning and improvement.
- Transparency: Adopt adaptive methods to ensure visibility into digital twin performance and conformance. Clarify the intent and why the digital twin matters to the organization. Ensure sufficient data quality to meet use-case demands. Grant access to those who need aspects of the digital twin, while restricting it from those who do not. Provide timely updates to the digital twin to support taking appropriate action. Use consistent formats for digital twins to aid interpretation and application to business needs.

Business Impact: Governance of digital twins is fundamental to realizing their value across the full product life cycle, as traditional project-based approaches will fail to sustain value across the long time spans that many digital twins will be required to support. These challenges increase the risk that CIOs someday will inherit a digital twin portfolio that is brittle, opaque and exposed. Thus, it is in the best interests of both the organization and the CIO to address potential shortcomings proactively. With digital twins poised to transform organizations as they enable business to drive new digital business models as well as update existing models, those that can maximize their value contribution will be best-positioned for sustained success.

Benefit Rating: Moderate

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Sample Vendors: Bentley Systems; GE Digital; Mavim; Microsoft; Software AG

Recommended Reading: "Strengthen 4 Elements for Successful Management and Governance of Digital Twins"

"Toolkit: Enterprise Readiness for Digital Twin Deployment"

"Adopt a Data Governance Strategy for Long-Term Digital Twin Success"

IoT-Enabled Product as a Service

Analysis By: Eric Goodness

Definition: IoT-enabled product as a service is a commercial model where businesses acquire operational assets as recurring operating charges. Acquisition is based on agreements defining fitness for purpose and desired outcomes relating to performance, availability and quality of output. Embedded IoT technologies leveraging common IoT design patterns and industry frameworks provide users, manufacturers and financial intermediaries the data required to ensure asset effectiveness and availability, and to mediate concerns and remedies for nonperformance.

Position and Adoption Speed Justification: While examples of traditional leasing (such as for autos and industrial equipment) are well-established in select industries, the adoption of IoT-enabled product as a service, based on the true spirit of "as-a-service" where fee structures are utilization-based and not grounded in minimum contract terms and revenue commitments; is nascent but growing.

To implement IoT-enabled product as a service, manufacturers, certified distributors and resellers, and, service providers must apply IoT innovation to create connected products. Embedded technologies enable remote product state monitoring, control and optimization, and, software release and change management for feature updates and security patches. Connected products are integrated with back-end business applications of the asset owner (not the user) to optimize support. For example, connected products are integrated to automate the procurement of consumables and spare parts or with field service management systems so the products can schedule repair without intermediaries at the customer site or within the manufacturer.

A technical driver for IoT-enabled product as a service is that all the technologies needed to implement such a business model are readily available at reduced costs. A commercial driver for IoT-enabled product as a service is the strong overall business trend to shift business costs from asset ownership and capital expenditure (capex) to asset subscription and operating expenditure (opex). Technical inhibitors to adoption of IoT-enabled product as a service include the complexity of end-to-end IoT business solutions and specific technical challenges, such as device management, security, integration and information management. Key commercial inhibitors include the relatively immature IoT-enabled product-as-a-service business model, challenging SLAs, outage penalties and access to managed assets.

User Advice: IoT-enabled product as a service has great potential for transforming how manufacturers offer their products and services, and how companies consume them. A good implementation of IoT-enabled product as a service means having a proven end-to-end IoT device to back-end application distributed architecture that supports a proven IoT-enabled product-as-a-service business model based on reliable outcomes with predictable SLAs for a reasonable cost. Such an implementation requires a provider's careful design, business acumen, good execution and sustained attention to detail.

Companies that are considering IoT-enabled product as a service should consider the following recommendations:

- Perform your own multiyear total cost of ownership analysis to validate the benefits of IoT-enabled product as a service.
- Update business processes to take advantage of IoT-enabled insights or benefits, such as personnel scheduling or supply chain for predictive maintenance.
- Reconcile whether aggressive time-to-deployment requirements are achievable with internal resources, and if not, whether help (such as via a system integrator) is required.
- Work to determine if the manufacturer engages with financial intermediaries to operationalize the "as-a-service" offerings. Determine if P&C coverage is available to mitigate the risks of engaging in such a model.
- Negotiate agreements that clearly establish mutually agreed SLAs and OLAs for IoT-enabled product-as-a-service performance and reliability.
- Factor in all nonrecurring and recurring charges, terms of agreement and penalties into your IoT-enabled product-as-a-service business model.
- Secure the rights to IoT-enabled product-as-a-service data, including mutual agreements on exactly which data and the methods are required for accessing it.
- Determine which other entities will have access to your data and how your data is monetized by the supporting ecosystem.
- Consider IoT-enabled product as a service for more standard, expected product outcomes and realize that offerings are still relatively immature.
- Ask for end-user IoT-enabled product-as-a-service references — then speak to them before engaging with external providers.

Business Impact: Potential benefits of IoT-enabled product as a service for customers (i.e., end users) include:

- Shift asset acquisition from capex- to opex-based subscriptions.
- Leverage of economies of scale innovation investments by the manufacturers/providers.
- Mitigate risks for asset selection and procurement by transferring responsibility for IoT-enabled product-as-a-service outcomes, innovation and upgrades to the manufacturer.
- Potential faster time to deployment and asset benefits (assuming your IoT-enabled product-as-a-service provider can deploy faster than you).

Potential challenges include:

- Reliance on a manufacturer's investments to modernize IoT-enabled product-as-a-service offerings.
- Potential commercial and technical challenges for accessing IoT-enabled product data.
- Integrating IoT-enabled product-as-a-service solutions with your back-end applications and data.
- Integrating heterogeneous IoT-enabled product-as-a-service offerings from multiple providers.
- Potential disruptions of IoT-enabled product-as-a-service offerings that become commercial failures.

Benefit Rating: Transformational

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Sample Vendors: Caterpillar; Danfoss; Hartford Steam Boiler; Michelin; Philips Healthcare; SAP; Xylem

Recommended Reading: "A Digital Business Technology Platform Is Fundamental to Scaling Digital Business"

"Digital Business Ambition: Transform or Optimize?"

"Digital Business Models Compendium"

"Show the Value of OT and IT Alignment, and Realize Digital Business Results"

Digital Twin of the Person

Analysis By: Marty Resnick; Alfonso Velosa

Definition: A digital twin of the person (DToP) not only mirrors a unique individual but is also a near-real-time synchronized, multipresence of the individual in both digital and physical spaces. This digital instantiation (or multiple instantiations) of a physical individual continuously intertwines, updates, mediates, influences, and represents the person in multiple scenarios, experiences, circumstances, and personas.

Position and Adoption Speed Justification: A simple DToP is already being used for medical and biotech use cases. For example, analyzing healthcare plans, preventative care, wellness and disease control uses a rudimentary DToP to predict future medical costs. Furthermore, the Citizen Digital Twin (a "social" subset of a DToP) is being used to help address health, safety, travel, membership, and social media impacts on society. The impact of DToPs will continue to grow in areas such as education, remote working, consumer shopping, gaming and social media.

User Advice: The "avatar" has often been considered a digital representation of someone in various situations, however, the avatar is just a visualization or digital rendition of the person and is not typically synchronized to the physical person it is linked to. But what really makes a DToP different is the role of the twin as a near-real-time proxy for the state or characterization of the physical twin, and the various levels of data fidelity that make this representation effective to achieve particular outcome. Outcomes range from monitoring a potentially hazardous declining health condition, for aberrant social behavior, or for safety in hazardous working conditions.

High fidelity situations (high level of data, high visualization) would include the ability to be represented in the following situations:

- Social experience
- Business meeting
- Consumer shopping
- Gaming

Lower fidelity (high level of data, low visualization):

- Medical
- Safety
- Healthcare
- Consumer 360
- Human Resources

Enterprises should begin to adopt the concept of DToP to facilitate more collaborative and engaging remote working situations, understanding and predicting customer demands, and accelerate new business models reliant on digital representations of people. Enterprises must develop strong digital ethics, security, and data governance policies to protect customer, employee and citizen privacy and data, while meeting legal and other compliance requirements.

Business Impact: Digital Twin of the Person opens up new and emerging business models but also opens up the door for additional security, privacy and ethical considerations. Currently, precursors or early versions of Digital Twin of the Person are used for medical, e-commerce and social monitoring. But as the concept expands, new citizen services, medical care and sales options will bring in a flood of experimentation by governments and commercial entities. Effective data-driven decision making and testing out of various scenarios will be possible with less risk and in a much more efficient way. New ways to serve citizens, patients, or shoppers will be enabled by real time understanding of their situation. In parallel, enterprises with poor security and digital ethics policies expose themselves to significant legal and regulatory risk.

For some enterprises, the critical link will be the connection between an asset and a person. The digital twin of the asset (e.g., a smart meter) will be connected with the digital twin of the person (e.g., a residential consumer) and may drive opportunities for serving the customer while driving cost and process optimization and new revenues.

Benefit Rating: Transformational

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Sample Vendors: Amazon; Apple; Insight Enterprises; NTT; Philips Healthcare; ScaleOut Software; Sim&Cure; Tencent

Recommended Reading: "Cool Vendors in Augmenting Human Experiences"

"Maverick* Research: Being Human 2040 — The Life of the Architected Human in a More-Than-Human World"

Things as Customers

Analysis By: Don Scheibenreif; Mark Raskino

Definition: A thing (or machine) customer is a nonhuman economic actor that obtains goods or services in exchange for payment. Examples include virtual personal assistants, smart appliances, connected cars and IoT-enabled factory equipment. These thing customers act on behalf of a human customer or organization.

Position and Adoption Speed Justification: Today there are more internet-connected machines with the potential to act as customers than humans on the planet. We expect the number of machines and ambient artificial intelligence (AI), like virtual personal assistants, with this capability to rise steadily over time. They are increasingly gaining the capacity to buy, sell and request service. Things as customers start simply by alerting human counterparts that they need attention. However, things will advance beyond the role of simple informers to advisors and, ultimately, decision makers. According to Gartner research, both CEOs and CIOs agree on the potential of this emerging trend. Forty-nine percent of CIOs and 25% of CEOs we surveyed in 2019 believe demand from machine customers will become significant in their industry by 2030. These leaders believe at least 25% of all consumer purchases and business replenishment requests on average will be delegated to machines. Today, most things simply inform or make simple recommendations. We do see some examples of things as more complex customers emerging, such as smart grid technologies. HP Inc. embraced this future when it created Instant Ink — a service that already enables connected printers to automatically order their own ink when supplies run low. Some Tesla cars already order their own spare parts, and Walmart has patented grocery autoreordering based in home IoT sensing. In B2B, U.S.-based industrial supply company Fastenal uses smart vending machines that proactively place orders when stocks run low. Thinking forward, an autonomous vehicle could determine what parking garage to take its human passengers to based on criteria such as distance from destination, price, online review score, parking space dimensions, valet options, etc. In this case, it is the parking garage marketing to the car, not the humans.

This is a long-term proposition and there are major barriers, hence the early position on the Hype Cycle. The largest barrier is trust. Can the human customer trust the technology to accurately predict and execute? And, can the machine customer trust the organization that offers the service? Other barriers include: complex AI technologies, security and risk, regulatory compliance issues, and data sharing. All this will mean that things as customers across industries will not reach the Plateau of Productivity for five to 10 years.

User Advice: We recommend the following:

- Create a “tiger team” of architects, engineers, data scientists, economists, linguists, psychologists, and business decision makers to explore the business implications of machine customers. Determine whether the enterprise has the right capabilities, processes, and systems to identify, serve, communicate, and take orders from machines as customers.
- Follow examples from organizations like Tesla, Google, Amazon and Caterpillar to look for evidence of capabilities and business model impact.
- Build your organization’s capabilities around artificial intelligence over the next five years. First in machine learning, then extending to other facets involved in machine customers processing information and making informed decisions.
- Identify use cases where your products and services can be extended to thing customers and pilot those ideas to understand the technologies, processes and skills required. Start with simple use cases driven by rules that can be easily configured and controlled by customers.
- Create scenarios to explore the market opportunities. Initiate collaboration with your chief digital officer, chief data officer, chief strategy officer, sales leaders, chief customer officers and others to explore the business potential of machines as your customers.
- Be mindful of the very real barriers. The complexity involved in developing a thing customer that can learn the depth and breadth of knowledge and preference trade-offs required to act on

behalf of a human customer in a variety of situations is complex. Some humans may initially be uneasy about delegating purchasing functions to machines. Consider what ethical standards, legal issues and risk mitigation are needed to operate in a world of machines as customers.

Business Impact: Over time, trillions of dollars will be in the hands of nonhuman customers. This will result in new opportunities for revenue, efficiencies and managing customer relationships. Digital-savvy business leaders seeking new growth horizons will need to reimagine both their operating models and business models to take advantage of this ultimate emerging market, whose numbers will dwarf the number of human customers on (and one day perhaps off) the planet. How do you sell to a thing? What will get a thing to buy from you when its decisions are based on algorithms, not emotion? How will your human customer service agents handle requests from millions of things? What does "customer experience" even mean for a thing? Things as customers have the potential to generate new revenue opportunities, improve productivity, increase operational efficiency, improve health/well-being and enhance security of physical assets and people. They will also result in new sources of competition, fraud, legal and taxation challenges, and operational challenges (like how to provide customer service for things).

Benefit Rating: High

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Sample Vendors: Amazon; AutoCrib; Caterpillar; Google; Tesla

Recommended Reading: "Machine Customers: The Next Massive Emerging Market"

"How Customer Experience Changes When Your Customer Is a Thing"

"Why Machine Customers May Be Better Than Human Customers"

"IoT-Based Thing Commerce Requires a Differentiated Customer Experience"

"The Future of Customer Self-Service: The Digital Future Will Stall Without Customer-Led Automation"

Information Products

Analysis By: Mike Rollings; Lydia Clougherty Jones

Definition: An information product, also known as a data product, is an offering that directly monetizes data by generating value, revenue or other financial benefits. It includes licensing, bartering or sharing of data and/or insights that can be proprietary or byproduct of business operations; or provided by IoT or other instrumentation of physical products and services; or a combination of proprietary, public and exogenous data.

Position and Adoption Speed Justification: Nontraditional sellers and providers of data, both technology providers and end-user organizations, are increasingly interested in information products similar to firms such as data brokers that have been licensing and selling information for years. This interest is driven by expanding recognition of the market value of enterprise data (such as that collected from Internet of Things devices) and the desire to develop innovative offerings that generate new revenue streams or enable new market entries. However, most organizations are ill-prepared for such endeavors, as they struggle to skillfully collect, curate, manage, measure and monetize data and analytics even for internal value creation. Enterprises have been and will be challenged to develop information products as the required skills and competencies differ significantly from the products and services they sell currently. This requires advancing data and analytics maturity while developing commercial-level product management skills that most organizations do not possess.

User Advice: The desire for new information-based revenue streams requires advances in treating information as an asset, changing organization’s culture to embrace data-driven concepts, developing information product management competencies and learning to ethically leverage data rights while adhering to data sovereignty restrictions. Data and analytics leaders can begin to underpin success by fostering a more data literate workforce, pursuing a data-driven strategy and creating a data and analytics operating model oriented by business outcomes. This includes formally measuring data asset and market value with a rigor like that applied to physical assets (applying infonomics) in order to identify the potential and realized value of information assets.

Organizations seeking to identify potential information products should develop customer advocacy competencies. Data and analytics leaders should engage business leaders to identify the most valuable opportunities for both current and potential stakeholders and plan how to exploit those opportunities. These needs should be mapped against available data, IoT-derived data and sourced data to conceive products and feed product innovation.

For those organizations with an urgent need to develop information products, attend to the above underpinnings and bring additional focus to establishing commercial style product management and agile delivery practices. Consider hiring a professional information product manager whose responsibilities will include information procurement, product pricing and licensing, market definition and product development, while leveraging existing product management and licensing disciplines. Consider co-development and deployment with a third party. Also evaluate emerging data marketplaces and exchanges that facilitate the selling, licensing and sharing of information assets.

Business Impact: The impact of information products depends on the industry sector and the role they play in generating economic value:

- Public-sector open data initiatives yield indirect benefits, such as increased public confidence and trust, economic development or aiding the “Data for Good” movement. But many of the information product competencies apply to improve delivery as open data consumers develop reliance on data feeds.
- Private-sector companies can benefit from products that range from monetized raw data to creating information-enabled products and services or even information platforms that serve

ecosystem participants. Internal and external data and analytics assets can be used to attract or retain talent, new customers, add new revenue streams to IoT-enabled products, enable market differentiation and open new markets.

- Data marketplaces and exchanges can benefit from increasing interest in information products by enabling publishing, curation, analysis and aggregation of data, revenue sharing, and matchmaking to new products.

Benefit Rating: High

Market Penetration: 1% to 5% of target audience

Maturity: Adolescent

Recommended Reading: “Essential Product Management Practices to Monetize Data and Analytics Assets”

“Applied Infonomics: How to Measure the Net Value of Your Information Assets”

“Applied Infonomics: 7 Practices for Chief Data Officers to Monetize Information Assets”

“Smart Data Sharing — Five Insights to Get It Right”

“The Extended Vehicle and Neutral Servers: The Access to Car Data Monetization”

“Tech Go-to-Market: Product Management Must Define and Communicate Compelling Roadmaps to Ensure Product Success”

“Data Monetization Will Be the Next Frontier for Digital Insurance”

“Magic Quadrant for Managed IoT Connectivity Services, Worldwide”

“The New Money: Help Your Clients Turn IoT Data Into Monetizable Data Products”

“Top 10 Strategic Technology Trends for Manufacturing Industries: Data Monetization”

Blockchain and IoT

Analysis By: Nick Jones; Benoit Lheureux; Avivah Litan

Definition: Blockchain and Internet of Things (IoT) refers to the use of blockchain in conjunction with IoT devices and technologies. Blockchain and IoT can be combined in many ways for purposes such as IoT payment, tokenization of IoT-related assets or services, identity validation, provenance tracking, utilization recording or billing, and secure firmware updates.

Position and Adoption Speed Justification: The combination of blockchain and IoT:

- Enables an immutable audit trail of key IoT data and related business events that is shared across multiple participants and can be independently verified by each party.

- Supports management of IoT objects by providing more-secure ways to identify them and perform tasks such as firmware updates.
- Can use IoT technology to provide secure hardware tokens to identify objects to blockchains.
- Will support smart contracts and distributed applications (aka dapps) that will enable sophisticated business models involving machines and people, or other machines.

The combination of IoT and blockchain is immature and faces many technical and business challenges. Many IoT devices are simple and lack adequate computational or networking resources to act as full nodes in a blockchain, so you must rely on proxies or gateways. The relative volatility of blockchain implementations involving protocol changes may be a challenge for long-lived IoT devices. Some blockchain implementations struggle to scale to the transaction rates that can be generated by large numbers of connected "things." In the long term, we expect the combination of IoT and blockchain to enable innovative devices and business models; however, the necessary evolution in blockchain and IoT will take five to 10 years to achieve maturity.

User Advice: CIOs, enterprise architects and technology innovation roles should look for situations in which IoT and blockchain enable new business capabilities and solve real-world problems, and where technology's immaturity and rate of change aren't impediments. Several large IoT platform vendors have demonstrated integration between their technology and blockchains, providing a simple path for pilot projects. There is also a good selection of smaller vendors and startups that support integration of IoT and blockchain. Private blockchains with known ecosystem members are likely to pose fewer technical and governance challenges. Beware of applications involving long-lived IoT devices and long-lived data, which will require the ability to periodically deploy blockchain technology updates in scale.

In situations where all that's required is immutable data storage without shared ecosystem ownership, business rules, or tokenization, consider immutable centralized databases or ledgers such as Datomic or Amazon QLDB as alternatives to blockchain.

Business Impact: Business opportunities often involve situations where the IoT devices participate in ecosystems where untrusted partners must store and share immutable information, or where tokenization enables a new business opportunity. Examples include:

- Smart packaging to track supply chain provenance of high value, sensitive or regulated products, such as food, pharmaceuticals, human tissue/biological materials, medical shipments
- Business models in which trustworthy tracking of equipment utilization or status is critical, or required by regulations (e.g., truck leasing or insurance)
- Business models that combine IoT and tokenization (e.g., smart trash cans providing credits for recycling)

- Cases in which blockchain can contribute to increased trust or security for IoT (e.g., trusted machine identity, trusted firmware updates)

Benefit Rating: Transformational

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Sample Vendors: Chronicled; IBM; IOTA Foundation (Tangle); modum

Recommended Reading: "Top 10 Strategic Technology Trends for 2020: Practical Blockchain"

"Integrating Blockchain With IoT Strengthens Trust in Multiparty Processes"

"Survey Analysis: IoT Adopters Embrace Blockchain"

At the Peak

IT/OT/ET Alignment

Analysis By: Kristian Steenstrup; Marc Halpern

Definition: IT/OT/ET alignment refers to the orchestration of information technology (IT), operational technology (OT), and engineering technology (ET) to mutually support each other through shared standards and governance. Each plays a complementary but mutually reinforcing role to the other two technologies. While IT records transactions and business processes, OT operates and monitors industrial assets (e.g., SCADA), and ET is used to define, design, simulate, analyze, visualize and validate those assets (e.g., CAD/CAM).

Position and Adoption Speed Justification: We have previously written about IT and OT alignment. Adding ET to the mix increases the complexity and resets the Hype Cycle clock as this is a new challenge for most. Commonality and interoperability are improved when OT enabled machines and ET and IT systems support the same hardware, operating systems and communications infrastructure. As a result, Gartner sees organizations implementing common architecture plans and common standards for the components acquired, and increasingly looking for vendors that support this direction. Most companies are just undertaking this exercise and are more aware of the obstacles and problems while still conscious of the benefits.

The entrenched separate positions and practices associated with OT and ET systems and their criticality, safety and stability, means that realignment takes time. Yet, this change must follow the realization of the impact of technology convergence, its opportunities and benefits, and the risk of doing nothing. For some organizations, the technical data integration of industrial assets takes place long before alignment (shared governance and practices), but without alignment, integration will be inherently unstable and unsustainable. A key underlying obstacle to alignment will be the different cultures and approaches of IT departments, manufacturing/operations and design/engineering, which will have to be orchestrated.

Because the benefits are becoming more apparent and publicized, we see progressive movement of IT/OT/ET alignment with clients who are working through the considerable complexities of culture and politics of getting this done.

User Advice: When the benefits of technology convergence have been recognized, it should cause IT and the operational business units to examine their technology management processes to determine:

- How much of what is done in IT is applicable to OT and ET insofar as supporting and securing technology platforms
- How the unique needs of OT and ET must be recognized and supported
- How to get them aligned by design

As OT systems take on IT architecture and characteristics and ET systems are used to design and build OT enabled equipment, organizations respond by aligning the standards, policies, tools, processes and staff between IT and the business departments. These departments traditionally are most involved in ET and OT system support. But this is not easily done, with the history of disconnect and distrust between IT and engineering departments that are managing the OT and ET systems. Alignment is dependent on process, standards, and cultural and governance harmonization. Organizations should include OT and ET requirements into their enterprise risk management efforts by adopting an integrated security strategy across IT, OT, ET, physical security and CPS for greater visibility.

Alignment requires combined hardware platform and architecture policies to ensure compatibility between IT, OT and ET systems by formulating compatible governance for software, communications, ecosystems and hardware. Alignment does not necessarily mean that IT departments and OT or ET management groups need to be one integrated organization, nor must integrating IT and OT/ET systems depend on alignment (but ideally it should). An enterprise architecture plan that embraces IT, OT and ET will be the key element of an alignment project. While usually IT-led, this alignment may be led from the engineering side in some cases.

One valuable method to help manage this transition and to map out organizational responsibilities for different parts of the technology environment is the responsible, accountable, consulted and informed (RACI) analysis.

Business Impact: The impact of IT/OT/ET alignment falls across many categories:

- Cost reduction by not duplicating licensing, maintenance and support for common software components
- Cost reduction by consolidating and collocating servers and back-end hardware in a common data center

- Agility by being able to start new hybrid IT/OT/ET projects quicker and reacting to changes in a consistent way

- Risk avoidance by aligning security, patching, disaster recovery and upgrading processes

- Benefits of using the same support and configuration tools, support contracts and purchase processes

- Access to ET and OT data in IT analysis such as predictive maintenance and production optimization

An obstacle to the alignment may be an increase in cost on the OT or ET side initially, as purchases are made to bring software up to the IT standard/version and to deal with any license compliance gaps. It is normal for software asset management (SAM) to involve significant resources in the early stages, with savings being identified once the software position has been baselined accurately and compliance issues resolved. Support and maintenance of software and hardware are usually where the quick wins can be identified. Yet, this is less frequently the case in OT environments, as much of the "IT" software used in this space is legacy and unsupported, so it doesn't incur maintenance costs. (ET is not usually as much of an issues). As a result, the benefits in terms of cost savings tend to be medium- or long term, not short term.

Benefit Rating: High

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Sample Vendors: Bentley Systems; Siemens

Recommended Reading: "2020 Strategic Roadmap for IT/OT Alignment"

"Innovation Insight for Engineering Technology: Why ET, IT and OT Are More Than the Sum of Their Parts"

IoT-Enabled Applications

Analysis By: Benoit Lheureux; Jim Robinson

Definition: An IoT-enabled business application is natively designed or architecturally enhanced to directly support or integrate with IoT, such that:

- It is integrated with IoT edge devices and platforms, possibly via IoT middleware.

- It ingests and analyzes IoT data and events to minimally improve situational awareness and produce a business-relevant finding, and optionally to additionally orchestrate a business response.

- To accomplish the above, it leverages digital twins.

Some enterprise applications (for example, APM, CRM and FSM) do this today.

Position and Adoption Speed Justification: Most business applications today are not yet IoT-enabled because they predate IoT and thus they were not designed to natively ingest and process real-time event data. But there are some emerging IoT-enabled applications (see “Market Guide for Digital Twin Portfolios and Enabling Technologies”). When IoT-enabled applications are not available, technology providers and enterprises create IoT-enabled applications by integrating IoT technology, which requires:

- Integrating with brownfield OT edge devices (for example, PLCs, SCADA, and historians) be used with the application.
- Making applications aware of IoT metadata (e.g., time-series sensor data) and integrating that with other traditional application data (e.g., asset master).
- Depending on the desired outcomes, identifying what forms of analysis are needed to produce useful insights and events.
- Enhancing existing application workflows and interfaces to accommodate IoT triggered events (for example, automatically creating “Fix It” tickets for equipment maintenance).

Given the emerging availability of packaged IoT-enabled applications and the ability — despite challenges — to implement IoT-enabled applications, we have accelerated this IP and now believe that it will take two-to-five years for IoT-enabled applications to become readily available across multiple industries.

User Advice: Companies adopting IoT must prepare for a future where many business applications are IoT-enabled. Thus, application leaders and architects should:

- Prioritize the most important desired IoT-enabled business outcomes in your business (see “Leverage Digital Twins to Deliver a Compelling Oil and Gas Industry Customer Experience” and “The Future of Field Service Management”). Use these to determine which of your business applications need to become IoT-enabled applications.
- To IoT-enabling an existing application plan to acquire digital twins as a separate software product (see “Survey Analysis: IoT Digital Twin Adoption Proliferates Across Many Sourcing Options”). Then plan to integrate these (often via APIs) with your applications, preferably via integration tools (see “Choose the Best Integration Tool for Your Needs Based on the Three Basic Patterns of Integration”).
- Design digital twins to generate events, for example to produce food dispenser replenishment requests in your FSM and procurement applications. Plan to integrate these digital twins with your existing business applications (see “What to Expect When You’re Expecting Digital Twins”).
- Encourage collaboration between IT and OT staff (see “As IT and OT Converge, IT and Engineers Should Learn From Each Other”). One impact will be the need to synchronize digital twin data

with existing business application master data.

- Design new IoT-enabled applications as small, fit-for purpose "miniapplications," e.g., equipment maintenance scheduling, replenishing a vendor machine, or reporting a patient's declining health condition. Additionally, factor proliferation of these applications in your application strategy (see "Innovation Insight for Packaged Business Capabilities and Their Role in the Future Composable Enterprise").

Business Impact: IoT will close the gap between billions of things — for example, products, people, assets and equipment — and applications across all industries and business processes. Thus, IoT-enabled applications will proliferate to address an ever-widening set of use cases. Examples include:

- IoT-triggered replenishment of consumables, such as chemicals, filters, bulbs, and food.
- Turbines, refrigerators and vehicles will self-diagnose imminent failures, provision spare parts, and trigger their own request for repair.
- Patients that are monitored by digital twins which trigger care requests via integration with healthcare provider dispatching applications.
- For business activities such as plant maintenance, building management, and smart agriculture, IoT endpoints will be linked to workflows in applications such as ERP.
- Retailers, hotels and airports will integrate event-streamed device data, consumer behavior, and inventory to better utilize spaces, improve user experience, increase safety (e.g., social distancing), trigger on-the-spot offers, etc.

The workflow in applications will be triggered by digital twins. While implementing such profound application enhancements will take years, the long-term benefits and impact of IoT on improved business process execution will be transformational. For example, by 2024 at least 50% of enterprise applications in production will be IoT-enabled.

Benefit Rating: Transformational

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Sample Vendors: C3.ai; GE Digital; Hitachi Vantara; IBM; Infor; Oracle; PTC; SAP; Schneider Electric; Uptake

Recommended Reading: "Market Guide for Digital Twin Portfolios and Enabling Technologies"

"Survey Analysis: IoT Digital Twin Adoption Proliferates Across Many Sourcing Options"

"What to Expect When You're Expecting Digital Twins"

"Innovation Insight for Packaged Business Capabilities and Their Role in the Future Composable Enterprise"

"IT Market Clock for ERP 2020 — Preparing for the 4th Generation of EBC"

Edge Analytics

Analysis By: Eric Hunter

Definition: Analytics is the discipline that applies logic (i.e., "rules") and mathematics ("algorithms") to data to provide insights for making better decisions. "Edge" analytics means that the analytics are executed in distributed devices, servers or gateways located away from corporate data centers or cloud servers closer to where data from "things" (commonly sensors) is being generated.

Position and Adoption Speed Justification: Edge analytics moved further along the Hype Cycle toward the Peak of Inflated Expectations, driven by increased expectations for edge analytics via machine learning and advances in the hybrid cloud. By 2023, Gartner predicts that more than 50% of enterprise-generated data will be created and processed outside the data center or cloud, up from less than 10% in 2019. Edge analytics offerings primarily support decentralized deployments of device-isolated insights. However, as connectivity advances and the demand for cross-device analytics increase, edge analytics will be tasked not only with providing edge-resident insights, but also to support conversion and compression to move data to hybrid cloud platforms for aggregation.

IoT platform and analytics vendors continue to add the ability to deploy and run small-footprint analytics packages on edge devices — supporting both endpoints and aggregation devices like an IoT gateway. It reflects the shifting balance between edge and cloud computing. Public cloud providers are further accelerating this trend with announcements from Amazon Web Services (AWS Outposts), Microsoft (Azure Stack), Google (Anthos) and IBM (OpenShift). As 5G networks continue to grow in relevancy, mobile edge computing (MEC) will also increase edge analytics use cases — particularly for latency sensitive deployments. This trend is being driven by several factors including rightsizing connectivity to the edge, real-time analytics and data privacy considerations.

User Advice: Analytics leaders should consider edge analytics across the following five imperatives:

- **Limited Autonomy:** An individual device, asset or even a larger distributed site must provide analytic insights even in the midst of disconnection from cloud or data center infrastructure and resources (driverless cars for instance).
- **Privacy/Security:** Regulations or data privacy laws require that data be kept within the location of origin or the organization deems the transfer of data to introduce too many security vulnerabilities.

- **Latency/Determinism:** Network connectivity does not have the ability to support desired latency or stability requirements.
- **Local Interactivity:** Cross-device interdependencies as part of a larger system require edge-resident analytics.
- **Data/Bandwidth:** It would cost too much to upload the full volume or fidelity of generated data, and there is no benefit to moving device-level data to a central location for aggregated analysis. Another scenario includes edge analytics for support of centralized cloud or data center analytic strategies by converting/compressing edge-generated data for network transmission.

Business Impact: Running analytics at the edge will become commonplace for both data and analytics and IoT architectures by the time it reaches the plateau.

Advantages include:

- **Faster response times:** Many sensors deliver digital and analog data at very low millisecond or submillisecond intervals. When that data is sent to a central location for analysis, delays are introduced, and it loses its value for real-time requirements.
- **Reduced network bottlenecks:** Minimizes the risk of congesting device networks with full-fidelity or high-bandwidth data transmission (video, millisecond interval sensor reads and analog sensors).
- **Data filtering:** This reduces the data management and storage overhead by using edge analytics to look for just the actionable data. As a result, only the necessary data is analyzed or sent on for further analysis.
- **Reliability:** The remote location can remain in operation even if the network, cloud servers or data centers are unavailable.
- **Reduced communications cost:** Device-only edge analytics eliminate communication costs while edge device-based conversion and compression can dramatically lower costs versus sending raw analog or full-fidelity digital data to a central cloud or data center.

Disadvantages include:

- **Increased complexity:** Remote, distributed analytics deployment and management make the deployment and management more complicated than for aggregated data in a single location — particularly when devices are heterogeneous in nature — lacking in standardization.
- **Reduced data granularity:** There is a potential loss of useful insight by discarding raw data stored locally as “data exhaust.”
- **Lack of cross-device analytics:** Unless device data is transmitted to a consolidated location from the edge, leaders can lose the ability to deliver cross-device insights and analytics.

- **Device maintenance and technical currency:** Edge analytics will require more capable devices that increase demands for monitoring and maintenance of device health along with introducing demands for keeping devices up-to-date with both software and hardware revisions.

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Sample Vendors: Amazon Web Services; Arundo; Element; FogHorn; Iguazio; Microsoft Azure; Particle; PTC (ThingWorx); SAS; TIBCO Software (Spotfire)

Recommended Reading: "Top 10 Strategic Technology Trends for 2020: Empowered Edge"

"How to Overcome Four Major Challenges in Edge Computing"

"Designing an IoT Reference Architecture"

"Deploying IoT Analytics, From Edge to Enterprise"

"4 Steps to Successful Edge Computing Deployments"

"Best Practices for Tech CEOs to Manage Edge-to-Cloud Products"

Digital Thread

Analysis By: Marc Halpern; Rick Franzosa; Simon Jacobson

Definition: A digital thread is a framework to collect, organize, associate, trace and present data for multiple factors. The multiple factors such as design, manufacturing, services, and repairs influence a product and/or process and their evolutions over their respective life cycles. Integrating and organizing semantically rich data with digital threads allows multiple users to access, integrate, organize, trace and transform disparate technical and knowledge-based data from multiple operational and enterprise-level systems.

Position and Adoption Speed Justification: The concept of a digital thread is not new. However, the positioning on the Hype Cycle reflects the nascence of adopting digital threads to connecting engineering and production in configure-to-order (CTO) and engineer-to-order (ETO) supply chains. Digital threads also apply to assets such as power plants, refineries, and servicing industrial equipment. The potential of digital thread to traceability of parts, materials and processes for maintaining, repairing, and upgrading products and assets remains largely untapped. Early adopters are discovering opportunities to enhance digital threads with analytics. For example, analytics related to manufacturing processes and costs as well as frequency of maintenance and repair needs offer insights into the how and why of improvements to products and assets.

The pace of which digital threads reach the plateau will be a factor of:

- Understanding both the complementary nature of digital twins as well as the interdependencies between digital twins and digital threads. Notably, digital threads are fundamental to digital twins. Simultaneously, the content of digital twins enriches the value of digital threads.
- The rate of advances in technology enablement and best practices in data governance necessary to enable digital threads
- The rate at which companies can adapt the uses of digital threads to product variants created from product platforms where common parts and subsystems can be mixed and matched for a wide variety of products.
- The relationship of digital threads to existing applications such as EAM, PLM, ERP, MES and to digital twin technology, when deployed.

User Advice: Those wanting to invest and manage the digital thread should:

- Focus on building the digital thread for secure traceability of products and the processes that evolve over their life cycles instead of confining it to engineering and production.
- Not restrict traceability to a single technical approach or process whether it be APIs, microservices, blockchain, or any other means. Use a combination of approaches that makes the most sense to retain traceability yet meet role and process business needs.
- Use the digital thread as a tool for improving efficient decision making, cost, quality, traceability and regulatory compliance.
- Adopt an industry data governance strategy for a digital thread by including members of your value network in planning for data oversight, data orchestration, data curation and data management.
- Overcome the absence of a complete data model by investing in standards to capture and normalize data from different systems.

Business Impact: The digital thread is a lever for continuity and traceability across the value chain. Analytics combined with traceability of product evolution from product design and manufacturing can advise customers on more effective maintenance and service. Compliance with regulations government bodies such as FDA and DoD will be more transparent and efficient. Analytical feedback from a product's service life can offer insight into continually improving products.

The digital thread will have the following impacts:

Risk: Medium — Besides more efficient compliance with regulations such as RoHS/WEEE, Reach, FDA and ITAR security, digital threads mitigate IP risk and concerns from OEMs and brand owners for revealing their process structures and suppliers for fear of disintermediation.

Technology Intensity: High — Beyond core systems (MES, PLM, ERP) the broader technologies and tools (cloud services, automated data synchronization/validation), to access, verify, validate, and synchronize data need time to mature. Even greater impact when digital twins are part of the technology stack.

Organization Change: Medium — Initially it will tighten collaboration and alignment gaps between R&D/engineering, manufacturing operations, sourcing, and IT. In the longer-term it will extend to sales and marketing functions which might either promote or allow some customers to have specific, nonstandard configurations; in long-term anticipate new organizations and teams to emerge which in turn creates new job opportunities.

Process Change: High — BOM changes might be a normal occurrence. However, the synchronization of different BOMs — and the ability to assimilate process changes related to BOM changes, as well as where new SLAs that bind responses from suppliers to provide data transparency and ultimately impacts traceability downstream once products are in the market. Not to be overlooked is the need to set up specific processes for data governance.

Competitive Value: High — Cost optimization and time savings come from shortened decision cycles and improved agility on both global and local bases. Accelerating innovation and bringing products to market are also not to be overlooked.

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Sample Vendors: Anark; Aras; AVEVA; Dassault Systèmes; GE Digital; Hexagon Manufacturing Intelligence; iBASEt; Microsoft; Siemens PLM Software

Recommended Reading: "Innovation Insight for the Digital Thread"

"Manufacturing Process Management Is Essential to Digital Thread"

"Choose the Best Integration Tool for Your Needs Based on the Three Basic Patterns of Integration"

"How to Achieve Better Business Model Strategies With Industry Data Governance"

Digital Business Technology Platform

Analysis By: Bill Swanton

Definition: A digital business technology platform is the combination of technologies that enables an organization to deliver digital business capabilities. It enables existing platforms for IT, customer engagement, data and analytics, ecosystem partners and the Internet of Things to sense business events, decide what to do, and implement a business response that creates value for those involved. Platforms share assets such as data, algorithms and transactions with business ecosystems to match, create and exchange services.

Position and Adoption Speed Justification: Companies use a variety of relatively new-to-market integration, API mediation, platform as a service (PaaS) and other cloud technologies to implement digital business technology platforms today (see "Survey Analysis: Building a Digital Business Technology Platform Requires New Technologies and Methods"). There is currently no specific market or vendor for an entire platform — companies need to assemble components and tools from generally available cloud frameworks and a cluttered market of Internet of Things (IoT) vendors. Some service providers are marketing their platforms, which are reusable assets inevitably sold in conjunction with significant services. While digital native organizations are adept at these technologies, traditional companies often struggle with new architectural approaches, such as microservices architecture, event-driven architecture, and programmable infrastructure that may be required for large-scale implementations. Complicating matters is the rapid change in these technology markets, which may cause ongoing refactoring of the platform.

Despite these challenges, we believe digital business technology platforms are moving rapidly to the Plateau of Productivity in two to five years because:

- Organizations are being driven to digital business to mitigate disruption of their core businesses and the distancing rules of COVID-19.
- Digital business technology platforms enable platform business models, which can create rapid market growth and potentially dominate industries (see "Winning in the Platform Game, Part 1: Understand the Game and Determine Your Role").
- Regulatory requirements in some regions are requiring organizations to share business services through digital platforms. For example, PSD2 requires banks in the European Union to provide mandatory access to customer accounts for regulated third parties.

User Advice:

- Work with business leaders to identify likely use cases (sense, decide, act) needed to implement your digital business based on the strategy (see "Use Gartner's Digital Business Layers to Communicate Your Digital Intent").
- Build out the digital business technology platform as needed to implement the initial digital use cases. The build out will take years and may require refactoring as the business scales and the technologies used mature. Given the limits most companies face on investment, the initial investment must be relatively small, with costs scaling with revenue, which precludes major upfront infrastructure and license costs (see "How to Build a Digital Business Technology Platform"). Treat the digital business technology platform as a continuously evolving product guided through its long life cycle by a product manager.
- Work with technology and service providers to determine what digital technologies are needed to implement the use cases in a way that will scale to the level the strategy envisions. Most

organizations do not yet have the skills to implement this technology so skills transfer needs to be a part of any service contract.

- Understand what APIs you might need to consume or provide to interact with customers and/or ecosystem partners inside or outside of the enterprise.
- Keep existing platforms loosely coupled by using techniques such as API mediation so you can modernize those platforms without disrupting your digital business build-out. Managing an inherently hybrid IT infrastructure for all these parts will be a major challenge.

Business Impact: DBTP enables an enterprise to become a digital business and deliver digital products and services to customers. Without it, it will be much harder for an enterprise to gain the business benefits of digital business. They empower people, businesses and things to give, take or multiply value creation for the enterprise. Digital platforms will make it easier for new market entrants, startups, competitors and, eventually, smart machines to create and pursue new business opportunities. Traditional businesses will have to build a digital business technology platform to compete and/or participate in these new markets. DBTPs provide an easier "funding/investment" target for business leaders to incorporate.

Benefit Rating: Transformational

Market Penetration: 20% to 50% of target audience

Maturity: Adolescent

Sample Vendors: Amazon Web Services; Google Cloud Platform; Microsoft Azure; NXN; Red Hat OpenShift xPaaS; VANTIQ; VMware

Recommended Reading: "How to Build a Digital Business Technology Platform"

"Use Gartner's Digital Business Layers to Communicate Your Digital Intent"

"Survey Analysis: Building a Digital Business Technology Platform Requires New Technologies and Methods"

"How to Govern a Digital Business Technology Platform"

Indoor Location for People Tracking

Analysis By: Tim Zimmerman; Annette Zimmermann

Definition: Many enterprises need to track employees for safety or productivity purposes. Vertical market indoor requirements for people tracking also include applications for customers, employees, infants or eldercare and, depending on the required outcome, each use case may require a different technology to achieve the goal.

Position and Adoption Speed Justification: Tracking people is different from tracking "things." When a tag is close to the human body, the energy necessary to "excite" a passive tag or to "beacon" from an active tag may not be enough to communicate. Depending on the position of the human body or the proximity of the tag to the body, the energy used for communication may be absorbed or blocked. The "tag" can be in many different shapes or sizes including wristbands, fobs, badges or smartphones. Depending on the frequencies used, which can range from 125 kHz to ultrawideband, the application may actually "lose track" of a person if the right technology is not selected.

While healthcare is a high-visibility market for people-tracking solutions to track patients, doctors and nurses, industrial markets including factories or construction sites are looking at this technology for employee safety and anti-collision purposes (with equipment such as forklift trucks). People-tracking solutions can also be used for process optimization when employees are performing identified tasks.

For years, vendors have tried to use either the same technology to track people and things or use a specific technology for a siloed use case. Enterprises were forced to evaluate the risk associated with being able to track people at less than 100% of the time. Some applications were able to accept the risk, typically in noncritical scenarios where safety or loss of life were not part of the decision process. Others were required to implement separate overlay technologies dedicated to tracking people and some projects were deemed unable to be implemented either because of the cost or lack of ability to achieve necessary business outcome.

Today, advancements in technologies are dedicated to addressing the issues associated with people tracking as well as vendors aggregating the input from multiple technologies in an effort to eliminate redundant infrastructure requirements.

User Advice: Enterprises that need to use location information for people tracking including line-of-business vertical markets such as retail, healthcare and the service sectors such as real estate, should evaluate the indoor positioning technology capabilities and business cases. Safety use cases in manufacturing factories or distribution centers may require granular location as well as movement (direction) data in order to prevent collisions.

Enterprises must identify the use case including the environment and the specific outcome that is needed. The selection of the right technology is imperative to ensure that the application does not "lose track" of the person before they are out of range of the technology to reestablish the location within the environment. Technologies such as Wi-Fi are used for proximity tracking where the use case does not require granularity. Frequencies such as 13.56 MHz, passive UHF, BLE or UWB are often used for zonal tracking when they are integrated into ID tags, wristbands or security badges that detect where employees are at a specific time and date. Other frequencies such as 433 MHz will go through the human body and are best when maintaining contact is imperative.

Business Impact: Surveyed end users reported that 95% of enterprises looking to track assets also wanted to track people as part of a cohesive solution. From a safety standpoint, not being able to track people in dangerous situations or environments results in not only avoidable injuries but also loss of life. In the U.S., some states are adopting personnel emergency notification or location requirements for industries such as hospitality and healthcare to ensure worker safety.

From a location standpoint, retailers want to know where customers are going within the store environment, while manufacturing and traditional office environments are using the information for process optimization.

Benefit Rating: High

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Sample Vendors: AiRISTA Flow; Gozio; GuardRFID; HID Global; Juniper Networks (Mist Systems); Quuppa; Zebra Technologies

Recommended Reading: "Magic Quadrant for Indoor Location Services, Global"

"Critical Capabilities for Indoor Location Services, Global"

"Market Guide for Indoor Location Application Platforms"

"When and Why Enterprises Should Implement RFID to Track Critical Assets"

IoT in Healthcare

Analysis By: Gregg Pessin

Definition: The IoT in healthcare is a collection of devices, applications, equipment, appliances and buildings that possess the intelligence and technology to connect, communicate and interoperate with each other using standards within the healthcare provider IT ecosystem of smart things. IoT in healthcare is foundational to the real-time health system.

Position and Adoption Speed Justification: The concept of IoT technologies specifically for use by healthcare has been growing moderately in hype and is positioned just past the peak this year. The hype is beginning to take a new shape as more data collection devices within the healthcare environment evolve into IoT edge devices and begin to interoperate using industry standards. This improvement supports semantic/healthcare interoperability and reduces integration complexity and cost. This evolution is expected to continue, plateauing in the next five to 10 years globally.

These common data collection and analytics platforms will combine with edge processing into IoT platforms, which will include clinical event buses with event listeners/responders. We envision clinical devices and data collection systems will publish data associated with events occurring in the care venue, detected by IoTs, to the service bus. Various response systems will subscribe to the service bus for specific event types and subsequently process them according to their purpose, such as delivering clinical alert notifications to the appropriate caregiver.

Today, the individual categories of IoT devices for healthcare continue to advance, each moving at their own pace — for example real-time location systems are advancing faster than lighting control. Tracked edge device categories include facility devices (security, building management and environmental control), patient monitoring (medical devices, clinical monitors, smart patient rooms and virtual care devices) and real-time location services (asset tracking, patient tracking, employee tracking and visitor tracking). The COVID-19 pandemic is increasing interest in IoT in healthcare but as of yet has not increased actual adoption enough to impact placement on the Hype Cycle.

User Advice: IoT in healthcare impacts a variety of clinical and business processes and, as such, will affect a range of stakeholders. Use the following points to guide your actions:

- Start small, experiment and look to other industries and ecosystem partners for ideas.
- Build business cases with ROI extending across core business processes.
- Engage your customers in the solution development. Use prototypes to help explore opportunities.
- Ensure the architecture teams are ready to incorporate IoT across IT and OT technology stacks. Increase your capabilities to leverage big data cost-effectively.
- Plan to invest in skills and technology to support healthcare specific IoT platform and IoT software integration, data and analytics, as well as managed security solutions.
- Select your technology and service providers based on their technology stack and their ecosystem of partners.
- Ensure there is end-to-end compliance of your IoT solution with health information protection legislation.

Business Impact: IoT in healthcare is foundational to digital business and, as such, will transform care delivery as it evolves and matures. Its projects will positively impact the healthcare providers' ability to deliver care more efficiently and cost-effectively. Connected things will drive revenue and improve operational efficiency and asset utilization. Other benefits include:

- Improved operations: Better productivity and increased efficiency, logistics and coordination
- Optimized assets: Asset utilization, health monitoring, reliability, predictive maintenance and asset performance management
- Enhanced services: Remote monitoring — telehealth/virtual care/proactive maintenance
- Increased engagement: Improved experiences of patients, care providers and others
- Improved well-being: Wellness, longevity and care delivery for a better quality of life
- Enhanced security: Protection of physical assets as well as safety of patients to reduce risk
- Better use of resources: Energy efficiency and long-term waste reduction

Benefit Rating: Transformational

Market Penetration: 5% to 20% of target audience

Maturity: Emerging

Sample Vendors: ALTEN Calsoft Labs; Connexall; IBM; Kaa; Philips; Siemens; ThoughtWire; Vivify Health

Recommended Reading: "Strategic Roadmap to the Real-Time Health System"

"Healthcare Provider's Unique IoT Challenges Demand a Platform Strategy"

"Survey Analysis: Healthcare Provider IoT Adoption Is Becoming Mainstream"

"Evolving IoT Security Risks Demand New Approaches From Healthcare Delivery Organizations"

IoT Services

Analysis By: Eric Goodness

Definition: IoT services encompass support, maintenance and professional services to provide a range of business and technical expertise in support of IoT plan, build and run services. Various frameworks, methodologies, and assets are within scope for IoT services. IoT services must be viewed within the broader remit of "digital services." The core outcomes of IoT services lie in the enablement of data acquisition and data contribution to broader digital business strategies.

Position and Adoption Speed Justification: Years of Gartner surveys continually point to the enterprises' lack of internal resources skilled in IoT technologies and how to apply and how to operationalize the integration of IT, OT and IoT. Adoption of ESPs for IoT services remains high in the market. There is a broad mix of providers, industrial equipment OEMs, traditional IT ISVs, IT and OT system integrators, niche IoT providers (hardware and software), offering a catalog of IoT services that spans:

- Advisory and consulting services that address business and technology issues.
- IoT-specific development and integration of legacy IT and OT, or ensuring that legacy enterprise applications benefit from IoT data acquisition.
- Installation and product support services aimed at the Microsoft Azure IoT Edge.

User Advice: Determining the suitability of the mix of providers is challenging for buyers. The market is fragmented and expertise is distributed unevenly. The leaders in IoT strategy lies with larger system integrators and consultancies. However, users have chosen to use the IoT platform vendors (of which there are hundreds upon hundreds of ISVs), no matter how small, as the main pool of ESPs for development and integration services. Maintenance and support services tend to be awarded to the device OEMs as a robust third-party maintainer (TPM) market has not emerged. Users must take steps now for your IoT service prioritization and provider selection process:

- Based on the defined business outcomes for adopting IoT, define the necessary IoT service requirements across the projects to determine when to contract an IoT service provider.
- Identify success metrics early and clearly to get POCs into field trials and production.
- Allow alternate mechanisms to achieve outcomes. This may require the abandonment of legacy vendor management approaches (e.g., approved vendor lists, RFP cycles) which threaten value recognition. The IoT is fueled by nontraditional service models, such as revenue sharing and contingent-fee contracts.

Business Impact: IoT contributes to digital business value propositions of "optimization" and "transformation" across all industries. Buyers seek IoT services to:

- Improve the processes related to strategy development, vendor due diligence and technology independent verification and validation relating to IoT technologies and business design patterns.
- Accelerate the time to solution to recognize internal (operations, processes) and external (market, customers) benefits.
- Reduce noncore resources and mitigate the risks of deployment, integration and support.

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Sample Vendors: Accenture; Atos; AT&T; Cognizant; Hitachi; Insight; KORE; Vodafone

Recommended Reading: "Emerging Technologies: Combinatorial Digital Innovation Delivers Product and Service Leadership"

"Deploy Leaner AI at the Edge: Comparing Three Architecture Patterns to Enable Edge AI"

"Architecting Machine Learning With IoT"

"Market Opportunity Map: Commercial IoT, Worldwide"

"Market Opportunity Map: Industrial IoT, Worldwide"

Model-Based Systems Engineering

Analysis By: Marc Halpern

Definition: Model-based systems engineering (MBSE) is a digital approach to addressing challenges by describing those challenges as digital models. Those models include relationships among the variables and systems that influence relevant behaviors to be understood and improved upon. The models can range from the very simple connecting few variables, to the very complex connecting many variables.

Position and Adoption Speed Justification: The technologies that enable MBSE, such as simulation, 3D modeling and information management, have their origins in the 1970s and 1980s while systems engineering has origins dating back to the 1940s. Although the enabling technologies are well established, the confluence of these technologies into MBSE began during the late 2000s at the Innovation Trigger. MBSE reached the Peak of Inflated Expectations about five years ago with the hype of digitalization and the need for systems engineering to support infusion of software into physical products and systems. Since then, MBSE evolved from university settings and research labs to startup companies, some of which have been acquired by well-established product life cycle management (PLM) and engineering software providers. Today, manufacturers in industries such as aerospace and defense, automotive, industrial machinery, natural resource processing, high tech and utilities make early investments in MBSE programs. While MBSE grows, it slides into the Trough of Disillusionment, challenged by:

- The time and cost to produce trustworthy models with sufficient fidelity to real-world systems
- Challenges transferring the knowledge of best MBSE practices from a small knowledgeable community of experts to a broader market
- Poor adoption of standards that would make long-term use and reuse of the models more efficient
- The difficulty of changing the behaviors of organizations in manners that would make MBSE practice more productive

So, while commercial providers continue to advance MBSE technology, the highlighted challenges inhibit its progress to the Plateau of Productivity.

User Advice: requirements management software. This integration should provide mapping between the requirements of the system being modeled and the technical specifications that meet those requirements.

MBSE success also requires planning for change management including changes to organizations, roles, processes and practices. The roles must include:

- Multidisciplinary roles with a focus on systems thinking
- Deep domain expert roles
- Expertise in modeling
- Expertise in simulation

Organizational structure must enable highly collaborative work across different disciplines. Simultaneously, the structure must allow for specialized deep domain work within each expert domain. MBSE processes must be incremental and iterative, oscillating between multidisciplinary top-down analysis and then deep domain bottom-up work that “bubbles up” to modified requirements that launches the next iteration of top-down work.

The effort should start with a pilot program of small scale to improve upon the design of a physical system, organization or process. Lessons learned should be applied to new initiatives, always with sensitivity that all businesses are systems of systems. This means that any system improved through MBSE can affect the performance of other parts of a business it impacts. For example, design of a physical system can influence the systems or organizations that manufacture, construct or maintain that physical system. If the physical system is a ship and MBSE impacts the design of the ship, then the layout of the construction yard movements of parts and materials, or even operation of supply chains, can be affected. Therefore, overall thinking about the business must become systemic. Using MBSE to improve or solve challenges with each subsystem (e.g., the ship) must also consider the other systems it affects (e.g., the shipyard or a supply chain).

In addition to adopting appropriate MBSE software, organizations should seek support from service companies with strong practice and experience in systems engineering.

Business Impact: MBSE replaces document-centric work environments with models. This makes information easier to navigate and understand, improving communications both within a company and with partners, suppliers and customers. Problem solving is also more efficient because use of models is more intuitive than sifting through volumes of documentation to find information and understand requirements and the relationships among critical elements of a system, or the system of systems which includes it.

MBSE also results in more disciplined decision making since it emphasizes the interrelationships of critical variables. That cultivates more “cause-and-effect” thinking, resulting in better, more cost-effective decision making.

Benefit Rating: Transformational

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Sample Vendors: Altair; Ansys; BigLever; Dassault Systèmes; Siemens

Recommended Reading: “Innovation Insight for Engineering Technology: Why ET, IT and OT Are More Than the Sum of Their Parts”

“Use 4 Building Blocks for Successful Digital Twin Design”

“Digital Business Is Transforming New Product Development Priorities”

Sliding Into the Trough

IoT Security

Analysis By: Barika Pace

Definition: Internet of Things (IoT) security works addresses software, hardware, network and data protection for digital initiatives involving IoT. The term is most often used in the context of business or marketing efforts, as opposed to cyber-physical systems security, which is a more descriptive and pragmatic term for security and risk practitioners. IoT security shares many of the same technologies and processes as IT, operational technology (OT) and physical security. IoT security provides safety, privacy and resilient for digital systems.

Position and Adoption Speed Justification: IoT security technologies and services are progressing but through the lens of a converging security ecosystem with end user and vendors seeking higher levels of integration with IT, OT and CPS solutions. IoT security continues to move at a modest pace. Areas such as digital trust, tamper-resistant device hardening techniques in hardware and firmware, secure cloud integration, remote access, device discovery, event detection and response systems, and improved consulting and system integration are contributing to the progress. Larger security providers continue to enter the market space and offer slightly higher levels of security product integration with IoT solutions. New IoT security technologies continue to emerge primarily as part of existing IT, OT and physical security technology refreshes. Increasing regulations (for example, GDPR and California's new SB-327 cybersecurity law) will continue to spur demand for IoT security products and services over the years to come. Over the past year these regulations and compliance requirements have fueled adoption. While merges and acquisitions this past year left some end users slower to adopt, the past is expected to remain on track through this current period. Furthermore, as the threat landscape continues to evolve, IoT security is maturing rapidly to address and adapt to the new threats, thus leading it into the adolescent phase, as demonstrated by increasing maturity in areas of safety and reliability.

User Advice: Security and risk management leaders, including business executives, chief digital officers, chief risk officers, chief information security officers (CISOs) and CIOs, should:

- Establish proofs of concept to discover, classify and manage all connected devices to ascertain risk landscape, raise organizational awareness and create business value by onboarding visibility tools that can have dual purpose for operational team
- Determine design gaps in capability, skills and infrastructure
- Elevate IOT security requirements into their enterprise risk management efforts by adopting an integrated security strategy across IT, IOT and CPS.
- Account for data privacy concerns brought about by the increasing regulations for IoT devices that process personal data
- Record all IoT assets, from sensors to large industrial equipment, and create visibility into their IoT networks and topologies

- Include IoT security into the expanding scope of responsibility now and into the future
- Prepare for increasing regulations by focusing on safety and privacy in IoT designs that safeguard data, people and the environment
- Analyze regulatory exposure to IoT security requirements
- Work on developing in-house IoT security expertise, including coordination with environmental, health and safety subject matter experts
- Invest in digital risk management to properly plan for IoT security in digital transformation projects
- Change governance and oversight of IT and OT projects to accommodate specific digital risk concerns that lead to IoT security decisions
- Restructure skill sets and support resources (that is, organizational accountability and responsibility) to accommodate differences in deployment and operation of digital initiatives requiring secure IoT systems
- Incorporate regulatory compliance requirements for IoT technologies within existing IT, OT, CPS and physical security regulation tracking and management.

Business Impact: High-profile cyberattacks can create compromises in verticals such as telecommunications, government, transportation, energy and utilities, and healthcare. Initiatives such as connected homes, smart cities, connected automobiles and medical devices are vulnerable as well. Cyberattacks have driven early IoT security spend in these verticals and initiatives. Growing attention and pressure from different layers of government may lead to potential regulations. The effects of cyberattacks also highlight the overlapping safety regulation and general safety management impacts of IoT security. In the short term, IoT security will continue to be the No. 1 barrier to entry to the IoT. In the longer term, these emerging security technologies will enable the IoT.

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Adolescent

Sample Vendors: 802 Secure; Armis; Darktrace; Forescout Technologies; Infineon Technologies; IOActive; Microsoft Azure; Prove & Run

Recommended Reading: “How to Secure the Enterprise Against the Internet of Things Onslaught”

“IoT Solutions Can’t Be Trusted and Must Be Separated From the Enterprise Network to Reduce Risk”

“Market Trends: IoT Edge Device Security, 2020”

"Market Insight: Tech CEOs Must Act Before Convergence Kills Your Stand-Alone OT/IoT Product Solution"

"Focus More on the Realities of Cyber-Physical Systems Security Than on the Concepts of IoT"

Digital Twin

Analysis By: Alfonso Velosa; Benoit Lheureux; Marc Halpern

Definition: A digital twin is a virtual representation of an entity such as an asset, person or process and is developed to support business objectives. The three types of digital twins are discrete, composite and organizational. Digital twin class elements include the model, rules, relations and data properties. Digital twin instance elements include the model, data, unique one-to-one association, and monitorability.

Position and Adoption Speed Justification: The idea of modelling people, physical assets, and processes continues to gain traction, especially as the architecture for the future of applications includes digital twins as features of an application, and as stand-alone supplements to portfolios of applications that address an entity.

- People: Digital twins are the evolution of trends including customer 360-degrees, patient electronic health records, and fitness monitors. Their near-term uses include health monitoring and employee safety, particularly in response to the pandemic.
- Physical assets: Digital twins adoption aligns to Internet of Things (IoT) trends. For owner/operators, near-term use includes lowering maintenance costs and increasing asset uptime for equipment users in factories, hospitals, utilities, etc… For product original equipment manufacturers (OEMs), near-term uses include product differentiation, business model differentiation through new product service models, and obtaining customer data.
- Processes: Digital twins are being developed to model IT organizations, financial exchanges, and processes such as purchase orders.

The digital twin profile has moved past the Peak of Inflated Expectations, based on enterprise confusion driven by conflicting vendor marketing and on challenges implementing digital twins. Gartner's CIO Survey 2020 shows that 6% of enterprises have implemented digital twins, although less than 1% of assets have digital twins. Another 41% of enterprises expect to deploy digital twins within three years. These trends lead us to shorten the time to plateau down to two to five years. In the next decade, digital twins will become the dominant design pattern for digital solutions.

User Advice: CIOs should work to guide and protect business adoption of digital twins:

- Business outcomes: Work with business leaders to establish clear business objectives for digital twins. In parallel, establish an IT vision for digital twins, to establish a coherent approach to support the business units.

- Technology: Start with models that are as simple as possible of the entities that are of interest for your business process, whether basic, such as the location of vehicles or a very high fidelity models of a human heart. Determine what data is necessary to "feed" the models and the types of analytics needed; a corollary here is the need to verify and drive data quality. Don't let the dearth of standards limit innovation. Assess how composite and organizational digital twins will require integration and custom development.

- Governance and accountability: Engage the business unit to identify champions, budget support, and to co-build the digital twin strategy and roadmap. Establish a joint business and IT governance process for digital twins, covering their alignment to business KPIs, short and long term value, and their updates and life cycle management.

- Digital ownership and ethics: Work with business and legal teams to establish a policy on ownership of the digital twin models and data, as well as who may participate. In parallel, establish a digital ethics policy to guide the organization to develop twins that positively support the enterprise while serving employees, customers or citizens. This policy will set guidelines to engage ecosystem stakeholders about what data may be shared and what monetization experiments to conduct.

- Vendors selection: Understand most technology providers are still developing their strategy and mostly offer enabling technology. A small number of technology providers have digital twin portfolios which align with specific vertical markets.

Business Impact: Digital twins are transformational as they enable business to drive new digital business models as well as update existing models. For example, they enable superior asset utilization, service optimization and improved customer experience. They create new ways to operate, such as consumption of physical outcomes instead of the capital expenditure acquisition of industrial assets, or new ways to drive an ecosystem or supply chains. And they will open new ways to monetize data.

Digital twins will challenge most enterprises to change their thinking of master data from an IT practice to one that engages the business units and IT to get a more comprehensive situational awareness of assets, people, or processes. In addition, a digital twin can be expensive to maintain, and its value centers on remaining a live model, synchronized with the entity.

Benefit Rating: Transformational

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Sample Vendors: AVEVA; Bentley Systems; C3.ai; Cognite; GE Digital; Mavim; Microsoft; QPR Software; Schneider Electric; ThoughtWire

Recommended Reading: "Market Guide for Digital Twin Portfolios and Enabling Technologies"

"Survey Analysis: IoT Digital Twin Adoption Proliferates Across Many Sourcing Options"

"Toolkit: Enterprise Readiness for Digital Twin Deployment"

"Market Trends: Software Providers Ramp Up to Serve the Emerging Digital Twin Market"

"Software Product Managers Should Exploit the Full Revenue Potential of Digital Twins"

Event Stream Processing

Analysis By: W. Roy Schulte; Nick Heudecker; Pieter den Hamer

Definition: An event stream is a sequence of event objects arranged in some order, typically by time. Event stream processing (ESP) is computing that is performed on event objects for the purpose of stream data integration or stream analytics (also called complex-event processing [CEP]). ESP is typically applied to data as it arrives (data "in motion"). It provides information about emerging threats or opportunities for near-real-time alerts, dashboards and sense-and-respond processes, or it stores data in a database for use in subsequent analytics.

Position and Adoption Speed Justification: Three factors are driving the expansion of ESP:

- The growth of the Internet of Things (IoT) and digital interactions (including clickstream data) is making event streams ubiquitous.
- Business is demanding continuous intelligence for better situation awareness and faster, more personalized decisions.
- Vendors are bringing out new and improved products, many of them open source or partly open source.

Companies have access to more streaming data from sensors, meters, control systems, corporate websites, transactional applications social computing platforms, news and weather feeds, data brokers, government agencies and business partners. ESP technology is maturing rapidly. It will eventually be adopted by multiple departments within every large company. ESP will reach the Plateau of Productivity within several years, largely by being embedded in IoT platforms, SaaS solutions and off-the-shelf packaged applications.

User Advice: Data and analytics leaders should:

- Use ESP when traditional DBMS architectures cannot execute fast enough to provide real-time information from high-volume event streams.
- Acquire ESP functionality by using a SaaS offering or an off-the-shelf application that has embedded CEP logic (but only if a product that addresses your specific business requirements is available).
- Build your own application on an ESP platform if an appropriate off-the-shelf application or SaaS offering is not available.

- Use free, community-supported, open-source ESP platforms if your developers are familiar with open-source software and languages such as Java, Scala or Python, and license fees are the primary consideration. Use vendor-supported closed-source platforms or products that mix an open-source core with value-added closed-source extensions for mainstream applications that require enterprise-level support and more complete sets of features.

- Use on-premises ESP in preference to cloud event processing services for low-latency applications such as IoT edge computing and financial trading, and for applications where most of the data originates on-premises.

- Use ESP technology that is optimized for stream data integration to ingest, filter, enrich, transform and store event streams in a file or database for later use.

Business Impact: Stream analytics provided by ESP platforms:

- Can support situation awareness through dashboards and alerts by analyzing multiple kinds of events in real-time.

- Enable smarter anomaly detection and faster responses to threats and opportunities.

- Can help shield businesspeople from data overload by eliminating irrelevant information and presenting only alerts and distilled versions of the most important information.

ESP is one of the key enablers of continuous intelligence and other aspects of digital business. It has transformed financial markets and become essential to smart electrical grids, location-based marketing, supply chain, fleet management and other transportation operations. Much of the growth in ESP usage during the next 10 years will come from three areas where it is already somewhat established: IoT, customer experience management and fraud detection applications. More than 40 ESP products or cloud event stream processing services are available on the market.

Benefit Rating: Transformational

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Sample Vendors: Apache Software Foundation; Confluent; Evam; IBM; Microsoft; Oracle; SAS; Software AG; TIBCO Software; Ververica

Recommended Reading: “Market Guide for Event Stream Processing”

“Adopt Stream Data Integration to Meet Your Real-Time Data Integration and Analytics Requirements”

“The Five Levels of Stream Analytics — How Mature Are You?”

"Technology Insight for Event Stream Processing"

"Innovation Insight for Continuous Intelligence"

IoT Edge Architecture

Analysis By: Aapo Markkanen

Definition: IoT edge architecture represents hardware, software and communications elements that optimize capabilities such as compute, storage, networking and analytics to be deployed closer to where IoT data is produced or consumed. Edge architecture defines how information generated by sensors and endpoints is aggregated and handled at the edge of a network or a data center. Under an IoT edge architecture, intelligence within a connected system is distributed according to where the use case requires it the most.

Position and Adoption Speed Justification: IoT edge architecture is further approaching the Trough of Disillusionment, reflecting a growing awareness of the involved technical challenges among both end users and vendors. The fact that edge processing and storage will be necessary solution elements in many IoT deployments has by now become clear to both sides of the market. End users are increasingly often including edge capabilities in their product and technology evaluation, while practically all major vendors targeting IoT enablement are trying to address the edge in one form or another. The implementations can be, however, hindered by issues such as limited device interoperability and difficult developer environments, as well as integration with legacy edge systems. Furthermore, the cost of implementing and operating edge computing products remains often prohibitively high, especially when deploying such products at scale. Consequently, the business case for deploying an advanced IoT edge architecture is not always there, even if the use cases for doing so are. The dynamic varies notably by industry vertical. For example, investing in an edge architecture in consumer IoT is not nearly as feasible as it is in industrial IoT, where applications typically require robust edge capabilities by necessity.

User Advice: There are many ways to implement an IoT edge architecture. Enterprises deploying IoT must align their overall technical architecture to the targeted business outcomes associated with the use case, determining where in the system the data should be handled in order to maximize its business value. Importantly, upgrading storage and processing capabilities at the edge is often also a good opportunity to adopt a wider event-based architecture. The established alignment must then be maintained throughout deployment and implementation. Further key recommendations include:

- Establish a formal IoT architecture that addresses device management, embedded software, security, local analytics, data filtering and normalization, protocol translation, data storage, as well as connectivity.
- Plan the edge deployment in the context of a wider edge-to-cloud strategy — and not in isolation, separate from cloud investments.
- Utilize vertical-specific, prevalidated edge solutions, where possible, as these can be readily deployed with the help of system integrators that can also contribute some degree of solution

customization as needed.

- Expect longer development cycles, as well as recurring maintenance commitments, if building edge solutions predominantly in-house.
- Carry out a thorough proof of concept before broad deployment — e.g., studying how the selected solution elements behave in the deployment environment, and assessing the implementation and integration requirements.
- Future-proof the edge deployment by using a modular design under which different technology elements can be later upgraded or replaced without undermining the system's other elements. In deployments with enough processing power and network bandwidth, containerized microservices should be considered.

Business Impact: A well-defined and carefully designed IoT edge architecture is a critical building block for the majority of IoT initiatives, particularly in industrial verticals. Optimal IoT edge architectures balance technical elements, such as data analytics, security and scalability, against the overall business requirements and integration complexity. The choices related to the edge architecture will have a direct impact on the IoT project's upfront costs (especially integration), as well as operational costs (especially communications). Such choices will also largely determine what level of flexibility the enterprise will have in terms of making changes to its IoT-enabled assets and, thus, the business operations that they contribute to.

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Sample Vendors: Advantech; Atos; Cisco; Dell; FogHorn; Lenovo; Microsoft; Rigado; Wind River; ZEDEDA

Recommended Reading: "Market Trends: Early Edge Computing Adopters Prefer Existing System Vendors; Cloud Providers Are Well-Placed"

"Market Guide for Edge Computing Solutions for Industrial IoT"

"How to Overcome Four Major Challenges in Edge Computing"

"Top 10 Strategic Technology Trends for 2020: Empowered Edge"

IoT Platform

Analysis By: Alfonso Velosa; Eric Goodness; Scot Kim

Definition: An Internet of Things (IoT) platform is a software that enables development, deployment and management of business solutions that connect to and capture data from IoT endpoints to improve operations such as monitoring remote assets or optimizing maintenance. Capabilities include:

- Device management
- Integration
- Data management
- Analytics
- Application enablement and management
- Security

It may be delivered as edge or on-premises software, or cloud IoT platform as a service, or a hybrid combination.

Position and Adoption Speed Justification: Enterprises continue adding IoT capabilities to assets and products, seeking benefits such as cost optimization, process optimization, better interactions with customers, and new opportunities such as product as a service. The sophistication, scale and business value of these interactions call for specialized technology resources, most often implemented as an IoT platform. While enterprises across all verticals are deploying IoT, the strongest impetus comes from asset intensive industries such as manufacturing or oil and gas.

Continued integration, culture, and security challenges, and schedule delays for IoT projects, as well as excess vendor hype has moved IoT platforms closer to the Trough of Disillusionment. 2020 sees many vendors struggling to maintain business and technology viability as end users delay deployments due to economic uncertainty and employee safety concerns. Further, most large vendors have yet to develop a clear IoT platform strategy that will drive scale. Yet there is increased vendor and enterprise focus on application enablement and solutions that deliver clear business results and shorter project payback. These trends lead us to shorten the time to plateau down to two to five years. Note that the speed of adoption continues to across the consumer, commercial and industrial verticals.

User Advice: CIOs should factor in the following issues:

- Deployments: Start with smaller IoT projects, identify IoT platform technology strengths and weaknesses, acquire implementation lessons, and verify alignment to business KPIs and project payback requirements.
- Architecture: IoT platform strategies should be aligned to either external business foci, such as for an OEM's connected product, or internal foci, such as for an owner/operator of assets. Identify the range of IoT projects for your enterprise, and segment them by their focus, complexity and business objectives. Use these insights to establish a distributed deployment and a platform of platforms architecture for using multiple IoT platforms for different enterprise

needs. Be aware that while this drives scalability and mitigates your vendor risk it increases your complexity and cost risk.

- Skills: IoT projects using IoT platforms require new skills. Improve team's capabilities such as integration, based on a skills gap analysis. Develop a plan for how IT personnel can complement the IoT platform skills within the business units, and drive IT-OT alignment. Plan to leverage a service partner to support critical initiatives.
- Customization: While no IoT platform will work straight out of the box, push your technology vendors to deliver vertical market modules and solutions optimized for your vertical.
- Vendor selection: Prioritize vendors you already work with, for their IoT platform. Evaluate candidate vendors on their fit-to-your-business objectives and technology. Expect roadmaps to continue to evolve quickly in the fast-changing IoT market. Key criteria center on the vendor's ability to scale from proofs of concept to operational-scale deployments, vertical market expertise, partner ecosystem, long term support capabilities, and references that show business results.

Business Impact: There is a significant opportunity for enterprise stakeholders to leverage IoT-enabled assets and business processes to achieve greater value. This includes making better decisions from the data and information generated by connected products, people and equipment. This improves decision making and provides better decisions about assets distributed across the enterprise and its external stakeholders. Unfortunately, this data has been largely locked in the assets — mostly due to lack of connectivity, but also because of lack of systems and governance processes to obtain and share this data systematically.

IoT platforms act as the intermediary between the "thing" and the business processes and applications. Therefore, they facilitate the introduction of a new potentially transformative wave of digital business innovation and digital transformation to enterprises. IoT platforms provide the middleware foundation to implement asset centered business solutions — and are part of a broader business process transformation.

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Sample Vendors: Alibaba Cloud; AWS; Eurotech; Flutura; Kaa; Litmus Automation; Microsoft Azure; PTC (ThingWorx); ROOTCLOUD; Samsung SDS

Recommended Reading: "Magic Quadrant for Industrial IoT Platforms"

"Critical Capabilities for Industrial IoT Platforms"

"Survey Analysis: As More Companies Deploy IoT, They Increasingly Focus on Best Practices and Payback"

“Competitive Landscape: IoT Platform Vendors”

Autonomous Vehicles

Analysis By: Jonathan Davenport

Definition: Autonomous vehicles use various onboard sensing and localization technologies, such as lidar, radar, cameras, GPS and map data, in combination with AI-based decision making, to drive without human intervention. This Innovation Profile does not cover ADAS features that require humans to supervise vehicle operations. While self-driving cars are getting most of the attention at present, the technology can also be applied to nonpassenger vehicles for transportation of goods.

Position and Adoption Speed Justification: There have been a number of signs of autonomous driving moving into the Trough of Disillusionment during the past year. Drive.ai and Starsky Robotics failed, Cruise cut 8% of its workforce, and Zoox is looking for a buyer, Continental has delayed AV investments after Q120 earnings plummeted and Audi has abandoned its plans to introduce the Level 3 traffic jam pilot feature into its A8 vehicles, which it had originally announced back in 2017. Likewise, Ford Motor Company made the decision to shift the launch of its self-driving services to 2022 to evaluate the long-term impact of COVID-19 on customer behaviors.

But there has been increased investment too. For example, Intel’s Mobileye has acquired Moovit and is developing an autonomous mobility as a service (MaaS) solution for the emerging robotaxi market. This plan shifts Intel from being a supplier of chips and self-driving systems for the automotive industry and places it in direct competition with automakers’ own mobility ambitions and the likes of Waymo, Baidu and Yandex. Likewise, autonomous vehicle pilots and trials have continued to be undertaken, though most continue to be supported by safety drivers. To overcome regulatory issues, many autonomous shuttle buses have been demonstrated on private road networks, such as at airports.

The efforts of automobile manufacturers and technology companies to develop autonomous vehicles have been prominently featured by mainstream media, leading to unrealistic and inflated expectations for the technology. Artificial intelligence (AI) is a critical technology for enabling autonomous vehicles, and development of machine learning algorithms for autonomous vehicles has accelerated. Key challenges for the realization of autonomous vehicles continue to be centered on cost reductions for the technology and industrialization. However, the challenges increasingly include regulatory, legal and societal considerations, such as permits for operation, liability, insurance and the effects of human interaction.

Continued advancements in sensing, positioning, imaging, guidance, mapping and communications technologies, combined with AI algorithms and high-performance computing capabilities, are converging to bring the autonomous vehicle closer to reality. However, in 2020, complexity and cost challenges remain high, which is impacting reliability and affordability requirements, as well as hindering the ability for companies to get regulatory approval.

User Advice: The adoption of autonomous vehicle technology will require increasing levels of technical sophistication and reliability that rely less and less on human driving intervention. Automotive companies, service providers, governments and technology vendors (for example, software, hardware, sensor, map data and network providers) should collaborate on joint research and investments to advance the required technologies, as well as work on legislative frameworks for self-driving cars.

Furthermore, consumer education is critical to ensure that demand meets expectations once autonomous vehicle technology is ready for broad deployment. Specific focus must be applied to the transitional phase, where autonomous or semiautonomous vehicles will coexist with an older fleet of nonautonomous vehicles.

Look for use cases, such as mining, agriculture or airports, where autonomous vehicles can operate in restricted areas safely without regulatory restrictions. Use these implementations to drive early revenue and gather data and insights to improve the performance of self-driving systems.

Autonomous vehicles will have a disruptive impact on some jobs, such as bus, taxi and truck drivers. Develop policies and programs to train and migrate employees who will be affected by automation to other roles.

Business Impact: The main implications of self-driving vehicles will be in the economic, business and societal dimensions. Automotive and technology companies will be able to market autonomous vehicles as having innovative driver assistance, safety and convenience features, as well as being an option to reduce vehicle fuel consumption and improve traffic management. The interest of nonmobility companies (such as Intel, Waymo, Apple and Baidu) highlights the opportunity to turn self-driving cars into mobile computing systems. These systems offer an ideal platform for the consumption and creation of digital content, including location-based services, vehicle-centric information and communications technologies.

Autonomous vehicles are also a part of mobility innovations and new transportation services that have the potential to disrupt established business models. For example, autonomous vehicles will eventually lead to new offerings that highlight mobility-on-demand access over vehicle ownership by having driverless vehicles pick up occupants when needed. Autonomous vehicles will deliver significant societal benefits, including reduced accidents, injuries and fatalities, as well as improved traffic management, which could impact other socioeconomic trends.

When autonomous driving enters the Trough of Disillusionment, it might be a good opportunity for new market entrants.

Benefit Rating: Transformational

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Sample Vendors: Audi; AutoX; Daimler Group; General Motors; Mobileye; Pony.ai; Tesla; Uber; Waymo

Recommended Reading: "Market Trends: Monetizing Connected and Autonomous Vehicle Data"

"Forecast Analysis: Autonomous Vehicle Net Additions, Internet of Things, Worldwide"

"Utilize Partnerships to Secure a Winning Position in the Autonomous Driving Ecosystem"

"Market Insight: Use Situationally Aware Platforms to Enable Safe Autonomous Vehicle Handovers"

"Maverick* Research: Autonomous Mobile Structures Will Fuel the Sharing Economy"

Internet of Things

Analysis By: Alfonso Velosa; Benoit Lheureux

Definition: The Internet of Things (IoT) is a core building block for digital business and digital platforms. IoT is the network of dedicated physical objects that contains embedded technology to communicate and sense or interact with their internal states and/or the external environment. IoT comprises an ecosystem that includes assets and products, communication protocols, applications, and data and analytics.

Position and Adoption Speed Justification: Gartner's CIO Survey 2020 shows that IoT is regarded by CIOs as one of the top five game-changing technologies, with enterprises vary widely on their IoT adoption depth and maturity. Enterprises on a global basis have ongoing IoT-enabled initiatives for use cases ranging from incremental benefits (for example, asset optimization or compliance reporting) to transformative benefits (for example, product as a service or guaranteed asset uptime). The more developed use cases center on fleet management and industrial equipment maintenance, where ROI is calculated from cost optimization such as reducing maintenance and fuel costs. Many enterprises are now exploring employee and citizen safety solutions using IoT enabled capabilities. Finally, Gartner's 2019 IoT Survey indicates that while enterprises expect a 3-year payback on average for their IoT projects, 42% expect payback in less than 2 years. In the 2020 economic downturn, many clients are pushing for even shorter project paybacks.

The hype has decreased from the highs in 2016 through 2019; we reflect this by moving the profile's position into the trough. Enterprises continue to address cost, complexity and scaling challenges implementing IoT-enabled business solutions, as well as increased adoption of contact-less monitoring solutions, drone inspections, etc. driven by the 2020 pandemic. Challenges include end-to-end integration complexity, the need to bridge cultural divides between IT and operations, confusing vendor marketing, especially as they increasingly shift to IoT-enabled business solutions, security concerns, and the 2020 pandemic disruption on IoT project schedules.

User Advice: CIOs should take action to address IoT concerns across the following areas:

- Business: Measure and deliver IoT value based on digital and strategic business objectives. If you are still experimenting, use a proof of business value approach. Build business cases with project payback of less than 18 months to account for implementation challenges and cultural resistance. Add employee and customer safety to your priority list of IoT projects and capabilities.

- Management: Build or contribute to an IoT center of excellence (COE) composed of IT, operational and business personnel. Use the COE to drive global alignment on best practices, alignment to business objectives, budgeting and people allocation. Remember that IoT is really about business process transformation, so focus on culture change first and technology second to ensure success.

- Architecture: Ensure the architecture teams focuses on both the IT and operational technology portfolio as well as the need to manage a multi-IoT platform approach. Ensure analytics and applications are part of the conversation.

- Skills: Invest in business and architecture skills to support project ideation and prioritization, as well as technical skills for IoT platforms, integration, analytics and security. Drive learning via projects with short-term outcomes, and include business leaders, IT leaders, and front-line workers.

- Vendors: Assess and select providers on how they lower project risk for your enterprise via their vertical market expertise, technical capabilities (including best-of-breed partners) and trained professional services partners. Ensure your vendors integrate into your IT infrastructure.

- Governance: Establish accountability, participation, predictability and transparency policies for IoT — addressing sponsorship, budgets, digital ethics, data ownership and rights to monetize IoT data, etc...

- Risk: Scan for threats from enterprises in your ecosystem who may use IoT capabilities to damage or limit your differentiation and competitiveness.

Business Impact: As an evolutionary business impact, IoT will impact most enterprises' internal operations, differentiation, competitive position, and product strategies. Connected things will help lower costs, drive revenue, and improve enterprise processes in these types of usage scenarios:

Optimization of a range of business processes:

- Cost optimization: Lower operating costs for energy reduction, maintenance minimization, minimizing inventory spoilage, lowering theft

- Operations optimization: Better productivity, increased efficiency, logistics and coordination

- Optimize assets: Asset utilization, health monitoring, reliability, predictive maintenance

- Conserve resources: Energy efficiency and pollution reduction

New revenue strategies:

- Generate revenue via improved products, contractual services, usage-based pricing, and monetizing IoT data
- Increase engagement: Improved experiences of consumers, citizens and others in order to improve loyalty and increase customer lifetime value

Safety focus:

- Drive employee and citizen safety by monitoring and checking people's health, shifting to over-the-air updates to avoid in person visits, fall monitoring for the elderly and remote workers.

Benefit Rating: Transformational

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Sample Vendors: ABB; Alibaba Cloud; Altizon; GE Digital; Hitachi Vantara; Tencent; Vodafone

Recommended Reading: "Predicts 2020: As IoT Use Proliferates, So Do Signs of Its Increasing Maturity and Growing Pains"

"Toolkit: Enterprise Internet of Things Maturity"

"Survey: Manufacturers See Quick Return on IoT Projects"

"Forecast: Enterprise and Automotive IoT, Worldwide"

Climbing the Slope

Asset Performance Management

Analysis By: Nicole Foust; Kristian Steenstrup

Definition: Asset performance management (APM) comprises software tools and applications for optimizing availability of operational assets (such as plant, equipment and infrastructure) essential to the operation of an enterprise. It uses data capture, integration, visualization and analytics to improve operations, maintenance timing, and maintenance and inspection activities to perform on mission-critical assets. APM includes the concepts of asset strategy and risk management, predictive forecasting and reliability-centered maintenance.

Position and Adoption Speed Justification: APM has become an important core competency for asset-intensive and asset-centric organizations. Realizing the business can move beyond the key use case of equipment reliability, organizations are leveraging APM to improve overall business operations. Innovation in enabling technologies such as cloud, IoT and AI/ML are widening the scope and decreasing the deployment cost, aiding more awareness and use of APM. The potential of reduced maintenance cost and downtime, coupled with higher levels of operational reliability is attracting other industries, however, all are progressing at a varied pace. Those that depend significantly on availability of their assets, such as manufacturing, utilities and natural resources industries, tend to be further along in their asset management strategy, and usually invest more heavily in APM. Other industries that rely on physical assets to some degree, such as retail and public sector, are beginning to embark on this journey but may not invest as heavily in APM solutions.

User Advice: Asset-intensive industries' CIOs seeking the next level of asset performance improvement should deploy APM. However, organizations should recognize that APM is characterized by a variety of approaches, including analyzing performance history to develop data-based maintenance strategies; using advanced analytics to detect patterns and predict equipment failure; and in some instances, simply using visualization of real-time operating and condition data to make better decisions.

Assess the maturity of your enterprise asset management (EAM) system and have a sustainable integration plan with your APM before investing in APM; this will ensure a solid foundation for advancing your asset management strategies. APM ideally follows the deployment of updated and sometimes the need to consolidate disparate EAM software. Although newer EAM products include APM capabilities, CIOs should not expect to get all APM capabilities from the EAM vendors themselves. While some EAM vendors continue investments in this area, most can only achieve support of a basic maintenance activities which includes condition based maintenance. This means that, in practice, third-party APM products may need to be interfaced into EAM.

Organizations realize the need for a combination of asset maintenance strategies to support a variety of asset types and situations across the business through a toolbox approach. Most APM vendors do not offer all levels of APM maintenance strategies, across all industries and asset types. Thus organizations may need more than one APM product, depending on the complexity of their businesses, the types of assets and their asset maintenance goals. (See "Mapping a Route to Asset Management and Reliability.")

OT, which is extended and augmented by the IoT, is the source of data concerning a physical asset. Asset maintenance capabilities will need to source data from the Internet of Things (IoT) and operational technology (OT) systems. Therefore, CIOs should ensure compatibility with the technical and process needs of reliability systems by getting involved in the planning of IoT monitoring of plants and equipment. Integration of APM with asset investment planning (AIP) tools and EAM is common in order to include data on asset condition, maintenance costs, criticality, budgets and risks, and then analyze it to produce capital investment plans over extended time. AIP is designed to support both short- and long-term capital investment decisions, integration with APM can be used to drive better forecasting.

Source good data — that is, historical service data and operational data — is a necessary condition for successful APM projects. Therefore, organizations looking to invest in APM should also expect to make investments in information management infrastructure to capture operational data where it doesn't exist today. APM leverages the convergence of IT and operational technology (OT), and will require resources familiar with both worlds' data structures and communication conventions. In some instances, companies looking at APM projects will benefit from cloud-based approaches to data sharing and multiparty collaboration.

Business Impact: APM is an important investment area for asset-intensive industries, including manufacturing, mining, oil and gas, transportation and utilities. Successful APM deployments can deliver measurable improvements in availability, as well as reduce maintenance and inventory carrying costs. Most APM projects are executed on the premise that data-driven decisions will improve equipment reliability and, therefore, reduce operational risk. Benefits such as improved uptime and cost savings can be substantial, typically delivering benefits measured in millions of dollars per year.

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Sample Vendors: ABB; AspenTech; AVEVA; Bentley Systems; GE Digital; IBM; SAP; SAS; Siemens; Uptake

Recommended Reading: "Best Practices for Choosing an Asset Management System Integrator"

"Market Guide for Asset Performance Management Software"

"Financially Optimized Maintenance Planning Using Asset Performance Management"

"Mapping a Route to Asset Management and Reliability"

"Optimize Utility Capital Expenditures With Asset Investment Planning Solutions"

"Magic Quadrant for Enterprise Asset Management Software"

Managed IoT Connectivity Services

Analysis By: Pablo Arriandiaga

Definition: Managed IoT connectivity services, also known as managed machine-to-machine (M2M) services, encompass connectivity hardware, software, and network and IT services that are generally bundled and managed by a third-party provider. These services enable enterprises to connect, monitor and control business assets and processes over a fixed or wireless connection. These services are key to informing and integrating purpose-built and stand-alone telematics systems, IoT platforms or legacy back-end IT (e.g., ERP, CRM) and OT systems (e.g., SIS, DCS).

Position and Adoption Speed Justification: The market for cellular-based-managed IoT connectivity services is mature for traditional 2G, 3G and 4G LTE networks, field-area networks (FANs) and satellite. Cellular, LPWAN, FAN and satellite are the connectivity technologies upon what providers in this market mainly have based their managed IoT connectivity services.

Market for 3GPP LPWAN is starting to accelerate due to national deployments in big countries such as China with NB-IoT or the U.S. with both networks. This acceleration will bring the price of the modules down in a position to compete with non-3GPP LPWAN technologies such as LoRa WAN or Sigfox, adding the value of being a standard, which guarantees its future evolution including seamless integration into 5G. Main challenge with 3GPP LPWAN are global deployments, needing roaming and interoperability that will need at least two years to mature. The new technologies that will accelerate growth in this market will be 5G and edge computing.

User Advice: Managed IoT connectivity services are a small component of an IoT solution but have a critical role due to the complexity of endpoints and connectivity types to manage. So, it is important that the managed IoT connectivity services solution components are appropriate and rightsized for broader IoT initiatives. The way of how connectivity is integrated in a broader proposition including edge devices and gateways, connectivity to the cloud, flexibility to include a variety of connectivity providers in a seamless way through technologies such as eSIM is very important.

Companies that are considering managed IoT connectivity services should consider the following recommendations:

- Invest time and resources to integrate multiple vendors' offerings that span the value continuum of IoT solutions. End-to-end IoT platforms are rare within these providers, leaving customers to source device engineering and resale, device management software, and other IoT platform elements.
- Look for vendors that could add more value on top of connectivity. Bundled solutions can be more cost-effective when including point solutions. Verticals that are well-served in this market are automotive, transportation and logistics, utilities or smart cities but increasingly manufacturing, retail and healthcare as well.
- Evaluate cellular and 3GPP LPWAN capabilities by requesting specific agreements with local providers, global points of presence to avoid latency and flexibility through multi-IMSI, eSIM and iSIM to add third-party connectivity into vendors' managed IoT connectivity platforms.
- Assess the evolution of the vendors' roadmaps and ecosystem by ensuring they include edge and cloud integration, APIs availability natively integrated with hyperscalers and roadmap for 5G and mobile private networks.
- Ensure that contract service-level agreements, delivery times and governance models avoid hidden costs and unclear responsibilities between the client and the vendor.

Business Impact: Managed IoT connectivity services have many benefits for enterprise users and governments. These services are part of broader telematics and IoT solutions to improve the efficiency of assets, provide data-driven decisions for asset utilization and offer incident management for enterprise asset.

Managed IoT connectivity services are an important set of facilitating technologies and services for use in operational technology (OT) and consumer environments. The architecture of these services is important if selected to ensure they support the secure integration of IT and OT.

When the portfolios and ecosystem integration of CSPs and IoT MVNOs broaden to consistently offer more value than connectivity, the number of solutions aimed at specific industry verticals will grow at a fast rate. Some traditional HW-related players are adding IoT MVNO capabilities, so they can provide a stronger and more secure proposition bundling device and connectivity management for commercial and industrial environments connecting the edge and the cloud.

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Early mainstream

Sample Vendors: Aeris; Arm; AT&T; Eseye; KORE Wireless; Orange Business Services; Telefónica; Telenor Group; Verizon; Vodafone

Recommended Reading: "Magic Quadrant for Managed IoT Connectivity Services, Worldwide"

"Critical Capabilities for Managed IoT Connectivity Services, Worldwide"

"Competitive Landscape: IoT Mobile Virtual Network Operators"

"Market Guide for Internet of Things Mobile Virtual Network Enablers"

IoT Integration

Analysis By: Benoit Lheureux

Definition: IoT integration refers to integration requirements and technologies needed to assemble end-to-end IoT-enabled business solutions that include IoT-specific integration challenges, such as integrating IoT devices, IoT data, digital twins and multiple IoT platforms. Other more traditional integration challenges include enterprise application and data integration, business process integration, SaaS integration, and B2B/ecosystem integration, as well as mobile app and legacy system integration.

Position and Adoption Speed Justification: IoT projects involve the integration of business application data and processes — competencies that are widely available. But such projects also introduced new integration requirements, such for as IoT devices, mobile apps, digital twins, hybrid edge-to-cloud infrastructure, large data volumes, and IoT time series event streaming and analysis. Most mid-to-large-sized companies can address some but not all these needs, so they are expanding their integration skills to compensate. Most IoT platforms offer some basic integration capabilities, including device communications (for example, MQTT) and API gateways management (for example, to govern API access), and a limited number of adapters to facilitate integration with a few applications. While many IoT platforms still do not support all IoT device protocols (e.g., OPC-UA), strong translation, complex application workflow, and a complete portfolio of adapters for business applications and SaaS to be integrated, we have moved this IP further toward the Plateau of Productivity because iPaaS (needed to address these needs) is widely available from third-party TSPs, and many of the larger TSPs that offer IoT platforms (e.g., GE Digital, Hitachi, IBM, Microsoft, SAP) do offer an iPaaS in addition to their IoT platform (see "Technology Insight for Enterprise Integration PaaS").

User Advice: Comprehensive integration skills and technologies will help IT leaders more successfully implement IoT projects. Nearly every IoT implementer has adopted an "API-first" approach for integration, using APIs provided by IoT platforms for IoT device connectivity, data synchronization and process integration. Typically, features include event-stream processing, RESTful APIs and, sometimes, message-oriented middleware (MOM), such as MQTT. However, these approaches, alone, do not address crucial integration needs such as semantic integration (to translate data from one format to another) or workflow (to orchestrate the linking of data, events and processes across many systems). IoT implementers must also at times integrate multiple IoT platforms, e.g., to get data from IoT-connected products from an OEM's IoT platform. Thus, IoT implementers often discover that they must also leverage stand-alone integration technology, such as iPaaS, API management, ESB suites and ETL tools in order to fully meet their IoT project integration requirements. Sometimes IoT implementers will also benefit from data exchanges, to help propagate IoT data to external business partners (see "Use APIs to Modernize EDI for B2B Ecosystem Integration"). For IoT project implementers, the goal is to more broadly adopt a pervasive integration approach using a holistic set of integration skills and technologies to address all forms of integration required in their projects. For example, IoT integration needs should be addressed in your hybrid integration platform (see "How to Deliver a Truly Hybrid Integration Platform in Steps").

Business Impact: All end-to-end IoT business solutions require device, application, data and process integration (see "Use the IoT Platform Solution Reference Model to Help Design Your End-to-End IoT Business Solutions"). The challenges are nontrivial, often involving extraordinary:

- Heterogeneity (that is, multiple types of IoT devices, products and equipment, data, vendors, and systems to integrate)
- Distribution (that is, IoT devices, products and equipment are often remotely located across long distances and multiple geographies)
- Performance and scalability (that is, large numbers of IoT devices, products and equipment with high API throughputs and large volumes of time series data)

The cost of such integration includes:

- Integration skills development and integration development time
- Integration middleware or services (ESB software, iPaaS, data integration tools and API management, data exchanges or brokers)

- Integration products focused on operational technology (OT) integration (such as from OSIsoft and Skkynet) may be needed and must be licensed separately
- IT services fees when outsourcing integration to a system integrator

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Sample Vendors: Alleantia; Dell Boomi; Informatica; Microsoft; Reekoh; Salesforce (MuleSoft); Skkynet; Sky Republic; SnapLogic; Software AG

Recommended Reading: "Market Guide for Digital Twin Portfolios and Enabling Technologies"

"Choose the Best Integration Tool for Your Needs Based on the Three Basic Patterns of Integration"

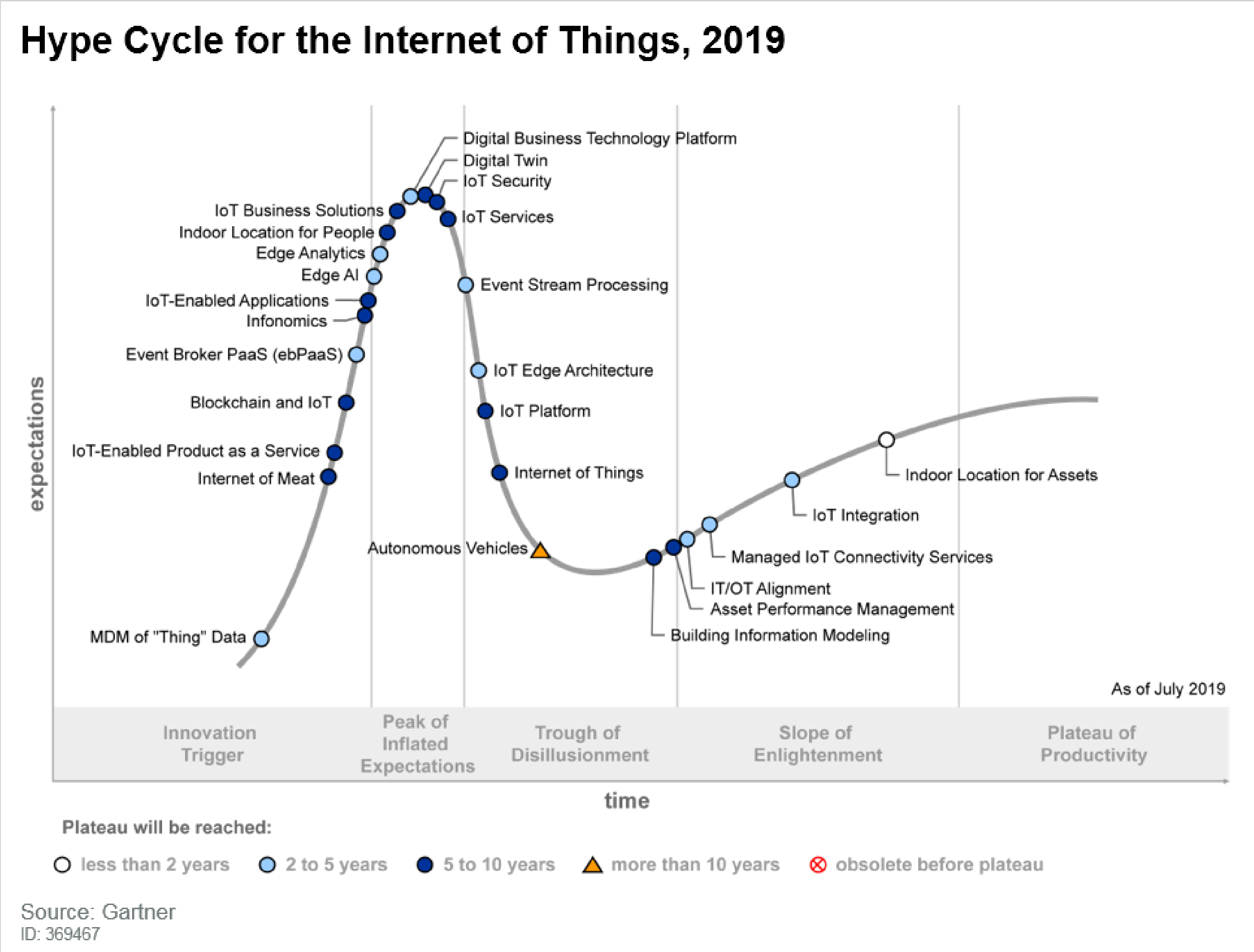
"What to Expect When You're Expecting Digital Twins"

"Survey Analysis: Digital Twins Are Poised for Proliferation"

"Use the IoT Platform Solution Reference Model to Help Design Your End-to-End IoT Business Solutions"

Appendixes

Figure 3. Hype Cycle for the Internet of Things, 2019



Hype Cycle Phases, Benefit Ratings and Maturity Levels

Table 1: Hype Cycle Phases

Phase	Definition
Innovation Trigger	A breakthrough public demonstration, product launch or other event generates significant press and industry interest.
Peak of Inflated Expectations	During this phase of overenthusiasm and unrealistic projections, a flurry of well-publicized activity by technology leaders results in some successes, but more failures, as the technology is pushed to its limits. The only enterprises making money are conference organizers and magazine publishers.
Trough of Disillusionment	Because the technology does not live up to its overinflated expectations, it rapidly becomes unfashionable. Media interest wanes, except for a few cautionary tales.

Phase	Definition
Slope of Enlightenment	Focused experimentation and solid hard work by an increasingly diverse range of organizations lead to a true understanding of the technology's applicability, risks and benefits. Commercial off-the-shelf methodologies and tools ease the development process.
Plateau of Productivity	The real-world benefits of the technology are demonstrated and accepted. Tools and methodologies are increasingly stable as they enter their second and third generations. Growing numbers of organizations feel comfortable with the reduced level of risk; the rapid growth phase of adoption begins. Approximately 20% of the technology's target audience has adopted or is adopting the technology as it enters this phase.
Years to Mainstream Adoption	The time required for the technology to reach the Plateau of Productivity.

Source: Gartner (July 2020)

Table 2: Benefit Ratings

Benefit Rating	Definition
Transformational	Enables new ways of doing business across industries that will result in major shifts in industry dynamics
High	Enables new ways of performing horizontal or vertical processes that will result in significantly increased revenue or cost savings for an enterprise
Moderate	Provides incremental improvements to established processes that will result in increased revenue or cost savings for an enterprise
Low	Slightly improves processes (for example, improved user experience) that will be difficult to translate into increased revenue or cost savings

Source: Gartner (July 2020)

Table 3: Maturity Levels

Maturity Level	Status	Products/Vendors

Maturity Level	Status	Products/Vendors
Embryonic	▪ In labs	▪ None
Emerging	▪ Commercialization by vendors ▪ Pilots and deployments by industry leaders	▪ First generation ▪ High price ▪ Much customization
Adolescent	▪ Maturing technology capabilities and process understanding ▪ Uptake beyond early adopters	▪ Second generation ▪ Less customization
Early mainstream	▪ Proven technology ▪ Vendors, technology and adoption rapidly evolving	▪ Third generation ▪ More out-of-the-box methodologies
Mature mainstream	▪ Robust technology ▪ Not much evolution in vendors or technology	▪ Several dominant vendors
Legacy	▪ Not appropriate for new developments ▪ Cost of migration constrains replacement	▪ Maintenance revenue focus
Obsolete	▪ Rarely used	▪ Used/resale market only

Source: Gartner (July 2020)

Evidence

The analysis and advice provided in this Hype Cycle document is built from constant scanning of the market, as well as from the aggregation of analysts' experience and ongoing interactions with end users, technology and service providers, and policymakers.

Each entry on this Hype Cycle has been prepared by subject matter experts. They have drawn on the body of research published within their respective field, and they have used related external secondary research sources. Many of the entries in this Hype Cycle are forward-looking. The descriptions and analysis given have been reviewed by analysts who are subject matter experts in the particular discipline that has been addressed. They also have been reviewed by other knowledgeable analysts outside the immediate discipline as a validity check to confirm that the research positions given are sound across relevant IoT market segments and technologies.