Hype Cycle for Managing Operational Technology, 2020

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Analyst(s): Kristian Steenstrup, Simon Jacobson, Ivar Berntz

Blurring of IT and OT boundaries provides opportunities for industrial organizations to become more integrated. This has heightened awareness for CIOs who are being pressured to work with other business areas to pursue the business benefits that integration can provide.

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What You Need to Know

Operational technology (OT) is hardware and software (e.g., process logic controllers and supervisory control and data acquisition systems) that detects or causes a change in industrial processes through the direct monitoring and/or control of physical devices and events in the enterprise. These systems leverage, or are integrated with IT and Internet of Things (IoT) components and architectures. CIOs and CTOs are learning to manage the risks of OT as technologies continue to evolve and become more interwoven.

This Hype Cycle profiles IT- and OT-related technologies, processes, techniques and services that will aid in managing, aligning and integrating OT with IT. CIOs, CTOs and other digital business leaders should use this Hype Cycle to assess the hype and maturity of the profiles described.

The Hype Cycle

Most OT has been designed to provide for critical operational functions, focusing on process optimization, safety and reliability — not security, maintainability or upgrades. OT architectures are historically proprietary, and terminology is often industry-specific.

Times are changing.

Boundaries that once existed between IT and OT organizations and assets are blurring. COVID-19 and market shifts happening prepandemic exposed risks, revealed opportunities to reduce costs, increased resilience and illuminated new revenue opportunities. In turn multiple stakeholders came to recognize the criticality for aligning and integrating IT and OT and are taking action.

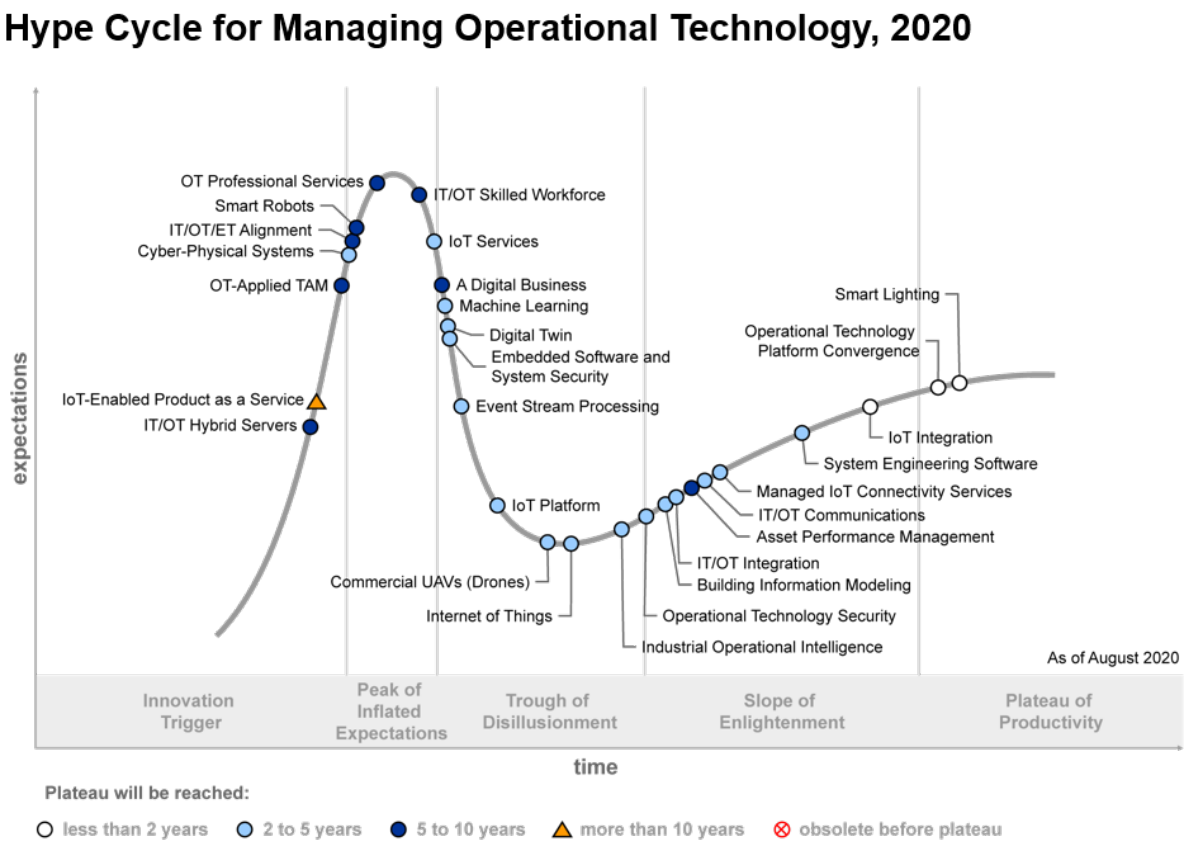
The time frame to plateau for many profiles on this year's Hype Cycle has accelerated — but this does not signal readiness for widespread trust and adoption yet. The various technologies, tools, methodologies and services continue to proliferate in 2020. Organizations must still focus on and judiciously invest in five aspects of IT and OT transformation benefits:

- Reduced operating costs through IoT/OT integration and OT-applied technology asset management (TAM).
- Reduced risks through OT security and embedded software and system security.
- Increased agility and speed with cyber-physical systems and IoT connectivity.
- New business models for competitive advantage and differentiation through IoT-enabled product as a service and IoT services.
- Organizational resiliency by extending the convergence and alignment of IT and OT to include engineering technologies (ET) and focusing on IT/OT skilled workforces (in some industries, this will extend to consumer technologies [CT]).

The distribution of technologies, processes, methods and services on the Hype Cycle illuminates ways to align and integrate these traditionally independent organizational, technology, process and cultural environments.

The positions on the Hype Cycle are considered in aggregate across industries and geographies, with the understanding that there are differences in adoption, maturity and company readiness.

Figure 1. Hype Cycle for Managing Operational Technology, 2020



Source: Gartner
ID: 450227

The Priority Matrix

CIOs should prepare for the transformational impact of innovations critical for managing OT that are only two to five years away from mainstream adoption in the marketplace. These are:

- Digital twin (to support asset visibility and optimization)
- Event stream processing (to support real-time responses)
- IoT (to enable direct data collection)
- Machine learning (to support artificial intelligence initiatives)

- System engineering software (for complex engineering environments)

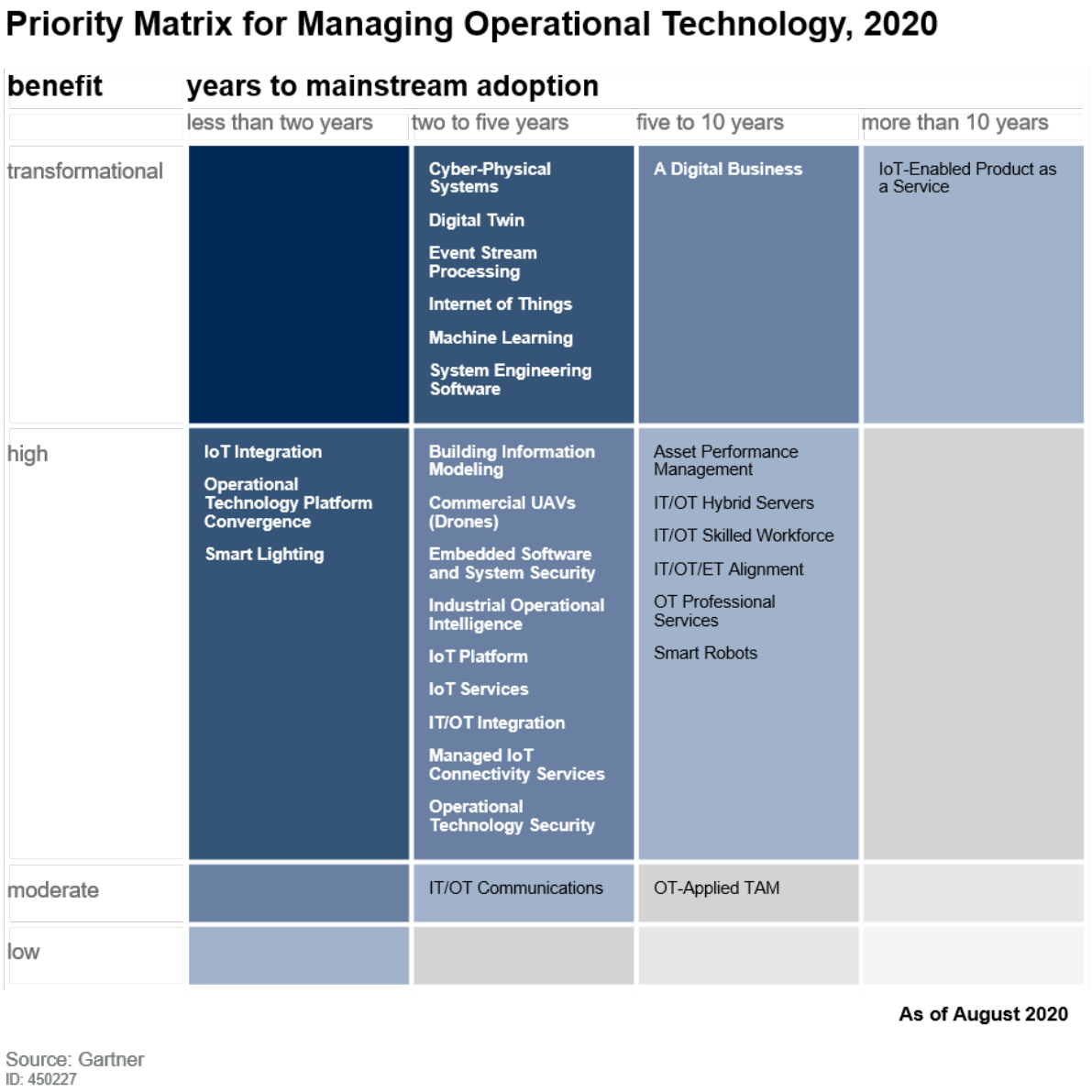
For CIOs in organizations that seek competitive advantage in their industries via technology-driven innovation, business cases for these technologies should already be prepared and proofs of concept should be completed or nearing completion soon. Plans for conducting pilots within a roadmap for ramping up to full-scale production environments should be starting within 12 to 18 months. Organizations with less appetite for taking technology risks and first-mover rewards, should plan to be “fast followers” regarding these innovations, with business cases under preparation. Because of the transformational nature of these technologies, every organization — regardless of its risk-reward profile — should be preparing to adopt these technology innovations. Falling too far behind the curve of technology diffusion in these areas could be damaging to the business in the medium to long term. The selection of which innovations are “most important” should always be done in the context of your own business strategy and goals.

Another considerable tranche of innovations is expected to deliver significantly high benefits within five years (refer to individual profiles for further details):

- IoT integration
- Operational technology platform convergence
- Smart lighting
- Building information modelling
- Commercial UAVs (drones)
- Embedded software and system security
- Industrial operational intelligence
- IoT platform
- IoT services
- Managed IoT connectivity services
- IT/OT integration
- Operational technology security (and risk management)

While not considered transformational in nature, the benefits that these innovations are expected to bring to mainstream technology adopters within five years make them investment priorities over the short term. CIOs must ensure that their business leaders are armed with these technologies as they compete in industries where OT is prominent, such as mining, material processing, manufacturing, power generation and distribution. This is true of operational technology platform convergence and smart lighting innovations, which are expected to reach mainstream adoption in less than two years. CIOs should be reaching production-ready capability and project milestones now.

Figure 2. Priority Matrix for Managing Operational Technology, 2020



Source: Gartner
ID: 450227

Off the Hype Cycle

The taxonomy of technologies across IT/OT, digital business and IoT arenas continues to evolve; changes to the profiles reflect this.

- IT/OT alignment — The name was changed to IT/OT integration as to better reflect the outcome instead of the process of achieving it.
- ITAM governance for OT — The name was changed to OT-applied TAM to better reflect its proximity with TAM for IT.

- Time-sensitive networking — This innovation is now part of edge networking in “Hype Cycle for Enterprise Networking, 2020.”
- Open SCADA — Interest in open SCADA has dwindled, as open SCADA initiatives are now being replaced by more generic IoT initiatives. In 2018, we declared open SCADA to be obsolete before the plateau, and decided consequently to eliminate this innovation profile from this Hype Cycle in 2020.

On the Rise

IT/OT Hybrid Servers

Analysis By: Tony Harvey

Definition: IT/OT hybrid servers are designed to interface, collect and process data from operational technology systems that provide real-time control of physical systems and industrial process. These servers are placed in operational environments such as factories and mines, and are designed to operate with higher resilience to shock, vibration, humidity and temperature than typical data center servers. They will also include industrial communications interfaces such as CAN bus, Modbus or Profinet and may include wireless or 5G technology.

Position and Adoption Speed Justification: IT/OT hybrid servers became available in 2018, but there has yet to be any major adoption of these systems. Although the servers appear to provide the necessary functionality and IoT is pushing systems further out toward the edge, there are still many barriers to adoption of IT/OT hybrid solutions. Industrial enterprises are cautious about the use of IT systems in industrial process control, where failure could result in loss of life or significant property damage and IT/OT hybrid server vendors need to demonstrate that they are secure and reliable before there is widespread adoption.

User Advice: IT/OT hybrid servers represent an opportunity and a risk for industrial enterprises. The potential benefits of using the data being generated by machines and industrial processes to drive cost efficiencies and deliver new solutions are enormous, but the security risks of allowing remote access to systems that, if interfered with, could result in loss of life, significant property or environmental damage and financial impacts must be resolved. Many OT systems were never designed to be connected to an open network such as the internet and have little to no security features.

CIOs looking to evaluate IT/OT hybrid servers must do so as part of an IT/OT integration program that should:

- Align IT/OT in areas of architecture, governance, security and software management, and infrastructure, support and software acquisition.
- Develop a blended IT/OT culture that mixes the rigor and risk awareness of the OT engineering mindset with the flexibility and tolerance for change that is inherent in an IT mindset.

- Embed risk and security training, awareness and talent in hybrid IT/OT teams to ensure that systems are designed with security in mind.
- Rationalize the costs for ongoing support, maintenance/updates and dependencies (networks, hardware, OSs, software and people) in a combined IT and OT environment.

Business Impact: IT/OT hybrid servers can help the enterprise realize the potential of the large pool of data that is generated by OT systems. The ability to use this data will generate new cost efficiencies and innovations in manufacturing and industrial control processes. As use of IT/OT hybrids expands, the requirements for security management, cross-service coordination between IT and OT, data sharing and service-level management will grow to where most larger enterprises will need to create an integrated IT/OT group that has full responsibility for these solutions. Smaller enterprises may need to work with specialist IT/OT consultancies to assist with the integration in the early stages.

Enterprises that do not adopt IT/OT hybrid servers may find themselves left behind as enterprises that successfully integrate these systems into their digital transformation strategy will lower their costs and deliver new services to market faster.

Benefit Rating: High

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Sample Vendors: Dell EMC; Hewlett Packard Enterprise; Lenovo; Schneider Electric

Recommended Reading: "Industrial Enterprise Customers Want to Accelerate IT-OT Convergence"

"IT/OT Convergence and Implications"

"As IT and OT Converge, IT and Engineers Should Learn From Each Other"

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"

OT-Applied TAM

Analysis By: Roger Williams

Definition: Technology asset management (TAM) for operational technology (OT) provides an accurate physical inventory of technology assets and an account of their costs and risks throughout their life to maximize the business value of technology. Technology assets include software, hardware and cloud services that generate, receive or process digital information to support business activity, regardless of environment.

Position and Adoption Speed Justification: Increasing IT/OT convergence, such as industrial IoT and blurred lines between IT, OT and line of business systems, is driving higher demand for TAM to be extended to OT systems. Software asset management (SAM) and, to a lesser extent, hardware asset management (HAM), are well-established disciplines for managing IT assets. Within OT, TAM includes the management of technology assets within the OT environment (such as servers supporting manufacturing systems) as well as the management of OT-specific systems that now include digital technology elements. Management of technology assets within the OT space has not historically fallen within IT's purview and receives less attention that managing physical assets.

Two trends are primarily driving attention on this topic:

- **Planning for IT/OT convergence is of growing interest.** Many Gartner clients have expressed interest during inquiries in being able to use a single approach to manage both IT and OT systems within the organization. For instance, patching of systems across IT/OT boundaries can introduce risks if vulnerabilities are not address in a timely manner. Strengthening skills, clarifying responsibilities and adopting consistent TAM approaches provide the context needed to improve the benefits delivered by technology assets within the OT environment while optimizing costs and risks (such as with OT security).
- **Software audits can trigger TAM engagement with OT.** As traditional IT software (including standard IT OSs such as Windows and Linux) has been introduced into OT environments, software vendors are increasingly extending license compliance audits into this space. They are also demanding consumption data relating to the use of their software by OT systems. OT software vendors are following the lead of the traditional IT software vendors in auditing for compliance with software license terms and conditions, increasing the risk of significant unbudgeted costs. When SAM discipline is initially applied, both over- and underlicensing are often identified, along with significant opportunities to leverage existing contracts and consolidate volume purchases.

User Advice: Assess existing TAM maturity and capability before considering how to extend it into the OT environment. If maturity and capability are high (as evaluated against standards such as ISO/IEC 19770), then existing TAM best practices can be extended and adapted to OT for both hardware and software. If maturity and capability are low, focus on improving overall TAM

capabilities by defining a business case and charter that addresses issues and concerns across both IT and OT environments, such as compliance, security and savings opportunities.

Baseline the OT environment to identify both traditional IT hardware and software assets that are present, and OT-specific digital technology assets that would benefit from TAM. This also included industry-specific systems such as healthcare and retail devices that have network connections and software. Depending on the technologies in use, IT tools such as SAM tools, IT service management tools, and IT asset discovery tools may suffice to enable this work. However, separate tooling such as engineering-focused SAM tools, OT security and other products may be appropriate.

Work with IT and OT procurement leaders as well as software asset management staff and sourcing teams to rectify any license compliance issues before attempting to focus on consolidation and cost reduction.

Ensure that useful OT practices are maintained and not supplanted by TAM, which should be considered as an enhancement rather than a replacement for existing practices. Leverage both the lessons from TAM (particularly regarding SAM) and useful practices developed by engineering and operations teams responsible for physical assets for both IT and OT assets.

Business Impact: Extending TAM into OT environments delivers benefits not only to the IT products used to support OT, but also to OT buyers, where existing processes and tools can be used to:

- Reduce the cost of IT hardware and software (both new purchases, support and maintenance costs) by leveraging existing contracts and technology procurement expertise
- Reduce the risk of future unbudgeted costs from software license compliance audits by identifying and remediating potential liabilities
- Optimize hardware inventories and life cycle configurations and address out-of-cycle network refreshes as well as bundling service contracts
- Provide data to a range of stakeholders to assist with decision making and planning. This includes identifying counterfeit software; recognizing hardware that may be out of service coverage; and standardizing software editions to reduce incompatibility and manage risks from unsupported software. It can also improve demand management and provisioning processes to effectively and efficiently deploy hardware and software to support business needs.

Benefit Rating: Moderate

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Sample Vendors: Axonius; Cyberbit; Flexera; Open iT; OpenLM; RayNet; RAY • ALLEN

Recommended Reading: “How Redefining IT Asset Management Will Enable Business Transformation for the Digital Age”

"Reduce Cost and Risks With Comprehensive IT Asset Life Cycle Controls"

"Expand Your ITAM Business Case to Gain Executive Support and Investment"

"As IT and OT Converge, IT and Engineers Should Learn From Each Other"

At the Peak

Cyber-Physical Systems

Analysis By: Katell Thielemann

Definition: Cyber-physical systems (CPS) are engineered systems that orchestrate sensing, computation, control, networking and analytics to interact with the physical world (including humans). They enable safe, real-time, secure, reliable, resilient and adaptable performance.

Position and Adoption Speed Justification: Already deploying in smart grids, smart buildings or autonomous vehicles, CPS are also core to future visions of smart manufacturing and Industrie 4.0. They represent the confluence of physical and virtual systems to connect people, products, data and processes within the manufacturing function. When connected to the supply chain, they can also enable a self-adaptive and autonomous production capability. This will change dynamics across multiple industrial ecosystems by automating unstructured processes, shortening cycle times, and improving product and service quality. Deployments extensively use robotics, cloud services, advanced analytics, machine learning and secure high-speed networks to orchestrate data and processes in real time. Unfortunately, because they connect both the cyber and physical worlds, CPS can also open the aperture to new security and safety threats.

Over time, CPS will replace precursors such as stand-alone conventional production process control and automation, materials handling systems (plus the sensor networks or machine networks), and transactional workflow systems to promote real-time information gathering and processing. Combining multiple platforms and systems underscores the need for interoperability standards and an increased focus on safety, security and resilience. Several frameworks are emerging, driven by the United States' National Institute of Standards and Technology (NIST), or Germany's Industrie 4.0-aligned RAMI 4.0 framework. Beyond upgrading IT and OT, revamping factory layouts and identifying where to judiciously automate process and data flows in/across the value chain is needed, CPS demands a level of security, orchestration and operating model overhaul that will drive manufacturers to revisit their corporate production systems and value chain relationships.

Other sectors (transportation, advanced weapons systems, smart buildings and healthcare) are advancing ahead of manufacturing. The increased pursuits of digital supply chains, the rise of strategic industrial modernization projects and advanced analytics are encouraging, and push CPS forward on this year's Hype Cycle. The two-to-five year time frame to the Plateau of Productivity represents the continued obstacles created by the variance of factory layouts and production styles — not to mention the maturity levels for both — to fulfilling the full vision for CPS, as well as the unique safety, security and resilience concerns that manufacturing operations need to address.

User Advice: When seeking to establish a CPS, pursue the following actions:

- Incubate small-scale pilots to push the potential impacts on connected products and orchestration of processes. Partner with academia, consortiums, suppliers and distributors in these pilots as necessary.
- Promote the use of standards and implementation recommendations to manage complexity, enable scalability and extensibility, and to ensure focus on security and safety imperatives.
- Expand your risk lens. This involves broadening focus from the means (information) to the outcome (the physical state change implemented). CPS security is particularly critical in production and operational-centric businesses and industries that produce an outcome other than more information. The effect of a disruption or corruption of information can lead to direct physical consequences that can be inherently unsafe. Digital business efforts accelerate this. As the risk lens expands to the physical plane, concerns over physical perimeter breaches, jamming, hacking, spoofing, tampering, command intrusion, denial of service (DoS) or malware implanted in physical assets all need to be taken into consideration.

Business Impact: The future of CPS in manufacturing operations will ultimately be predicated on a blend of operating models, science, engineering, supply chain, safety, security and technology. CPS will carry transformative impacts across:

- **Risk: Medium —** Many building blocks for CPS in manufacturing are too early in their life cycles to associate with risk as pilots are being incubated. However, companies that lag in their convergence and alignment of IT and OT to create transparency and efficiency will be left behind.
- **Technology intensity: High —** CPS requires costly upgrades, mastery of artificial intelligence, sensors, secure connectivity, and capability for integrating and managing information to optimize production and distribution costs at a magnitude larger than today's systems can handle. The rapid proliferation of IoT data alone will challenge existing OT information infrastructures and disrupt existing approaches to security, process automation and data integrity.
- **Organization change: High —** Self-adaptive and automatically reconfigurable systems change the very nature of decision making — not only who makes them, but also how, why, where and when.
- **Process change: High —** CPS mandates process redesigns across traditional manufacturing silos internally. Extensions to the supply chain will also impact many areas, such as SLAs or pricing and inventory discussions. Evolving regulatory compliance and data ownership policies will impact data governance and privacy policies.
- **Competitive value: High —** When optimized, CPS can dynamically reconfigure product supply networks to accommodate variability, capture new opportunities or achieve new outcomes that add value to the customer.

Benefit Rating: Transformational

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Sample Vendors: AVEVA; Bosch.IO; Fujitsu; Google; Hitachi; IBM; Microsoft; Siemens

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

"How to Develop a Security Vision and Strategy for Cyber-Physical Systems"

"Facing New Vulnerabilities — Cyber-Physical Systems"

"Driving Digital Business Transformation for Industry Leadership: A Supply Chain Perspective"

"Cool Vendors in Manufacturing Industry Solutions"

"Cool Vendors in Cyber-Physical Systems Security"

"Magic Quadrant for Industrial IoT Platforms"

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"

Smart Robots

Analysis By: Annette Jump

Definition: Smart robots are electromechanical form factors that work autonomously in the physical world, learning in short-term intervals from human-supervised training and demonstrations or by their supervised experiences on the job. They sense environmental conditions, recognize and solve problems. Some can interact with humans using voice language, while some have a specialized function, like delivery or warehouse robots. Due to advanced sensory capabilities, smart robots may work alongside humans.

Position and Adoption Speed Justification: Smart robots have had significantly less adoption to date compared with their industrial counterparts (predefined, unchanged task) — but they received great hype in the marketplace, which is why smart robots are positioned climbing the Peak of Inflated Expectations. In the last 12 months, many of the established robot providers expanding their product line and new companies entering the market. Here are few examples:

- Whiz robot from SoftBank Robotics that will be sold under robot-as-a service (RaaS) model and originally be available only in Japan.

- Furhat Robot from a Swedish startup (Furhat Robotics) developing social robots.
- Smart Robotics that has introduced a robot valet for parking cars in France (Lyon).
- Temi robot from temi that will target home assistance for elderly and will incorporate Amazon's Alexa.

The market is becoming more dynamic though the cost of entry and user tech sophistication are still high. Also, the time lag between product announcements and launch dates remain quite long at six to 12 months. Some products are killed before they reach broad availability. Recent market examples of slow adoption and withdrawals are Rethink Robotics, very low rate on renewal contracts for SoftBank Robotics' Pepper three-year contracts and decision of Henn na Hotel, a Japanese hotel, the first hotel chain to replace smart robots with humans. Specialization also is very important to success, as no smart robot can address all industry specific use cases. Despite some advancements in AI, product and material experimentation in 2019 and early 2020, the progress is still slow, as companies are still trying to identify business valuable use cases. Therefore, the position of "smart robots" has not changed versus 2019 and still remains on the Innovation Trigger curve. Hype and expectations will continue to build around smart robots during the next few years, as providers execute on their plans to expand their offerings and explore new technologies, like reinforcement learning to drive continuous loop of learning for robots.

User Advice: Users in light manufacturing, distribution, retail, hospitality and healthcare facilities should consider smart robots as both substitutes and complements to their human workforce. Begin pilots designed to assess product capability, and quantify benefits. Examine current business- and material-handling processes into which smart robots can be deployed; also, consider redesigning processes to take advantage of the benefits of smart robots with three- to five-year roadmaps for large-scale deployment. Smart robots could also be a quality control (QC) check at the end of the process, rejecting product with faults and collecting data for analysis.

Business Impact: Smart robots will make their initial business impact across a wide spectrum of asset-centric, product-centric and service-centric industries. Their ability to do physical work, with greater reliability, lower costs, increased safety and higher productivity, is common across these industries. The ability for organizations to assist, replace or redeploy their human workers in more value-adding activities creates potentially high — and occasionally transformational — business benefits. Typical and potential use cases include:

- Logistics and warehousing: Product picking and packing, e-commerce order fulfillment, locating and moving goods
- Medical/Healthcare: Patient care, medical materials handling, prescription filling
- Customer care
- Goods delivery due to social distancing and quarantine with COVID-19
- Manufacturing: Product assembly, stock replenishment, support of remote operations
- Delivery of packages and food
- Reception/Concierge in hospitality, retail, hospitals, airports, etc.

- Other: Disposal of hazardous wastes

Benefit Rating: High

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Sample Vendors: Aethon; Amazon Robotics; Google; iRobot; Panasonic; Rethink Robotics; Savioke; SoftBank Robotics; Symbotic; temi

Recommended Reading: "Top 10 Strategic Technology Trends for 2020: Autonomous Things"

"Forecast: IoT Enterprise Robots by Use Case, Worldwide, 2018-2028"

"Preparing for a Future When Your Next Manufacturing Employee Will Be a Robot"

"Top 10 AI and Sensing Technology Capabilities for Personal Assistant Robots in 2020"

OT Professional Services

Analysis By: Kristian Steenstrup

Definition: Operational technology (OT) professional services encompass professional services delivered by consulting companies with engineering capabilities and engineering services, OT system integrators and by OT system OEMs. The services focus on IoT-enabling data collection and control of equipment (integration), such as heavy machinery as well as OT cybersecurity, product management tools and processes. Providers supporting these services typically offer industry-specific or product-specific OT system knowledge.

Position and Adoption Speed Justification: Business initiatives driven by the proliferation of digital business and Industrie 4.0 continue to increase enterprise spending on OT professional services. Added to this is interested in integrating Industrial IoT into OT platforms.

Industrial verticals like power, oil and gas, manufacturing and transportation are prime markets for the use of OT professional services. The market is split between OT vendors offering professional services, pure OT service providers and IoT based companies. IoT also creates the opportunity for the IT-centric service providers to disrupt the OT professional services market.

The position of this innovation profile is stalled. We expected that industrial focused enterprises will continue to gain confidence, leveraging technologies such as IoT, as well as deploying digital solutions across the enterprise. However, the use of OT professional services struggles to gain traction with businesses. The conservative and risk-averse nature of the market creates slower growth than we would see in an equivalent IT-oriented market and providers struggle to provide enough marketing to tip the balance.

User Advice: Industrial companies are moving forward in the deployment of digital solutions, particularly predictive and condition-based maintenance. This increases the need for OT expertise

in support of these digital solutions — some consider building or expanding in-house capabilities, and some consider sourcing expertise externally from OT professional services providers. CIOs should:

- Seek providers that support your industry to apply domain-specific operations knowledge. OT professional services innovation is an inherently verticalized function. These providers should have an understanding of the OT systems (design and function); data processing and analytics methods; operational data flows; the level of integration required between IT and OT; and the opportunity to leverage OT data for business gain.
- Create a capability assessment that defines your internal OT service expertise, as well evaluation criteria to identify and select the best-fit OT professional services provider.
- IoT-industry-focused standards and regulations are more prevalent as IoT and other digital business technologies continue to mature. Partner with OT professional services providers that are aware of such standards, regulations and consortia not only within your industry, but also from a geographic perspective.

OT professional services providers bring deep vertical knowledge, equipment knowledge and updated strategies to manage and leverage OT environments. Gain a full understanding of today's OT professional services market, including the provider's IoT partnerships, to make the best sourcing decisions.

Business Impact: OT professional services are most applicable for the asset-intensive industries, such as power, utilities, oil and gas, manufacturing, construction and transportation. OT professional services support these industries to deploy digital solutions for business initiatives that drive key outcomes, such as cybersecurity, asset optimization, operational efficiency and provide operational cost reductions and savings. Many clients will look to their OT vendors to provide these services as they are most familiar with the equipment and OT systems deployed

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Sample Vendors: Black & Veatch; Emerson; Genpact; Hitachi; L&T Technology Services; Rockwell Automation; Schneider Electric; Siemens; Tech Mahindra; Wipro

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

"The Importance of OT Integration for Industrie 4.0"

IT/OT Skilled Workforce

Analysis By: Saniye Alaybeyi

Definition: IT/OT skilled workforce is a critical resource for asset-centric industries with substantial infrastructure, plant and equipment. Digital businesses need employees who address IT and

operational technology (OT) with integrated skills to avoid duplication, promote efficiency and provide rapid response to digital business requirements. Knowledge and experience to manage IT infrastructure and software, along with engineering and operations expertise, are desired, along with understanding of reliability, security and safety objectives.

Position and Adoption Speed Justification: Individuals with specific IT, OT and vertical industry/domain experience are being hired or trained to manage or lead IT/OT integration activities. With the proliferation of artificial intelligence, the importance of domain experience is increasing. Data scientists are not domain experts, they need IT/OT skilled workers to help them define problems for artificial intelligence or machine learning. New and more automated projects and facilities create a demand for holistic oversight over the integration of information, safety, data, people and processes. Cost cutting, productivity gains and workforce reduction are drivers for converged IT and OT skills. Enhanced plant automation to create productivity gains and workforce reduction are increasing. Job demand instigated by IT/OT alignment outpaces resource availability. This shortage constrains projects that need fully aligned and integrated IT/OT organizations. The trend to IT/OT integration is gaining momentum as IT/OT hybrid projects, including AI and machine-learning-based automation, becoming more common. OT (and industrial Internet of Things [IoT]) project plans now use a combination of IT systems and modern, connected and converged OT systems. This combination is evident in, for e.g., smart utility grids, automated manufacturing, remote control mining operations, automated transportation, and smart city initiatives with building automation, smart streets, smart lighting and related technologies — hence, the profile's movement on the Hype Cycle is to Post Peak Position.

User Advice: Continue to hire and/or develop and train employees who leverage advances such as those found in the "industrial internet" (including IoT) to encompass IT and OT products and services. The following characteristics should be sought:

- **Hybrid skill sets:** This skill set combines IT and OT knowledge, mindset and experience applied to IT/OT governance, policy, planning, security and architecture. Hybrid skill sets represent the common skills applicable across multiple vertical industries, and they will serve as a starting point for IT/OT skilled workforce development. Those skill sets are considered foundational for most mature IT/OT organizations.
- **Vertical industry expertise:** This skill set provides specific capabilities in vertical industries using a hybrid skill foundation, but it is tailored to the functions of that vertical. Industry-specific skills customize the foundational process and capabilities that are found in hybrid skill sets, so that teams can deal with specific initiatives unique to the vertical industry. Specialized teams with these skills may be assembled or hired to address these initiatives as they are implemented.

Seek candidates with experience in oversight of integration of information and physical state processes. These skills may include regulatory compliance and legal knowledge in vertical industries, and security expertise across the supply chain of that vertical. Some IT/OT skill sets are rare and lag other IT/OT alignment efforts. Asset-centric industries should train and recruit individuals with hybrid IT/OT skills. These skills are developed in mature organizations for specific

vertical needs. This trend has gathered momentum as IT/OT hybrid projects become more common. Outsource when skills are not available internally or there is difficulty in terms of hiring externally.

Business Impact: Joint IT/OT skill sets are now available, either from service firms or within the organization, and they are emerging as high-value assets. The emerging field of DevOps is also impacting skills and maturity. IT skills dominate certain areas, such as digital security. However, engineering and operations skills address specific concerns where reliability and safety are involved. HR departments in affected industries now have formal job descriptions and personnel specifications as the required hybrid IT/OT skilled workforce needs to develop. If this critical area is not staffed, the organization will miss out on competitive and cost-saving digital business opportunities.

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

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

"OT Security Best Practices"

"A Comprehensive AI-Enabled Predictive Maintenance Plan Starts With Business Understanding"

"As IT and OT Converge, IT and Engineers Should Learn From Each Other"

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"

Sliding Into the Trough

A Digital Business

Analysis By: Jorge Lopez

Definition: A "digital business" is an organization or unit inside an organization in which a product set and business model are only made possible by the use of information and digital technology.

Position and Adoption Speed Justification: The dominant discussion about digital business has changed to transformational or more incremental change (such as optimization). What remains unchanging into 2020 is the conviction of board directors and CEOs that they must act in response to significant and disruptive industry change. Of board directors globally, 83% say digital technology will lead to substantial or complete industry transformation, according to the 2020 Gartner survey, View From The Board of Directors. In contrast, the same survey shows that boards judge their own efforts as tepid, with respondents, on average, saying their digital strategies are not well developed and that they struggle with the overall ROI of their digital transformation efforts. This tension between what the leadership of most organizations believe will happen, and what those same corporations are reporting on current results, indicates a strain between the vision of digital business and the reality of implementation. The message received by corporate boards is "keep working on disrupting the industry to ensure we don't get disrupted ourselves."

In addition to these observations from primary research data, we also are seeing that industry examples we have been watching for three or more years are now making their vision into a reality. Examples include the move by Apple into healthcare by medically certifying the Apple Watch to detect heart abnormalities such as arrhythmia. BHP's vision to build "the fully autonomous mine" is now being realized with connected efforts by partners such as Caterpillar. Amazon, who focused on its promise to deliver in an hour, changed its business to enter supply chain/logistics and is not the No. 1 provider in the world. The U.S. Air Force has now successfully tested the technology and vehicles for its ambitious "Loyal Wingman" program, where an F-35 fighter jet is helping guide a swarm of newly deployed autonomous jet drones.

As industry after industry pursues its ambition and observes the fate of segments of each industry in the wake of COVID-19, we will see the rise of technology and services providers offering ways to design and execute on digital business. The risks, at first, will be high, as untested technologies and methodologies are put into practice. It will be important to ensure a consistent view of digital business, and for that we recommend reading "Four Definitions Make A Strategy Planning Process More Effective."

User Advice: Leading organizations' CIOs and digital business executives should:

- Study how leading corporations are building out their visions for the future of their industry, especially in the wake of the global pandemic. Look at what Toyota, with its Woven City, Amazon, in supply chain/logistics, BHP in autonomous mining, Caterpillar in autonomous systems and Honda with its SAFE SWARM are doing. This will be highly instructive to the sort of dedication and execution required to make a reality out of business

- Lay out plans that take your business through the economic downturn caused by the global pandemic. Digital business becomes a necessity in removing the friction of how a business works and, thus, gains higher priority.
- Resist the temptation to make your case about technology. Focus on what it will take to disrupt your industry. What new capabilities or business models will shift the industry in your favor? Let the technologies be chosen based on the guidance of the use cases that drive value. For example, financial services wealth management is working hard to co-opt roboadvisors so as to keep out new entrants. This act of self-defense is also driving down their own expectations for profit, which will mean their business model will be different in the next 36 months.
- Ensure you make transformation a priority in a small part of your business, while optimizing the rest, when analyzing your business portfolio to make changes. Do this until the approach to transformation is better understood internally.

Business Impact: The opportunity in digital business is the ability to:

- Shape the future of an industry as well as your role within it (Apple in healthcare, BHP in mining, Toyota and its Woven City).
- Create new industries (Google in search and translate, Amazon in supply chain and logistics with 60-minute fulfillment of orders).
- Capture adjacent industries (Caterpillar and autonomous systems for mining, Amazon and pharmacy with PillPak).

In each case, the successful capture of the industry-disrupting goal takes the winner to new heights in industry business performance. We expect to see failed attempts to translate the promise of digital business into business performance, but not among the winners in each industry, where we expect industry-leading performance over the next ten years.

Benefit Rating: Transformational

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Recommended Reading: “Executive Leadership: Digital Business Transformation Primer for 2020”

“Toolkit: Strategic Industry Maps of AI Use Cases”

Machine Learning

Analysis By: Pieter den Hamer; Carlie Idoine; Shubhangi Vashisth

Definition: Machine learning is an AI discipline that solves business problems by utilizing mathematical models to extract knowledge and patterns from data. There are three major approaches that relate to the types of observation provided: supervised learning, where observations contain input/output pairs (also known as “labeled data”); unsupervised learning

(where labels are omitted); and reinforcement learning (where evaluations are given of how good or bad a situation is).

Position and Adoption Speed Justification: Machine learning is still a popular concept, given its extensive range of impacts on business. The triggers of its massive growth and adoption have been growing volumes of data, advancements in compute infrastructure and the complexities that conventional engineering approaches are unable to handle. As organizations continue to adopt these technologies, we recently see focus on aspects that relate to ML explainability and operationalization. Augmentation and automation (of parts) of the ML development process improve productivity of data scientists and enable citizen data scientists in making ML pervasive across the enterprise. In addition, pretrained ML models are increasingly available through cloud service APIs, often focused on specific domains or industries. New frontiers are being explored in synthetic data, new algorithms (e.g., deep learning variations) and new types of learning. These include federated/collaborative, generative adversarial, transfer, adaptive and self-supervised learning, all aiming to broaden ML adoption.

User Advice: For data and analytics leaders:

- Focus on the business problem. Start with simple business problems for which there is consensus about the expected outcomes, and gradually move toward complex business scenarios.
- Assemble a (virtual) team that prioritizes machine learning use cases, and establish a governance process to progress the most valuable use cases through to production.
- Utilize packaged applications, if you find one that suits your use case requirements. These often can provide superb cost-time-risk trade-offs and significantly lower the skills barrier.
- Nurture the required talent for machine learning. Partner with universities and thought leaders to keep up to date with the rapid pace of advances in data science. Create an environment conducive to continuous education, and set explicit expectations that this is a learning process and mistakes will be made.
- Provide guidelines and monitor compliance with respect to security, privacy, bias and explainability.
- Leverage the augmentation and automation of ML activities, avoiding unnecessary low level coding and alleviating labor intensive tasks for expert data scientists, while making ML accessible for citizen data scientists.
- Explicitly manage “MLops” for deploying, integrating and monitoring ML models, not underestimating time and complexity. To be successful, early involvement is required of both business stakeholders and IT for integration and operations.
- Focus on data as the fuel for machine learning by adjusting your data management and information governance strategies to enable your ML team. Data is your unique competitive differentiator and adequate data quality, such as the representativeness of historical data for current market conditions, is critical for the success of ML.

Business Impact: Machine learning drives improvements and new solutions to business problems across a vast array of business, consumer and social scenarios:

- Automation
- Drug research
- Customer engagement
- Supply chain optimization
- Predictive maintenance
- Operational effectiveness
- Workforce effectiveness
- Fraud detection
- Resource optimization

Machine learning impacts can be explicit or implicit. Explicit impacts result from machine learning initiatives. Implicit impacts result from products and solutions that you use without realizing they contain machine learning.

Benefit Rating: Transformational

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Sample Vendors: Alteryx; Databricks; Dataiku; DataRobot; H2O.ai; IBM; MathWorks; Microsoft; SAS; TIBCO Software

Recommended Reading: "Magic Quadrant for Data Science and Machine Learning Platforms"

"Critical Capabilities for Data Science and Machine Learning Platforms"

"Toolkit: RFP for Data Science and Machine Learning Platforms"

"3 Types of Machine Learning for the Enterprise"

"Top Organizational Pitfalls of Machine Learning Initiatives"

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” 6

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

Embedded Software and System Security

Analysis By: Ruggero Contu; Barika Pace

Definition: Embedded software and system (ESS) security is a technology and practice designed by engineers and developers to protect hardware and firmware from cyberattacks and assist in delivering integrity and confidentiality of the data that those systems process. ESS may have varying life cycles, including ones measured in decades and may be subject to both physical and digital attacks of varied forms and strengths.

Position and Adoption Speed Justification: ESS security is evolving to address growth in the industrial, commercial and consumer markets. This is happening also through support of secure microcontroller units (MCUs) that act as the basic hardware to protect the embedded software, data storage, processing power and communications between devices. The historic ESS design lacked security, focused on reliable and maintainable code, with little emphasis on protection. OT and IoT introduce new application and platform security requirements for ESS. ESS hardware and firmware standards aren't universally adopted, although international standards for handling data security, authentication and encryption do exist. However, these techniques have not yet been tested in hostile environments where IoT devices may operate. Device hardware may have to last decades. Device discovery, provisioning, upgrading and remediation must be protected. Expect new regulatory initiatives, such as the one announced by the U.K. government in May 2019, aimed to driving a better security by design approach, the approved California Security of Connected Devices Law and also the in-force European GDPR privacy requirements. These are likely to accelerate adoption of more stringent ESS security practices. The increasing compliance requirements as well as increased security awareness within enterprise and consumer sector are the main factors behind the progress in the positioning and adoption. As a result of these facts, some Hype Cycle progress has been made since 2017 in standard system-on-chip designs, more flexible configurations to meet industry-specific requirements, and integration with existing key management and secure data read/write mechanisms. As such, it has passed the Peak of Inflated Expectations and marked progress will begin to accelerate in these areas.

User Advice: ESS security is critical for organizations deploying endpoints and edge computing for IoT and OT systems. ESS requirements are complex: Devices can have long field lives, are physically accessible to attackers and require long-term management. Security and risk management leaders must:

- Establish governance and planning practices that incorporate embedded security functionality into design and management.
- Expand security architecture and planning to address decentralization of processing architecture into the network and to edge computing.
- Allocate organizational responsibilities to coordinate counterparts and business managers using ESS in business scenarios.
- Drive service-level agreements and audits of ESS-affected systems to ensure high-risk systems are designed properly.
- Address supply chain and partner ecosystem security via skill set and process changes to address their critical role in ESS.

Business Impact: Increasing ESS usage is a symptom of the changes reshaping current information and IT security technologies, processes and organizations. This will impact the enterprise in:

- Secure fit-for-purpose and less expensive technologies in business scenarios: ESS use in devices affects how chip vendors, service providers, manufacturers, developers and others plan. ESS use reshapes semiconductors, electronics industries, business scenarios and pricing.

As environments grow more complex, business scenarios must expand to include ESS considerations.

- ESS allows for more monitoring and data collection of digital business performance, enabling big data initiatives to be augmented with information from OT security, IoT security and physical security data, and providing data context for business intelligence. ESS also contributes to advanced machine learning and broader artificial intelligence initiatives in security by contributing hardware-based and firmware-based performance and behavior.
- The scale of deployments using ESS requires changes in how organizations employ enterprise security intelligence. New tools to reduce data complexity for security are becoming available. ESS security is evolving, but is ultimately determined by ESS development, deployment and use in digital business initiatives and the risks they incur.

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Sample Vendors: Arm; CENTRI; Green Hills Software; Infineon Technologies; Intel; Microsoft Azure; Mocana; Qualcomm; Symantec; Thales

Recommended Reading: "Market Trends: IoT Edge Device Security, 2020"

"Forecast: Enterprise and Automotive IoT Edge Device Security, Worldwide, 2018-2024"

"Emerging Technology Analysis: Cyber-Physical Systems Security Is an Opportunity for Security Product Managers"

"How to Develop a Security Vision and Strategy for Cyber-Physical Systems"

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

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 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"

Commercial UAVs (Drones)

Analysis By: Aapo Markkanen

Definition: Commercial unmanned aerial vehicles (UAVs, also known as drones) are small helicopters, fixed-wing airplanes, multirotors and hybrid aircrafts that have no human pilot on board. They are either remotely controlled by human pilots on the ground or outfitted for autonomous navigation. This analysis relates to UAVs used for commercial purposes — excluding consumer and military drones.

Position and Adoption Speed Justification: In 2020, commercial UAVs have nearly reached the bottom of the Trough of Disillusionment. In the technical sense, drones are a relatively mature technology and capable of increasingly sophisticated tasks. However, their wider adoption is often held back by national regulations that restrict or even outright prevent many use cases. In particular, flying drones beyond visual line of sight (BVLOS), above people or in restricted airspace, such as close to airports, are types of operations that are heavily regulated, if not entirely unpermitted, in most countries. Additionally, the scarcity of trained and licensed drone pilots, as well as the high

cost of vertically specialized end-to-end drone solutions — which cover the devices, the supporting software and the flight operations — hold back large-scale adoption among end users. Autonomous flights would represent a major boost to the market, but their enablement for routine usage requires both further regulatory changes and technology advancements.

User Advice: Overall, a corporate drone program should have both short-term and long-term objectives. This is because commercial UAVs can deliver major operational benefits on a routine basis already today, but future technological or regulatory developments can significantly increase their applicability. For instance, once a major market introduces less restrictive regulation on BVLOS flights, the potential of drones in its territory can shoot up practically overnight. Meanwhile, permitting routine BVLOS operations will trigger substantial near-term investment and innovation among the affected technology and service providers. Organizations considering drones, therefore, should not solely plan on the basis of available technology, but also factor in the local regulatory outlook. It makes sense to proactively identify relevant regulatory and technological changes and take advantage of them as early as possible.

The Low Altitude Authorization and Notification Capability (LAANC) initiative in the U.S., facilitating flights in restricted airspace, is one such example users should be aware of. Today, the leading use cases include aerial photography, mapping and surveying, volume measurement, and remote inspection. All of these can be considerably enhanced by the right analytics, so as part of their UAV planning, the adopters should also take into account how they can exploit the captured data in the best possible way. Use cases involving physical tasks — such as delivering cargo or repairing assets — are currently largely in their nascency, but they can be expected to become gradually more viable over the medium term. However, benefits of commercial UAVs in applications that rely on completion of physical tasks will take longer to materialize than in the ones that focus on data capture and analysis.

Business Impact: Most of all, commercial UAVs represent a technology to enhance the capabilities of the roles such as land surveyors, insurance inspectors, and camera operators who traditionally perform labor-intensive tasks in potentially unsafe conditions. As such, drones offer productivity improvements by reducing and/or redeploying headcount, while enabling real-time data capture and improving employee safety. Examples of industry verticals where commercial UAVs can particularly add value include agriculture, construction, emergency services, extractive industries, media and entertainment, as well as utilities. In most of the verticals, the value of commercial UAVs is in reducing operating expenditure and improving safety, but there are also revenue-generating opportunities in industries such as cinematography, surveying and logistics. In 2020, the COVID-19 crisis is set to speed up drone adoption across various use cases such as public safety and traffic monitoring. Also, use of autonomous delivery drones may accelerate during the crisis.

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Early mainstream

Sample Vendors: Cyberhawk; Delair; DJI; DroneDeploy; Kespry; Nightingale Security; PrecisionHawk; Sky-Futures; Unmanned Life; Zipline

Recommended Reading: "Top 10 Strategic Technology Trends for 2020: Autonomous Things"

"Forecast Analysis: IoT Enterprise Drone Shipments, Worldwide"

"Why Autonomous Flying Drones Must Be on the Radar of Mobility Sector CIOs"

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"

Industrial Operational Intelligence

Analysis By: Nicole Foust; Zarko Sumic

Definition: Industrial operational intelligence (OI) combines capabilities formerly found within other operations systems. Capabilities include the ability to capture, store and visualize time series data (from historian software); model assets and processes for business user context; provide situational awareness and initiate field actions; provide operations-focused analytics; and offer support for asset performance management.

Position and Adoption Speed Justification: Industrial OI continues as a critical platform to monitor and add context to large volumes of multistructured data and information from a diverse set of OT and IT data sources. It enables utilities to manage operational performance with a broader business context than is possible with individual SCADA systems, energy management systems, data historians, or other plant and control center applications. In a sense, industrial OI recombines capabilities from these more-mature applications into a new application category focused on getting more business benefit from operational technology (OT) data. Stand-alone legacy systems have not moved as quickly regarding the requirement to create and manage multiple data models, use of data mining, and discovery tools, and leveraging advanced analytics. Stand-alone legacy systems have not moved as quickly regarding the requirement to create and manage multiple data models, use data mining and discovery tools, and leverage advanced analytics.

The role of industrial OI in industries such as utilities has recently been elevated by the growing interest in AI, which dictates a new focus on analytics and the need to manage big data. The development of industrial OI in utilities is occurring in parallel with other industrial sectors, including manufacturing, metals and mining, oil and gas, and transportation. Some vendors can provide industrial OI capabilities across multiple sectors. The size of the market opportunity has attracted the interest of more generic OI platform vendors, some of which have entered the industrial OI market.

The market for industrial OI spans the full gamut of industrial sectors. Ten years from now, industrial OI will be the primary application by which organizations in these industries manage their operations

in real time. It will support real-time situational awareness, predictive “what if” capabilities and event-driven collaboration. Operational errors attributed to imperfect information or lack of information at the point of decision making will mostly be a thing of the past. However, broader adoption still faces a number of barriers, including the limitations of existing solutions, poor integration and alignment of IT and OT, and cultural resistance to information sharing.

User Advice:

- Recognize that deploying industrial OI has both OT and IT impacts and, therefore, requires governance. It should be undertaken as part of a broader initiative that converges and aligns IT and OT.
- Create more value from OT data by investing in industrial OI solutions. In some instances, your existing vendors are building out the necessary capabilities. However, keep in mind the limitations of legacy architectures, and don’t rule out using more generic OI platforms. To justify your OI investments, focus on specific benefit opportunities and identify suitable use cases for your industry. Examples of energy and utility applications include control center situational awareness, transmission and distribution network operations, and monitoring of geographically dispersed assets.
- Start small and expand over time to leverage both OT and IT data sources, and to provide a closed loop that links operational and business performance to deliver operational improvements. Define how real-time OI needs to be. Identify which users need what information and when to support advanced decision making. In addition, ensure that your industrial OI investment supports information usage, value and dissemination, which match the speed of your operations and support just-in-time decision making.

Business Impact: Industrial OI supports operational decision making in plant management, transmission and distribution network operations. A key capability of industrial OI is to define and maintain persistent functional and operational models (or relationships) that create understandable business context for users.

The benefits that accrue from industrial OI will include more efficient and effective operations, better optimization of asset investments, and the ability to dynamically manage operational performance in the context of multiple constraints and a changing business environment. Industrial OI will also help mitigate operational risk. More timely management of data streams coming from historians and real-time production systems, combined with advanced and augmented analytics, will help utilities to uncover potential problems and begin developing better predictive capabilities.

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Sample Vendors: ABB; Dassault Systèmes; OSIsoft; PTC; SAP; Schneider Electric

Recommended Reading: “Top 10 Trends Driving the Utility Industry in 2020”

“Magic Quadrant for Enterprise Asset Management Software”

“Market Guide for Asset Performance Management Software”

“3 Practices Utility Company CIOs Should Include in an Integrated EAM-GIS Solution Strategy”

Operational Technology Security

Analysis By: Ruggero Contu

Definition: Operational technology (OT) security is the practice of protecting critical production and operation systems and services in asset-centric enterprises. OT security addresses industrial automation and control as well as other nonindustrial use cases where physical state changes depending upon secure, safe and reliable function. It also addresses the impact of using IT, IoT and physical security technology and practice when doing so. OT security is part of comprehensive digital security for digital transformation.

Position and Adoption Speed Justification: OT security technologies provide controls to secure OT environments, with the aim to preserve reliability and safety of production and operations environments. Established international standards, such as IEC 62443, European NIS, NIST 800 Series guidance frameworks, among others, provide product and service providers with direction related to function with vertical specific requirements that the OT security market is starting to address.

The OT security market consists of IT security companies that have extended capabilities of existing solutions to address specific OT functional differences and requirements. They also extended capabilities to address specific OT system providers adding security controls to their OT platform offerings and specialist OT security companies that have come to market to address specific OT-related security needs. Recent offerings address industrial IoT (IIoT) requirements as well.

Obstacles in OT security remain in coverage across all verticals and all major OT systems. They also address legacy OT system requirements, keep pace with regulatory requirements and changes to those requirements, provide cultural and organizational challenges in IT/OT integration, and provide scalability and support globally. OT security providers are making progress and expanding market presence (as 2020’s Hype Cycle shows) as a result of improved maturity on the buyer side. A selected number of products are entering a phase of significant adoption. IIoT security technologies are leading future evolution with less expensive offerings, more extensive data collection and flexible command functionality.

User Advice: Security and risk managers should:

- Pursue a cyber-physical approach to achieve an IT/OT/IoT alignment and integration strategy for digital security that underscores governance, strategy and planning as a more centralized process reporting, toward an adaptive security approach.

- Accelerate OT security assessments with reputable and specialist consulting firms to assist in finding risks and gaps to be addressed by the security controls and infrastructure, and implement skills training and awareness schemes for converging IT and OT where possible.
- Map OT leading performance indicators against IT/OT leading risk indicators to write security policies consistent with maintaining and improving performance.
- Apply OT security controls based on digital security policies across OT infrastructure where needed.
- Build repeatable processes for service portfolio management to manage the growing security service portfolio supplementing in-house OT security systems.
- Develop coordination in the OT supply chain to assess partner security controls affecting your organization.
- Focus early infrastructure purchasing on asset discovery, monitoring and reporting, anomaly and incident detection and response, vulnerability management, access control, endpoint security and network segmentation.
- Focus on organizational and cultural challenges by restructuring as required and establishing complete communication and awareness programs between IT and OT.
- Apply pressure on equipment vendors to ensure that their (future) systems are secure by design.
- Apply defense-in-depth strategies to OT security.

Business Impact: OT security is of major relevance to asset-centric organizations such as those considered to be part of national critical infrastructure (for example, energy and utilities, transportation, oil and gas, manufacturing, and natural resources) and other general industrial verticals. It is also found in commercial markets in areas such as building automation and facilities management, healthcare, and retail. OT security is also useful in addressing specific engineering needs for protecting real-time, event-driven systems that have high impact on safety of people and environments. As such, adoption rates for OT security solutions have risen year over year as understanding and market availability have provided options for organizations.

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Sample Vendors: Barracuda; Cisco; Claroty; Forescout Technologies; IBM; Kaspersky; Microsoft; Nozomi Networks; PAS; Radiflow

Recommended Reading: “Competitive Landscape: Operational Technology Security”

“Secure Your OT With Basic Security Hygiene”

“OT Security Best Practices”

“Market Guide for Operational Technology Security”

“How to Develop a Security Vision and Strategy for Cyber-Physical Systems”

“Market Insight: Act Before Convergence Kills Your Stand-Alone OT/IoT Security Product Solution”

“Market Trends: IoT Edge Device Security, 2020”

Climbing the Slope

Building Information Modeling

Analysis By: Marc Halpern

Definition: Building information modeling (BIM) is the process of managing data and information about facilities and physical infrastructure using an agreed-upon digitally enabled shared knowledge resource. This shared data and knowledge resource supports decision making from earliest conception to demolition, and traceably captures the decisions and the outcomes of those decisions.

Position and Adoption Speed Justification: BIM today is climbing up the Slope of Enlightenment. BIM concepts originally evolved during the late 1970s (Innovation Trigger) from civil engineering and architectural engineering departments at universities. By 2002, BIM reached the Peak of Inflated Expectations as commercial software vendors started hyping BIM and we began to see some startups. However, engineering and construction firms were slow to adopt BIM and by the mid-to-late 2000s, BIM began sliding into the trough. As the internet became increasingly mainstream throughout the 2000s, exchange and interoperability building information in digital format became more realistic and more widely accepted. Also, acquisitions of BIM providers and startups began. Nemetschek Group acquired GRAPHISOFT in 2006 and Hexagon acquired Intergraph during 2010. BIM slid into the Trough of Disillusionment about 2012 and began its ascent of the Slope of Enlightenment about 2015 as BIM increasingly became a cloud platform with technologies from existing architecture, engineering and construction (AEC) applications.

Recent accelerated adoption is also being encouraged by European regulations such as the U.K.’s mandate requiring that all publicly funded construction work must comply to BIM maturity Level 2 as defined by the British Standards Institution (BSI). This is one measure to help in fulfilling its target of reducing waste in construction by 20%. As BIM adoption continues to increase, Gartner clients request more guidance on best IT planning for BIM. Increasingly, they express concern about availability of BIM technology based on standards to ensure the viability of their BIM investments over the life cycles of their facilities.

User Advice: Like digital twins and PLM, BIM is a big corporate initiative that extends beyond technology. To successfully adopt and deploy BIM, CIOs must:

- Reduce the risk of failed BIM implementations by phasing the implementations into smaller, focused projects that build upon each other.

- Use both the BSI Levels 0 through Level 4 maturity model, and successively incorporate 2D BIM to 7D BIM categories of data as the company moves from one level of BIM maturity to the next.
- Involve stakeholders such as engineers, designers, construction planners and facilities operators in facilities life cycles to define requirements, and gain their support to positively encourage broader potential BIM user communities about BIM.
- Encourage BIM adoption by convincing supportive senior executives to redefine job performance metrics that encourage potential users to adopt BIM as a repository for designing, accessing content of, and supporting construction projects and facility maintenance.
- Address BIM data architecture challenges by assigning IT architects responsible for BIM implementation to work with key BIM stakeholders in engineering, construction management and facility maintenance.
- Assign a BIM lead to run a project defining corporate standards for creating and modifying BIM models, and establish a training program to educate the user community.

BIM data is coming from multiple silos related to engineering, construction, maintenance, and finance — all with different management policies. CIOs need to work with the CFOs and the facilities leaders together to sort out the data and implementation blueprint, as well as the service modeling. That is specifically key in these COVID times as well as post pandemic when buildings need to enable physical distancing, information management about crowds, etc.

Business Impact: Requests to implement BIM will typically come from business operations. However, there are benefits for CIOs as well. Most notably, BIM enhances the positive impact that CIOs have on business operations, elevating the influence of the CIO in the senior executive ranks. BIM also extends the influence of the CIO to facilities support.

The impact on facilities support goes beyond design and construction of facilities used for operations and by customers to also include operation and maintenance of the facilities. The value of having a single organizing framework for structured content, unstructured content, documents and models eliminates the costs of managing multiple applications that are otherwise needed to maintain and reuse that data. These content management benefits mitigate the costs of implementing BIM, although maintaining it increases overall information and technology costs. The biggest business benefits come from supporting the life cycles of facilities. BIM information and technology now contribute to the business because of money and time saved in design, construction, operation and maintenance.

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Sample Vendors: Autodesk; Bentley Systems; Hexagon (Intergraph); Nemetschek Group

Recommended Reading: "Adopt a Data Governance Strategy for Long-Term Building Information Modeling Success"

"Technology Insight: BIM Addresses Digital Workplace and Asset Management Priorities"

"Market Guide for Integrated Workplace Management Systems"

"Innovation Insight: How CIOs Can Leverage the IoT to Break Down Building Management Silos"

"Covid-19 Fast Response for Manufacturing CIOs"

IT/OT Integration

Analysis By: Kristian Steenstrup

Definition: IT/OT integration is the end state sought by organizations (most commonly, asset-intensive organizations) where instead of a separation of IT and OT as technology areas with different areas of authority and responsibility, there is integrated process and information flow. This includes technical software integration, and also integration of resources.

Position and Adoption Speed Justification: Technical integration to capture OT data is maturing as expected, but few organizations have a mature, systemic approach to IT/OT resource integration. For most IT and OT are managed by separate groups with different approaches to technology and different vendors in use. Integration can be initiated by IT departments; however, business units will seek integration when faced with challenges such as dealing with cybersecurity, rising support costs, safety concerns, disaster recovery or software administration. Without aligned planning, the integration of IT, OT and Internet of Things (IoT) will be challenging to create sustainable supported integration solutions in the near term. The current position reflects the slow progress CIOs make in changing their organizations and overcoming cultural resistance.

User Advice: Clear opportunities and demonstrable benefits exist when integrating the systems. Data and information can be shared, and process flows become continuous and coherent, with minimal interruptions. Evaluate the IT/OT integration challenges and benefits in your specific industry. Achieve consensus across groups and with senior management, and create an alignment activity first to manage governance and standards. Sustainable integration needs well-planned IT/OT alignment. Then, progressively add a more integrated approach to technology. This integration should extend at least to data exchange and platform maintenance, with particular attention paid to communications, cybersecurity and enterprise architecture. In some companies, that commonality will lead to an organization no longer delineated between IT and OT. IT/OT alignment discussions are required to arrive at common standards for platforms, security and architecture. Completely integrated approaches to IT and OT are difficult to achieve because of the deeply rooted tradition in many businesses, where engineers and operations staff have been the "exclusive owners and operators" of OT. As IT and OT platforms and technologies converge (become more alike) through increasing use of IT products within OT, a successful digital business manages both IT and OT together but differently. Traditional "ownership" becomes shared responsibility, even though accountability for operations may not shift.

Business Impact: IT/OT integration results in integrated systems, processes and teams of people as technology domains with different areas of authority and responsibility come together. The benefits of IT/OT integration for asset-intensive digital businesses will be an organization much more capable of managing, securing and exploiting data, information and processes. For example, a company might implement a basis for better reliability and maintenance strategies through more direct access to condition and use data for plants and equipment. Operational intelligence will provide better production management, quality control, responses to events in the supply chain and more efficient production processes. The result will be a more agile and responsive organization. The data from OT systems will be the fuel for better decision making in areas such as operations (adjusting and responding to production events), energy consumption, material consumption, product quality, safety and reliability.

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Sample Vendors: Accenture; Cisco; Eurotech; PTC (ThingWorx); Rockwell Automation

Recommended Reading: "The Importance of OT Integration for Industrie 4.0"

"Magic Quadrant for Industrial IoT Platforms"

"2020 Strategic Roadmap for IT/OT Alignment"

"How to Prepare for the Impact of Next-Generation Manufacturing Innovations"

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"

IT/OT Communications

Analysis By: Tim Zimmerman

Definition: Operational technology (OT) continues to incorporate IT standards-based technology for line-of-business processes. The need to address deterministic performance, latency-sensitive application requirements and the move from proprietary communications protocols to IT standards such as IEEE 802.3 and 802.11 are part of every OT to IT communication migration strategy.

Position and Adoption Speed Justification: OT must be highly available, resilient and reliable to meet mission-critical demands in markets as diverse as manufacturing, utilities and smart city. OT supports activities in which downtime or failure can not only impact productivity, but also can threaten worker safety. Industry-standard technologies continue to make improvements in areas such as performance, latency and security that allow these technologies to be integrated into solutions which historically would have required proprietary solutions and separate networks.

This innovation profile is moving slowly through the Hype Cycle because of the mission-critical nature of the operations and the long refresh cycles of market. Additionally, there is a change of ownership from the line of business which traditionally governs OT to the CIO where IT resides will affect the rate of adoption. IT vendors will continue to advance technology that can be used in OT

environments including the requirements of reduced latency being addressed with the fine timing standard, IEEE 802.11mc, and higher performance by IEEE, 802.11be. Yet, the market will continue to move slowly with eight- to 10-year refresh cycles, although it will be motivated by cost optimization requirements. Industries (including utilities, energy, media, transport and government) using substantial OT will continue to evaluate the technology improvements, but heavy regulatory compliance will continue to drive slower adoption speed.

User Advice: Enterprises using proprietary OT communications solutions without proper information management governance, such as security or communication policies, should document and incorporate technical requirements mandated for use in the associated business process.

Enterprises should periodically review their requirements and risk against the existing implementation to see if switching to standards-based components is viable from risk, performance, latency, migration, environmental (for example, temperature, humidity and vibration) and cybersecurity viewpoints.

Noncritical workflows and equipment may already be able to take advantage of networking IT solutions without compromising the business outcome while providing cost optimization opportunities.

All upgrades should be thoroughly tested to ensure compliance with existing IT and OT requirements.

Business Impact: Enterprises must understand and document all requirements for OT applications and systems. Industrial and business processes should be carried by a well-designed, converged IT and OT infrastructure. Effective IT and OT interworking, including issues of upgrading from legacy solutions, is a necessary precursor to obtaining transformational effects in combining IT and OT systems and operations beyond simple reporting. The trend is for OT to increasingly use IT-derived technologies and to become integrated with IT environments, although investment cycles for OT are an order of magnitude longer than those for IT.

Any IT/OT integration needs to be driven by the specific industry's best practices especially in regards to security and latency. In addition to a single governance and operational model, enterprises can often realize substantial savings in the acquisition of networking IT components because of traditionally higher cost of OT solutions, as well as in the ongoing capital expenditures associated with the service and maintenance of the equipment.

Benefit Rating: Moderate

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Sample Vendors: ABB; Cisco; Emerson; GE; Hitachi; Honeywell; Huawei; Rockwell Automation; Schneider Electric; Siemens

Recommended Reading: "Emerging Technology Analysis: Time-Sensitive Networking"

"Magic Quadrant for Industrial IoT Platforms"

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"

System Engineering Software

Analysis By: Marc Halpern

Definition: System engineering software enables the design, modeling, simulation, and analysis of assemblages that can include related physical parts, software logic, organizations and processes.

Position and Adoption Speed Justification: The concepts of functional analysis and system modeling have been present for decades. However, the importance of these disciplines has been elevated by:

- The rapid rate of infusing software in physical products
- The importance of system engineering concepts to the creation of digital twins
- The value of system engineering toward the planning and execution of complex projects
- The usefulness of system engineering as a tool for understanding complex organizations and ecosystems

Historically, engineers, business planners and managers used spreadsheets for the majority of system modeling and analysis. During the past five years, specialty vendors and PLM vendors have incorporated system engineering into their product suites to compete with specialist system engineering vendors. Also, larger software vendors have been acquiring smaller specialty system engineering software vendors. All of the companies asked during random checking across manufacturers in industries such as aerospace and defense, automotive, and industrial machinery reported the use of commercial system engineering software today while this was not the case five years ago.

Many functional domains found across a system lead to complexity. Therefore, the software providers, while making progress, do not yet meet the complete set of user needs that would make such capability more intuitive and easier to use. In addition, software vendors and early adopters are on a steep learning curve regarding organizational requirements, new roles, processes and best practices to succeed with enterprisewide system engineering initiatives. Also, manufacturers in industries such as high tech electronics and durable consumer appliances increasingly use system engineering software. As use of system engineering approaches increases, best practices are increasingly being identified and promoted by organizations such as the International Council on Systems Engineering (INCOSE).

User Advice: Large manufacturers of complex engineered products and systems involving operational technology should be investing in this class of software if they haven't already. Industries with the greatest need include consumer electronics, military electronics, aerospace and defense products, transportation vehicles, industrial equipment, and heavy machinery. Ideally, these large manufacturers should use system engineering software with product requirements management software. Beyond products, they should use system engineering approaches to manage facilities, assets, manufacturing operations, organizations, and even natural ecosystems. System engineering is also useful for designing and using digital twins.

Manufacturers with less complex products should audit their performance in requirements management and in the ability to systemically define and design product platforms. Designing a product platform involves using system engineering techniques that can "mix and match" parts and technologies within the platform to create many variants of a product. If they are not satisfied with the results of those audits, manufacturers should invest in system engineering, product portfolio management and product requirements management to buttress their performance at designing their products as systems.

Users in all industries should prioritize the quality of interfaces between requirements management software and system engineering software when choosing among candidate software providers. This integration should provide mapping between the requirements and the specifications that meet those requirements. Additionally, integration of the system engineering software itself should enable users to link critical design parameters from the system models to the technical specifications.

Planners of system engineering programs who use such software should be conscious of differences in the following:

- Hardware development, which is done through sequential project structures
- Development of "onboard" software, which applies agile or Scrum development methods

They must orchestrate the hardware and software development carefully, with great sensitivity to the interconnections between hardware features and evolving software logic.

Planning for change management, including organizational, role, process and practice changes, needs to be part of the initiative.

Business Impact: System engineering has the potential to transform how businesses operate. Successful system engineering programs help businesses create new classes of products, as well as a greater variety of products within a single product family, much more rapidly. They will be able to efficiently convert current engineer-to-order business to more scalable configure-to-order business which delivers products faster. This conversion simplifies the ability to validate customer-specific product configurations.

System engineering is also essential to coping in the emerging age of IoT and digital business. For example, as owners of assets in asset intensive industries invest more in IT/OT convergence, they often need access to engineering content beyond IT and OT to support their decision making on asset maintenance, repairs, and upgrades. In any industry, system engineering adds clarity to any process, organization, or service enabling continual improvements.

Benefit Rating: Transformational

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Sample Vendors: BigLever; Comet Solutions; Dassault Systèmes; ESTECO; Jama Software; MathWorks; Modelon; Phoenix Integration; PTC; Siemens

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

"Survey Analysis: Digital Twins Are Poised for Proliferation"

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

"Manufacturing CIOs Must Advance the I&T Operating Model to Improve Digital Value"

“Five Approaches for Integrating IoT Digital Twins”

“Digital Business Is Transforming New Product Development Priorities”

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”

Entering the Plateau

Operational Technology Platform Convergence

Analysis By: Kristian Steenstrup

Definition: Operational technology (OT) platform convergence occurs because current OT platforms (OT is hardware and software that detects and/or causes a change in the physical device) are increasingly using IT architecture. Typically, this is characterized by OT vendors moving from proprietary platforms to Microsoft, UNIX and Linux operating systems and TCP/IP communications.

Position and Adoption Speed Justification: Over the past 20 years, OT architecture has converged with IT architecture to deliver diverse industrial solutions. This convergence has moved past the Trough of Disillusionment, and convergence is becoming the normal state for such systems. Parallel to this and more recently Industrial IoT has emerged to extend and augment OT which is more easily achieved because of convergence. As a result of cybersecurity failures, managing proprietary and converged platforms is important to staff members responsible for the OT products, to IT staff members, and to the OT vendors themselves.

Platform convergence isn't driven by the end users, but by vendors that update their OT systems over time. Long-lived OT systems are rarely replaced until a plant refurbishment, so full convergence on-site happens over a decade or more. Vendors (such as GE, Schneider Electric, ABB and Siemens) undertake significant investments in their software portfolios and users develop OT solutions on IT architectures

Since first identifying this trend in 2005 most new OT systems use IT architecture and platforms and are therefore converged. Even with the longer life spans than IT software and hardware (the OT system change-out rate is much slower) we have seen this progression over the last 15 years to a point where it is now the norm.

User Advice: Clients in asset-intensive organizations should manage converged OT software more like they manage IT software portfolios than as if they were simply mechanical components, because the converged platforms have more in common with IT systems than their antecedents. Companies should measure the convergence impact using their own contexts:

- First, how much OT exists? For asset-intensive companies with substantial infrastructure, plant and equipment, this is a significant issue, because the automation of heavy equipment, plants and facilities with OT software is growing.
- Second, how much of the installed OT base is new-generation or "converged" OT (that is, based on IT operating systems and networking)?

For some companies with less converged OT or older plant and equipment, immediate change may not be required (depending on the criticality of the OT that is converged). For others with a preponderance of converged OT, governance changes are needed to manage the software life cycle of the OT systems. This is particularly the case with security where OT platforms cannot longer hide behind "security through obscurity." Change management initiatives must be developed to ensure support for IT and OT alignment and integration. This involves both the office of the CIO and an

operations group preparing for change. Even if they are not integrating IT and operations departments, OT leaders should look to established best practices for configuration management of the software. See the separate item on Technology Asset Management (TAM for OT).

Business Impact: The convergence of IT and OT has consequences:

- OT systems are becoming more interoperable, more complex and more accessible to the rest of the technology world because of convergence of platforms, and at the same time this is accelerated because of IoT extending and augmenting OT.
- Users are experiencing more capability and product function as OT vendors leverage the updated architecture.
- Systems can be upgraded more frequently to take advantage of the latest technology developments (such as virtual machines) without compromising safety and reliability, and information can cross traditional IT and OT boundaries more readily.
- As OT systems become more open, they are exposed to new and potentially more damaging cybersecurity threats. As a result, OT software management needs to adapt so that software security, patching, upgrading and disaster recovery are managed with defined tools and processes.

Demand will rise for a consistent enterprise wide approach to the management and oversight of OT products. The organization must plan and manage standards, platforms, architecture, and leverage Technology Asset Management (TAM) and software asset management (SAM), the configuration management database (CMDB), security, patching, upgrades, and disaster recovery. These duties may go to the existing IT departments. Sometimes, companies are creating corporate OT support groups within the existing operations or engineering groups to formalize these responsibilities, manage the software life cycle in a consistent and coherent way, and accommodate the unique requirements that OT environments demand.

IT departments that get involved with OT products face operational impacts as they come to terms with the different vendors and often higher-availability requirements of OT systems. The benefits that come from standardization include more timely and better access to information across the organization, and improved efficiencies.

Benefit Rating: High

Market Penetration: More than 50% of target audience

Maturity: Mature mainstream

Sample Vendors: ABB; GE; Honeywell; Rockwell Automation; Schneider Electric; Siemens

Recommended Reading: “The Importance of OT Integration for Industrie 4.0”

“Magic Quadrant for Industrial IoT Platforms”

“2020 Strategic Roadmap for IT/OT Alignment”

“OT Security Best Practices”

“Competitive Landscape: Operational Technology Security”

Smart Lighting

Analysis By: Nick Jones

Definition: Gartner defines smart lighting as a lighting system that is connected to a network and can be monitored and controlled from a centralized system or via the cloud. Advanced smart lighting systems include controls, connectivity, analytics and intelligence. They usually exploit LED technology for energy efficiency.

Position and Adoption Speed Justification: Smart lighting is being rapidly adopted. It is driven by energy savings, which can approach 70%, compared with conventional lighting. Application areas include offices, homes, industrial plants and city street lighting. Lighting may be controlled and connected in several ways, including Power over Ethernet (PoE), and wireless or wired networks. Advanced smart lighting systems integrate with building management systems to optimize illumination and energy consumption using a combination of light management and building controls, such as sun blinds. Modern smart lighting systems that support programmable color can provide features, such as circadian lighting, where subtle color variations are claimed to improve worker well-being.

The sensors used by smart lighting systems can also support other applications, such workspace optimization. Vendors are exploiting opportunities to integrate other features, such as Li-Fi, location tracking, occupancy counting and Bluetooth beacons, into light fittings. Basic smart lighting for energy-saving purposes will advance rapidly through the Hype Cycle, because it’s a well-developed technology, although advanced features (e.g., circadian lighting and workspace optimization) will develop more slowly.

User Advice: In indoor situations, CEOs, CFOs, facilities managers and CIOs should explore opportunities for smart lighting to save money and provide safer and more effective working conditions. Buyers should look for opportunities to integrate smart lighting with building management and integrated workplace management systems to achieve additional benefits. Organizations responsible for retrofitting smart lighting into existing buildings or streets that wish to minimize capital expenditure (capex) should explore lighting-as-a-service models. In such cases, contractors replace and operate lighting hardware, which is funded by a long-term subscription or a percentage of electricity savings.

City planners should explore smart street lighting to save energy and to improve citizen safety and quality of life using contextual dynamic controls. Smart street lighting systems can also provide the physical and networking infrastructure to support other smart city sensors and initiatives.

Sophisticated smart light fittings may include additional features, such as Bluetooth beacons, which can help support initiatives including indoor navigation when used in conjunction with a mobile app. Users should be cautious before adopting smart lighting with integrated data transmission technologies, such as Li-Fi, which we expect to achieve limited market traction through 2023.

Organizations should also explore how analytics can be applied to the data generated by smart lighting systems — e.g., to better understand and optimize office space usage or pedestrian/traffic behavior in streets.

Business Impact: The benefits of smart lighting include energy savings, improved working conditions, better space utilization and reduced operating expenditure (opex).

Smart lighting can save more than 70% of the lighting energy bill, compared with incandescent lighting. Secondary benefits include improved productivity from superior or safer working conditions, cost savings from optimizing office space utilization and improved levels of citizen services. However, we do not expect Li-Fi integrated with smart lighting to be widely adopted, because the business value is limited.

Indoor and outdoor smart lighting also provides operational savings in areas such as inspection and maintenance — e.g., because smart lights can test themselves so emergency lighting doesn't need expensive regular manual inspections. In specific situations, such as street lighting, there may be additional benefits. These include the ability to increase illumination in the event of incidents to aid first responders, and savings from reducing the cost of secondary functions, such as cleaning lights. (Small increases in illumination are less expensive than manual cleaning.)

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Early mainstream

Sample Vendors: Acuity Brands; American Industrial Partners (Current); Digital Lumens; Enlighted; OSRAM; Panasonic; Signify; Telensa; Tridonic

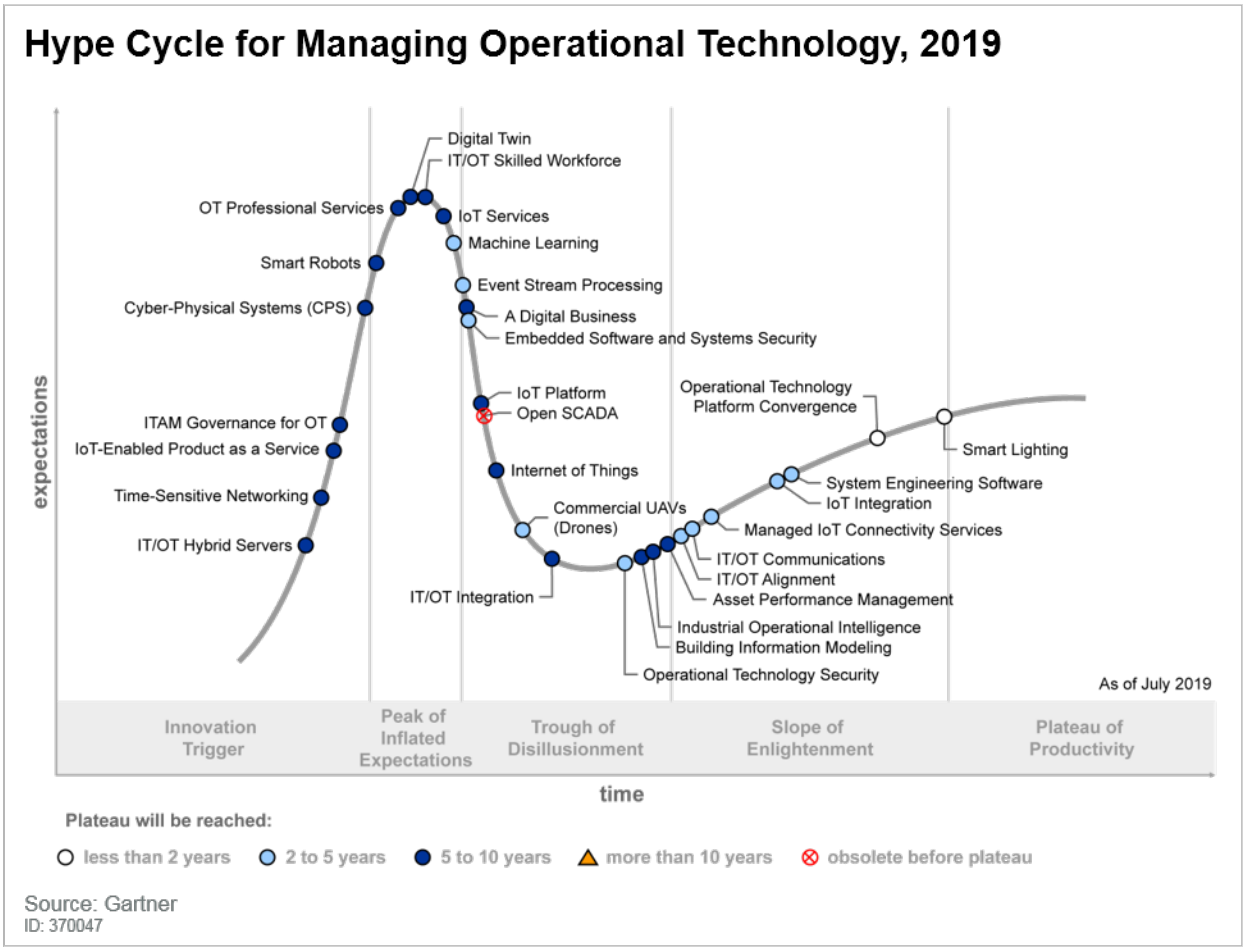
Recommended Reading: "Evolve Your Smart Building Solutions in the IoT Area"

"Turning Smart Cities Into Intelligent Urban Ecosystems"

"Emerging Technology Analysis: Approach Li-Fi With Caution Because Adoption Will Be Slow"

Appendixes

Figure 3. Hype Cycle for Managing Operational Technology, 2019



Source: Gartner
ID: 370047

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.
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 (August 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 (August 2020)

Table 3. Maturity Levels

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-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 (August 2020)

Gartner Recommended Reading

Some documents may not be available as part of your current Gartner subscription.

Understanding Gartner's Hype Cycles

2020 Strategic Roadmap for IT/OT Alignment

Guide Contract Management With the EaaS Customer Bill of Rights

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

OT Security Best Practices

As IT and OT Converge, IT and Engineers Should Learn From Each Other

Magic Quadrant for Industrial IoT Platforms

Time-Sensitive Networking Will Fuse IT and OT Network Connectivity

The Importance of OT Integration for Industrie 4.0

GARTNER HEADQUARTERS

Corporate Headquarters
56 Top Gallant Road
Stamford, CT 06902-7700
USA
+1 203 964 0096

Regional Headquarters
AUSTRALIA
BRAZIL
JAPAN
UNITED KINGDOM

For a complete list of worldwide locations,
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