Hype Cycle for Manufacturing Digital Transformation and Innovation, 2021

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Initiatives: Manufacturing Digital Transformation and Innovation; Manufacturing IT Optimization and Modernization

This Hype Cycle reveals opportunities for CIOs to gain business advantages through concepts and technologies that require significant changes to processes, IT infrastructure and decision making. Besides adding value to manufacturing businesses, they increase windows of competitive advantage.

Strategic Planning Assumptions

- By 2025, manufacturers will lower operational costs by 10% by combining hyperautomation technologies enabled by artificial intelligence (AI) and new operational processes.
- By 2025, at least 40% of manufacturers will increase workforce productivity and customer reach, and enhance customer experience, by adding virtual experiences to business activities.

Analysis

What You Need to Know

Manufacturing industries are being transformed by new business models and strategic technologies that fit within Industrie 4.0. Manufacturers can capitalize on advancements made in AI, visualization, simulation and greater connectivity across enterprises.

The CIO is essential to enabling the advances. This Hype Cycle helps CIOs understand the business benefits and current maturity of these opportunities (see Executive Essentials: Evolve Your Role as CIO). CIOs, other IT leaders and business leaders such as those responsible for new product development, manufacturing operations and product service should discuss these opportunities and use this Hype Cycle to define an innovation and transformation roadmap.

The Hype Cycle

This Hype Cycle includes innovations that advance manufacturers' activities from product design through product service life. The value goes beyond the physical product and physical assets of the business, which combine with technology that makes customer experiences, manufacturing and service more intuitive. For example, AI is automating more design. Manufacturing is becoming more autonomous. Products and equipment can inform customers when they need service and repair. The products report back to manufacturers about customer usage patterns and experiences. CIOs and other IT leaders interested in enabling these capabilities should adopt an innovation framework (see Jump-Start Your Innovation Journey With a Customizable Innovation Framework).

In contrast to this Hype Cycle, the companion Hype Cycle for Manufacturing Digital Optimization and Modernization, 2021 focuses on adopting IT advances to modernize, integrate and streamline established capabilities.

Technologies and innovation profiles are clustered around the Peak of Inflated Expectation and Trough of Disillusionment. The technologies clustered near the Peak of Inflated Expectation include:

- AI in material informatics
- Cyber-physical systems
- Generative design
- Machine learning
- Prescriptive analytics

They largely depend on advances and experience in AI to succeed. By 2025, manufacturers will lower operational costs by 10% by combining hyperautomation technologies enabled by AI and redesigned operational processes.

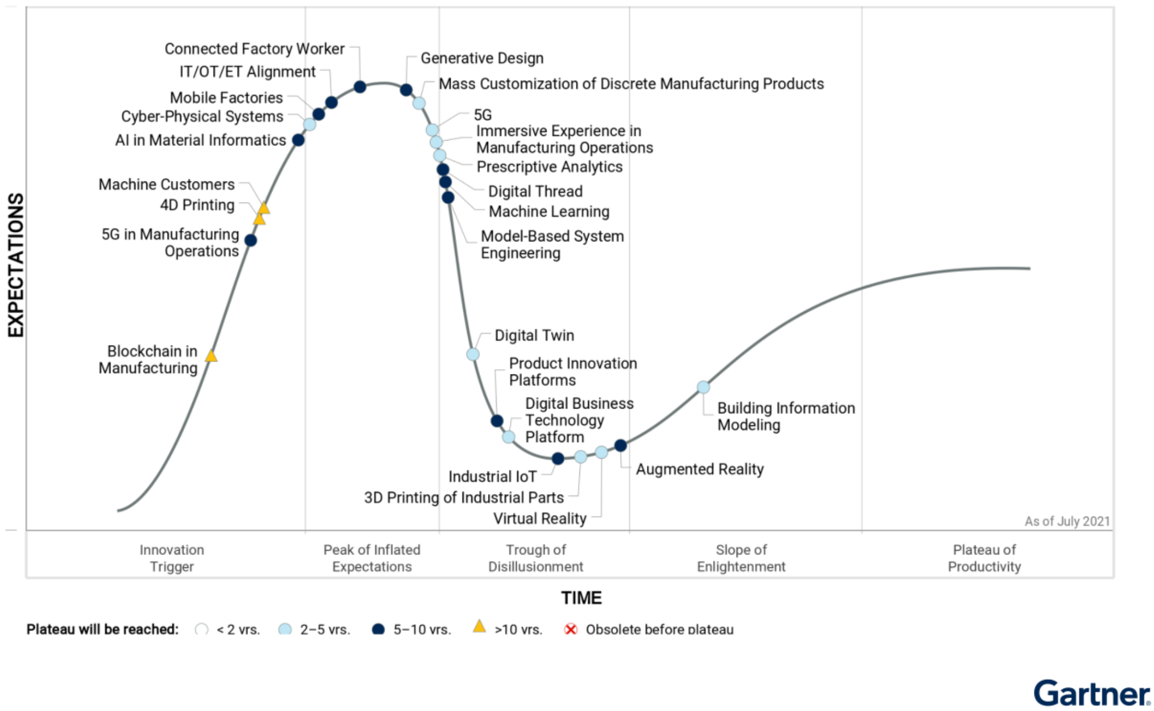
The technologies clustered near the Trough of Disillusionment include:

- Augmented reality (AR)
- Virtual reality (VR)
- Product innovation platforms

They require convergence of multiple technologies. Visualization, simulation, analytics, data management and IT connectivity via cloud can deliver long-term value by blending virtual and physical experiences. Although the technologies are used broadly, their orchestration delivers value well beyond their individual value. However, the technical complexities and the learning curve to use them effectively within an Industrie 4.0 approach make the Slope of Enlightenment more difficult to climb.

As manufacturers become more proficient at model-based system engineering (MBSE) and alignment of IT, operational technology (OT) and engineering technology (ET), implementation will become more efficient. By 2025, 40% of manufacturers will increase workforce productivity, customer reach and customer experience by blending virtual and physical experiences.

Figure 1: Hype Cycle for Manufacturing Digital Transformation and Innovation, 2021



Source: Gartner

Downloadable Graphic: Hype Cycle for Manufacturing Digital Transformation and Innovation, 2021

The Priority Matrix

The Priority Matrix summarizes business impact versus maturity for opportunities on the Hype Cycle. The opportunities closest to the upper-left corner of the matrix have the highest urgency. This Priority Matrix indicates that cyber-physical systems, digital business technology platforms, digital twins and mass customization of discrete manufacturing products have the highest priority.

Cyber-physical systems use sensors, robotics, cloud services, analytics, machine learning, and secure, high-speed networks to deliver products and orchestrate data and processes in real time — automating manufacturing operations. New-generation products can also be cyber-physical systems.

Digital business technology platforms and digital optimization are necessary for manufacturers in all industries that want to improve their engagement with customers and other assets that are increasingly connected. Manufacturers need these platforms to transform their businesses to manufacturing as a service.

Digital twins are virtual representations of entities such as assets, processes, organizations and people. Manufacturers are investing in digital twins today primarily to monitor and maintain manufacturing operations, factories and assets within factories. However, digital twins have great potential to enhance consumer products.

CIOs should work with business leaders to implement carefully selected pilot programs for these initiatives and scale them up as they gain more experience with them.

Table 1: Priority Matrix for Manufacturing Digital Transformation and Innovation, 2021

(Enlarged table in Appendix)

Benefit	Years to Mainstream Adoption			
	Less Than 2 Years	2 - 5 Years	5 - 10 Years	More Than 10 Years
Transformational		Cyber-Physical Systems Digital Business Technology Platform Digital Twin Mass Customization of Discrete Manufacturing Products	5G in Manufacturing Operations Connected Factory Worker Generative Design Mobile Factories Model-Based System Engineering	4D Printing
High		5G Building Information Modeling Immersive Experience in Manufacturing Operations Prescriptive Analytics	Augmented Reality Digital Thread Industrial IoT IT/OT/ET Alignment Machine Learning Product Innovation Platforms	Blockchain in Manufacturing Machine Customers
Moderate		3D Printing of Industrial Parts Virtual Reality	AI in Material Informatics	
Low				

Source: Gartner (July 2021)

Off the Hype Cycle

- Smart dust — We decided that it does not fit the scope of this Hype Cycle.
- Smart assets — Subsumed as cyber-physical systems.
- Things as customers — Now represented as machine customers.
- Digital experience platforms — The category is too broad for a manufacturing-specific Hype Cycle.
- IP protection in 3D printing — Too niche to 3D printing. Subcategory of 3D printing of industrial parts.
- Connected home — Not sufficiently specific to manufacturers' business needs.
- Industrial operations intelligence — This functionality is core to most manufacturing operations applications today. Therefore, this independent Innovation Profile is discontinued.
- Connected car platforms — Not sufficiently specific to manufacturers' business needs.
- Digital optimization — The category is too broad for a manufacturing-specific Hype Cycle.

On the Rise

Blockchain in Manufacturing

Analysis By: Sohard Aggarwal

Benefit Rating: High

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Definition

Blockchain consists of cryptographically signed, irrevocable transactional records shared by all participants in a network. Each record contains a time stamp and reference links to previous transactions. Anyone with access rights can trace back any transactional event, at any point in its history, belonging to any participant.

Why This Is Important

Blockchain technologies are still emerging and are not ready for widespread use in manufacturing. Proofs of concept are currently running in the areas of:

- Track and trace in supply chain (auditability of counterfeit parts and goods)
- Managing smart contracts
- Payment or trade finance
- Improvement of warranty management
- Maintenance records and worker certification

Business Impact

- Blockchain guarantees the provenance and authenticity of products by simplifying traceability in ingredients, parts, components, labeling, formulas and finished goods.
- Blockchain brings additional order and the right balance of transparency, security and process discipline to the ecosystem.
- Data encryption can support in securely automating workflows, such as handling of contracts, payments and warranties, and can protect customer information during these exchanges.

Drivers

- **Demand for transparency across value chain —** Consumers are increasingly moving toward brands that provide transparency in their sourcing, manufacturing practices and environmental impact. Deploying blockchain-based tracking mechanism increases consumer trust, while manufacturers can use it as a key differentiation factor.

- **Adoption of Internet of Things (IoT) and digital twins —** As manufacturers increasingly deploy IoT-based sensors and digital twins in the value chain, they generate valuable data across the product life cycle. IoT and blockchain configuration can be leveraged to track origin and physical movement, while digital twins can monitor things and related events, generating new revenue opportunities, cutting costs, and improving trust among participants and customers.

- **Automating and managing complex relationships —** Blockchain-enabled smart contracts create a mechanism for transparency, visibility and consistency. Manufacturers can improve efficiencies by automating adjudication of preapproved contract terms. A smart contract is a computer program or protocol that facilitates, verifies or executes the terms of a contract.

- **Building trust and confidence —** Manufacturers can leverage what has essentially become digital product/brand benefits that can provide value in the form of additional customer/buyer confidence. Adoption in the value chain can simplify regulatory data capture and independent sharing of data to users, increasing trust and confidence.

- **Protection and management of digital and IP rights —** In the past 20 years, manufacturers have increasingly invested resources to offset counterfeit products, which directly impact brand value and revenues due to lost sales and inability to maintain prices throughout the product life cycle. Adoption of blockchain can help manufacturers with identifying counterfeits and protecting the brand.

See more in The Real Business of Blockchain: How Leaders Can Create Value in a New Digital Age.

Obstacles

- Manufacturers share and manage sensitive data from suppliers and customers. Moving over authority from a centrally controlled institution to multiparty consortia can be deeply unsettling, even for organizations that have undergone significant digital transformation.

- The underlying platform required for scalability must evolve to become more efficient, while preserving transaction security and data confidentiality.
- Integration with legacy applications and platforms in manufacturing will be difficult due to complexity and lack of blockchain maturity.

User Recommendations

- Prepare for the blockchain by continuing to tighten up on standards and requirements as they relate to product sourcing, manufacturing, assembly, distribution, storage and payment.
- Participate in standards boards (where appropriate) to ensure that you are in alignment with the rest of the industry, your suppliers and your customers, in case you are asked or required to participate in a blockchain.
- Identify the unique points of value and risk in your value chain, engage cross-functionally within your organization, and map these points to known industry pilots to assist in building the business case.
- Assess the value and impact by identifying the key cost drivers and the integration of other technologies like IoT sensors, advanced analytics and AI needed to deploy alongside the blockchain technology.
- Leverage blockchain to securely manage and distribute data, use and properly account for product design, and protect intellectual property rights and product specifications.

Sample Vendors

Chronicled; Everledger; Hyperledger; Loyyal; Provenance

Gartner Recommended Reading

Blockchain Basics for ERM

Emerging Technologies: Implementing Blockchain Smart Contracts in a Business Process

Emerging Technology Analysis: Protecting Consumer Brands With Blockchain

Garbage In, Garbage Forever: Top 5 Blockchain Security Threats

5G in Manufacturing Operations

Analysis By: Andrew Stevens

Benefit Rating: Transformational

Market Penetration: 5% to 20% of target audience

Maturity: Embryonic

Definition

5G data services for manufacturing operations are tailored, next-generation mobile broadband and cellular data services. Future 5G data services supporting manufacturing will not rip and replace existing service models from IT. Future services will supplement, augment and gradually phase in alongside existing data and communications services (such as Wi-Fi, 3G and 4G) delivered in areas such as machines, application interfaces, functional operations dashboards or personal mobile devices.

Why This Is Important

5G can significantly mobilize data speed and capacity as well as enhance business functionality. With manufacturing environments already heavily burdened with applications needing to process vast amounts of data, new generations of 5G data communications services in conjunction with edge and distributed computing ecosystems could enable new digital factories and enhanced new services anticipated for both personal users and also enterprises.

Business Impact

5G for manufacturing operations is in the very early phases of evolution and this is reflected in its early positioning in this year's Hype Cycle at the Innovation Trigger. The speed of communication services providers (CSPs) and/or specialist service providers to provide enterprise data services will be dependent on their prioritization and allocation of resources for managing both private/campus 5G networks and larger-scale mobile networks.

Drivers

- For the first time, 5G introduces a new spectrum of data-centric technology applications for manufacturing and supply chain use cases such as network slicing, edge computing with embedded analytics, low-latency and mixed reality (MR) spectrum applications. Evolving use cases will likely strongly leverage these new enablers alongside ranges of technologies such as IoT and edge analytics, either singular or more likely in combination/sequence.

- Accelerated identification of viable use cases for deploying 5G data services in manufacturing operations will be dependent on objective evaluation of 5G's ability to empower and augment existing data services provision across legacy, current and planned technology applications.

- Early pilots for emerging 5G in manufacturing operations have been observed in sectors such as automotive, industrial engineering and aerospace. Initial momentum has been especially targeted to initiatives and objectives across the following areas of operations including smart factory and Industry 4.0, digitalization and data mobility, advanced automation networks, and predictive maintenance.

- Recent pandemic events have elevated the need for manufacturing operations to consider options for more remote, untethered or virtualized operations. 5G is well-positioned to drive viable manufacturing planning for a new era of remote working and operations through reliability and integrity of data feeds. This could support improvements to worker safety or productivity, remote onboarding, training or certifications, or to help augment traditional operations tools for enhanced process optimization and continuous monitoring of quality and yield. For example, a migration to virtualized operations and transactions and new opportunities for e-learning through connected headsets or smartglasses could be enabled through 5G powered MR, augmented reality (AR), virtual reality (VR) applications.

Obstacles

- Manufacturing operations leaders will need to familiarize quickly (but not become out-and-out experts) on many of the new technical concepts and modeling tools presented through 5G; e.g., spectrum, latency, MR/extended reality (XR) and network slicing.
- Careful organizational resources assignment of new roles and technical responsibilities for collaboration in delivering, communicating and embedding 5G will be critical for successful early use-case adoption.
- Digital and cybersecurity must be rigorously co-assessed as part of all 5G engagements especially in its ability to push data out the edges of the enterprise and for it to shape and influence digitized workspaces.

User Recommendations

- Position 5G as a strategic data enabler and opportunity to reassess planned technology infrastructure by ensuring formalized communications and change management processes are phased in parallel in areas including immersive experience, AI, analytics and specialized IoT applications.
- Work closely with IT colleagues to map early use-case pilots and service propositions paying special attention to the correct frequency spectrum allocations needed. For example it is high-frequency millimeter wave (mmWave) that will likely support new 5G applications, especially across critical processing streams systems that encounter heavy data traffic and require very low-latency responsiveness and agility low- to mid-frequency spectrums.

Sample Vendors

China Telecom; Ericsson; Huawei; Nokia; Orange; Telefonica

Gartner Recommended Reading

5G as a Service: Deployment Scenarios of Private Networks in the 5G Era

Ask These Four Questions About Enterprise 5G

Market Trends: 5G Opportunities in IoT for Communications Service ProvidersMarket Trends: 5G in Manufacturing

The 2020 Top Strategic Technology Trends for Manufacturing Operations

4D Printing

Analysis By: Michael Shanler, Miriam Burt

Benefit Rating: Transformational

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Definition

Four-dimensional printing (4DP) is a technique whereby the materials are encoded with a dynamic capability — either function, confirmation or properties — that can change via the application of chemicals, electronics, particulates or nanomaterials. The printing technology includes added functionality to sequence, mix and place specific materials that will have a calculated effect.

Why This Is Important

- 4DP is an emerging technology in the embryonic stage. This technology adds another dimension to the 3D printing (3DP) process by creating an object designed to change shape after it leaves the print bed.
- The concept of this “shape shifting” technology is being developed through collaborative efforts between academia and technology firms.
- This technology will drive next generation materials and innovations.

Business Impact

- 4DP will have significant impacts on design. While smart materials, which represent the “fourth dimension” for materials, have actually been around for several decades, usage of 3DP technology to drive 4DP is a rather new development and has a lot of interest from R&D teams.
- 4DP makes it possible to create technology-based products that could disrupt the life science industry.

Drivers

This technology is still in the Trigger phase, but is quickly rising up the Peak of Inflated Expectations:

- Recent scientific advancements in biology, chemistry, electronics and 3DP will accelerate the discipline.
- Over the next few years, 4DP research will generate interest and hype, especially as traditional 3DP technologies, which operate as a platform for 4DP, become widely adopted.
- Shape-shifting materials have already been leveraged in the automotive, aerospace, defense and medical industries. Dynamic and self-assembling materials have already begun to disrupt the way engineers think. These possibilities are all innovation drivers that will accelerate this technology.

R&D teams are seeing advances in material science and are looking to include new technologies to innovate product designs and functions:

- Shape-shifted materials that can reduce the drag coefficient of an airplane or vehicle during different environments might help optimize efficiency.
- The sole of an adaptive running shoe can adjust to wet versus dry pavements and improve grip.
- A self-assembling medical stent can reduce surgery times and improve patient outcomes.
- Implants can change shape once they come into contact with body heat to conform with wound areas and lead to better surgical outcomes.
- A dynamic valve in an irrigation system can improve irrigation on a farm. A roof on a house could change form to facilitate draining, and walls could increase or decrease in thickness during the winter or summer to improve insulation values.

Obstacles

- Material science research for 3DP is still an underserved market. Software is still at a niche stage for programmable materials with self-assembly characteristics. Modeling the geometries, determining interactions for changing states and calculating the energy (such as those from heat, shaking, pneumatics, gravity and magnetics) is no easy task.
- There are an immense number of scientific and formulation-based patents that may impact business cases for new materials, applications, and scientific and engineering areas.

User Recommendations

- Improve 4DP processes through R&D partnerships with material companies to develop and enhance specifications for 4D-suitable materials.
- Determine how 4DP can drive product innovation with engineering and product teams. Ask those teams about requirements for infrastructure, data and informatics.
- Evaluate, with business leads, the best approach for bringing in the technology. Do quick scenario planning with a focus on skills, technology, governance and data to play out "build, buy or rent" scenarios.
- Investigate partnerships as the primary method for getting into the game with either current 3DP vendors or academics with materials expertise and capabilities.

Sample Vendors

Autodesk; Geosyntec Consultants; HP; MIT; Stratasys

Gartner Recommended Reading

The Manufacturing CIO's Role in Adopting and Scaling 3D Printing

Innovate Faster With Digital Twins and 3D Printing

Machine Customers

Analysis By: Don Scheibenreif, Mark Raskino

Benefit Rating: High

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Definition

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

Why This Is Important

Today there are more internet-connected machines with the potential to act as customers than humans on the planet. We expect the number of machines and pervasive artificial intelligence (AI), like virtual personal assistants, with this capability to rise steadily over time. They are increasingly gaining the capacity to buy, sell and request service. Machine customers will advance beyond the role of simple informers to advisors and, ultimately, decision makers.

Business Impact

Over time, trillions of dollars will be in the control of nonhuman customers. This will result in new opportunities for revenue, efficiencies and managing customer relationships. Digital-savvy business leaders seeking new growth horizons will need to reimagine both their operating models and business models to take advantage of this ultimate emerging market, whose numbers will dwarf the number of human customers on (and one day perhaps off) the planet.

Drivers

- According to Gartner research, both CEOs and CIOs agree on the potential of this emerging trend. Seventy six percent of CIOs and 61% of CEOs we surveyed in 2019 believe demand from machine customers will become significant in their industry by 2030. On average, these leaders believe at least 21% of their revenue will come from machine customers by 2030.
- Today, most machines simply inform or make simple recommendations. We do see some examples of machines as more complex customers emerging, such as smart grid technologies. HP Inc. embraced this future when it created Instant Ink — a service that already enables connected printers to automatically order their own ink when supplies run low. Some Tesla cars already order their own spare parts, and Walmart has patented grocery auto reordering based on home Internet of Things (IoT) sensing.
- In B2B, U.S.-based industrial supply company Fastenal uses smart vending machines that proactively place orders when stocks run low. Thinking forward, an autonomous vehicle could determine what parking garage to take its human passengers to based on criteria such as distance from destination, price, online review score, parking space dimensions, valet options, etc. In this case, it is the parking garage marketing to the car, not the humans.
- The rise of machine customers begs some important questions. These include: (1) How do you market to, sell, service and obtain feedback from a machine customer?; (2) What will get a machine customer to buy from you when its decisions are based on algorithms, not emotion?; (3) What does “customer experience” even mean for a machine customer?
- Machine customers have the potential to generate new revenue opportunities, increase productivity and efficiency, improve health/well-being and enhance security of physical assets and people. They will also result in new sources of competition, fraud, legal and taxation challenges, and operational challenges.

Obstacles

- **Trust —** Can the human customer trust the technology to accurately predict and execute? Conversely, can the machine customer trust the organization that offers the service? The complexity involved in developing a machine customer that can learn the depth and breadth of knowledge and preference trade-offs required to act on behalf of a human customer in a variety of situations is staggering.

- **Fear —** Some humans may initially be uneasy about delegating purchasing functions to machines. And, organizations will have to consider what ethical standards, legal issues and risk mitigation are needed to operate in a world of machines as customers.

- **Technology that works —** Other barriers include: complex AI technologies, privacy, security and risk, regulatory compliance issues and data sharing.

- All this will mean that machine customers across industries will not reach the Plateau of Productivity for at least five to 10 years.

User Recommendations

- Create scenarios to explore the market opportunities. Initiate collaboration with your chief digital officer, chief data officer, chief strategy officer, sales leaders, chief customer officers and others to explore the business potential of machines as your customers.

- Identify specific use cases where your products and services can be extended to machine customers; and pilot those ideas to understand the technologies, processes and skills required.

- Build your organization’s capabilities around digital commerce and AI over the next five years. First in machine learning, then extending to other facets involved in machine customers processing information, making informed decisions, and performing purchase transactions. Or, join other platforms that already have those capabilities if you don’t have the resources to build them yourself.

- Follow examples from organizations like Tesla, Google, Amazon and HP to look for evidence of capabilities and business model impact.

Sample Vendors

Amazon; Google; HP; John Deere; Tesla

Gartner Recommended Reading

Machine Customers: The Next Massive Emerging Market

How Customer Experience Changes When Your Customer Is a Thing

Why Machine Customers May Be Better Than Human Customers

Meet Your Machine Customers: 10 Machines That Will Drive Business Growth in the 2020s

IoT-Based Thing Commerce Requires a Differentiated Customer Experience

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

AI in Material Informatics

Analysis By: Michael Shanler

Benefit Rating: Moderate

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Definition

AI-enabled material informatics solutions are software and services that apply advanced learning techniques to materials-related big data for better predicting results by the characteristics of each material. Typically, life sciences organizations apply the resulting insights to the use, selection, discovery and development of materials in downstream engineering, and product development and manufacturing.

Why This Is Important

- This technology enables organizations to move beyond loosely packaged materials databases with light search functionality.
- Clients are looking to simplify either customized, proprietary in-house systems; outsourced work with CROs that perform material science; or modify their own drug-discovery-oriented cheminformatics applications or electronic laboratory notebooks (ELNs). Machine learning and advanced analytics for these approaches are on the rise.

Business Impact

- Making investments in advanced materials informatics reduces the amount of time it takes to drive materials through in silico design processes.
- The technology can drive candidates for new materials that were previously undiscoverable using existing methodologies.
- The technology can be applied to streamline recipe formulation as well as modeling reductions for toxicity and carcinogenicity.

Drivers

- As investments in materials engineering and science increase, and software engineers begin to embrace data science and machine learning capabilities, the footprint of AI-enabled material informatics solutions will expand and become more prominent.
- The desired capability is now part of strategic plans at many small and large enterprises including medical devices, diagnostics equipment manufacturers, food and beverage, oil and gas, materials, chemicals, crop science, battery, electronics manufacturers, automotive, and aerospace and defense.
- Many organizations are looking to replace their current “standard” approach and move to newer and more advanced solutions. They want to better leverage the output and data streams from these solutions for downstream engineering software, such as CAD, CAE and PLM.
- Process integration will further fuel innovations and inspire new startups to bring more capabilities to market. We also expect established engineering software companies to look toward these smaller materials and informatics companies as potential acquisition targets, or areas where they build their own capabilities. This trend will continue because the synergies between materials informatics and R&D engineering enable a broader perspective on the overall product life cycle.
- This technology is rapidly climbing the Innovation Trigger phase on the Hype Cycle because today, most manufacturers with R&D programs are starting to explore these and other AI-related solutions in the domain of materials development.

Obstacles

- Many clients report that building out an AI strategy requires data that is configured to be machine-learning-readable, yet many organizations have not performed the data refinement needed.
- Clients often report that their own internal R&D datasets lack standards, governance and data principles.
- Most clients are still operating without a platform strategy to manage and govern scientific, laboratory, and formulation data, which is required to power and train the algorithms with proper datasets.
- CIOs report that they have multiple competing internal AI-platforms, analytics software packages and custom-made software that is difficult to keep validated.
- Developing an AI-enabled materials strategy means addressing data and infrastructure fundamentals (such as data management, platform requirements, data resolution) while engaging shadow IT in the lab, which is often challenging to influence.

User Recommendations

- Collaborate with R&D and manufacturing business leads for understanding which capabilities need to be augmented in the life cycle roadmap. While advanced analytics applications represent a new space, the R&D staff required to operate these systems must be more scientifically oriented.
- Assess targeted pilots as it will take five to 10 years before these systems are fully simplified to mesh seamlessly into broad product development processes.
- Map the value of these systems to arrange data, especially if the system will “learn” based on existing datasets. Ensure stakeholders understand the fidelity and resolution of vendor-provided or public datasets.
- Align the materials informatics strategy to the product life cycle strategy before extending the application to the rest of the R&D enterprise. Most new instances of AI-enabled materials informatics will be targeted toward specific R&D functional areas and disciplines.

Sample Vendors

Ansatz AI; Citrine Informatics; DataRobot (Nutonian); Enterra Solutions; Exabyte.io; MatSci AI; Tilde Materials Informatics; Turing; Uncountable

Gartner Recommended Reading

A Framework for Applying AI in the Enterprise

Innovation Insight for AI-Augmented Development

Magic Quadrant for Data Science and Machine Learning Platforms

Successfully Implementing AI in Department of Defense and Military Supply Chains

At the Peak

Cyber-Physical Systems

Analysis By: Katell Thielemann

Benefit Rating: Transformational

Market Penetration: 20% to 50% of target audience

Maturity: Adolescent

Definition

Cyber-physical systems (CPS) are engineered systems that orchestrate sensing, computation, control, networking and analytics to interact with the physical world (including humans).

Why This Is Important

Already being deployed in smart grids, smart buildings or autonomous vehicles, CPS are also core to smart manufacturing, as well as technology deployments under the OT, IIoT and IoT umbrellas. They represent the confluence of physical and virtual systems to connect people, products, data and processes. Deployments can use sensors, robotics, cloud services, analytics, machine learning and secure, high-speed networks to orchestrate data and processes in real time.

Business Impact

Whether in transportation, smart building or healthcare, cyber-physical systems change dynamics by orchestrating data flows between previously disconnected systems, automating unstructured processes, shortening cycle times, and improving product and service quality. In industrial environments, CPS are replacing stand-alone production process control and automation, materials handling systems and transactional workflow systems to promote real-time information gathering and processing.

Drivers

- Customer or citizen demand for more, faster, cheaper and better products/services
- New digital business models
- Productivity and maintenance improvements
- Labor cost reduction made possible by CPS

- CPS-enabled operational excellence and enhanced operational data gathering
- Improved situational awareness in operations or mission-critical environments
- Need to keep up with competitive landscape

Obstacles

- Since CPS connect both cyber and physical worlds, security is particularly critical in production and operational-centric industries. As the risk lens expands to the physical plane, beyond cybersecurity, concerns over physical perimeter breaches, jamming, hacking, spoofing, tampering, command intrusion or malware implanted in physical assets need to be addressed.
- Several deployment-related obstacles also exist. These include complex architectural requirements and design approaches from many disciplines involved; sense and control loops that must be designed to evolve with business needs; need for significant computational resources; and a variety of sensory input/output devices.
- Business goals need to be determined for CPS deployment, including data analytics expectations.
- Interoperability with legacy systems is lacking.
- As CPS are usually highly automated, new skills are needed for operating and maintaining.

User Recommendations

- Determine the business value of CPS deployment by weighing benefits against cost, complexity and security.
- Promote the use of standards and interoperability recommendations to manage complexity, enable scalability and extensibility, and to ensure focus on security and safety imperatives.
- Make sure that any deployment is negotiated with CPS OEMs to ensure upgrades can be easily incorporated, as emerging technologies such as cloud computing and 5G will greatly impact these systems.

Sample Vendors

ABB; Honeywell; Rockwell Automation; Schneider Electric; Siemens; Yokogawa

Gartner Recommended Reading

How Cyber-Physical Systems Impact Organizational Risks

Facing New Threats — Cyber-Physical Systems

Facing New Vulnerabilities — Cyber-Physical Systems

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

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

Mobile Factories

Analysis By: Simon Jacobson, Kamala Raman

Benefit Rating: Transformational

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Definition

Mobile factories are self-contained production units constructed of ready-for-use modules that can be deployed into markets and assembled at a fraction of the traditional time, cost and risk of conventional capacity.

Why This Is Important

Operational resilience is essential even as cost efficiency continues to pressure organizations. Mobile factories are a unique way to develop flexible, fit-for-purpose capacity at less than 50% of traditional costs. Early adopters that have operationalized this strategy often aim to explore demand in uncertain new markets with the intent to scale up should the market be profitable. Mobile factories require emphasis on long-term planning, network design, procurement, logistics and segmentation.

Business Impact

Manufacturers seeking to test new market opportunities or simply offer new products and services in their current markets should explore mobile factories. This is an innovative approach to leveraging technology and creating resiliency in the network with simplified production setups and significantly lower capital investment, scale-up cost, risk to competitiveness, flexibility or compliance. Standard parts, design and build can lead to high operational efficacy even in developing markets.

Drivers

- The need to test demand uptake in new and often small markets
- Regionalization and reshoring/nearshoring of manufacturing networks and activities (e.g., final assembly/packaging/finishing)
- Cost objectives that limit installation of conventional capacity in untested markets
- Enhanced focus on localization and penetration of new markets with as little risk as possible
- Surging interest in smart factories and preconfigured solutions and reliable capacity that utilize combinations of new manufacturing techniques and automated systems
- Leverage of competitive zeal and innovation prowess for deploying highly flexible, simple and cost-effective production capacities at a fraction of capex

Obstacles

- Supply chain as a service (SCaaS), varied external manufacturing options or asset light models might be more viable options to lower costs and risk in certain geographies and industries.
- Organizational DNA that doesn't promote risk and innovation.
- Misaligned capital planning processes/collaboration across product supply, manufacturing and engineering.
- Growing product volumes and mixes stretch the limits of fit-for-purpose capacity.

User Recommendations

- Define objectives for the role of modular factories in the factory network. Make cost efficiency and speed to market — as opposed to manufacturing efficiency metrics — your barometer of success.
- Limit scale-up costs by collaborating with machine builders and developing standard configurations for accelerated ramp-up and cost-effective ongoing maintenance.
- Ensure feasibility by rigorously investigating local infrastructure (e.g., energy reliability and supplier proximity), tax laws, government subsidies and talent availability. Even though processes are simplified, people are still needed.
- Embed mobile factories as one kind of capacity orientation within a broader smart factory strategy.
- Develop a transfer or wind down strategy using global orchestration and local execution. Not all mobile factory deployments will be successful. This requires firm time frames on when to see results by running cost models to evaluate total costs to serve against commercial price points.

Gartner Recommended Reading

Evaluate These Factors in a Global Manufacturing Site Selection Activity

Reshaping Global Supply Chains: Will the RCEP Create a Pan-Asia Trading Bloc?

Top Reasons Supply Chain Design Initiatives Fail and What to Do About It

Innovation Insight for Smart Factory

IT/OT/ET Alignment

Analysis By: Kristian Steenstrup, Marc Halpern

Benefit Rating: High

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Definition

IT/OT/ET alignment refers to the orchestration of information technology (IT), operational technology (OT), and engineering technology (ET) 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., GIS, CAD/CAM).

Why This Is Important

For asset intensive industries such as manufacturing, system interoperability is improved when OT-enabled machines and ET and IT systems share 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 beginning this exercise and are more aware of the benefits while still conscious of the obstacles and problems.

Business Impact

We see movement of IT/OT/ET alignment with clients who are working through the complexities of culture and politics. This change follows the realization of technology commonality, its opportunities and benefits, and the risk of doing nothing.

The impact of IT/OT/ET alignment is mainly focused on two aspects:

1. More efficient use of technology support resources across IT, OT and ET investments

2. Easier sharing of data from design documents (ET) to operational systems (OT) and business administration

Drivers

- 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.
- Easier access to ET and OT data for IT analysis such as predictive maintenance and production optimization.
- Leverage of OT performance data in product development using ET systems.
- Design of ET systems that better cater to OT effectiveness and future OT system support and data acquisition.

Obstacles

- Possible 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.
- Common 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.
- The benefits in terms of cost savings tend to be medium or long term, not short term.
- The entrenched separate positions and practices associated with OT and ET systems and their criticality, safety and stability, means that realignment takes time.
- Different cultures and approaches of IT departments, manufacturing/operations and design/engineering, which will have to be orchestrated.

User Recommendations

- Examine technology management processes to determine how much IT process is applicable to OT and ET, how the unique needs of OT and ET must be recognized and supported, and how to get them aligned by design, not as an afterthought.
- Include OT and ET requirements in enterprise risk management by adopting an integrated security strategy across IT, OT, ET, physical security and CPS for greater visibility.
- Create combined hardware platform and architecture policies to ensure compatibility between IT, OT and ET systems by formulating compatible governance for software, communications and infrastructure.
- Use RACI analysis to help manage this transition and to map out organizational responsibilities for different parts of the technology environment.

Sample Vendors

Bentley Systems; PTC; Siemens

Gartner 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

How IT Standards Can Be Applied to OT

Alternative Organizational Models for IT/OT Alignment

Connected Factory Worker

Analysis By: Simon Jacobson

Benefit Rating: Transformational

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Definition

Connected factory workers leverage various digital tools and data management techniques to improve and integrate their interactions with both physical and virtual surroundings, while improving decision accuracy, proliferating knowledge and lessening variability.

Why This Is Important

Manufacturers are under pressure to integrate their factory workforces with their virtual and physical surroundings. They must change cultures from a “break-fix” mentality to being data-driven without sacrificing intuition, efficiency and engagement. It’s as much a technology construct that changes how factory workers access information and knowledge to work differently, as it’s a change management exercise in workforce development, behavioral shifts and integrated continuous improvement.

Business Impact

The pandemic forced organizations to pivot investments to enhance the operator experience:

- Technologies focus on executing standard work, connecting IT and OT domains, and improving collaboration in and across sites.
- Initial successes are rooted in operational excellence and flexibility.
- Greater returns appear when initiatives are part of a formal workforce development strategy that spans knowledge management, talent management and organizational design, and include learning and development.

Drivers

- Workforce gaps are widening. Digitization in factories is intensifying, while operational know-how fades. New workers are tech-savvy but lack access to best practices and know-how. Tenured workers might have the knowledge, but not the digital nous needed.
- The nature of work in factories is being (re)designed, digitized and improved, impacting worker productivity and communication.
- Intensified digitization, fluctuating labor availability and costs, and social distancing requirements are opportunities to integrate workers with both physical and virtual environments.
- Embedding new technologies into daily work impacts output. It emphasizes the importance of having the right information available to match the task or decision at the moment of need, regardless of interface.

Obstacles

- Overlooking “what’s in it for me?”: This prevents building a pull-based system for persona-based talent capabilities with continuous learning at its core. Involving workers in the solution design and implementation process helps adoption.
- Defensive buying: Hype means provider vision outweighs capabilities. If technology acquisition isn’t done in a planned, coordinated fashion, process change and security will become costly.
- Establishing trust in artificial intelligence (AI): Providers are aggressively pushing AI to the front line. However, incomplete and/or incorrect data, models or applications will impact recommendations, pay or career advancement, and lessen trust.
- Underinvesting in governance: Providing workers with tools to either build their own experiences or redefine standard work eliminates time and effort. Yet, shadow IT and anarchy arise without dedicated operational excellence/continuous improvement teams to manage common requirements and risks.

User Recommendations

- Strike a balance between digital enablement and cultivating future competencies by framing your initiative as part of a broader manufacturing workforce development program.
- Meet the need for diversity of skills, roles and jobs by developing a broad array of connected factory worker use cases anchored by standard work. This lays the foundation for automating non-value-added tasks and enabling data and tools to improve decision making.
- Make your focus the creation of a “data-driven” culture in manufacturing operations by diligently avoiding a scenario where employee creativity and ingenuity is stifled.
- Prepare to balance governance and flexibility during implementation by having clarity on where enterprise standards must give way to local ways of working.

Sample Vendors

Augmentir; Microsoft; Parsable; Poka; PTC; REVER; SwipeGuide; TeamViewer; Tulip; Zaptic

Gartner Recommended Reading

Innovation Insight for the Connected Factory Worker

The 2020 Top Strategic Technology Trends for Manufacturing Operations

Supply Chain Executive Report: Developing the Supply Chain Professional of 2025

Optimizing Production Post-COVID-19 Swings the Pendulum From Managing Things to People

Generative Design

Analysis By: Marc Halpern

Benefit Rating: Transformational

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Definition

Generative design is an automated process that systematically evolves a design, using algorithms that learn from prior designs. The approach continually improves its ability to create designs, based on an objective and conditions that the design must meet.

Why This Is Important

Generative design has great potential to automate non-value-added design activities. Despite the hype surrounding it, it is understood and adopted by a small minority of its potential market. Potential generative design users are attracted by the concept that generative design can be multidisciplinary. Its criteria can include aesthetics, cost, sustainability, function, reliability, manufacturability and serviceability. As such, software continuously improves.

Business Impact

- Generative design accelerates design activities by eliminating manual design iterations.
- By automating some design, organizations can discover alternative designs, and generate new design knowledge, giving companies more time to focus on innovative design.
- Generative design makes the use of 3D printing more viable for industrial parts, because generative design can produce designs that are expensive to manufacture by conventional means but relatively inexpensive to produce using 3D printing.

Drivers

- As experienced designers and engineers retire, their knowledge leaves with them. Manufacturers seek ways to either recreate or retain knowledge. While generative design cannot fully recreate the cultivated knowledge acquired over decades of experience, it can partially offload design burden from remaining and new employees.
- It provides manufacturers with greater ability to manage the periodic changes in demand for design and engineering skills. Designers and engineers leave with the knowledge they gained when laid off during low-demand periods. Manufacturers struggle with sufficient design capacity during high-demand periods. Generative design offsets the business risks caused by fluctuations in demand and available design and engineering talent.
- The hype surrounding artificial intelligence (AI) encourages the exploration and adoption of generative design, which is AI applied to design activities.
- Generative design technologies continue to gain capability, as technologists continue to advance the maturity of generative design, making it increasingly attractive to adopt.

Obstacles

- Users face the risk that parts that are generatively designed in isolation deliver poor performance when included in assembled products. The need to further validate the parts may raise doubts about the efficacy of this technology.
- Potential users often confuse simulation and optimization techniques with generative design. Generative design uses simulation and optimization techniques but adds machine learning, which enables the designs to continually improve in systematic and automated ways.
- Like many AI applications, generative design algorithms require “training” to reliably automate certain categories of design. Users must build confidence as to when they can adopt generative design and when they should be cautious because the design requirements are outside the scope of what a particular generative design algorithm can reliably perform.
- Veteran designers and engineers may be resistant to adopting this technology, because they view it as unreliable or a job threat.

User Recommendations

CIOs should:

- Set expectations for generative design value by working with design and engineering leaders to assess and determine how generative design performs and its limitations before adopting and implementing.
- Increase the likelihood of generative design success by suggesting a knowledgeable resource be assigned to input design goals and constraints into the software. This requires skills in describing requirements in a syntax and semantics that the generative design engine can digest.
- Provide training in generative design processes for designers and engineers.
- Acquire extensive compute power for generative design algorithms to work. Assess the extensive compute capabilities of the cloud.
- Explore the use of generative design with 3D printing.

Sample Vendors

Augmenta; Autodesk; Dassault Systèmes; ELISE; ESTECO; nTopology; PTC; Siemens

Gartner Recommended Reading

The Manufacturing CIO's Role in Adopting and Scaling 3D Printing

Mass Customization of Discrete Manufacturing Products

Analysis By: Marc Halpern, Michelle Duerst

Benefit Rating: Transformational

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Definition

Mass customization is a design, manufacturing and product-delivery approach that allows customers to personalize a product based on selections of predefined features and constraints. This allows for personalization of assembled products without a significant increase in the time or cost to produce.

Why This Is Important

The demand for personalized assembled products has been growing for several decades. However, the cost and time to personalize products has inhibited the ability to fulfill this growing market expectation. The enabling technologies and processes make mass customization available to a greater number of discrete manufacturers, making them more competitive and giving them closer connections to their customers.

Business Impact

Mass customization increases profitability and market reach. It affects:

- **Product development:** Design product platforms rather than individual products, reducing workload
- **Manufacturing organizations:** More agile manufacturing operations produce products with multiple assembled options
- **Marketing and sales:** Online for customers to easily select combinations of product features, saving cost
- **Product service:** More comprehensive access to customer-specific product configurations

Drivers

- Manufacturers recognize that customers increasingly want personalized products within every market.
- Digital technologies enable expanded access to broader markets with more diverse preferences for customized products.
- Our 2021 CIO survey suggests that manufacturers want to deliver more personalized service to customers to gain greater loyalty and increase revenues (see 2021 CIO Agenda: A Heavy Manufacturing Perspective).
- A greater number of commercial technologies for mass customization are available. These include more sophisticated product configurators and more affordable 3D printing technologies. These technologies make mass customization more scalable, efficient and profitable.

Obstacles

- Product development must be refocused from designing products to designing product platforms, which requires extended engineering skills.
- Supply chain management becomes more challenging as the demand for parts and materials fluctuates more. Operating lean becomes more challenging.
- Investments in manufacturing operations must address the need for greater agility. Delivering individualized products for different customers requires rethinking manufacturing operations.
- Mass customization involving 3D printing involves steep learning curves to achieve sufficient quality of printed parts.
- Servicing individualized products becomes more challenging. Service organizations need investment to track configurations and service history of individualized products.
- Manufacturers are reluctant to replace existing product configurators, which contain tacit product knowledge that manufacturers may risk losing if they adopt a new configurator.

User Recommendations

- CMOs must engage with business units from R&D, regulatory and product managers to identify products that can be customized, determine cost implications and decide on pricing.

CIOs must work with:

- Data architects to enable data access across product specifications, product configurators, ERP software, product life cycle management (PLM) applications, manufacturing execution system (MES) software and supply chain applications.
- Business leaders to coordinate workflow across R&D, regulatory and supply chains to ensure compliance with regional government regulatory issues.
- R&D leaders to ensure designers and engineers have the software and training to design product platforms.
- Business leaders across product development, sourcing, manufacturing and service to revise how bills of materials (BOMs) are defined and managed.

- Those responsible to document and label individualized products.
- Service leaders to ensure that field organizations have information to service individualized products.

Sample Vendors

ATLATL; Configit; KBMax; Modular Management; Tacton; Valtech; ZeroLight

Gartner Recommended Reading

Innovation Insight for Model-Based System Engineering

Proving the Value of a Digital PLM Ecosystem: Discrete Manufactured Consumer Goods

Proving the Value of a Digital PLM Ecosystem: B2B Discrete Manufacturing

2021 CIO Agenda: A Heavy Manufacturing Perspective

Consumer Goods Trend: Personalized Products

Consumer Goods Trend: Direct-to-Consumer

Consumer Goods Trend: Digital + Product

5G

Analysis By: Peter Liu, Sylvain Fabre

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Definition

5G is the next-generation cellular standard by the 3rd Generation Partnership Project (3GPP). The standard targets maximum downlink and uplink throughputs of 20 Gbps and 10 Gbps, respectively, latency below 5 milliseconds, and massive scalability. New system architecture includes core slicing as well as wireless edge.

Why This Is Important

5G is a critical enabler of the digital transformation of the enterprise and is key to China's "new infrastructure" strategy. Leverage 5G capabilities like network slicing along with low latency and high bandwidth. New services that have more strict connectivity requirements can be enabled, such as AR/VR, smart cities, autonomous driving, IoT and smart manufacturing. China is leading the global 5G development and adoption, and enterprise CIOs are showing continued interest in the evolution of 5G.

Business Impact

- 5G brings up to 10 Gbps of capacity and provides high-quality connectivity options for enterprise networking, which can effectively support various digital transformation initiatives.
- The introduction of network slicing and edge computing allows a business to tailor virtual networks that map to its IT needs.
- 5G enables other emerging technologies, such as AR/VR, robotics and Internet of Things (IoT), to further drive enterprise digital transformation both internally as well as externally in customer engagements.

Drivers

- As part of its post-COVID-19 relief package, China is ramping up plans to construct new digital infrastructure across the country — including 5G networks, artificial intelligence (AI), IoT. These drive the 5G investment and deployment.
- 5G offers fiberlike bandwidth and latency capabilities, but with significantly shorter deployment time, as there is no need to lay cables to the office/branch. With this advantage, 5G can be positioned as a comparable alternative to fiber for the enterprise data network.
- The growing number of cloud-based applications accessed from mobile devices creates a gap that translates to a new requirement for connectivity: secure, reliable and high-bandwidth wireless networks.
- 5G features, such as network slicing and service-based architecture, allow networks to be purpose-built for use cases (e.g., ultra-low latency and security) and be more responsive to the application and IT environments they support. These networks can potentially work with existing SD-WAN solutions or overlay fixed networks.
- There is a growing interest in private mobile networks across multiple industries. 5G is expected to be the preferred option for enterprises for their private wireless network, especially to support future applications such as robotics and mixed reality.
- Chinese enterprise CIOs show great interest in 5G and proactively collaborate with CSPs and vendors to develop 5G services, which drives innovation and accelerates adoption.
- Fast shipment and penetration of 5G devices is another driver for 5G network rollout.

Obstacles

- Alternative connectivity options such as Wi-Fi and fiber continuously challenge the necessity of 5G adoption in enterprise networks.
- Costs of the equipment and devices are major concerns for enterprise CIOs when considering 5G technology especially for enterprises that want to build their own private 5G network. Current private 5G networks normally are deployed in a silo mode to support niche applications, which hardly justifies the investment.
- The majority of 5G vertical use cases are still in the conceptual and developmental stage. These use cases are mainly driven by the network vendors and CSPs. While 5G will enable various industry applications, the real value to the end users remains unclear.
- The 5G-related capabilities and standards are still evolving. Therefore, 5G continues to suffer from immaturity, substantial hype, and unrealistic expectations about features and availability sets. In addition, major enterprise innovation opportunities are based on 3GPP R16 and R17, which are not largely available in today’s 5G deployment.

User Recommendations

- Plan for 5G adoption by considering the match between the 5G connectivity service and use-case requirements. Cut through the “5G washing,” and set realistic expectations by understanding the multilevel technology dependencies that impact 5G adoption.
- Assess the potential for initial 5G adoption as a continuum of services, such as SD-WAN or IoT-type applications. Proactively engage with CSPs to understand the deployment specifics of how these services integrate with their business-focused 5G services.
- Enhance your customer experience and brand advantage through leveraging 5G to offer new applications such as AR/VR on mobile devices in the mass market.
- Validate expected network performance by requiring the underlying CSPs to provide the coverage data for branch locations, frequencies used and expected throughput.

Sample Vendors

Baicell; Comba; China Information and Communication Technologies Group (CICT); Ericsson; Huawei; Nokia; Qualcomm; Samsung; ZTE

Gartner Recommended Reading

U.S. Telco 5G Plans Take Shape

Invest Implications: Emerging Technologies: Emergence Cycle for mmWave 5G

Product Leaders to Communicate 5G Value Through Practical Use Cases

Emerging Technologies: 5G Technology Spending, 2020 Survey Trends

5G as a Service: Deployment Scenarios of Private Networks in the 5G Era

Market Guide for 5G Network Ecosystem Platform Providers

Creating Your Enterprise 4G and 5G Private Mobile Network Procurement Strategy and RFQ

Immersive Experience in Manufacturing Operations

Analysis By: Simon Jacobson, Marc Halpern

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Definition

There are three kinds of immersive experiences — augmented reality (AR), virtual reality (VR) and mixed reality (MR). Immersive experience enables the perception of being physically present in a nonphysical world or enriching people's presence in the physical world with content from the virtual world.

Why This Is Important

Immersive experiences transform how workers perceive, interact and control the physical and digital worlds. These new experiences:

- Enable factories to sustain resource efficiency and reliable supply amid concerns of global labor availability.

- Enhance judgments about actual or planned items in the physical world, based on the visualization of 3D models and related information.
- Accelerate problem solving and broadening continuous improvement dialogue through virtual or remote access.

Business Impact

Immersive experiences are a low-risk way to connect the virtual and physical worlds and amplify human capabilities by impacting:

- Efficiency as simulations and remote work (equipment acceptance, supplier audits) eliminate time and cost without consequence to performance.
- The nature of work by redefining jobs and roles as certain tasks shift off-site.
- Knowledge management across value chains as collaboration levels increase.

Drivers

- Exposure to the risks of available labor and depleting knowledge in manufacturing over the past 18 months — manufacturers have shifted investments to improve the employee experience, in turn accelerating what was already a strong interest in immersive experiences.
- Cost and time savings — as well as efficiencies — from remote collaboration to fill specialist skills gaps (maintenance), audit suppliers or commission new equipment in the absence of on-site availability.
- Ambition to standardize how certain methods and procedures are executed.
- Ability to onboard new or contingent employees and new partners faster through digital overlays with content (work instructions to 3D models) and guided procedures to create experiential learning and training simulations at the point of need.
- Low benefits ceiling — Error proofing, resource efficiency (primarily labor) and shortened training cycles are easily measurable minimal viable outcomes.
- Ability to capture, retain and reuse manufacturing knowledge within immersive experience technology.

Obstacles

- Manufacturing workforces lack the digital dexterity and struggle to adapt to new experiences.
- AR/MR and VR are separate technologies that will all drive future immersive experiences. Today, they do this separately through purpose-built solutions.
- The supplier ecosystem must expand beyond narrow use cases and limited breadth and quality of content.
- The time and resources to create, test and deploy immersive experiences pose scalability challenges. These are factors of the 3D environment that surround a user for VR and the range of workflows and real-time information in the form of text, graphics, video and other virtual enhancements integrated with real-world objects for AR/MR.
- Anticipating differences in expectations and human-machine interactions and accounting for those differences when setting up immersive experiences make it challenging to define the scope of implementation.

User Recommendations

- Focus on the immediate need with AR/MR. Remote knowledge and connecting workers will help create communities of knowledge that are needed to keep operations running. Evaluate VR for higher consequence situations.
- Devise a strategy for how immersive experiences will integrate with core processes and incumbent applications. This will help identify feedback loops between operator interactions and these applications.
- Investigate the human-machine interface (HMI) for the proposed environment to evaluate response times, the quality of the displays, and the intuitiveness and ergonomics of interacting with the content.
- Don’t confine the development of use cases to internal operations. Examine how partner use cases, especially for maintenance and quality, can be leveraged. Partners may be developing their own business models for equipment and product as a service, which can supplement your existing resources.

Sample Vendors

Apprentice; Augmentir; iQ3Connect; Microsoft; PTC; ScopeAR; TeamViewer; Voovio

Gartner Recommended Reading

Supply Chain Brief: Successful Return-to-Work Strategies for Factories

The 2020 Top Strategic Technology Trends for Manufacturing Operations

Top 10 Strategic Technology Trends for 2020: Multiexperience

2021 Top Trends in Manufacturing Industries

The 2021 Supply Chain Technology Themes

3D Design and Device Convenience Hinder AR and VR Adoption

Prescriptive Analytics

Analysis By: Carlie Idoine, Peter Krensky

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Definition

Prescriptive analytics is a set of capabilities that specify a preferred course of action to meet a predefined objective. The most common types of prescriptive analytics are optimization methods, a combination of predictive analytics and rules, heuristics, and decision analysis methods. Prescriptive analytics differs from descriptive, diagnostic and predictive analytics in that the technology explores multiple outcomes and provides a recommended (and sometimes automated) action.

Why This Is Important

Prescriptive analytics provides capabilities to further automate/augment decision making to improve business responsiveness and more optimal outcomes. From a “purist” perspective, the term “prescriptive analytics” is a broad category with little hype, encompassing components with varying positions across the Hype Cycle and various levels of maturity. Such components include optimization, rules combined with predictive techniques and decision intelligence.

Business Impact

Prescriptive techniques support:

- Strategic, tactical and operational decisions to reduce risk, maximize profits, minimize costs, or more efficiently allocate scarce or competing resources.
- Recommendations for a course of action that best manages the trade-offs among conflicting constraints and goals.
- Exploration of multiple scenarios and comparison of recommended courses of action.
- Strategic and tactical time horizons as well as real-time or near-real-time decision making.

Drivers

- Maturing and expanding data science initiatives, better algorithms, more cost-effective cloud-based computing power and a substantial increase in available data.

- With improvement in analytics solutions, data quality, skills and broader use of predictive analytics, prescriptive analytics will continue to advance.

- In addition, the increasing popularity of graph techniques provides a great substrate for prescriptive analytics techniques, highlighting early signals for actions, causality links and forward paths of actions, facilitating the implementations of decisions and actions.

- The post COVID-19 reset with a focus on optimization and other advanced techniques with an emphasis on prioritizing actionable, proactive insight — as opposed to the more traditional reactive reporting.

- AI platforms and decision management tools increasingly include prescriptive techniques, driving user acceptance and potential value to the organization.

- Prescriptive analytics ranges from relatively straightforward rule processing to complex simulation and optimization systems.

- Prescriptive analytics continues to evolve, responding to ever greater complexity in business, with more need for more advanced prescriptive analytics and composite AI, e.g., combining rules/decision management with machine learning or optimization techniques.

- Organizations continue to improve and optimize their decision making, by applying decision intelligence and decision modeling to support, augment or automate decisions more effectively. Prescriptive analytics is a key enabler of this approach.

Obstacles

- Lack of expertise for how and where to apply prescriptive techniques.
- Lack of formal operationalization methods and best practices.
- Historic requirement for separate advanced analytics software that specializes in prescriptive techniques with little cohesion across the analytic capability continuum from descriptive to diagnostic to predictive to prescriptive.
- Even established use cases can fall victim to common data science challenges such as data quality, bias and talent shortages.
- Although it is a necessary competence, prescriptive analytics does not automatically result in better decision making.

User Recommendations

- Start with a business problem or decision where there are complicated trade-offs to be made, multiple considerations and multiple objectives.
- Understand the breadth of prescriptive analytics' approaches and decision models available, and which best cater to the nature of your specific business problems and skills.
- Look for packaged applications that provide specific vertical or functional solutions, and service providers with the necessary skills.
- Gain buy-in and willingness from stakeholders — ranging from senior executives to front line workers carrying out the recommended actions — to rely on analytic recommendations.
- Ensure that your organizational structure and governance will enable the company to implement and maintain functional, as well as cross-functional, prescriptive analytics recommendations.

Sample Vendors

AIMMS; Decision Lens; FICO; Frontline Systems; Gurobi; IBM; River Logic; SAS; Sparkling Logic; Veriluma

Gartner Recommended Reading

When and How to Combine Predictive and Prescriptive Techniques to Solve Business Problems

Predicts 2021: Analytics, BI and Data Science Solutions — Pervasive, Democratized and Composable

Worlds Collide as Augmented Analytics Draws Analytics, BI and Data Science Together

Effective Use of Supply Chain Analytics to Mitigate Business Disruptions

Sliding into the Trough

Digital Thread

Analysis By: Marc Halpern, Rick Franzosa, Christian Hestermann

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Definition

A digital thread is a framework that enables the collection, organization and presentation of data for multiple factors that influence a product or process and their evolutions over their respective life cycles. This integration and organization of data and information allow multiple users to access, integrate, organize, trace and transform disparate technical and knowledge-based data from multiple operational and enterprise-level systems.

Why This Is Important

The vision of a digital manufacturing business includes digital threads as a fundamental concept. The digital thread connects multiple data and information sources across design, manufacturing and supply chain systems and processes. It can then connect the evolution of design requirements through production and then delivery and service to ensure a compliant and quality product is delivered to the customer.

Business Impact

- Digital threads improve the efficiency of decision making, cost, quality, traceability and regulatory compliance.
- They provide insights to changes in cost and quality metrics by changes to product designs and configurations through digital threads.
- This dynamic nature of digital threads can streamline execution of standard work and improve the dynamics of engaging suppliers.
- A digital thread can help organizations determine what the most beneficial digital twin investments will be.

Drivers

- Manufacturers across multiple industries understand digital thread's criticality to mitigate the complexities and risks associated with new configurations (and product-specific variants) or rising customer demand for smaller order quantities.
- Technology advances and growing experience at governing data are enabling digital threads. Growing volumes of data come from a rising number of connected products supported by IoT platforms, edge devices and sensors. New technologies and tools (cloud services and automated data synchronization and validation) can access, verify, validate and synchronize data — as well as analytics for simulation and pattern analysis. This is more than core MES, PLM and ERP systems.
- The broad vision of product life cycle management encourages digital thread investments. Digital threads encompass a wide time horizon and provide history and context specific to a product's or process's life cycle.
- Compliance with regulations, such as those of the U.S. FDA and ITAR, will be more transparent and efficient.
- Managing BOMs across suppliers through customer value chains is an obstacle to efficient product design through service throughput for manufacturing businesses. Digital threads address the BOM challenges.
- Cost optimization and time savings come from shortened decision cycles and improved agility on both global and local bases. Accelerating innovation and bringing products to market are also not to be overlooked.

Obstacles

- **Intellectual property protection concerns and cyber risks:** These can dissuade members of value chains from participating in digital twin initiatives.
- **Difficulty achieving consensus on architecture and scope:** Different roles in value chains have a stake in digital threads. Each of these roles has different priorities, different content needs and different ways of interacting with data. Satisfying each role causes delays and increases scope, cost and the risk of failure.
- **Vendor lock-in:** Manufacturers that rely on a few vendors to deliver large "chunks" of digital threads will likely become increasingly dependent on that vendor, particularly as the content and workflows added to a digital thread increase over time.

- **Technology obsolescence:** Technology advances rapidly expand the possibilities of digital thread architectures. The risk of obsolescence derives from committing to digital thread technologies that become obsolete before the intended life span of the digital thread.

User Recommendations

Supply chain leaders and CIOs looking to invest in and manage the digital thread should:

- Focus on building the digital thread as a representation of a product and the processes that evolve over their life cycles, instead of confining it to engineering and production.
- Use the digital thread as a tool for improving efficient decision making, cost, quality, traceability and regulatory compliance.
- Adopt an industry data governance strategy for a digital thread by including members of your value network in planning for data oversight, data orchestration, data curation and data management.
- Overcome the absence of a complete data model by investing in standards to capture and normalize data from different systems.
- Include open standards as much as possible in the digital thread roadmap.

Sample Vendors

Anark; Aras; AVEVA; Dassault Systèmes; DataNovata; Hexagon Manufacturing Intelligence; iBASEt; Microsoft; PTC; Siemens

Gartner Recommended Reading

Innovation Insight for the Digital Thread

Machine Learning

Analysis By: Simon Jacobson

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Emerging

Definition

Machine learning is a technical discipline that identifies patterns and generates predictions based on the analysis of large sets of data. There are three major subdisciplines related to the types of observation provided. These are supervised learning (observations contain input/output pairs [aka labeled data]), unsupervised learning (labels are omitted) and reinforcement learning (evaluations are given of how good or bad a situation is).

Why This Is Important

Rather than relying on manual or conventional analytics, ML takes advantage of massive amounts of text, videos, images and other data to identify patterns, generate insights and predict future outcomes. In manufacturing operations, ML is an essential enabler of smart factories and connected workers. It can improve different facets of operational excellence and boost reliability of supply, while freeing up human resources to focus on higher-value tasks.

Business Impact

ML has a high benefit and can provide incremental improvements. ML algorithms identify undetected patterns with less preconceived user assumptions or relations. They rely on data to identify patterns to generate insights and predict trends. These insights improve over time, as algorithms self-learn from prior performance. ML, however, is not a panacea. Successfully cultivated strategies are built on common workstreams and digital roadmaps that promote scalability so maximum value is gleaned.

Drivers

- Algorithms are not new in manufacturing, yet the adoption of modern tools lags other supply chain functions, such as planning. The possibility is very attractive of taking advantage of available data and relying on the algorithms to identify patterns and correlations, and predict outcomes to find the best course of action and improve performance as part of a closed-loop system. In the past year, pilots have increased, as companies become more bullish on automation as a way to efficiently run shifts and maximize the value of production data. Typical use cases include eliminating unplanned downtime and stoppages, increasing yield optimization, reducing energy usage, improving product quality or stabilizing production processes.

- This zeal — combined with pandemic-driven objectives to identify trends and plan resources and capacity more effectively — pumps up the ML hype. Adoption, however, will be staggered. On the one hand, providers, in an effort to modernize incumbent systems, are simplifying their tools to develop algorithms. On the other hand, this needs time to evolve and mature (especially for advanced techniques such as unsupervised learning), and organizations need to move beyond targeted use cases rather than the holistic ones listed.

Obstacles

- Data complexity: Having the right data in the right format and context to train models on is the biggest expense of time. Each of the following provides different kinds of data: IT and OT across legacy data sources, vision systems, edge devices and transactional systems — to name a few.

- Heterogeneous partners: ML is an integral part of provider offerings spanning industrial IoT platforms, hyperscalers, OT providers, and multiple point or niche solutions. This creates selection and integration challenges.

- Skills: There is high demand — and insufficient supply — for data science, engineering and infrastructure talent to develop, test, train and maintain algorithms.

- Bias: Lack of algorithmic trust, combined with concerns over job loss and upskilling requirements, can limit maximizing ML's value.

- Current factory workers lacking the digital skill sets needed to maximize the value of ML: They hide this behind a lack of trust in algorithms.

User Recommendations

- Assess the speed of response and frequency of prediction needed. In many instances, traditional analytics techniques, such as descriptive and diagnostic analytics, can be more effective.
- Quantify the technical resources and skills development required for process engineers, data scientists and other production workers to not only build and train ML models but also interpret the signals.
- Ensure the availability, readiness and context of the data that will be used by ML algorithms. Given the diverse use cases and that ML relies on training datasets to identify patterns and relationships, having the right data is essential.

Sample Vendors

Amazon Web Services; Braincube; Celonis; Drishti; Flutura; Google; Microsoft; PTC; Rockwell Automation

Gartner Recommended Reading

Leading Upskilling Initiatives in Data Science and Machine Learning

3 Types of Machine Learning for the Enterprise

A Guidance Framework for Operationalizing Machine Learning

Machine Learning Engineer — A Role That Bridges the Gap Between Data Science and IT

Top 5 Strategic Technology Trends in Manufacturing Industries for 2021

Model-Based System Engineering

Analysis By: Marc Halpern

Benefit Rating: Transformational

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Definition

Model-based system engineering (MBSE) is a digital approach to creating models and simulating behaviors to understand systems and systems of systems. Those models prioritize the relationships among key variables within the systems, as well as environmental or operating conditions that influence behaviors, to understand and improve them.

Why This Is Important

MBSE — and its ability to cost-effectively model the behavior of systems — has become important in many industries and the government, as the performance of products, infrastructure, processes and organizations has become increasingly complex and interdependent. A growing number of roles addressing IT, manufacturing, transportation, infrastructure, and environmental and governmental issues look to MBSE as a means of understanding challenges and solving problems.

Business Impact

MBSE does the following:

- Replaces document-centric work environments with models
- Makes information easier to navigate and understand
- Cultivates more “cause and effect” thinking, resulting in better, more disciplined, cost-effective decisions
- Supports the planning and implementation of digital threads and digital twins
- Makes problem solving more efficient, since models connect and relate critical information instead of having to sift through disconnected documents

Drivers

- The need for MBSE among manufacturers has been heightened by the increased use of software as a part of physical systems.
- MBSE can improve the organizational structure in digital enterprises to enable highly collaborative work across different disciplines.
- Manufacturers seek to design and deliver individualized products more efficiently by designing product platforms instead of products. Product platforms are sets of product modules and features that can be mixed and matched to deliver variants of products. MBSE is an efficient means of designing product platforms, instead of products.
- MBSE is core to designing digital threads and digital twins. Digital threads and digital twins are central to digital business strategies among manufacturers.

Obstacles

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

User Recommendations

- Seek support from service companies with strong practice and experience in system engineering.
- Start with a pilot program of small scale to improve on the design of a physical system, organization or process.
- Apply lessons learned to new initiatives, always with sensitivity that all businesses are systems of systems, as any system improved through MBSE can affect the performance of other parts of a business that the system impacts.
- When using MBSE to improve or solve challenges with each subsystem (for example, the ship), account for the other systems that it affects (for example, the shipyard or a supply chain).
- Ensure integration provides mapping between the requirements of the system being modeled and the technical specifications that meet those requirements.
- Plan for change management, including changes to organizations, roles, processes and practices, with experts in multidisciplinary roles with a focus on system thinking.

Sample Vendors

Ansys; Dassault Systèmes; IBM; Maplesoft; MathWorks; Modelon; PTC; Siemens; Sparx Systems

Gartner Recommended Reading

Innovation Insight for Model-Based System Engineering

Digital Twin

Analysis By: Alfonso Velosa, Marc Halpern, Benoit Lheureux

Benefit Rating: Transformational

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Definition

A digital twin is a virtual representation of an entity such as an asset, person, organization or process. The three types of digital twins are discrete, composite and organizational. Digital twin elements include the model, data, unique one-to-one association and monitorability. Digital twins are created in enabling platforms, such as analytics or simulation solutions, IoT platforms, or CRM applications.

Why This Is Important

Enterprises are using digital twins to create virtual representations of previously opaque entities or activities for process, cost or other business improvements. For instance, improved patient outcomes due to visibility of the entire patient across the siloed systems, or reductions in unplanned outages by monitoring the equipment state are now possible. Technology providers see digital twins and associated information products and services driving new customer outcomes and revenue streams.

Business Impact

- Digital twins enable business to enrich decisions — for example, to lower maintenance costs, increase asset uptime and improve performance.
- For OEMs, digital twins contribute to differentiation, new service models and obtaining customer data.
- Digital twins of people contribute to improved health monitoring, employee safety and customer transactions.
- Digital twins will help drive new business models, such as product as a service, as well as new data monetization approaches.

Drivers

- Enterprises are accelerating their adoption of digital twins to support a broad variety of business outcomes: reducing cost structure through improved remote monitoring of assets; optimization of equipment and processes by aligning asset digital twins into a range of solutions, such as predictive analytics and field service management; product differentiation via stakeholder visualization and control of assets, as well as new customer monetization strategies via digital-twin-enabled services.
- Asset-intensive industries, such as oil and gas, have leveraged lessons from their extensive digital history toward using digital twins to improve business operations.
- Military equipment and service companies on a global basis have seen a consolidated push toward using digital twins and model-based system engineering from the national ministries or departments of defense.
- Leading-edge enterprises are implementing digital twins to model IT organizations, financial exchanges, and processes such as purchase order approvals and fulfillment — for cost optimization and process improvement purposes.
- Consortia such as the Digital Twin Consortium and the National Digital Twin Programme at the Centre for Digital Built Britain contribute to digital twin visibility and business cases.
- Technology providers have woken up to the potential ways they can serve their customers and drive new revenue models using their digital-twin-enabling product portfolios.
- Improvements in models of all types employ analytics, visualization and simulation capabilities to understand, predict and automate business actions.

Obstacles

- Enterprises lack clear business objectives for digital twins. They lack consensus on the scope, structure, process or teams to start developing business-focused digital twins.
- Few enterprises have the fusion teams of skilled business, finance, and technology people and the collaboration between these people.
- These fusion teams must conceive, create and maintain the core models that are synchronized to the real entities, yet few enterprises have the budgets to do so.
- Digital twins challenge most enterprises technically due to the blend of operational and information technologies needed to develop and maintain them.
- While consortium and standards bodies are emerging, they are all generally immature, with many vendors pushing proprietary formats. We lack standards for a broad range of digital twin integration, evolution and other technical issues.
- Few vendors have a viable go-to-market strategy to build a digital twin business, creating market confusion and excess hype.

User Recommendations

- Work with business leaders to establish realistic expectations for how digital twins can support business outcomes and establish KPIs to measure success.
- Engage the business unit to identify champions, get budget support and co-create the digital twin strategy.
- Avoid digital twin projects that lack a business sponsor and objective, as they will waste resources and undermine adoption.
- Identify IT gaps and build a roadmap to drive IT organization learning opportunities, its investment plan for internal skills, and partner selection strategy.
- Build an IT digital twins technology roadmap to mitigate the hype around proprietary vendor approaches. Incorporate best practices for software asset development and management, security and privacy, and integration.
- Assess the use cases and architectural and technical implications of composite and organizational digital twins.
- Develop a long-term governance strategy.

Sample Vendors

Amazon; AVEVA; Cognite; Cosmo Tech; GE Digital; Microsoft; Thynkli; Voovio; XMPro

Gartner Recommended Reading

Use 4 Building Blocks for Successful Digital Twin Design

What Should I Do to Ensure Digital Twin Success?

What Data and Analytics Leaders Need to Know and Do About Digital Twins

Essential Product Management Practices to Monetize Data and Analytics Assets

Product Innovation Platforms

Analysis By: Marc Halpern

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Definition

A product innovation platform is an IT infrastructure intended to cultivate continuous creativity and inspire new and better products throughout full life cycles and across generations of a product.

Why This Is Important

- Manufacturers seek better means of enabling product developers, distributed geographically, to work together more effectively at new product development.
- CIOs seek platforms as a service such as product innovation platforms to reduce the IT costs of maintaining the many applications used to conceptualize and design new products.

Business Impact

- Manufacturers have greater agility to develop new products with product development team members working in different locations.
- Product development teams can adapt with greater agility to changing requirements and market conditions.
- Social networking plays a greater role in new product development, enabling a greater infusion of new ideas and domain expertise earlier in the product development phase.
- Cloud becomes the primary platform for IT-enabled product development capabilities.

Drivers

- Product development team members working from remote locations, instead of at a central location, need a platform with rich collaboration capabilities that also includes requisite design and engineering functionality.
- Supply chains and customers are increasingly involved in new product development. Manufacturers, suppliers, and customers need a common IT platform that makes communication for product development more efficient.
- Manufacturers seek ways to shorten product development times and reduce costs. They see product innovation platforms as a means to accomplish that.
- IT organizations, in an effort to reduce the total ownership costs of product development applications that demand high-performance computing, seek SaaS and managed services from external partners.
- Product development applications, used for decades, are becoming obsolete. Manufacturers seek to modernize the IT infrastructure and applications used for new product development.

Obstacles

- Manufacturers are so deeply invested in their current product development and PLM environments that it is difficult for engineers and designers to adapt to the new ways of working that product innovation platforms require.
- Product innovation platforms are insufficiently open to working easily and reliably with third-party applications and their data.
- Cleansing legacy data and enabling new data architectures to work efficiently and effectively with product innovation platforms proves daunting.
- Product innovation platform functionality is not sufficiently mature.

User Recommendations

- Enable CIOs and IT leaders to keep abreast of product innovation platforms as these platforms continue to evolve and are adopted to enhance product design, manufacturing activities and product services.
- Acknowledge that these are conceived to run in the cloud and that performance will be a priority, particularly for graphics-intensive visualization, modeling and simulation activities.
- Potential adopters must be acutely aware of software architecture when judging the level of performance running in the cloud and at what cost.
- Make open architecture a priority when selecting these platforms to ensure that they work with complementary applications such as CRM, ERP, and MES.
- Take caution to ensure that the platform meets cybersecurity needs.
- IT organizations should use product innovation platform adoption as an opportunity to update product development data and product data architectures.
- Value networks must ensure that they establish guidelines for sharing and protecting intellectual property.

Sample Vendors

Aras; Autodesk; Dassault Systèmes; Eurostep; Onshape; PTC; SAP; Siemens

Gartner Recommended Reading

2021 CIO Agenda: A Heavy Manufacturing Perspective

Digital Business Technology Platform

Analysis By: Bill Swanton

Benefit Rating: Transformational

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Definition

A digital business technology platform (DBTP) integrates and orchestrates new and existing platforms for IT, customer engagement, data and analytics, ecosystem partners and Internet of Things. It senses business events, decides what to do and implements a response that creates value for those involved. Platforms share data, algorithms and transactions with business ecosystems to match, create and exchange services.

Why This Is Important

A DBTP enables enterprises to build a digital business and deliver digital products and services to customers and partners. Without it, enterprises will be unable to gain the business benefits of digital business. DBTPs empower people, businesses and things to give, take or multiply value creation for the enterprise.

Business Impact

DBTPs make it easier for new market entrants, startups, competitors and smart machines to create and pursue new business opportunities. Leveraging DBTPs, organizations can rapidly respond to core business disruptions, such as revamping supply chains disrupted by the COVID-19 pandemic. DBTPs also enable platform business models, which can create rapid market growth and, potentially, dominate industries.

Drivers

- Competition is shifting to digital delivery of value added services, in addition to the traditional products and services. So, traditional businesses need to build a DBTP to compete and/or participate in new digital markets.
- Regulatory requirements in some regions require organizations to share business services through digital platforms. For example, PSD2 requires banks in the EU to provide mandatory access to customer accounts for regulated third parties, a trend now being followed in many other regions.
- Service providers help almost all initial DBTP developments by providing skills, training and reusable assets inevitably sold in conjunction with significant services.

Obstacles

- Managing an inherently hybrid IT infrastructure for the platform and existing applications is a major challenge.
- There is currently no specific market or vendor for a base platform suitable for building digital use cases and data assets. Companies need to assemble components and tools from generally available cloud frameworks, a cluttered market of Internet of Things vendors, public and private APIs and other IT assets.
- While digital-native organizations are adept at these technologies, traditional companies often struggle with new architectural approaches required for large-scale implementations, such as microservices architecture, event-driven architecture and programmable infrastructure.
- A skills learning program is critical as most organizations do not yet have the skills to implement and manage this technology. So skills transfer and culture change need to be a part of any service provider contract.

User Recommendations

- Work with business leaders to identify use cases for your digital business.
- Build out the DBTP as needed to implement the initial digital use cases. The process will take years and may require refactoring as the business scales and the technologies mature. Treat the platform as a continuously evolving product guided through its long life cycle by a product manager.
- Work with technology and service providers to determine what technologies are needed to implement the use case. Most organizations do not yet have the skills to implement this technology so skills transfer needs to be included.
- Ascertain what APIs you might need to consume or provide to interact with customers and/or ecosystem partners inside or outside of the enterprise.
- Keep existing platforms loosely coupled by using techniques such as API mediation so you can modernize those platforms without disrupting your digital business build-out.

Sample Vendors

Amazon Web Services (AWS); Google; Microsoft; NXN; Red Hat; Vantiq; VMware

Gartner Recommended Reading

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

How to Build a Digital Business Technology Platform

Building a Digital Business Technology Platform Requires Clear Goals and a New Team With Cloud Skills

Building a Digital Business Technology Platform Requires New Technology and Service Provider Support

Industrial IoT

Analysis By: Simon Jacobson, Eric Goodness, Milly Xiang

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Definition

The industrial Internet of Things (IIoT), a subsegment of IoT, is used to improve asset management decision making and operational visibility, and control for plant infrastructure and equipment within asset-intensive industries and environments. These include industries such as manufacturing and natural resources, transportation and logistics, and utilities.

Why This Is Important

IIoT can improve the reliability and accessibility of factories by augmenting existing operation technologies (OT) with various sensors, gateways and edge devices. This improves how vast sources of data (historic and real time, spanning IT and OT sources) are accessed, analyzed and leveraged. New opportunities for edge architectures and digital twins, which improve operational excellence or identify future opportunities for automation, continue to emerge.

Business Impact

In manufacturing operations, IIoT is a core building block for smart factories and digital supply chains. It is also foundational for improving reliability across networks of factories. Improving the transparency of production improves safety, quality and flexibility as well as optimizes some processes in and across sites. It also contributes to managing cost-efficiency and building resiliency in product supply networks.

Drivers

- Digital initiatives seeking to modernize their operations, boost operational excellence and improve (prolong the life cycle) asset performance. Also, IIoT has become increasingly entwined with cloud, analytics, AI and ML techniques to transform how some complex processes are managed, and driving new ways of working.
- Ambitious automation plans and exploration of how certain processes can be managed remotely as institutional knowledge depletes.
- Smart manufacturing, Industrie 4.0, proliferating industry consortia and nationally driven industrialization initiatives place IIoT at the center of their platforms.
- Establishment of distributed manufacturing networks and “as a service” models.

Obstacles

- Organizational complexity and process (re)engineering.
- IT and OT heterogeneity spurs architectural debates.
- Components for a successful IIoT implementation are complex and of diverse maturity levels.
- Security concerns go beyond data confidentiality, integrity and availability, to encompass the safety and reliability of physical operations.
- IIoT projects inherently introduce new integration challenges requiring firms to navigate a sea of standards, reference models and proprietary protocols.
- Resource requirements (skills, cost and integration) are continually underestimated.
- An ever-proliferating set of provider options in an already crowded market that creates complications for manufacturing systems' strategies.
- ROI for initial investments is proven, while systematic approaches for repeated successes across multiple sites elude organizations.

User Recommendations

- Develop a plan to map data, processes and use cases with site capabilities. Then segment use-case pursuits into those that will enhance the core of operations as well as those that will foster future innovation and process capabilities.
- Use a maturity-based continuum to develop the roadmap by aligning current and future use with both site and supply chain business objectives. Leverage a maturity-based continuum for a holistic planning of architecture, deployment models, standard work and interoperability.
- Ensure alignment between IT, OT, engineering technologies (ET), frontline workers and line-of-business stakeholders. This ensures accurate budgeting of resources, identifying the role of standards and clarification of expected benefits.
- Diligently examine the trade-offs around buy/build/acquire/partner based on in-house capabilities, time, budget and deployment environment.

Sample Vendors

Amazon Web Services; Augury; Flutura; Litmus; Microsoft; PTC; Rockwell Automation; Software AG

Gartner Recommended Reading

Magic Quadrant for Industrial IoT Platforms

Critical Capabilities for Industrial IoT Platforms

3D Printing of Industrial Parts

Analysis By: Arjun Boparai, Marc Halpern

Benefit Rating: Moderate

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Definition

3D printing (3DP) of industrial parts refers to the use of 3DP to produce a finished item, subassembly or intermediate product. It can also be used to print tools, jigs, fixtures, dies and molds that would be used during the production of finished goods. This applies to OEMs and their suppliers, which can produce items on an assembly line or in a machining, casting or forming line using 3DP.

Why This Is Important

Manufacturers continue to use 3DP, given the perceived cost and time advantages, to produce customized complex products just in time and simplify supply chain logistics and manufacturing operations. CIOs must become familiar with 3DP because it is an operational technology (OT) enabled by engineering technology (ET), but depends on IT to operate efficiently and effectively.

Business Impact

3DP for industrial parts is being leveraged to eliminate bottlenecks in manufacturing and supply chain operations. It reduces the inventory required for spare parts and tools and can produce customized products with new material combinations and complex geometries. It transforms manufacturing operations and service with its ability to produce industrial parts just in time instead of purchasing them.

Drivers

- 3DP directly uses 3D data from geometric design models, either created from scratch or scanned from existing products. 3DP eliminates additional work needed to translate 3D data into execution instructions for mainstream manufacturing operations.
- 3DP offers design and structural freedom, leading to development of in-house capabilities such as prototyping and design verification. Since it is an additive procedure, expensive raw material and resources are not wasted.
- The technology advances the ability to increase energy efficiency and durability of products, especially across the aerospace, defense and automotive industries. It can produce products with complex shapes and high strength and weight resistance, which cannot be produced with traditional manufacturing techniques.
- Consumers increasingly demand personalized products, which can be delivered more rapidly through 3DP. Additionally, these individualized products are more scalable and less costly than other manufacturing approaches, where the major cost arises from the molding process for low volume products.
- 3DP is part of a technology convergence trend that stimulates innovation where there are advances in material science and the ability to embed technologies (e.g., sensors, actuators, computer chips, with the potential to be created through nano 3DP) in larger 3D printed parts.
- 3DP advances the popular goal of lean manufacturing, with shorter lead time, since inventories of spare parts can be reduced and supply chain operations can be streamlined.
- 3DP helps in improved cost position, higher design reuse, faster product launch and introduction, and better aftermarket services resulting in improved competitive value.

Obstacles

- The investment cost of equipment and production time continue to be a major challenge for the technology to produce industrial parts.
- Multiple parties are involved in the 3DP process, which results in the technology's siloed adoption. This has led to the lack of integration between 3D printers and designing software (OT and ET component) and workflow software such as MES, ERP and SCM (IT component).
- Owing to limited materials available for the production of industrial parts, there are concerns around the reliability and performance of these products, especially under adverse environmental conditions of high temperature, resistance and chemical exposure.
- Insufficient training, education and awareness to use any 3DP technologies and materials efficiently is decreasing the uptake of the technology.
- IP related to industrial products' ideas and design must be safeguarded, or it would be subject to financial losses and lost growth opportunities.

User Recommendations

- Partner with the decision-making teams in the organization, such as finance, engineering and operations teams, to validate the viability of 3DP technologies by building an investment case.
- Align the involved parties to create a connected workflow to create an IT-ET-OT alignment.
- Audit and invest in IT components needed to connect 3D printers with workflow and design applications such as CAD, PDM, ERP and MES that capture content needed for 3DP operation.
- Augment the production of tools and fixtures by encouraging the use of 3DP. This would result in shorter lead time and pay for the initial cost and time investment.
- Work with supply chain leaders to assess the potential impact of 3DP on your extended supply chain across activities such as sourcing of parts, maintenance, overhaul and repair.
- Monitor the advances in 3DP and materials technology and discuss with decision makers to evaluate the benefits to manufacturing and supply chain operations.

Sample Vendors

3D Systems; EOS; GE Additive; Markforged; Materialise; Stratasys

Gartner Recommended Reading

The Manufacturing CIO's Role in Adopting and Scaling 3D Printing

Top 10 Strategic Technology Trends for Manufacturing Industries: 3D Printing

The IT Impact of 3D Printing on Business Models

Virtual Reality

Analysis By: Tuong Nguyen, Auria Asadsangabi

Benefit Rating: Moderate

Market Penetration: 1% to 5% of target audience

Maturity: Adolescent

Definition

Virtual reality (VR) provides a computer-generated 3D environment (including both computer graphics and 360-degree video) that surrounds a user and responds to an individual's actions in a natural way, either through immersive head-mounted displays (HMDs) or room-based systems.

Why This Is Important

VR is extremely useful for simulating high-cost, high-risk, high-insurance or otherwise high-consequence situations. Examples include space exploration, industrial settings such as energy and utilities, combat training, empathy-based decision training, and situations where advanced visualization and HMDs can benefit the task or customer interaction. VR offers higher degrees of visual fidelity and personalization over what flat-screen-based (2D) systems can provide.

Business Impact

3D simulations can benefit organizations in a number of ways. VR can:

- Reduce training costs compared to building expensive, centralized training facilities or planned equipment downtime to train employees.

- Reduce risk by providing task simulation.
- Improve design cycle time. For example, building physical products requires adapting 3D concepts into 2D for planning and then adapting back to 3D for implementation. These translations have high potential to introduce errors between steps and iterations.

Drivers

- The global COVID-19 pandemic increased demand for VR.
- Much of this was due to consumer demand and reflected in the growth of VR HMD sales.
- Enterprise interest also increased as pandemic-related restrictions prompted organizations to actively seek alternative solutions for customer engagement, remote training and collaboration. Gartner client inquiries for VR increased by 36% in 2020 (compared to 2019). Among Gartner technology buyers (end users) it was a 51% increase.
- While interest was overwhelmingly consumer, it doesn't imply that VR is ready for the enterprise, but some areas are showing early value: 3D content development industries such as gaming and architecture, engineering, and design; 360-degree video such as live events, tours and documentation; training simulations for empathy and decision-making skills — e.g., high-consequence situations such as soft skill training and training in expensive or inaccessible locations such as space or deep sea exploration, surgical training, and onboarding for dangerous or remote locations such as an oil rig.

Obstacles

Potential customization requirements and limited scalability means VR experiences tend to be much more expensive than AR ones — outweighing potential benefits in many situations.

We have kept the VR profile in the same position and believe it's closer to five years until the Plateau of Productivity due to the following reasons:

- The supplier ecosystem has been slow to advance products.
- Breadth and quality of content remain limited.

- Solutions lack scalability.
- There is a lack of enterprise-ready solutions.

User Recommendations

- Use VR to support your organization’s efforts for training, visualization and collaboration tasks requiring 3D content (such as BIM and CAD).
- Identify procedures and experiences that may benefit from virtualized visual interactions (such as tours and training procedures).
- Discover potential benefits of VR by benchmarking traditional practices against VR experiences.
- Focus on a small number of pilots based on platforms designed to meet enterprise requirements.
- Avoid point solutions.

Sample Vendors

EON Reality; Facebook; Google; HTC; Insta360; Matterport; Motive; Ricoh; Sony; Strivr

Gartner Recommended Reading

Augmented Reality and Virtual Reality Will Transform Selling

Virtual Reality and Augmented Reality for Remote Workers

Augmented Reality

Analysis By: Tuong Nguyen, Auria Asadsangabi

Benefit Rating: High

Market Penetration: 1% to 5% of target audience

Maturity: Adolescent

Definition

Augmented reality (AR) is the real-time use of information in the form of text, graphics, audio and other virtual enhancements integrated with real-world objects and presented using a mobile, head-mounted display (HMD) or projected graphics overlays. It is this "real world" element that differentiates AR from virtual reality. AR aims to enhance users' interaction with the environment, rather than separating them from it.

Why This Is Important

AR is the next era of experience or interface (via the form of a digital filter) that enhances the user's surroundings with real-time, relevant, interesting, actionable information. This has an impact on both enterprises and consumers. As such, AR is broadly applicable across many markets, including entertainment, industrial design, digital commerce, marketing, mining, engineering, construction, energy and utilities, logistics, manufacturing, healthcare, and education.

Business Impact

- Current technology is best suited for purpose-built, specialized solutions. As such, position and adoption speed will vary by vertical and industry.
- Current horizontal tasks seeing the most traction are procedural tasks, situational video, visual design and customer engagement.

Drivers

- We have moved the AR profile forward by one position to represent the continued momentum of this Innovation Profile; it will take five to 10 years for the ecosystem, marketplace and technologies dependencies to sufficiently evolve to significantly increase the use of AR.
- Market interest is growing steadily, but current solutions are better described as AR-inspired solutions — experiences that contain elements of AR and offer limited, purpose-built capabilities. AR adoption continues mainly in enterprise applications. Based on Gartner inquiry (22% increase in inquiries in 2020 over 2019, 35% among end users/technology buyers) and industry news, B2B AR continues to gain traction as more enterprises are seeing the value of using AR in their workflow.
- For enterprises, AR can provide value by furnishing checklists for training and maintenance or for remote telestration in see-what-I-see video collaborations. HMD sales reflect the burgeoning pilot deployments using hands-free AR devices. Advancements in HMD hardware (lighter, more durable, safer, etc.) will provide more compelling hands-free use cases for AR as well. For the benefit of consumers, AR offers brands, retailers and marketers the ability to seamlessly combine physical campaigns with their digital assets.

Obstacles

- Content: The amount of digital content and associated AR experiences will need to be increased by orders of magnitude to make AR useful for the mass market. For example, consumer-facing implementations are still struggling to show consumers consistent value beyond narrow use cases like virtual try-on and social/messaging filters. The experiences that do show value are siloed from other experiences and interactions.
- Control: Interacting with both physical and digital elements in 3D space requires a mix of “vocabularies” of different interface modalities (speech, motion, touch, gesture, etc.) that need to be defined and standardized to make AR interactions intuitive.
- Convenience: Ease of access to form factors that make AR experiences seamless and valuable needs improvement. For example, handheld devices deliver a poor user experience for extended AR usage.

User Recommendations

- Decide on the audience for your AR experience. Internal- and external-facing solutions are not currently transposable.
- Restrict initial trials to a specific task or goal. Set benchmarks against unaugmented solutions to understand risks and benefits.
- Set the business goals, requirements and measurements for your AR implementation before choosing a provider.
- Determine a clear intention for your deployment to ensure value. For external-facing implementations, use AR as an extension of your brand and experience. For internal-facing implementations, use AR as a tool that will enhance employee job function. This could include, for example, delivering context-specific information at the point of need for mobile workers, better leveraging experts (using one-to-many video support) in plant and maintenance operations, or enhancing business processes via AR-based training and instruction.

Sample Vendors

8th Wall; Apple; Atheer; Google; Librestream; Microsoft; PTC; Scope AR; TeamViewer Frontline; Wikitude

Gartner Recommended Reading

Emerging Technologies: Kick-Start Adoption With Essential Enterprise Augmented Reality Business Practices

Emerging Technologies: Top Use Cases for Enterprise Augmented Reality

Virtual Reality and Augmented Reality for Remote Workers

Emerging Technology Analysis: Augmented and Mixed Reality Opportunity for 3D Design Software and Vertical ISVs

Emerging Technologies: AR Cloud Will Create a Multilayered Crowdsourced Canvas of the World

Cool Vendors in Augmenting Human Experiences

Emerging Technologies: Head-Mounted Displays for Augmented, Mixed and Virtual Reality

Climbing the Slope

Building Information Modeling

Analysis By: Marc Halpern, Bettina Tratz-Ryan

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Definition

Building information modeling (BIM) is the discipline supported by software to capture, organize and manage information needed to design, create, evolve and operate facilities from earliest conception to demolition.

Why This Is Important

Organizations in many industry sectors including construction, government, manufacturing and retail need better means of organizing and accessing content about their facilities to streamline facilities design, construction, management, operations, modernization and demolition. Increases in regulations governing facilities design, construction, operations and maintenance compounded by the number of roles involved in these activities require better means of managing and accessing information.

Business Impact

BIM delivers the following benefits:

- Reduces lost time and unnecessary costs associated with using wrong or out-of-date content throughout the life cycles of facilities
- Improves ability to find and access content to support any activity such as facilities design, construction, operation, upgrade, maintenance and demolition of facilities
- Improves collaboration across many roles responsible for the life cycles of facilities
- Enhances sustainability and circularity over the life cycles of facilities

Drivers

- As the costs of constructing and operating facilities continue to rise, facilities owners, construction firms and operators seek means to make life cycle activities more efficient, reducing cost and time.
- Product development team members working from remote locations, instead of at a central location, need a platform with rich collaboration capabilities that also includes requisite design and engineering functionality.
- Technology advances and growing experience with BIM encourages more companies to adopt it.
- Prevalence of SaaS for other business software encourages cloud-native BIM.
- Manufacturers, utilities and architectural engineering and construction firms seek better means of complying to a growing number of regulations that they believe BIM will support more efficiently.
- Stakeholders in facilities seek to reduce costly mistakes with BIM by enabling better access to more timely and accurate information.
- BIM enables improved collaboration across roles participating in life cycle activities from remote locations.

Obstacles

- Manufacturers are deeply invested in their current culture and processes, making it difficult to adapt to new ways of working that BIM requires.
- Reaching consensus on BIM priorities and architecture proves challenging given the number of roles both inside and outside an enterprise involved.
- BIM champions struggle to make compelling business cases for the investment.
- Building BIM content in proprietary design software formats will decrease its utility over time, cause vendor lock-in and increase the cost to maintain BIM.
- BIM projects will fail if scope creep creates higher-than-expected costs and lower-than-expected ROI. Insufficient supplier, partner and customer participation in BIM initiatives can lead to gaps in key content. Inflexible or incorrect BIM model design undermines future usefulness or possibly makes them obsolete before the end of a facility’s service life.

User Recommendations

- Reduce the risk of failed BIM implementations by phasing the implementations into smaller, focused projects that build upon each other.
- Structure BIM initiative using governance or maturity models (see How to Achieve Better Business Model Strategies With Industry Data Governance). Use both the BSI Levels 0 through Level 4, and incorporate 2D BIM to 7D BIM categories of data as the company moves from one level of BIM maturity to the next.
- Address BIM data architecture challenges by assigning IT architects to work with key BIM stakeholders.
- Encourage BIM adoption by redefining job performance metrics that encourage potential users to adopt BIM.
- 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.

Sample Vendors

Autodesk; Bentley Systems; Hexagon (Intergraph); Nemetschek Group; RIB Group

Gartner Recommended Reading

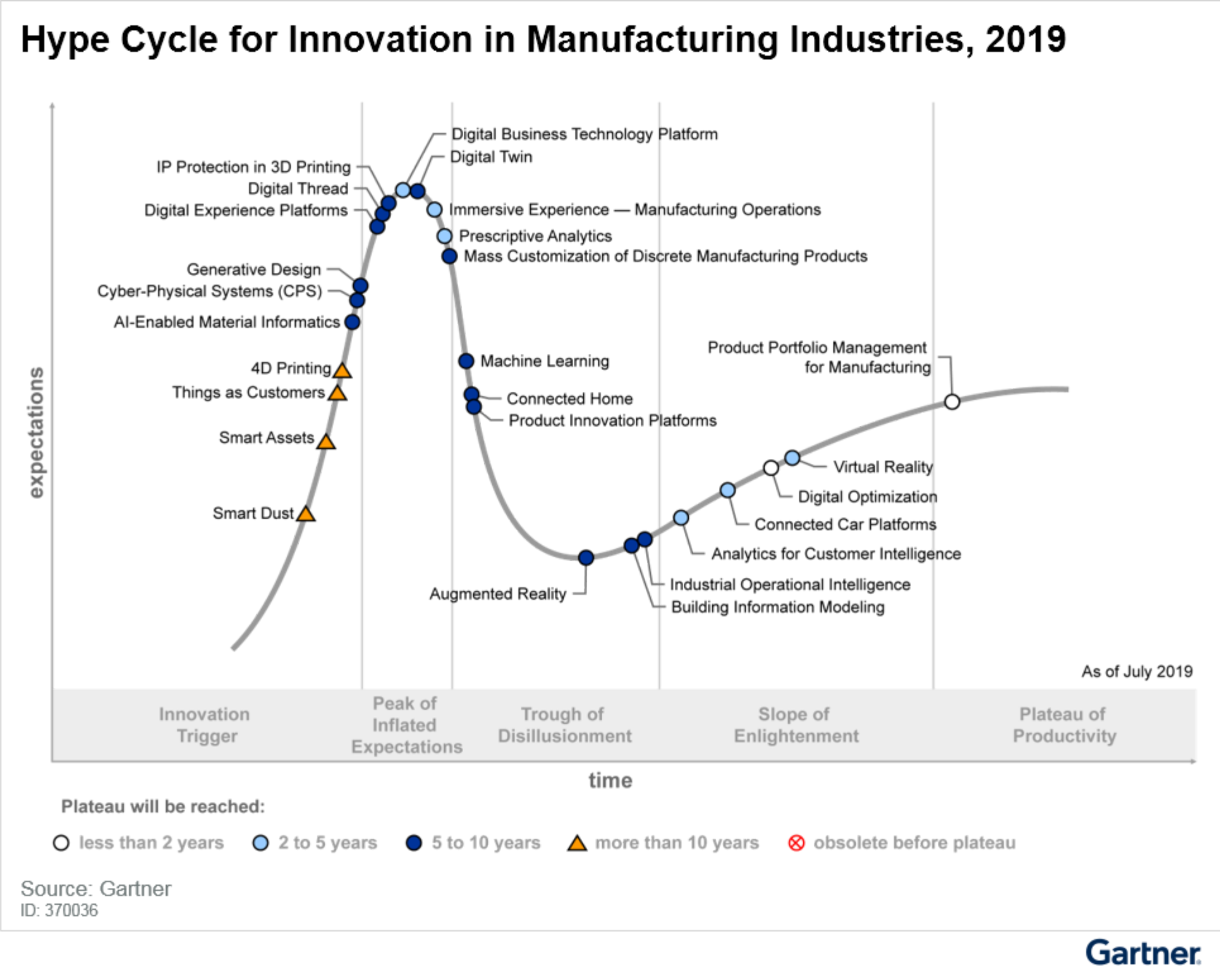
Innovation Insight for Model-Based System Engineering

Predicts 2021: Manufacturing Digitalization Roadmap for Agility and Revenue Generation

How to Achieve Better Business Model Strategies With Industry Data Governance

Appendixes

Figure 2. Hype Cycle for Innovation in Manufacturing Industries, 2019



Source: Gartner (July 2019)

Hype Cycle Phases, Benefit Ratings and Maturity Levels

Table 2: Hype Cycle Phases

(Enlarged table in Appendix)

Phase	*Definition*
Innovation Trigger	A breakthrough, public demonstration, product launch or other event generates significant media 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 innovation is pushed to its limits. The only enterprises making money are conference organizers and content publishers.
Trough of Disillusionment	Because the innovation 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 innovation'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 innovation 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 innovation to reach the Plateau of Productivity.

Source: Gartner

Table 3: 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 (required)

Table 4: Maturity Levels

(Enlarged table in Appendix)

Maturity Levels ↓	*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 (required)

Document Revision History

Hype Cycle for Innovation in Manufacturing Industries, 2019 - 29 July 2019

Hype Cycle for Innovation in Manufacturing Industries, 2018 - 26 July 2018

Hype Cycle for Process Manufacturing and PLM, 2017 - 19 July 2017

Hype Cycle for Process Manufacturing and PLM, 2016 - 18 July 2016

Hype Cycle for Process Manufacturing and PLM, 2015 - 24 July 2015

Hype Cycle for Process Manufacturing and PLM, 2014 - 15 July 2014

Hype Cycle for Process Manufacturing and PLM, 2013 - 31 July 2013

Recommended by the Authors

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

2021 Top Trends in Manufacturing Industries

Top 5 Strategic Business Trends in Manufacturing Industries for 2021

Top 5 Strategic Technology Trends in Manufacturing Industries for 2021

Toolkit: Industrie 4.0 Program Governance

Hype Cycle for Manufacturing Operations Strategy, 2020

Jump-Start Your Innovation Journey With a Customizable Innovation Framework

Executing on Innovation: Design the Process From Idea to Value

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Table 1: Priority Matrix for Manufacturing Digital Transformation and Innovation, 2021

Benefit	Years to Mainstream Adoption			
	Less Than 2 Years	2 - 5 Years	5 - 10 Years	More Than 10 Years
Transformational		Cyber-Physical Systems Digital Business Technology Platform Digital Twin Mass Customization of Discrete Manufacturing Products	5G in Manufacturing Operations Connected Factory Worker Generative Design Mobile Factories Model-Based System Engineering	4D Printing
High		5G Building Information Modeling Immersive Experience in Manufacturing Operations Prescriptive Analytics	Augmented Reality Digital Thread Industrial IoT IT/OT/ET Alignment Machine Learning Product Innovation Platforms	Blockchain in Manufacturing Machine Customers
Moderate		3D Printing of Industrial Parts Virtual Reality	AI in Material Informatics	
Low				

Source: Gartner (July 2021)

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Phase ↓	*Definition* ↓

Source: Gartner

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