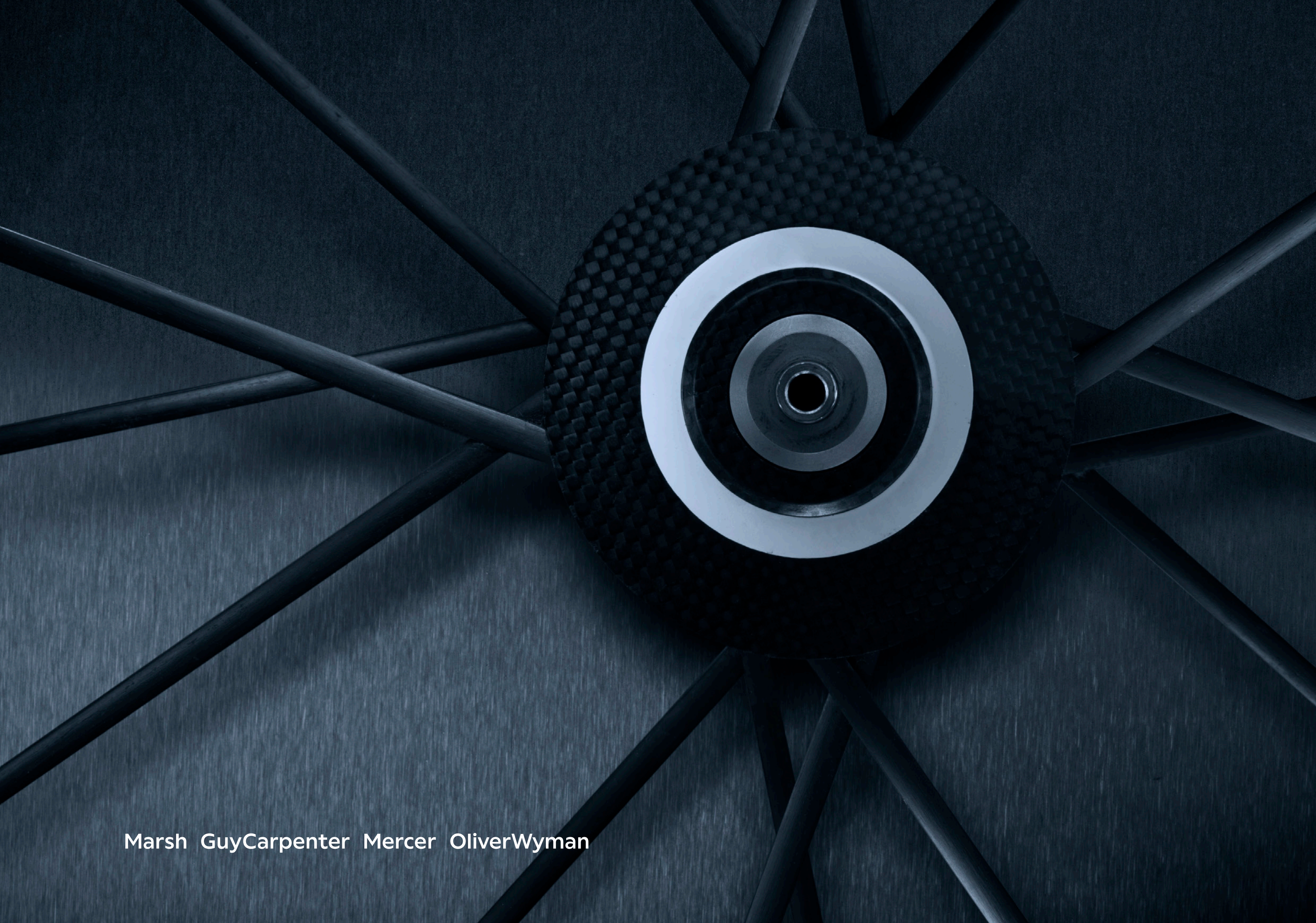
MarshMcLennan

Harnessing technology convergence

Lessons from smart manufacturers



Marsh GuyCarpenter Mercer OliverWyman

KEY TAKEAWAYS

1 The confluence of complementary technologies is creating a range of capabilities in smart factories that are increasing the efficiency of the manufacturing process from product design to assembly

- For instance, capabilities like AI-fueled 3D print prototyping minimize R&D costs while remote controlled, predictive maintenance reduces downtime
- Artificial intelligence can also be used in concert with remote sensors to create self-organizing shop floors and fully unmanned production lines, enabling some manufacturers to better navigate pandemic-induced disruptions

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2 Businesses in other sectors can emulate smart manufacturers to create competitive advantage by identifying capabilities to achieve more radical technology portfolios

- Used effectively in combination, technologies like 3D printing and deep learning can facilitate new competencies like hyper-personalized user experiences
- However, incorporating complex technology and innovative tools has always been challenging and doing so with multiple technologies is even harder

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3 Anticipating challenges with selecting and integrating technologies is critical to identifying trade-offs, avoiding lock-in, ensuring compatibility with legacy infrastructure, and quantifying risk exposure

- Firms must assess the dynamic cyber threat landscape associated with using these new technologies both independently and in concert with one another
- The lack of global consensus on cyber underscores the need for firms and insurers to actively define relevant terms to ensure contract certainty for the coverage provided by existing policies against technology-based mishaps

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4 The evolving technological landscape necessitates engaging internal and external stakeholders to ensure a smooth rollout

- Security requirements should be explicitly stated in contracts and cybersecurity personnel should partner with third parties to identify and address vulnerabilities
- Through investment in reskilling and upskilling, firms can assuage employee concerns about potential redundancies, build resilience in light of the global shortage of tech workers, and lower expenses by avoiding severance payments and hiring costs

Introduction

The collective value of bringing multiple, complementary technologies together in factories is helping smart manufacturers improve the efficiency, safety, and reliability of their operations. Indeed, smart manufacturers' tactics can be extended to other industries, when the right approach is adopted.

Technology has long been fundamental to building competitive advantage — by reducing costs, enhancing flexibility, and improving customer satisfaction. But it has become abundantly clear that no single technology, no matter how powerful, is proof against disruption and changes in consumer demand. Indeed, if the process of creative destruction maintains its current pace, half of the companies that currently comprise the S&P 500 could be replaced in the next decade.[1]

The COVID-19 pandemic has also shown the need for companies to adjust rapidly to disruptions in the supply chain and to changing consumer needs. For instance, after automakers placed microchip orders on hold at the beginning of the pandemic as demand for vehicles dropped sharply, semiconductor manufacturers pivoted, redirecting production to address the huge spike in demand for chips aimed at the laptop, gaming device, tablet, and consumer electronics markets. Such product mix changes come at a high price, as retooling a product line is both costly and time-consuming. When demand from automakers returned unexpectedly, chipmakers lacked spare capacity to meet the demand for automotive chips. The resulting shortage in automobile chips halted the production of more than 1 million cars and triggered a US government executive order to comprehensively review semiconductor supply chains.[2]

Some manufacturers, leveraging technology, have navigated pandemic-induced shifts better than others. A Chinese steel manufacturer was able to avoid major disruptions to its operations by using artificial intelligence in tandem with robots and monitoring devices to create feedback loops. This allowed for a self-organizing shop floor and unmanned production lines. Socially distanced workers using intelligent remote-control systems managed quality control and maintenance.[3]

The arrival of 5G mobile networks has been crucial in enabling such technologies to work together seamlessly. Approaches and processes that were once considered impractical, if not impossible, are becoming a reality. The speed, capacity, and ultra-low latency of 5G help connected technology ecosystems make businesses nimbler, paving the way to competitive advantage. Powered by 5G, novel combinations of Artificial Intelligence (AI), Internet of Robotic Things (IoRT), 3D printing, and other emergent technologies will transform traditional business models in other industries and sectors and create new revenue growth and efficiencies.

To emulate smart manufacturers, businesses must first identify the necessary capabilities to deploy and determine which technology advances would guarantee greater agility and flexibility (see "Recent Technological Advances" below). Firms must also preempt challenges to integrating these technologies and ensure they can roll them out smoothly. Looking beyond implementation, business leaders must mitigate technology risks in partnership with external stakeholders and manage their workforce through the transition.

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1 Anthony, S., Viguerie, S., Schwartz, E., & Van Landeghem, J. (2017, November). *2018 Corporate Longevity Forecast: Creative Destruction is Accelerating*. Retrieved March 24, 2021.

2 Campbell, P. (2021, April 28). *Semiconductor shortage to halt mini production in Oxford*. Retrieved April 29, 2021.

3 Wang, Y. (2020, February 25). *Smart manufacturing, logistics to help Baosteel maintain steady output*. Retrieved March 24, 2021.

Recent Technological Advances

TECHNOLOGY	OVERVIEW
Fifth generation mobile network (5G)	• A new wireless standard of mobile networks characterized by high speed, increased reliability, and ultra-low latency • Thanks to their greater bandwidth, 5G download speeds are expected to eventually be 20 times faster and capable of handling over 100 times more traffic than their 4G predecessors • From more immersive experiences to greater dependability of connected devices, 5G could power innovations that are not viable under existing mobile networks • **Estimated annual market size by 2024:** $343.7 billion at a CAGR of 34.2%
Edge computing	• Edge computing minimizes latency issues by storing data closer to where it's being produced (the edge), rather than at a centralized location • It enables real-time data-crunching capabilities that facilitate smart manufacturing, accelerated analytics, and use of augmented reality • **Estimated annual market size by 2024:** $250.6 billion at a CAGR of 12.5%, enabled by integration with Internet of Things (IoT) devices
Internet of Robotic Things (IoRT)	• IoRT harnesses the capabilities of autonomous robotic systems and the connectivity of IoT devices to create an ecosystem in which machines can collect, monitor, and make decisions based on real-time data • From enabling smart homes to increasing the efficacy of hospitals in delivering key services, IoRT has many functionalities • **Estimated annual market size by 2024:** $71.4 billion at a CAGR of 12.5%
Deep learning in Artificial Intelligence (AI)	• Deep learning is a subset of machine learning where artificial neural networks — algorithms that mimic the human brain — learn from vast amounts of data • Data is initially used to create a model that exhibits certain behaviors. The deep learning algorithm then performs the task repeatedly, autonomously training itself to improve as it receives feedback • From making personalized recommendations to powering autonomous cars, deep learning has many uses and, in some cases, can even surpass human performance • **Estimated annual market size by 2024:** $94.4 billion at a CAGR of 43.7%
3D Printing	• 3D printing is a form of additive manufacturing that allows an object to be created layer by layer from a digital file • It can be used to make shoes, medical devices such as bionic hands, spare parts for cars and aircrafts, and even food • **Estimated annual market size by 2024:** $40.8 billion at a CAGR of 25.7%
Radio-Frequency Identification (RFID)	• RFID technology enables data to be captured in smart labels. Unlike barcodes, which must be aligned with an optical scanner, RFID tags provide greater convenience by transmitting data through radio waves • Although RFID was discovered several decades ago, advances in complementary technologies such as artificial intelligence have made it a vital source of data and traceability in modern supply chains. Blockchain, another emerging technology, is also likely to play a key role facilitating trust and traceability in supply chains in the future • **Estimated annual market size by 2024**: $22.6 billion at a CAGR of 11%

Source: Marsh McLennan Advantage analysis, Statista market size statistics. Retrieved April 29, 2021.

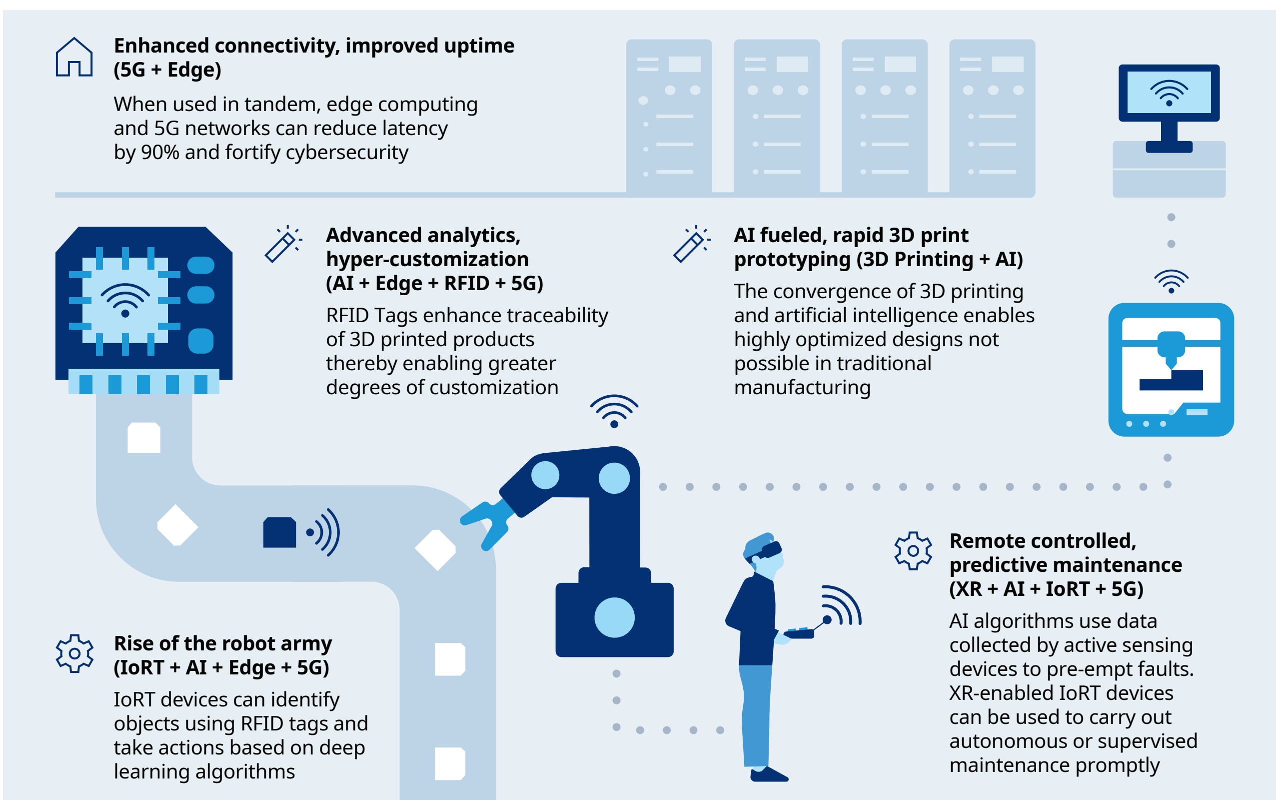
Complementary Technologies in Smart Factories

Smart manufacturers are leveraging the combinatory power of technologies to minimize retooling costs, create more product mix possibilities, and enhance business continuity.

Manufacturers have long been ahead of the curve in terms of technology adoption: According to a well-regarded technology analyst, the level of automation in the broader US economy is only now reaching the automation levels that US manufacturing achieved in the early 1990s.[4]

Presently, smart manufacturers are using complementary technologies supported by real-time analytics and decision feedback loops to improve efficiency — of research and development, product assembly and even auxiliary functions like factory maintenance (see Exhibit 1).

Exhibit 1: The tech ecosystem of a smart factory shop floor



Impact of Competencies: Enable the foundation Enhance product design Optimize processes

Source: Marsh McLennan Advantage

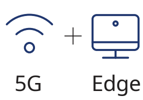
4 ARK Investment Management LLC. (2021). *Big Ideas 2021*. Retrieved April 29, 2021.

The competencies created by integrating different technology portfolios increase efficiency in three areas: First, by enabling the foundation that facilitates the meshing of other technologies; second by enhancing product design; and, finally, by optimizing production and supporting processes.

Enabling the Foundation

Quick and reliable transmission of data between devices is foundational to the autonomous technologies at the heart of smart manufacturing. High-speed networks require other technical infrastructure to make for seamless communication between devices situated across several endpoints that may be physically distant from one another.

Enhanced connectivity, improved uptime



Aside from higher speeds and enhanced traffic capacity, 5G can also reduce end-to-end latency — albeit by a mere 2 percent. But lag time can be further reduced by using 5G in tandem with edge computing to bring latency down to 10-20 milliseconds (a 90 percent reduction),[5] enabling real-time functionalities such as augmented reality troubleshooting.

The combination of 5G and edge computing minimizes disruptions in connectivity that would bring production to a halt. It also provides protection against threats emanating from:

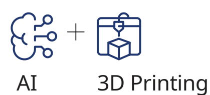
- Non-malicious sources: Reducing dependence on a single central server, thus bolstering business continuity in the case of faults
- Nefarious sources: Eliminating the need to send data to a central server, thereby limiting the scope for interception and the chance of central servers becoming the targets of attack

The foundation connectivity and processing afforded by 5G and edge computing enables other complementary technologies that increase efficiency across the production cycle, from prototyping to production.

Enhancing Product Design

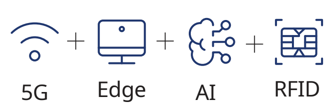
Creating new products and modifying old ones is an iterative process of conceptualizing, designing, prototyping, and market testing. Technology reduces this time-consuming and expensive process, helping manufacturers retain a competitive edge.

AI fueled, rapid 3D print prototyping



On average, research and development costs constitute more than 5 percent of a manufacturing firm's expenses.[6] The pairing of 3D printing — additive manufacturing that builds objects, layer by layer — with AI-optimized designs can reduce prototyping costs by 75 percent and shorten the product-cycle time.[7]

Advanced analytics, hyper-customization



Companies can offer personalization as a way to differentiate themselves from the competition: As much as 80 percent of consumers are more likely to

5 Vizzard, G. (2020, February 25). *5G network transforms the industrial, transportation and commercial landscape with real-time AI and accelerated response times*. Retrieved March 24, 2021.

6 Govindarajan, V., Rajgopal, S., Srivastava, A., & Wang, Y. (2019, May 20). *R&d spending has dramatically surpassed advertising spending.* Retrieved March 24, 2021.

7 D'Aveni, R. (2015, November 16). *The 3-d printing revolution.* Retrieved March 24, 2021.

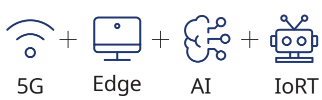
make a purchase when a firm offers customization.[8] But without the help of technology, such personalization can be prohibitively expensive.

The use of sensors, RFID tags, and other connected devices provides greater operational visibility and rich data for AI-enabled decision algorithms. This makes for greater safety, quality control, and granular traceability, which in turn enable more personalization. The individualized product can be monitored during assembly, enabling a relatively low-cost customer feedback loop.

Optimizing Production and Support Processes

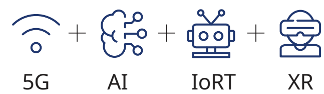
From Kanban[9] to lean manufacturing principles, manufacturers are always looking to enhance production processes. Already, these technologies can improve throughput, quality, and productivity.

Rise of the robot army



Manufacturers allocate significant resources for monitoring production to ensure business continuity. Using IoRT devices and AI-powered algorithms in tandem with data from sensors, factories can reduce monitoring costs by up to 90 percent.[10]

Remote-controlled, predictive maintenance



Production interruptions and downtime can be costly — running as high as $260,000/hour.[11]

The use of AI-powered extended reality (XR) simulations can preempt and prepare for maintenance training, remote assembly, and other contingencies to minimize expenditures. AI algorithms use data from sensors to run simulations and anticipate failure; then IoRT devices enable autonomous and timely maintenance.

Workers can also use XR to guide robots to areas of the factory that are inaccessible or where conditions pose a danger to in-person maintenance. Doing that calls for vast amounts of data to be transmitted in real-time, requiring the speeds and ultra-low latency offered by 5G in tandem with edge computing.

The efficiencies generated illustrate how smart manufacturers are harnessing the value of complementary technologies. However, the integration of multiple technologies also brings with it increased complexity and challenges — which firms in other industries will need to navigate to replicate the success of smart manufacturers.

8 Epsilon. (2018, January 9). *New Epsilon research indicates 80% of consumers are more likely to make a purchase when brands offer personalized experiences.* Retrieved March 24, 2021.

9 Kanbanize. (n.d.). *What is Kanban? Explained in 10 Minutes: Kanbanize.* Retrieved May 06, 2021.

10 Robotics and Automation News. (2019, October 29). *Factories can save up to 90 per cent in valve monitoring costs with wireless IoT sensors.* Retrieved March 24, 2021.

11 Arsenault, R. (2019, November 08). *Stat of the week: The (Rising!) cost of downtime.* Retrieved March 24, 2021.

Medicine, Mead, and More
The Broader Scope of Smart Manufacturing

The scope for integrating different technologies transcends traditional "widget" manufacturing and underscores its value across a range of industries, including the pharmaceutical and food and beverage sectors.

For example, access to health data from wearable devices — processed using artificial intelligence — is enabling pharmaceutical companies to provide people with customized vitamins and medications. This, coupled with advances in gene-editing technology, specifically the use of antisense RNA (a molecule that can be calibrated to correct and regulate the expression of related genes in host cells), facilitates the formulation of hyper-personalized medication that can treat rare diseases.[12] Two of the leading vaccines for COVID-19 also utilized this technology.

For breweries, IoRT devices can identify production bottlenecks, and AI-powered manufacturing execution-system algorithms can simulate and quickly find next-best alternatives to minimize interruption.[13] The combined power of these technologies enables real-time commodity market monitoring, which helps manage variance and cost of ingredients. Increased traceability through modern tagging technologies also supports demand-driven supply chains.[14]

Integrating a symbiotic suite of technologies can even optimize farming. Thanks to 5G, sensors and AI-enabled cameras can identify and regularly track the health of individual crops, and IoRT devices can efficiently eliminate weeds and parasites to maximize yields.[15]

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12 Temple, J. (2020). *10 Breakthrough Technologies 2020.* Retrieved March 24, 2021.

13 Nimbalkar, S., Supekar, S., Meadows, W., Wennings, T., Guo, W., & Cresko, J. (2020, July). *Enhancing Operational Performance and Productivity Benefits by Implementing Smart Manufacturing Technologies in Breweries.* Retrieved March 24, 2021.

14 Wetzel, J., & Damsgard, C. (2020, November 20). *Smart manufacturing in the food industry.* Retrieved March 24, 2021.

15 Vision Online Marketing Team. (2019, July 31). *Machine vision Saving Agriculture: One crop at a time.* Retrieved May 07, 2021.

Emulating Smart Manufacturers: A Look Ahead

Incorporating complex technology and innovative tools has always been a challenge, as manufacturers can attest. And doing so with multiple technologies is even harder. To ensure that the reward is worth the risk, it's essential to anticipate the challenges with the selection, integration, and upkeep of innovative technologies.

From the use of 3D printing in making complex medical devices,[16] to banks' implementation of AI-enabled machine vision to authenticate clients,[17] diverse industries have adopted technologies that began in manufacturing to improve their processes.

When Technologies Collide

A suite of complementary technologies akin to those utilized by smart factories can equip firms in other sectors with a host of capabilities that align with business priorities — product/service leadership, customer intimacy or operational excellence. For example, the technologies that make remote maintenance a reality in smart factories can be used to improve the safety and reliability of urban transit systems.[18]

Similarly, firms that choose to prioritize service leadership can invest in tech-enabled workforce training, which is enabled by the confluence of XR, IoRT devices and AI. In sectors like healthcare that are skill dependent, these technologies aid practitioners in pre-empting challenges that may arise in complex surgeries and can serve as a platform for training residents and medical students.

Even in product-focused sectors like fashion, in which success is predicated on customer intimacy, the convergence of AI and 3D printing is facilitating hyper-personalized user experiences by eliminating retooling costs. A major American orthopedic footwear company is leveraging these technologies to provide their customers with custom-built shoes at relatively low prices.[19]

Businesses can also achieve operational excellence by capitalizing on tech-hardened cyber protection tools or leveraging the combinatory power of XR, IoRT and AI to enable analytics-fueled inventory optimization. A leading German logistics provider is doing so by giving its employees smart glasses which can recognize products, identify barcodes and suggest storage locations based on real-time factory capacity.[20]

To recreate these competencies and match the success of smart manufacturers, companies should identify desired capabilities and supporting technology portfolios based on their business priorities (see Exhibit 2).

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16 Pacific Research Laboratories. (2020, September 08). *Understanding the history of 3d printing in medicine.* Retrieved March 24, 2021.

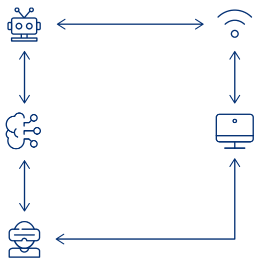
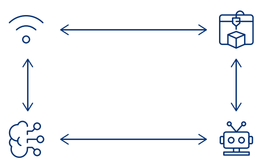
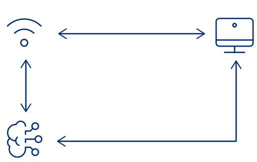
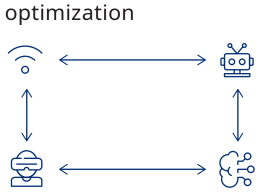
17 Joshi, N. (2019, September 9). *How Machine Vision Can Transform Financial Services.* Retrieved March 24, 2021.

18 Space1. (n.d.). *AR, MR, VR for Rail Industry.* Retrieved March 24, 2021.

19 AMFG. (2020, October 01). *3D Printing and Mass Customisation: Where are we today?* Retrieved April 19, 2021.

20 DHL. (2014). *Augmented Reality in Logistics.* Retrieved April 19, 2021.

Exhibit 2: Value derived from leveraging complementary technologies

CAPABILITY AND UNDERLYING TECHNOLOGIES	DESCRIPTION	VALUE FOR BUSINESS
Business Priority: Product/Service Leadership		
Tech-enabled workforce training 	• **Extended reality (XR)** is being used to facilitate immersive learning at the workplace. The ability to gamify the process makes this a more engaging form of training than most conventional approaches • **AI-powered** extended reality simulations can be used to train workers in sectors that depend on the human mastery of skills • **5G** and **edge computing** are critical to XR because its use is predicated on minimal lag time. Furthermore, AI algorithms can be used to simulate scenarios and preempt issues that may arise	**Value for Business** • Remote learning enablement • Engaging, immersive training modules through gamification • Increased preparedness for contingencies/complex procedures through simulations
Business Priority: Customer Intimacy		
Hyper-personalized user experience 	• Using **RFID** chips, each product with its associated customization request is trackable during assembly, enabling a relatively low-cost customer feedback loop • Using **5G networks, 3D printing** can be executed quickly, prototyping costs can be minimized, and customers can receive products quickly • **Deep learning algorithms** that predict customer behavior and preferences can fuel hyper-customization	• Improved demand forecast accuracy • Greater scope for targeted marketing • Enhanced customization capabilities • Reduce prototyping costs
Business Priority: Operational Excellence		
Tech-hardened cyber protection 	• Devices can operate on independent networks within the same physical infrastructure using **5G** network slicing and **edge computing** • This reduces the impact of a potential cyberattack and is crucial because IoRT systems are highly susceptible to security risks and potential breaches of data privacy, given the mammoth amounts of information they collect and process • Simultaneously, the predictive capabilities of **machine learning algorithms** can be used to identify potential points of failure	• Reduced susceptibility to cyberattacks • Improved business continuity
Analytics-fueled inventory optimization 	• While **AI algorithms** that use **active sensors** can potentially direct IoRT devices to reorganize warehouses and find products to optimize distribution, warehouse staff and managers may need to remotely control operations • **Extended reality** enables them to use robots to locate products and reorganize the warehouse using an interactive 3D layout	• Optimized warehouse management • Reduced delivery lead time

5G Networks — Extended Reality — Edge Computing
Artificial Intelligence — 3D Printing — Internet of Robotic Things

Source: Marsh McLennan Advantage

Greater Complexity, Bigger Challenges

Answering a set of overarching design questions can help to address challenges and mitigate risks, ensuring that businesses are prepared for contingencies. This will allow businesses to forecast and prepare for future technological needs and make for more robust risk analysis (see Exhibit 3).

Exhibit 3: Key design questions and related challenges

	SAMPLE DESIGN QUESTIONS	CHALLENGES TO BE ADDRESSED
Selection	• What is the firm's key differentiating characteristic — product/service leadership, customer intimacy, or operational excellence? • Which underlying technologies need to be meshed to create relevant capabilities? • How can technological lock-in be avoided? • What are our competitors and new market entrants doing?	• Identifying trade-offs and opportunity costs of implementing the technology portfolio to determine the course of action — whether to be an early adopter or a fast follower • Foreseeing issues that may arise in meshing different technologies — compatibility, security, vendor roadmap alignment, and more • Gauging the actions of new market entrants — often unencumbered by legacy infrastructures — which may deploy technologies more quickly, elevating the urgency for action
Integration	• How do we integrate — both across new technologies and with legacy infrastructure? • What are the existing technology limitations today (and in the future)?	• The lack of universal standards for emergent technologies frequently leads to compatability issues, especially when companies need to employ multiple vendors • Integrating newer technologies like IoRT devices and edge computing with a complex legacy infrastructure in a multi-cloud environment
Maintenance	• How do vendor roadmaps align across the suite of technologies deployed? • What should be done to prepare for future upgrades and technology advancements while guarding against vendor lock-in? • What new processes and skills are required to run, maintain, and enhance these capabilities?	• Developing an IT systems management framework and operating guidelines for these technologies when system standards and regulations have not been fully established • Understanding and planning across multiple vendor roadmaps — enhancement synchronization, update management, and more • Balancing bandwidth across network endpoints, as firms would conventionally allocate higher bandwidth to central data servers
Protection	• How can these technologies be deployed to reduce cyber exposure? • Where exposure is unavoidable, how can it be proactively mitigated?	• Understanding the evolving cyber threat landscape associated with these new technologies — independently and in concert • Quantifying cyber exposure (data, brand, liability) and using insurance to offset risk

Source: Marsh McLennan Advantage

By anticipating issues that may arise while selecting and integrating technologies, firms can manage the potential fallout of increased technological complexity. This entails coordination across multiple vendors to ensure that new technologies are compatible with one another and existing tech infrastructure. Compatibility must be regularly re-evaluated as vendor solutions mature. And it requires training employees to manage new technologies, as well as communicating with suppliers and distributors to facilitate supply chain integration and transparency.

Ongoing maintenance and enhancements should be planned for in advance. The new environments created by these convergent technologies require new methods to manage them. Existing IT frameworks and processes must be augmented to support the new hardware and platforms. If core components lose synchronization with one another, the increased complexity of these distributed networks can complicate and impede decision-making by end users, a phenomenon that can be exacerbated by divergent vendor roadmaps.

Businesses must also be wary of cyber risk exposure. Although technologies such as edge computing reduce overall vulnerability to cybersecurity threats, they expand the threat surface. This could lead to data centers, which may be geographically dispersed, becoming more susceptible to security risks and potential breaches. Although the use of AI-enabled security can mitigate this by enabling quick detection and response, taking such risks into account warrants an active review of cyber risk management strategies.[21]

Such convergence of technologies can often lead to increased cyber risk exposure. Traditionally, businesses have relied on their property insurance policies to cover physical loss or damage that ensues from a cyber event; recently, insurers have been introducing exclusions for these secondary losses associated with cyber events. After the 2017 NotPetya and WannaCry cyberattacks that led to losses in excess of $8 billion, several global regulators have mandated that insurers provide clarity on how cyber risk is addressed[22] in all their policies in order to give clients a clear understanding of the coverage provided by their policies. Still, there is no global consensus on what “cyber risk” constitutes, underscoring the need for firms and insurers to actively define relevant terms in individual policies.

These cyber events, which are often a result of reduced security barriers stemming from increased technological complexity, have tangible spillover impacts on society. Incidents of technology enabling the misuse of personal information — or even creating the mere fear of an incursion occurring — exposes firms to reputational risks, accentuating the need for businesses to devise effective technology governance frameworks[23] and take deliberate steps to facilitate trust.

By anticipating issues that may arise while selecting and integrating technologies, firms can manage the potential fallout of technological complexity.

21 Marsh McLennan Advantage. (2020). *MMC Cyber Handbook 2021.* Retrieved May 20, 2021.

22 O’Brien, S., & Davis, E. (2020). *Silent Cyber No Longer Silent?* Marsh McLennan. Retrieved May 20, 2021.

23 Hoster, B., Riddell, G., & Smith-Bingham, R. (2021). *Governing Artificial Intelligence.* Marsh McLennan. Retrieved May 20, 2021.

Managing the Transition

To be successful in leveraging this convergence of technologies, businesses will need to continuously grapple with dynamic cyber threats, evolving privacy regulations, and persistent workforce concerns. Mitigating these risks will necessitate engaging ecosystem constituents preemptively and persistently.

Defusing Cyber Threats, Protecting Privacy

The recent malware attack on SolarWinds that spread to its clients, including the US government, highlighted the need to continuously engage various stakeholder groups — third-party providers, employees, and consumers — when adopting and using new technologies.[24] This can be achieved by explicitly stating security requirements in contracts with vendors, mandating the use of track-and-trace programs to establish provenance within systems, and assigning cybersecurity personnel to partner with external stakeholders in identifying and addressing potential vulnerabilities.

Internally, cyber intrusion safeguards should be tailored to each layer of the technology environment appropriately:

- **Device:** In some ways, this is one of the most complex layers to manage due to the proliferation of devices. To maintain safety, fit-for-purpose security protocols should be adopted for each device type — mobile phones, computers, data servers, 3D printers, intelligent sensors, drones, and industrial robots.
- **Cloud**: The engine of many technology environments, the cloud is a natural place to house centralized security tools to identify and quarantine malicious traffic. Of course, many businesses rely upon cloud service providers, which tend to be a source of risk themselves, heightening the importance of effective vendor management practices.
- **Network**: Whether data is being transmitted via 5G or other means, the network layer is critical to curtailing the spread of malicious code. Securing the network requires robust transfer protocol analytics to isolate inside and outside network traffic, attachment routing protection, and denial of service protection.
- **Edge computing**: While edge computing expands the threat landscape, it also presents an opportunity to partition malicious traffic before it spreads. Robust edge operating systems, threat detection, and quarantine techniques can limit the impact of an incursion.
- **Third-party access**: As previous incursions have demonstrated, exposure to vendors and supply-chain partners must be assessed and managed. Today, there are no common industry-wide frameworks for managing third-party cyber risks, making it paramount that companies define and adapt their own policies, rules, and standards for managing access to their systems and data.

By facilitating the storage and use of data near where it is collected, edge computing affords firms some additional benefit by limiting which jurisdiction's cybersecurity laws govern individual data centers. However, companies need to continually monitor changing regulations, especially those, like the

24 Smith, B. (2020, December 18). *A moment of reckoning: The need for a strong and global cybersecurity response.* Retrieved March 24, 2021

California Consumer Protection Act (CCPA), that list tangible financial penalties for data breaches[25] not only for organizations based in California but also for firms with customers in the state. To protect user data and consequently themselves, companies that collect personal data should reinforce privacy by design, when developing cyber safeguards.

Cybersecurity isn't merely a technology problem; 62 percent of executives[26] believe that the greatest threat to their organization's cybersecurity is the failure of employees to comply with data security rules. The increased complexity of using multiple technologies exacerbates this risk. As working from home became the norm during the pandemic, employees unaccustomed to the use of commonplace safeguards like multi-factor authentication and using VPNs increased the risk of cyberattack for employers. This highlights the need for robust human controls in addition to technological ones: cybersecurity guidelines, processes, and ongoing training reinforced with vigilance tests can raise employee awareness and minimize the probability of a cyberattack.

Helping the Workforce Evolve

Employees, especially those who aren't a part of the technology workforce, are rightly wary that large-scale automation will cut the need for labor. Even when technology adoption doesn't lead to fewer jobs, it usually results in a shift in the skills needed by businesses. Effectively managing this transition requires active investment in reskilling workers as well as coordinated and consistent leadership communication.

Companies will need to cultivate a workforce that consists of domain experts with technical knowledge as well as generalists who can identify relationships between different processes and information flows to identify opportunities and make data-driven decisions.

Under current scenarios, the global shortage of tech workers is expected to cross 85 million by 2030; the cost of recruiting and retaining qualified employees will likely increase further.[27] This will likely be exacerbated by the increased complexity of harmonizing different technologies that will require workers to have knowledge of an even broader suite of technologies. Investment in reskilling and upskilling can help lower expenses by avoiding severance payments and hiring costs. It also demonstrates management's commitment to the existing workforce, fostering employee loyalty. Two-thirds of businesses believe that the return on investment in reskilling can be seen within a year — a major American telecommunications company even managed to fill over 70 percent of its job vacancies by reskilling workers to facilitate career pivots.[28]

Beyond securing technical skills, companies should also revisit their business unit leadership competency models to get a better view into which skill domains — quality, operations, problem-solving — are of greatest importance to the future state workforce and ensure alignment with new workplace requirements invoked by tech convergence. In practice, this often means incubating and developing leaders that exemplify professional competencies[29] such as:

- **A strategic, innovation-oriented mindset**: The volume of data generated by these new technologies creates a strategic advantage — but only for those with the talent to separate the signal from the noise. Fluidity and adaptation are critical success factors in this new operating paradigm.

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- **Conceptual thinking:** In order to fully capture the value at these technological intersections, employees will not only need to change the way they work, but also how they visualize linked processes, weigh the impact of information, and translate insight to action.
- **Social skills:** Technological transformation increases connectivity between people, not just machines. Robust networking skills can make for collaborative decision-making and allow leaders to draw upon diverse, even nontraditional backgrounds to make better decisions.

Effective change management practices are also essential to keeping the workforce engaged[30] during this transition as the integration of multiple technologies will transform existing business functions. Leadership communication and employee directives should be coordinated between the C-suite and all relevant departments — HR, corporate communications, IT, and legal. As an example, many companies rely on their IT and legal teams to develop technology-related protocols and ensure compliance. However, HR and communications teams are also critical to elevating employee awareness and promoting a robust cybersecurity culture. Indeed, this is a particularly acute obligation in an increasingly remote working environment, which underscores the need for cross-functional collaboration and the essential role of HR in cyber risk management for complex technology ecosystems.[31]

Compelling communication is more than just a tool for providing direction; it also demonstrates an understanding of workforce concerns. By actively soliciting feedback from workforce constituents at all levels and following through with action when warranted, business leaders can help employees feel that their voices have been heard, thereby transforming the human element of the transition into an asset rather than an impediment.

Disruption occurs most profoundly when new tools are used to augment existing processes in novel ways. To avoid being blindsided, businesses would be wise to look beyond what their immediate competitors are doing. True competitive advantage may lie over a more distant horizon as novel combinations of these technologies transform existing business models and create new revenue growth and opportunities for efficiency improvements.

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