

The Five SMART Technologies to Watch

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We identify five emerging technology trends (summarized by the acronym SMART) that we believe will significantly impact business over the next five years. CIOs and business leaders should evaluate these trends to identify new opportunities and challenges.

Key Findings

- SMART (sensors and the Internet of Things, maker machines, augmentation of humans, robotics and thinking machines) trends will have a significant impact on the development of the new digital industrial economy and the rise of digital business.
- Investigations show that at least two trends (and often more) will give rise to major disruption (as well as new revenue-generating opportunities) in almost every organization and across all industries and geographies.
- The trends are all in early stages, facing no showstopping technological barriers, and are available in early versions today. However, each trend gives rise to significant and challenging questions in nontechnical areas, including regulation, legality, ethics and morality, which will pose significant and ongoing challenges to IT and business leaders.

Recommendations

CIOs and business leaders:

- Immediately initiate a serious technology review and threat assessment of each of these technologies if they have not already been done.
- Collectively prioritize and evaluate the impact of these trends on your organization and industry, and initiate pilot projects to evaluate in greater depth.
- Revisit existing business and digital strategy plans, and ask how (and to what extent) these trends change assumptions, introduce previously unanticipated risks or threats, or provide new revenue opportunities. Amend those strategies as appropriate.

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Analysis

Many organizations spend time and resources on horizon scanning and technology evaluations (using a variety of techniques and tools such as Gartner's Hype Cycles). However, the complex interactions of individual technologies mean that a broader approach to evaluation is required. Breadth should not be misconstrued as superficial or high level, but rather more inclusive and holistic. This research calls out five broad disruptive trends that are not only of interest to technology aggressive (Type A) companies, but will both impact and provide considerable opportunities for less aggressive adopters (the mainstream, Type B organizations) that may seek to explore these trends to initiate revenue growth or enter new markets.

We use the acronym "SMART" to list these technology trends and to capture the heavy emphasis on information, knowledge and decision making that runs as a common thread through all five technology trends. The trends are:

- **S**ensor Networks and the Internet of Things
- **M**aker Machines (encompassing 3D printing and additive manufacturing)
- **A**ugmented Humans (e.g., wearable and embedded devices, and the growing exploration of neurological and physiological enhancements of human capabilities)
- **R**obotics (e.g., simple industrial warehouse robots, humanoid robots and the current generation of autonomous devices, including vehicles)
- **T**hinking Machines (e.g., intelligent systems epitomized by Apple's Siri and IBM's Watson, which are steadily advancing the ability of technology to support — or even make — decisions based on complex discovery and evaluation of relevant information)

As with many emerging technology areas, variations in terminology must be expected as markets develop. For example, the use of thinking machines is seen by some individuals as inaccurate, since it suggests an anthropomorphic capability to think. Elsewhere in Gartner research, these systems

(and some autonomous devices that we include under robotics) are included in a broader "smart machines" category. Whatever you choose to call these technology trends and however you choose to group the many subsidiary technologies are not the primary issues and should not be used as excuses to postpone or avoid serious investigation of their potential impact.

As a result of our own internal scanning and evaluation processes, we present these five trends as highly significant and impactful. At the same time, they neither replace nor invalidate important current trends, such as those described by the Nexus of Forces (cloud, information, social and mobile). In reality, these current trends create the environment and circumstances under which business and societal acceptance of these SMART technologies will be encouraged and accelerated. Equally, with the passage of time, additional significant trends may yet emerge to rival the potential impact of these SMART technologies.

Sensor Networks and the Internet of Things

The Internet of Things describes the growing number of intelligent objects (or things) that are being connected to the Internet. There has been massive interest and significant growth over the past 18 months in this area, although the variety of nomenclature creates confusion. Although there are differences of scope and focus among the Industrial Internet (GE), the Internet of Everything (Cisco) and Smarter Planet (IBM), to name but a few, all essentially describe the same concept — a growing universe of Internet-connected devices that are expected to create new efficiencies, new revenue streams and new business opportunities. Gartner defines the "Internet of Things" as the network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment.

2014 has already been described in some media as "The Year of the Sensor," which captures the rising growth of this concept of connected, sensing devices across consumer, business and industrial (operational technology) sectors. Many of the future applications of this technology are not yet clear, but the number of sensors expected to be installed over the next few years and the incremental value they might produce are forecast to be substantial. Gartner's "Forecast: The Internet of Things, Worldwide 2013" indicates the number of connected devices (excluding PCs, tablets and smartphones) will increase almost thirtyfold to more than 26 billion units by 2020 and deliver an overall global economic value-add of \$1.9 trillion, of which 80% will derive from services.

For further exploration of this trend, refer to the following recent Gartner research:

"Hype Cycle for the Internet of Things, 2013"

"Predicts 2014: IT and OT Convergence Results in Changed Organizations"

"Uncover Value From the Internet of Things With the Four Fundamental Usage Scenarios"

"The Information of Things: Why Big Data Will Drive the Value in the Internet of Things"

"The Internet of Things Is Moving to the Mainstream"

"Innovation Insight: The 'Internet of Everything' Innovation Will Transform Business"

Maker Machines

3D printing is a rare example of a single technology that has become truly disruptive by itself. Such disruption is generally the result of the combined impact of several complementary technologies. The growing number of low-cost consumer-targeted 3D printers (often referred to as maker machines) offer experimenters, entrepreneurs and startups a low-cost entry to discovering a rich and varied range of new opportunities. At the same time, growth in the market at the industrial end (building on a longer but not widely publicized history of additive manufacturing) is increasingly legitimizing this technology as new opportunities are discovered and new materials are introduced. Gartner estimates the 3D printing market to be worth almost \$6 billion by 2017, growing with a compound annual growth rate (CAGR) of more than 80% (see "Market Trends: 3D Printing, Worldwide, 2013").

The ability to create customized parts, often with features that cannot be replicated by other more conventional manufacturing means, rewrites the long-standing rules of manufacturing. Every part can be uniquely customized, manufacturing cost is unrelated to volume, and parts can be manufactured at remote locations without the conventional economies of scale. Companies such as GE are creating subassemblies for jet engines using 3D printers, jewelers are creating unique items in precious metals, and cutting-edge automotive companies are creating parts for high-performance vehicles as well as plastic parts for long-out-of-production vehicles. The diversity of emerging uses and examples of 3D printing appears limitless, and the growing interest, in the medical sector, in creating items in both inorganic and organic materials makes this a strong contributor to the human augmentation trend described below.

Although mass manufacturing will not be wiped out in the near future, the integration of appropriate maker machines into the manufacturing process and logistics pipeline not only is highly disruptive to existing organizations that believe their size and manufacturing capabilities are a barrier to entry, but also exposes a wide range of new opportunities for smaller organizations to level the playing field and even tilt the competitive advantage in their direction.

For further exploration of this trend, refer to the following recent Gartner research:

"Predicts 2014: 3D Printing at the Inflection Point"

"Strategic Technology Trends — 3D Printing Transforms Organizations"

"How 3D Printing Disrupts Business and Creates New Opportunities"

"Use the Gartner Business Model Framework to Determine the Impact of 3D Printing"

"Emerging Technology Analysis: 3D Printing"

Augmented Humans

Inherent in the development of digital business is the concept of the blurring of the digital and physical worlds. Although the overarching concept of digitally connected humans with cyborglike implanted electronics is the stuff of science fiction (and raises a plethora of complex ethical, legal and moral issues), the journey toward this future state is already well underway. The explosion of

mobile device usage has led many users to be within a few feet of their devices 24 hours per day (reports in the popular press). Such a close affinity is substantiated by simple observation, and the even more rapid uptake of tablet devices emphasizes the desire for 24/7 access and connectivity. 2014 is already seeing a strong emphasis on wearable devices, such as Google Glass, representing a further move toward human integration with the device and cloud-based environment beyond. In-body implants are deemed acceptable in cases of medical need, but the idea of body modification is well-established in many cultures, so implanted technology is merely a matter of time. The realization of enhanced capabilities and the restoration of diminished faculties (and their possible extension beyond normal human limits) will attract, repel and raise a multitude of ethical, regulatory and legal considerations to be grappled with in the years to come.

In parallel developments, there is also growing interest in the (physically) less invasive techniques to augment human capabilities through neurological stimulation, biochemistry and other nonsurgical techniques. These alleviate some of the issues, but raise equally challenging problems of their own.

In the short- to midterm, the impact of human augmentation will be more about the holistic view of the humans (employees or customers) taken as units, with their immediately accessible technology (e.g., wearable devices, handheld devices and smart clothing) and the readily accessible information and decision support capabilities at their immediate disposal and under their personal control. The limited availability of Google Glass has already led to significant security and privacy concerns, and even outright bans on its use in some locations (mirroring similar but less extreme concerns over smartphones in the past). That alone is indicative of the potentially disruptive nature of this trend in the future.

For further exploration of this trend, refer to the following recent Gartner research:

"Innovation Insight: Neurobusiness Validates Behavioral Sciences as a Transformational Business Discipline"

"Maverick Research: Living and Leading in the Brain-Aware Enterprise"

"Maverick Research: The Future of Humans: Get Ready for Your Digitally, Chemically and Mechanically Enhanced Workforce"

"Market Trends: Enter the Wearable Electronics Market With Products for the Quantified Self"

"Cool Vendors in Wearable Electronics for Health and Fitness, 2013"

Robotics

Mention of robotics instills images of automated production lines on the factory floor or laser-welding giants from science fiction. The business reality is far broader than that. Apart from assembly lines, robots such as those from Kiva (now owned by Amazon) have become a significant element of high-efficiency warehousing and logistics. Research in academic institutions has advanced the capabilities of human assistants substantially, driven by the impending labor shortages resulting from decades of demographics and extending human longevity. Japan's

academic and commercial institutions have been at the forefront of this research field for many years, although many other countries are now starting to focus on this area.

Robotic assistants are appearing in retail environments to advise customers, complementing their virtual counterparts in the online world. However, it is in the field of autonomous transport, especially cars, that the most significant and headline-grabbing advances have been made over the past few years. The well-reported progress of Google's autonomous vehicle (in sharp contrast to the significant development by traditional automobile manufacturers that often goes unreported outside the industry) has captured the imagination and encapsulated the fears and concerns of many.

In military areas, the developments in infantry support robots by Boston Dynamics (recently acquired by Google) and the increasing use of drones (with varying degrees of autonomous capabilities) are both impressive and deeply worrying. The idea of robots, be they semihumanoid or not, making decisions about actions that could potentially injure humans is amplified by the thought that they could be equipped to deploy lethal force. The developments have already resulted in calls for the use of armed robots to be outlawed in warfare, but this highlights the contradiction that many weapon systems are already highly automated. It comes down to the question of, "Whose finger is on the trigger?" or, in the case of a vehicle, "Who bears the responsibility in an accident?"

These questions, rather than any advances in technology that might be required, lie at the heart of the challenge of robots in business and will take time to resolve. There is already a debate over when (rather than if) legal clarification (perhaps along the lines of Isaac Asimov's often-referenced "Three Laws of Robotics") might be required. Well-known robotic developments, such as Honda's Asimo, may have a price tag (if it were available as a product) in the millions, but recent advances in consumer products (perhaps marketed as toys but with potentially advanced capabilities) have practically eliminated cost as a barrier to entry. Video-equipped quadcopter drones provide aerial surveillance of civil disturbances for less than \$300, and longer-range self-guided drones costing just a few thousand dollars can be deployed in the southern oceans to monitor whaling activities. Baxter, an easily programmable robotic capable of repetitive tasks, can be purchased for little more than \$20,000, opening up the option of replacing human workers to even the smallest of companies.

There is no doubt that robotics is well-established and the impact on businesses over the coming decade will be both extensive and imaginative. However, the intersection of robots and human labor will raise challenges for both regulators and lawmakers, and by extension, for business leaders as well, who will be torn between their deployment for competitive advantage and the potentially crippling litigation that might ensue in the event of accidents.

For further exploration of this trend, refer to the following recent Gartner research:

"Innovation Insight: Mobile Robot Innovations Move New Business Opportunities"

"Hype Cycle for Human-Computer Interaction, 2013"

"Predicts 2014: Automotive Companies' Technology Leadership Will Determine the Industry's Future"

"Market Trends: Advanced Driver Assistance Systems"

"Hype Cycle for Emerging Technologies, 2013"

"Predicts 2014: Global Logistics Differentiating the Future"

Thinking Machines

In academic and technical circles, the use of the term "thinking machines" is often controversial and debatable, but the term perhaps captures the popular understanding of their potential more than more technical terms, such as "cognitive computing," or equally loaded terms, such as "artificial intelligence." Whatever the terminology used, these systems threaten to disintermediate many knowledge workers in the way that robots and industrial automation have displaced the manual worker in the past. For that reason alone, they are highly disruptive.

The significant (and highly complex) advances being made in machine learning approaches (by companies such as Google, IBM and many other smaller organizations) alongside ongoing academic research are driving rapid advances in this space. These can be challenging for those without deep expertise to appreciate in detail but have huge implications for the power and capability of these systems both now and in the future.

Cloud-based systems, such as Apple's Siri, and numerous virtual assistants have not captured the headlines in the way that IBM's Watson did in winning the popular TV show "Jeopardy!" but raise similar issues. These systems are capable of assessing huge quantities of information in search of the best answer to a question (as well as understanding the question in the first place) to provide an objective, impartial and unbiased suggestion. Whether that result is the answer is a moot point. In the case of systems such as Siri, the user has requested an answer (perhaps to a simple question, such as "Where is the nearest Indian restaurant?") but may only be presented with a single result, which begs the question. "Why that one?" and leaves a doubt as to the hidden algorithms and influences that were taken into account. Likewise, when a powerful decision support engine like Watson provides a suggested diagnosis and treatment to an oncology patient, it may be the doctor who delivers the answer, but since they still bear the liability, can they afford to disagree with such an exhaustive summarization of the corpus of knowledge?

As with robotics, it will be the legal, ethical and regulatory issues that will challenge extensive deployment of thinking machines in business, but the drive to do so in the hunt for competitive advantage will be powerful.

For further exploration of this trend, refer to the following recent Gartner research:

"Artificial Intelligence Finally Delivers Real Value for Business Applications"

"CIO Advisory: Why CIOs Should Be Concerned About Siri and Other Voice-Controlled Assistants"

"Smart Machines Lead to Competitive Advantage as Well as Ethical Challenges"

"Smart Machines Mean Big Impacts: Benefits, Risks and Massive Disruption"

"Google, Apple Siri and IBM Watson: The Future of Natural-Language Question Answering in Your Enterprise"

"IBM Bets on New Watson Unit to Ignite Smart Machine Era Growth"

The Common Threads That Link the SMART Technologies

The disparate nature of these trends is misleading, since they share a number of common characteristics that, in no small way, amplify their significance and relevance to business organizations in every industry:

- Each trend is in the early stages of progression through the Gartner Hype Cycle and will likely take five to 15 years (or even longer) to reach the plateau and mainstream deployment in a broad range of enterprises.
- Early examples of each of these technologies are available commercially and may appear futuristic. Although these early examples will appear crude and limited in a few years' time, they provide the ability for every organization to get hands-on experience at the current time at an affordable cost.
- Surprisingly, for such apparently advanced technologies, there do not appear to be any significant technical road blocks that would bring future developments to a halt.
- Each individual technology has the potential to create significant disruption, discontinuity or individual organizations, industries and, perhaps, even societies. Given the significant levels of congruence between these trends, this impact is likely to be significantly amplified.
- Each trend has a strong relationship to data, information and even decision making — either as a generator of data (in the case of sensor networks and augmentation) or as a consumer of information (as with robotics and thinking machines).
- The continued growth and deployment of each technology breaks new ground and challenges the current status in regulatory, legal and ethical areas. These areas (especially matters of ethics and morals) are frequently dismissed by technology leaders as matters for others to concern themselves over. However, the time has now come for a serious and informed debate on such matters by business leaders. Despite the challenging ethical and legal debates that are yet to come, history demonstrates that this Pandora's box of technology, once opened, is very unlikely to be closed again. Collectively, society, business leaders, politicians and lawmakers will have to reach an equitable compromise on the extent and nature of their deployment and the checks and balances that may be required to control their misuse in the future.

Taken in their entirety, these common factors justify the selection of these technology trends as key disrupters for the coming decade and worthy candidates for the investigation, evaluation and action by CIOs and business leaders of all organizations.

The SMART Technologies and Digital Business

As the impact of the Nexus of Forces (cloud, information, social and mobile) becomes more pervasive and permeates the business environment, leading organizations are already looking to the

future to identify the next big thing and seek further competitive advantage. We are on the brink of a new digital industrial economy, characterized by the advancing use of sensors and the growth of the Internet of Things to generate more data and create new value through the blurring of the digital and physical worlds. We describe this coming era as "digital business" (see "Lead in the Digital Industrial Economy Using Insights From Symposium's Analyst Keynote").

As the number of connected devices and sensors increases, new data volumes increase, introducing a newly disruptive force into business. Devices (things) become significant players in the decision-making process and become significant actors or influencers in transactions. In many cases, the growing universe of smart devices will create a new category of machine-machine transactions. The SMART technologies are an inherent part of this next evolution of business, creating a new universe of end devices (sensor networks), increasingly integrating humans into the digital world (human augmentation), delivering machines and systems to undertake a growing range of tasks (robotics), including many that we previously considered beyond their capabilities, and finally, enabling those same systems to solve complex problems, effectively making decisions without specific programming (thinking machines).

Although digital business will rely on numerous technologies, some more mature than others, we believe that the SMART technologies introduced here will play a pivotal role and will create a powerful platform for those leading companies wishing to fully exploit the new revenue opportunities that the new wave of digital business promises.

Understanding the Impact of the SMART Technologies

Individually any one of these trends can (and most probably will) cause significant disruption to existing organizations, while creating new opportunities for others. However, these are not isolated trends, and they combine and contribute to create an even more impactful outcome that will disrupt entire industries and lead to changes in the social fabric in some instances. For example:

- A smart consumer device (such as an intelligent smoke alarm [see www.nest.com]) provides not only an improved customer experience to the purchaser but also a revenue stream to the original vendor (with much higher margins than traditional thermostats). As a connected sensor, it then creates a demand (opportunity) for a range of connected services (such as alarm sensing and emergency services notification), all of which create new opportunities for a service provider. Once a single service has been established, the options are in place to link other smart devices in the home and, thus, extend the revenue opportunity.
- 3D printing clearly disrupts manufacturing but has secondary impacts in many other areas. If products can be printed remotely, then logistics and warehousing demands change, reducing the revenue potential of allied organizations. The reduction of lost sales due to out-of-stock situations, the ability to customize parts and the ability to cost-effectively reduce batch sizes are significant gains. However, intellectual property protection comes under pressure, and sales tax revenue may be impacted by the transfer of the point of manufacture.

With these two technologies combined, it is easy to imagine a scenario in which a device senses an imminent failure (in itself or some other system it is monitoring), communicates that to a central system (for a thinking machine to make a rule-based decision based on multiple parameters) that, in

turn, sends commands to a local delivery point to use 3D printing to create a replacement part, and then communicates the availability of that part to the user, making an appointment to have a service engineer call to replace the potential failure before it happens. This increasing role of intelligent devices (the things in digital business mentioned above) has huge consequences for the involvement of humans in many activities and raises significant liability and regulatory issues. For example, the increasing number of robots deployed in manufacturing (see "[1 Million Robots to Replace 1 Million Human Jobs at Foxconn? First Robots Have Arrived](#)"), combined with 3D printing of parts, implies significant changes in labor requirements, which will have implications for government policies due to unemployment and loss of income tax revenue. Likewise, if thinking machines eliminate (or, at the very least, reduce) the number of clerical and junior/middle-ranking knowledge workers, the demand for office space will decline with significant impact on commercial real estate markets and lessors.

The high-impact, broad reach and, sometimes, rapid advance of these technologies require IT leaders to urgently assist their business colleagues to understand the potential impact (and opportunities) and act decisively to avoid being significantly disadvantaged.

Recommendations for CIOs and Business Leaders

The SMART technologies introduced here are more than an interesting list of future trends to be considered and then passed to an innovation group or technology think tank. Experience over the past six months in describing these trends to business and IT leaders across different industries and geographies has clearly demonstrated that at least two, and usually three, are typically anticipated to prove significantly disruptive (in both a positive and negative sense) for every organization. Therefore, we strongly recommend that every CIO initiate the following actions within the next three months:

- Use the information in this research and associated reference materials to instigate a serious technology review and threat assessment of the potential impact and/or opportunities posed by each of these technologies on both their own organization and the broader industry sector in which they operate. Take the opportunity to include inputs from elsewhere in the business, such as marketing, product development, manufacturing and so on to gain a holistic perspective.
- Seek to prioritize the trends to determine your own shortlist of what is the most impactful (in terms of immediacy or level of disruption posed). Be very suspicious if you feel able to disregard more than two of these trends as either low-impact or nonimmediate.
- Seek additional funding to initiate further investigations, and pilot projects to identify not only immediate "low-hanging fruit opportunities" but also a portfolio of longer-term risks and rewards.
- In collaboration with those responsible in your organization for business and digital strategy, revisit your existing plans and strategies, and ask whether these technology trends change assumptions, introduce previously unanticipated risks and threats, or provide new complementary revenue opportunities.
- Be bold! The oncoming wave of digital business will sweep aside many organizations that fail to both identify and respond decisively to the new digital industrial economy. The SMART

technologies introduced here are key components of the digitalized platform that underpins and enables digital business. Organizations that fail to firmly embrace at least two of these technologies and integrate them into their overall business operations are unlikely to survive the competitive threat posed by more aggressive organizations and will steadily lose market position over the coming decade.

Gartner Recommended Reading

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

"Predicts 2014: The Business Impact of the 'SMART' Technologies"

"The Disruptive Era of Smart Machines Is Upon Us"

"Maverick* Research: Ethics Are at the Center of the Nexus of Forces"

"Maverick* Research: Surviving the Rise of 'Smart Machines,' the Loss of 'Dream Jobs' and '90% Unemployment'"

"Agenda Overview for Business Innovations and Emerging Trends, 2014"

Evidence

This research is based on extensive horizon scanning of emerging trends carried out by Gartner over many years, combined with detailed insight and analysis from Gartner analysts and others who are experts in the relevant fields. Over the past six months, these trends have been introduced to, and the importance and implications have been discussed in detail with, many senior IT and business leaders from different industries and in different geographies to further validate their significance.

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