A Consumer Products Perspective

Tech Trends 2014

Inspiring Disruption

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Contents

Introduction

WELCOME to Deloitte's fifth annual *Technology Trends* report. Each year, we study the ever evolving technology landscape, focusing on disruptive trends that are transforming business, government, and society. Once again, we've selected 10 topics that have the opportunity to impact organizations across industries, geographies, and sizes over the next 18 to 24 months. The theme of this year's report is *Inspiring Disruption*.

In it, we discuss 10 trends that exemplify the unprecedented potential for emerging technologies to reshape how work gets done, how businesses grow, and how markets and industries evolve. These disruptive technologies challenge CIOs to anticipate their potential organizational impacts. And while today's demands are by no means trivial, the trends we describe offer CIOs the opportunity to shape tomorrow—to inspire others, to create value, and to transform "business as usual."

The list of trends is developed using an ongoing process of primary and secondary research that involves:

- Feedback from client executives on current and future priorities
- Perspectives from industry and academic luminaries
- Research by alliance partners, industry analysts, and competitor positioning
- Crowdsourced ideas and examples from our global network of practitioners

As in prior years, we've organized the trends into two categories. Disruptors are areas that can create sustainable positive disruption in IT capabilities, business operations, and sometimes even business models. Enablers are technologies in which many CIOs have already invested time and effort, but that warrant another look because of new developments, new capabilities, or new potential use cases. Each trend is presented with multiple examples of adoption to show the trend at work. This year, we've added a longer-form *Lesson from the front lines* to each chapter to offer a more detailed look at an early use case. Also, each chapter includes a personal point of view in the *My take* section.

Information technology continues to be dominated by five forces: analytics, mobile, social, cloud, and cyber. Their continuing impact is highlighted in chapters dedicated to wearables, cloud orchestration, social activation, and cognitive analytics. Cyber is a recurring thread throughout the report: more important than ever, but embedded into thinking about how to be secure, vigilant, and resilient in approaching disruptive technologies.

For the first time, we've added a section dedicated to exponential technologies, working with Singularity University to highlight five innovative technologies that may take longer than our standard 24-month time horizon for businesses to harness them—but whose eventual impact may be profound. Examples include artificial intelligence, robotics, and additive manufacturing (3-D printing). The research, experimentation, and invention behind these "exponentials" are the building blocks for many of our technology trends. Our goal is to provide a high-level introduction to each exponential—a snapshot of what it is, where it comes from, and where it's going.

From a Consumer Products lens, we provided industry sector specific perspective on majority of the topics including CIO as a venture capitalist (how to leverage brand categories perspective for portfolio planning), crowdsourcing (specific strategies including crowdfunding, flexible workforce and data analysis contests), wearables (discussing the Empowered Employee and the Persistently Connected Consumer) and digital engagement (Omnichannel Brand Engagement, Ubiquitous Sensors and other topics).

Each of the 2014 trends is relevant today. Each has significant momentum and potential to make a business impact. And each warrants timely consideration—even if the strategy is to wait and see. But whatever you do, don't be caught unaware—or unprepared. Use these forces to inspire, to transform. And to disrupt.

We welcome your comments, questions, and feedback. And a sincere "thank you" to the many executives and organizations that have helped provide input for Tech Trends 2014; your time and insights were invaluable. We look forward to your continued innovation, impact, and inspiration.

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Enablers

Technical debt reversal

Lowering the IT debt ceiling

Technical debt is a way to understand the cost of code quality and the impacts of architectural issues. For IT to help drive business innovation, managing technical debt is a necessity. Legacy systems can constrain growth because they may not scale; because they may not be extensible into new scenarios like mobile or analytics; or because underlying performance and reliability issues may put the business at risk. But it's not just legacy systems: New systems can incur technical debt even before they launch. Organizations should purposely reverse their debt to better support innovation and growth—and revamp their IT delivery models to minimize new debt creation.

TECHNICAL debt is not a new term, but it's gaining renewed interest. Originally coined by Ward Cunningham in 1992, the phrase describes the "not quite right" code typically introduced with initial software releases because of an incomplete understanding of how the system should work.[1] Organizations that regularly repay technical debt by consolidating and revising software as their understanding grows will likely be better positioned to support investments in innovation. And like financial debt, organizations that don't "pay it back" can be left allocating the bulk of their budgets to interest (i.e., system maintenance), with little remaining to develop software that can support new opportunities.

Technical debt is often the result of programmers taking shortcuts or using unsophisticated techniques. It's typically misfeasance, not malfeasance. For example, a developer may copy and paste code blocks without thinking through the longer-term consequences. If the code ever needs to be updated, someone will have to remember to fix it in each instance.

But sometimes, technical debt is simply the result of dealing with complex requirements. To meet a project deadline, complicated proprietary code may be developed, even though simpler alternatives may have been available. With each such action, technical debt proliferates. This is like high-interest, short-term borrowing. If you don't pay off the debt promptly, compounding kicks in.

The impact of accumulated technical debt can be decreased efficiency, increased cost, and extended delays in the maintenance of existing systems. This can directly jeopardize operations, undermining the stability and reliability of the business over time. It also can stymie the ability to innovate and grow.

Articulating technical debt is the first step in paying off its balance. With new tools for scanning and assessing software assets, CIOs can now gauge the quality of their legacy footprint—and determine what it would cost to eliminate the inevitable debt. A recent study suggests that an average of $3.61 of technical debt exists per line of code, or an average of more than $1 million per system.[2] Gartner says that "current global IT debt is estimated to stand at $500 billion, with the

$3.61

Technical debt per line of code within a typical application.[1]

35 PERCENT

The defect removal efficiency of most forms of testing.[2]

$312 BILLION

Estimated global annual expenditure on software debugging in 2012.[3]

52 PERCENT

Portion of total effort spent repairing architecturally complex defects, though they account for only 8% of all defects.[4]

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potential to rise to $1 trillion by 2015."[3] While the idea of debt doubling in a year's time may seem astonishing, we're in the midst of unprecedented investments in disruptive technologies—often with deep hooks into core systems. The push for rapid innovation in unproven domains is also leading to compounding debt.

These estimates address only the literal definition of technical debt—how much it would cost to fix the exposed code quality issues. But there's also another dimension, which we call "architectural debt." Architectural debt refers to the opportunity costs associated with system outages or the inability to deliver new capabilities. In some cases, architecturally complex defects can absorb as much as 52 percent of the total effort spent repairing defects.[4] They can also derail new initiatives.

Technical debt is not limited to legacy systems; every new project has the potential to add to the backlog. With that in mind, you should incorporate the cost of technical debt into project management processes and portfolio reporting. This kind of transparency can not only raise awareness of quality among development teams, but can also provide a foundation for talking to the business about the hidden cost of IT delivery. By documenting your debt-decreasing efforts, you can account for those efforts—important progress that would likely not otherwise be visible (or appreciated).[5]

The ability to quantify technical debt can provide a common point of reference for the C-suite when you are deciding how to prioritize IT projects for an organization. Typically, technical debt should be paid down within the context of delivering against business priorities by incrementally refactoring existing solutions and using improved development processes to minimize new debt accumulation. Incorporating techniques described in our *Real-time DevOps* chapter[6] can help reduce waste generated when software is developed.

Some organizations may also need to spur projects that address especially messy issues such as bolstering performance, preventing production issues, or preparing for future strategic investments. The goal is a sustained, prioritized reduction of the balance sheet, where each project systematically improves on the baseline.

For most organizations, technical debt comes with the territory, an unavoidable outcome of decades of technology spend. The big question is: How will you manage the liability? Understanding, containing, and mitigating technical debt can be a platform, not only for a stronger IT foundation, but for a renewed level of trust and transparency with the business.

Consumer Products Perspective

The issue of technical debt sometimes does not get as much attention in the Consumer Products industry as in other industries like Retail or Transportation – the logic being that the prevalence of defined ERP packages in CP makes the problem far less acute. However, addressing technical debt is still a major challenge for many CP organizations. Companies often have a significant footprint of custom code potentially due to ERP customizations with ABAP or service-oriented integrations for enabling enterprise transformation logic (ETL) across the landscape.

As a result, the incurred technical debt—whether from poor software architecture and software development decisions or evolving needs—shackles the rate of change possible within the IT landscape reducing agility and increasing software development complexity. To reverse technical debt, there are a few time-tested practices that CP CIOs should consider:

- **Link technical debt reversal to portfolio design** – Keeping a separate portfolio bucket for either landscape modernization or agility enhancement can protect the sanctity of these investments – and helps safeguard that other priorities don't trump these needs.

- **Create visible architectural artifacts** – The pithy saying "out of sight, out of mind" is even more relevant to the world of CP, where technology innovations like analytics or big data are revolutionizing the use of IT. Hence, it is important to create simple architectural artifacts (like technical debt heat maps) that clearly indicate the current state of the landscape – and which can serve as visible reminders for the organization – as strategic planning fever takes effect before the start of the new fiscal year. Annual reassessments of these technical debt maps are important to gauge the progress of the organization in alleviating technical debt.

- **Sensitize the Architecture Review Process (ARP)** – Develop a set of simple metrics and diagnostics such as lines of code or the number of coding concerns flagged by static code analysis tools that the ARP can use to assess and suggest mitigations for as periodic architecture reviews and approvals for projects are conducted. Also, incorporating static code analysis tools within the SDLC process is important for CP organizations to consider.

Lessons from the front lines

Express delivery of quality

To keep up with the over 150 billion pieces of mail delivered each year,[7] the United States Postal Service (USPS) depends in large part on the quality and effectiveness of its IT systems. So when quality concerns became apparent during one of its IT modernization projects and the USPS was facing budget concerns, USPS leadership proactively took action to manage the organization's technical debt.

First, USPS used the SQALE[8] method for assessing the quality of its technical debt across four software dimensions: reliability, performance, security, and changeability. With a clearer picture of how much technical debt existed and where, USPS developed a roadmap to remediate the critical software issues and transition to long-term sustainment following CISQ[9] standards. For example, USPS instituted automated unit test scripts, minimum code coverage testing levels, and static analysis of the source code. These changes improved application quality and performance.

Going forward, USPS is also applying these same measurable standards to other projects by including them as standard oversight and acceptance criteria in their statements of work. And because incorrect project estimates can introduce technical debt, USPS is revamping its project estimation techniques by requiring the use of both parametric and bottom-up estimating techniques. With these changes, USPS is starting to see both improved quality and more accurately planned IT costs across its portfolio.

Cleaning up shop

DB Systel, a subsidiary of Deutsche Bahn, is one of Germany's leading information technology and communications providers, running approximately 500 high-availability business systems for its customers. In order to keep this complex environment—a mix of packaged and in-house–developed systems that range from mainframe to mobile—running efficiently while continuing to address the needs of its customers, DB Systel decided to embed processes and tools within its development and maintenance activities to actively address its technical debt.

DB Systel's software developers have employed new tools during development so they can detect and correct errors more efficiently. Using a software analysis and measurement platform from CAST, DB Systel has been able to uncover architectural hot spots and transactions in its core systems that carry significant structural risk. DB Systel is now better able to track the nonfunctional quality characteristics of its systems and precisely measure changes in architecture- and code-level technical debt within these applications to prioritize the areas with highest impact.

By implementing this strategy at the architecture level, DB Systel has seen a reduction in time spent on error detection and an increased focus on leading-practice development techniques. The company also noticed a rise in employees' intrinsic motivation as a result of using CAST.[10] With an effective technical debt management process in place, DB Systel is mitigating the possibility of software deterioration while also enriching application quality.

Countdown to zero technical debt

NASA's Mars Science Laboratory project was classified as a "flagship mission"—the agency's first in almost a decade. It was a $2.5 billion project to land a car-sized, roving science laboratory, Curiosity, on Mars. The rover launched in 2011 and landed on Mars on August 5, 2012, with the continuing objective of determining whether Mars ever contained the building blocks for life.

Building a roving science lab is an immense challenge. Curiosity is an order of magnitude larger than any rover that had previously landed on Mars: It weighs almost a ton, stands seven feet tall, contains a robotic arm that could easily pick up a person, and includes a laser that vaporizes rocks. Curiosity's software is essentially the brain of the rover—integrating its many hardware functions to provide mission-critical functionality such as the descent and landing sequence, autonomous driving, avionics, telecommunications, and surface sample handling.

The software initially developed for Curiosity was inherited from previous rover missions. The core architecture was developed in the 1990s on a shoestring budget. The Curiosity project put approximately four years of work into building on top of that architecture for NASA's most complex mission to date. As the launch date approached, NASA started to see that the project wasn't coming together: The software had bugs and inexplicably failed tests; there were issues with the hardware and the fabrication of key components.

The project faced a difficult question: Do we push on towards a 2009 launch or delay the mission? The unique aspect of launching a mission to Mars is that the opportunity only exists once every 26 months, when Earth and Mars align. If they delayed the launch two years, there was a risk that the project might be cancelled altogether.

The project team decided to postpone the mission and began an incredible regrouping effort. The software team had to quickly decide whether to fix the current software or to start over completely from scratch. Given the existing software's technical debt, it was unlikely they could determine the magnitude of the lurking issues, or confidently plan for new project milestones. The decision was made to tear down the foundation and rebuild using the old code as a reference.

The team started from the beginning: revisiting the requirements, software design, coding, and reviews, and testing and implementing standard processes. The team instituted what they called the "Power Ten," a set of 10 basic rules each developer followed. The team developed coding standards, implemented multiple automated code analyzers and testing tools, and established a cadence of releases—one every four months. They unit tested every line of code and instituted code reviews early in the development lifecycle. Two hundred code reviews produced 10,000 peer comments and 25,000 tool comments—each one reviewed and resolved.

The results were staggering: 3.5 million lines of code, over 1 million hand-written, across 150 different modules. But this time, the numerous bugs and unexplained failures were gone. The standards, though they required additional work, added stability and quality. And with the fresh start, the team were adamant that technical debt be minimized—building a new foundation for future missions.

Though NASA's approach required a remarkably difficult decision, the results were worth the effort. The world can now watch as Curiosity tells us more than we ever dreamed we might know about Mars. And the achievements of the mission led to the announcement of a new $1.5 billion mission to Mars in 2020.

Combating system complexity

Military Health System (MHS), a unit within the United States Department of Defense, provides billions of dollars' worth of health services to over 9 million beneficiaries.[11] Facing enterprise-wide budget cuts, MHS began looking for ways to provide the same level of care with reduced resources. With dozens of IT systems built over 20 years ago, including clinical systems, supply chain, and billing, MHS recognized that reducing its technical debt was one way the organization could reduce its IT budget and improve business efficiency.

MHS embarked on a transformation with portfolio rationalization at the forefront in an effort to streamline its investments. Using an application health grid that removed potential subjectivity, MHS measured the business value, technical maturity, and cost of each of its systems. Business value was determined by how many business processes are supported. The technical maturity analysis focused on four areas: external stability (an evaluation of third-party software, hardware, and associated vendors); internal stability (an architectural evaluation); system availability; and security. The rationalization effort helped MHS identify over a dozen systems with high levels of technical debt that could be decommissioned—saving the organization over $50 million in ongoing operating costs within the first phase of the transformation.

MHS continues to use data-driven analytics implemented through SEMOSS.[12] The transformation that began with portfolio rationalization has now moved into optimization and dynamic portfolio planning. Reviewing a system's technical composition in combination with functional capabilities allows MHS to protect itself against future technical debt and make informed decisions about its overall IT portfolio.

My take

Larry Quinlan, global chief information officer, Deloitte Touche Tohmatsu Limited

Technical debt doesn't just happen because of poor code quality or shoddy design. Often, it's the result of a series of good or necessary decisions made over time—actions individually justified by their immediate ROI or the needs of a project. There are many examples: skipping a software update or infrastructure upgrade because there wasn't a clear business benefit; building point-to-point interfaces into a small departmental app to get it into the business's hands more quickly; choosing a product you already own to build a prototype in order to avoid a drawn-out vendor selection and procurement process.

The path to technical debt can be paved with good intentions, but when combined, can lead you to quality and architectural issues.

But good intentions don't give you a pass to ignore technical debt. Leading IT organizations can, and should, actively manage and reverse technical debt. These organizations have a vision for robust platforms ready to fuel growth and use nimble business-aligned delivery models to innovate, fulfill unexpected business-driven requirements, and ultimately solve business problems.

There are two aspects that are important to technical debt management. The first is to know where you stand. Reversal starts with visibility—a baseline of lurking quality and architectural issues. Develop simple, compelling ways that describe the potential impact of the issues in order to foster understanding by those who determine IT spending. Make technical debt a metric that your IT organization is conscious of—not just in planning and portfolio management, but in how projects get delivered.

The second is with the actual management of technical debt. There are a couple of ways to approach it: a big bang approach that fixes everything at once (which almost never works) or a selective approach to systematically reduce the backlog. Consider what is needed in the next year or two to assist with achieving your strategic goals. This will allow you to identify the parts of your portfolio that should be upgraded to achieve those goals. When it comes to each of your platforms, don't be afraid to jettison certain parts.

At Deloitte, we deliberately separate our IT budget into core and business-driven investments so business users can choose investments driven by their priorities. A server upgrade rarely trumps a functional requirement when battling for fixed investment funds. That's why architecture, platform, and technical debt investments are part of our core investment bucket—with priorities set by the IT organization. My philosophy is: What's the point of having a CIO if I need a committee to approve every upgrade? By keeping the core investments separate from the business-driven investments, we are able to avoid the technical debt we might otherwise accrue.

Preventing technical debt requires a philosophy that addresses the known and expected requirements with an underlying, agile platform. CIOs need the courage to make the investments that reduce technical debt—and the knowledge and the team to know where and when to make those investments.

Where do you start?

Technical debt calculation can begin when you have clear visibility to the quality of code for legacy systems as well as projects on the horizon. Only with both sets of information can you make the trade-offs necessary to manage technical debt effectively. For companies eager to get ahead of the technical debt curve, here are some important steps:

- **Assess the status of code for all significant investments.** Calculate your technical debt. Know the size of the hole you're in—and whether or not it's getting deeper. Evaluate the importance of each system to understand whether the technical debt has to be addressed—and in what timeframe. Aim for surgical repairs when possible, but recognize that some aging systems may be beyond incremental fixes. Prevention is preferred, but early detection at least allows for a thoughtful response.

- **Find out how future investments are dependent on your legacy systems.** Is your architecture ready for new initiatives? Can it scale appropriately? How well are back-end complications understood and fed into planning efforts? Should you launch legacy modernization efforts now to get ahead of impending business demands?

- **Think through the availability of talent to support debt remediation.** For some aging systems, your resources may not be sufficient for cost-effective updating. Talent should be factored into your analysis. Think of it as a multiplier on top of the raw technical debt calculation—and use it to define priorities and timelines.

- **Hold developers accountable.** Consider rating and rewarding developers on the quality of their code. In some cases, fewer skilled developers may be better than volumes of mediocre resources whose work may require downstream reversal of debt. Regularly run code complexity reviews and technical debt assessments, sharing the results across the team. Not only can specific examples help the team improve, but trends can signal that a project is headed in the wrong direction or encountering unexpected complexity.

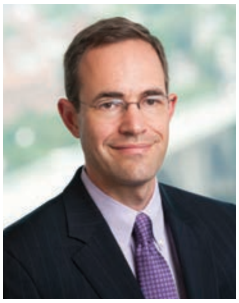
- **Spread the wealth (and the burden).** Communities are great ways to identify and address technical debt. Peer code reviews are leading practices for informal spot checks. Formal quality assessments by seasoned architects can find issues that would be undetectable with standard QA processes. Learn from open source communities, where quality is continuously refined by the extended pool of developers poring over each other's code.[13]

- **Determine your debt repayment philosophy.** Companies have different profiles when it comes to debt for the various parts of their asset pools. Debt is not inherently bad; it can fuel new investments and accelerate product launches. But left unchecked, it can be crippling. There's no single right answer for the appropriate amount of technical debt, but its accumulation should be a conscious, transparent decision.

Bottom line

When CIOs operate like venture capitalists,[14] technical debt is a big part of the financial picture. Without a clear view of the real cost of legacy systems, CIOs lack the information required to make effective decisions about new initiatives and investments. While it's important not to get obsessed with technical debt, it's also critical to understand and plan for it. Every new project automatically comes with technical debt as a cost of doing business. Reversing technical debt is a long-term investment, but if left unaddressed, it can bankrupt your ability to build for the future. Capers Jones, a long-term technical debt specialist, once said: "If you skimp on quality before you deliver software, you end up paying heavy interest downstream after the software is released for things you could have gotten rid of earlier, had you been more careful."[15] He was right.

Authors



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Exponentials

One more thing . . .

EACH year, this report analyzes trends in technology put to business use. To be included, a topic should clearly demonstrate its potential to impact businesses in the next 18 to 24 months. We also require a handful of concrete examples that demonstrate how organizations have put the trend to work—either as early adoption of the concept or "bread crumbs" that point toward the fully realized opportunity. Our criteria for choosing trends keeps us on the practical side of provocative, as each trend is relevant today and exhibits clear, growing momentum. We encourage executives to explore these concepts and feed them into this year's planning cycle. Not every topic warrants immediate investment. However, enough have demonstrated potential impact to justify a deeper look.

Because we focus on the nearer-term horizon, our *Technology Trends* report typically only hints at broader disruptive technology forces. This year, in collaboration with leading researchers at Singularity University, we have added this section on "exponential" technologies, the core area of research and focus at Singularity University. The fields we chose to cover have far-reaching, transformative impact and represent the elemental advances that have formed technology trends both this year and in the past. In this section, we explore five exponentials with wide-ranging impact across geographies and industries: artificial intelligence, robotics, cyber security, additive manufacturing, and advanced computing.

In these pages we provide a high-level introduction to each exponential—a snapshot of what it is, where it comes from, and where it's going. Each exponential stems from many fields of study and torrents of research. Our goal is to drive awareness and inspire our readers to learn more. Many of these exponentials will likely create industry disruption in 24 months or more, but there can be competitive opportunities for early adoption. At a minimum, we feel executives can begin contemplating how their organizations can embrace exponentials to drive innovation. Exponentials represent unprecedented opportunities as well as existential threats. Don't get caught unaware—or unprepared.

My take

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Author, *Abundance: The future is better than you think*

In 2012 the world experienced what I call "the new Kodak moment." A moment in time when an exponential technology put a linear thinking company out of business. Kodak, the company that invented the digital camera in 1976, and had grown to a 145,000-person,[1] 28-billion-dollar global company at its peak, ultimately filed for bankruptcy in 2012 as it was put out of business by the exponential technology of digital imagery. In stark contrast, another company—also in the digital imagery business—called Instagram, was acquired in that same year by Facebook for $1 billion. Instagram's headcount: 13 employees.

These moments are going to be the norm as exponentially thinking startups replace linear businesses with unprecedented products and services. Although a daunting challenge, exponential technologies offer extraordinary opportunities to the businesses that can keep pace with them.

The lessons learned from Kodak are the consequences of failing to keep up with what I call the "six Ds." The first D is digitization. Technology that becomes digitized hops on Moore's Law and begins its march up the exponential growth curve. Like many companies, Kodak was blindsided by the next D—deceptive growth. When a product, such as imagery, becomes digitized, it jumps from a linear path to an exponential trajectory. The challenge is that early exponential doublings are deceptive. The first Kodak digital camera was only 0.01 megapixels. Even though it was doubling every year, when you double 0.01, to 0.02, 0.04, 0.08, 0.16, this doubling of small numbers near zero looks to the mind like linear growth, and is dismissed. It's only when you continue forward past what is called the "knee of the curve" that it begins to change. Double seven times from "1" and you get to 128. Twenty-three more doublings (a total of 30) gets you to 1 billion. Business leaders often perceive the early stages as slow, linear progress. Until, of course, the trend hits the third D—disruption.

By the time a company's product or service is disrupted, it is difficult to catch up. Disruptive growth ultimately leads to the last three Ds—dematerialization, demonetization, and democratization, which can fundamentally change the market. The smartphone in your pocket has *dematerialized* many physical products by providing their virtual equivalents—a GPS receiver in your car, books, music, and even flashlights. Once these equivalents gain market traction, the established product's commercial value can plummet. It becomes *demonetized*. iTunes®,[2] for example, is impacting the value of record stores. eBay is doing the same to specialty retailers. Craigslist has stripped newspapers of classified advertising revenue. Once products become dematerialized and demonetized, they become *democratized*—spreading around the world through the billions of connected devices we carry around.

Many business leaders confront exponentials with a stress mindset. They realize that the odds of survival aren't great. Babson College noted that 40 percent of the Fortune 500 companies in 2000 didn't exist 10 years later.[3] However, the other side of the coin is an abundance mindset—awareness of the limitless opportunity. Between now and 2020, the world's population of digitally connected people will jump from two to five billion.[4] That growth will also add tens of trillions of dollars in economic value.

To land on the opportunity side of the coin and avoid shocks down the road, companies can take two immediate steps:

- **Conduct an impact assessment:** Identify the top five strengths that differentiate your company. Then look at which exponentials could potentially erode those strengths. Also look at the flip side. What are the top five pain points that exponentials could eliminate? How?
- **Evaluate the threat:** Determine how your company's products or services could be dematerialized or demonetized. Exploiting market adjacencies is a key part of the equation. Google, for example, is focusing on autonomous cars and Microsoft continues to make forays into gaming. The goal is to not only figure out who might disrupt your business's pond but whose pond your company can disrupt.

Your competition is no longer multinational powerhouses in China or India. Your competition now is the hyper-connected startup anywhere in the world that is using exponential technologies to dematerialize and demonetize your products and services. Someone in New York can upload a new idea into the cloud, where a kid in Mumbai builds on it and hands it off to a Bangladeshi company to handle production and marketing. Companies need to make sure their plans are in sync with this world and its dynamics.

Lastly, companies should consider their strategy in the context of leveraging two types of exponentials: First, pure exponential technologies such as artificial intelligence, synthetic biology, robotics, and 3D printing; and second, what I call "exponential crowd tools": crowdsourcing, crowdfunding, and prized-based competition incentive models. If companies then marry this portfolio of exponential assets with the understanding that today's grandest societal and planet challenges are also today's most promising commercial market opportunities, it can truly be a formula for abundance.

Exponential snapshots

Artificial intelligence

Computer science researchers have been studying Artificial Intelligence (AI) since John McCarthy introduced the term in 1955.[5] Defined loosely as the science of making intelligent machines, AI can cover a wide range of techniques, including machine learning, deep learning, probabilistic inference, neural network simulation, pattern analysis, decision trees and random forests, and others. For our purposes, we focus on how AI can simulate reasoning, develop knowledge, and allow computers to set and achieve goals.

The ubiquity and low-cost access to distributed and cloud computing have fueled the maturity of AI techniques. AI tools are becoming more powerful and simpler to use. This maturity is the first part of the story: how AI is becoming democratized and can be applied across industries, not just in areas such as credit card processing and trading desks, where AI has been gainfully employed for 45 years. The next part of the story focuses on our desire to augment and enhance human intelligence.

We are increasingly overwhelmed by the flood of data in our lives—1.8 zettabytes of information are being created annually.[6] But we are saddled with an ancient computing architecture that hasn't seen a major upgrade in more than 50,000 years: the brain. We suffer from cognitive biases and limitations that restrict the amount of information we can process and the complexity of calculations we can entertain. People are also susceptible to affectations and social perceptions that can muddy logic—anchoring on first impressions to confirm suspicions instead of testing divergent thinking.

AI can help solve specific challenges such as improving the accuracy of predictions, accelerating problem solving, and automating administrative tasks. The reality is that with the right techniques and training, many jobs can be automated. That automation is underway through many applications in several fields, including advanced manufacturing, self-driving vehicles, and self-regulating machines. In addition, the legal profession is availing itself of AI in everything from discovery to litigation support. DARPA is turning to AI to improve military air traffic control as automated, self-piloted aircraft threaten to overrun air-spaces. In health care, AI is being used in both triage and administrative policies. The world's first synthetic bacterium was created using AI techniques with sequencing.[7] Energy firms are using AI for micro-fossil exploration in deep oil preserves at the bottom of the ocean. AI can also be leveraged for situational assistance and logistics planning for military campaigns or mass relief programs. In sum, AI represents a shift, a move from computers as tools for executing tasks to a team member that helps guide thinking and can do work.

Despite these successes, many of today's efforts focus on specific, niche tasks where machine learning is combined with task and domain knowledge. When we add biologically inspired computing architectures, the ability to reason, infer, understand context, develop evolving conceptual models of cognitive systems, and perform many different flavors of tasks becomes attainable.

In the meantime, AI faces barriers to its widespread adoption. Recognize that in developed nations, its use may encounter obstacles, especially as labor organizations fight its increased use and its potential to decrease employment. The ethics of AI are also rightly a focus of attention, including the need for safeguards, transparency, liability determination, and other guidelines and mechanisms that steer toward responsible adoption of AI. But these realities should not curb the willingness to explore. Companies should experiment and challenge assumptions by seeking out areas where seemingly unachievable productivity could positively disrupt their businesses.

Inspired by lectures given by **Neil Jacobstein**, *artificial intelligence and robotics co-chair, Singularity University*

Neil Jacobstein co-chairs the artificial intelligence and robotics track at Singularity University. He served as president of Singularity University from October 2010 to October 2011 and worked as a technical consultant on AI research for a variety of businesses and government agencies.

Robotics

Mechanical devices that can perform both simple and complex tasks have been a pursuit of mankind for thousands of years. Artificial intelligence and exponential improvements in technology have fueled advances in modern robotics through tremendous power, a shrinking footprint, and plummeting costs. Sensors are a prime example. Those that guided the space shuttle in the 1970s were the size of foot lockers and cost approximately $200,000. Today, they are the size of a fingernail, cost about 10 cents, and are far more reliable.

Robotics is fundamentally changing the nature of work. Every job could potentially be affected—it's only a matter of when. Menial tasks were the early frontiers. Assembly lines, warehouses, and cargo bays have been enterprise beachheads of robotics. But that was only the beginning. Autonomous drones have become standard currency in militaries, first for surveillance and now with weapon payloads. Amazon fulfillment centers are largely automated, with robots picking, packing, and shipping in more than 18 million square feet of warehouses.[8] The next frontier is tasks that involve gathering and interpreting data in real time. Eventually these tasks can be replaced by a machine, threatening entire job categories with obsolescence. Oxford Martin research predicts that 45 percent of US jobs will be automated in the next 20 years.[9]

On the not-so-distant horizon, for example, gastroenterologists won't need to perform colonoscopies. Patients will be able to ingest a pill-sized device with a camera that knows what to look for, photograph and, potentially, attack diseases or inject new DNA. Boston Dynamics is rolling out Big Dog, Bigger Dog, and Cheetah—robots that can carry cargo over uneven terrain in dangerous surroundings. Exoskeletons can create superhuman strength or restore motor functions in the disabled. Remote health care is coming. It will likely arrive first with robotics-assisted virtual consultation, followed by surgical robots that can interpret and translate a surgeon's hand movements into precise robotic movements thousands of miles away. Companies are also pursuing autonomous cars. Personal drone-based deliveries could disrupt retail. The limits are our imaginations—but not for long.

Robotics should be on many companies' radars, but businesses should expect workplace tension. To ease concerns, companies should target initial forays into repetitive, unpleasant work. Too often robotics is focused on tasks that people enjoy. Equally important, companies should prepare for the inevitable job losses. Enterprises should identify positions that aren't likely to exist in 10 years, and leverage attrition and training to prepare employees for new roles. The challenge for business—and society as a whole—is to drive job creation at the same time that technology is making many jobs redundant. Ideally, displaced resources can be deployed in roles requiring creativity and human interaction—a dimension technology can't replicate. Think of pharmacists. After as much as eight years of education, they spend the majority of their time putting pills into bottles and manually assessing complex drug interactions. When those functions are performed by robots, pharmacists can become more powerful partners to physicians by understanding a patient's individual situation and modifying drug regimens accordingly.

At the end of the day, there are two things robots can't help us with. The first is preservation of the human species, a concern more civic and philosophical than organizational. But the second is more practical—indefinable problems. For example, robots can't find life on Mars because we don't know what it might look like. Everything else is fair game. Be ready to open the pod bay doors of opportunity—before your competition does.

Inspired by lectures given by ***Dan Barry****, artificial intelligence and robotics co-chair, Singularity University*

Dan Barry is a former NASA astronaut and a veteran of three space flights, four spacewalks, and two trips to the International Space Station. He is a licensed physician and his research interests include robotics, signal processing with an emphasis on joint time-frequency methods, and human adaptation to extreme environments.

Cyber security

A few hundred years ago, a robbery consisted primarily of a criminal and an individual victim—a highly personal endeavor with limited options for growth. The advent of railroads and banks provided opportunities to scale, allowing marauders to rob several hundred people in a single heist. Today, cyber criminals have achieved astonishing scale. They can attack millions of individuals at one time with limited risk and exposure.

The same technological advances and entrepreneurial acumen that are creating opportunities for business are also arming the world's criminals. Criminal organizations are employing an increasing number of highly educated hackers who find motivation in the challenges of cracking sophisticated cyber security systems.[10] These entrepreneurial outlaws are a new crime paradigm that is reaching frightening levels of scale and efficiency.

A few examples illustrate the daunting landscape: Hackers are available for hire online and also sell software capable of committing their crimes. A few years ago, for example, INTERPOL caught a Brazilian crime syndicate selling DVD software that could steal customer identities and banking information. The purveyors guaranteed that 80 percent of the credit card numbers pilfered through the software would be valid. Its customers could also contact a call center for support.

Cyber criminals are also leveraging the crowd. Flash Robs, for example, are becoming a new craze where social media is used to bring individuals to a specific store to steal goods before police can arrive. Another crowdsourced crime looted $45 million from a pre-paid debit card network. Hackers removed the card limits. Thieves then bought debit cards for $10 and withdrew what they wanted. In just 10 hours, the crowd made more than 36,000 withdrawals in 27 countries.

What looms on the horizon is even more daunting. With the Internet of Things, every car, consumer appliance, and piece of office equipment could be linked and ready for hacking. As fingerprints become the standard means of authentication, biometrics will become a powerful source of ingenious theft.

The experience of the US Chamber of Commerce portends the future. The organization's photocopiers, like many, are equipped with hard drives that store printed documents. In the past, industrial criminals disguised as repairmen removed the devices. However, when the chamber installed thermostats connected to the Internet, hackers could breach the copiers. Officials only discovered the attack through a defect that inadvertently sent the hackers' documents to the copiers.

There are steps that companies can take to combat cybercrime. The first is to establish risk-prioritized controls that protect against known and emerging threats while complying with standards and regulations. Companies should also identify which of their assets would likely attract criminals and assess the impact of a theft or breach. Organizations should then become vigilant and establish situation risk and threat awareness programs across the environment. Security and information event management capabilities can be enhanced and new functionality can be mined from tools including endpoint protection, vulnerability assessment/patch management, content monitoring, data loss prevention, intrusion prevention, and core network services. The final step is building resilience: the ability to handle critical incidents, quickly return to normal operations, and repair damage done to the business.

Companies can also turn to the crowd. Security professionals have knowledge that can help investigations and warn of potential threats. The legal environment is also important. Business leaders should advocate for laws and policies that seek to contain cybercrime and also avail themselves of resources provided by federal agencies.

Cybercrime is accelerating at an exponential pace. In the not-so-distant future, everything from our watches to the EKG monitors in hospitals will be connected to the Internet and ready to be hacked. Companies should be prepared to survive in an environment where these threats are commonplace.

Inspired by lectures given by **Marc Goodman***, chair for policy, law, and ethics and global security advisor, Singularity University*

Marc Goodman is a global strategist, author, and consultant focused on the disruptive impact of advancing technologies on security, business, and international affairs. At Singularity University, he serves as the faculty chair for policy, law, and ethics and the global security advisor, examining the use of advanced science and technology to address humanity's grand challenges.

Additive manufacturing

The technology that supports additive manufacturing, or 3D printing, is more than 30 years old. Its recent popularity has been fueled in part by patent expirations which are driving a wave of consumer-oriented printers. Prices have fallen, putting the technology within the reach of early adopters. 3D printing is democratizing the manufacturing process and bringing about a fundamental change in what we can design and what we can create.

But the story goes much deeper than hobbyists and desktop models. The cost of a 3D printer ranges from a few hundred to a few million dollars. The machines can print with hundreds of materials, including nylons, plastics, composites, fully dense metals, rubber-like materials, circuit boards, and even genetic tissue. Breakthroughs in speed, resolution, and reliability demonstrate potential not only for scale but also for unlocking new possibilities.

The real exponential impact, however, is in the simplicity of the supporting tools. They provide a means to digitize existing objects, customize and tweak open source designs, or create brand new designs based on structural and industrial engineering know-how. Intuitive, easy-to-use tools allow "things" to be created, manipulated, and shared.

In essence, 3D printing makes manufacturing complexity free of charge, allowing otherwise impossible designs to be realized. Objects are built one layer at a time, depositing material as small as 100 nanometers exactly where and when needed. Mechanical items with moving parts can be printed in one step—no assembly required. Interlocking structures mimicking nature's design laws are possible with nearly unlimited geometrical freedom—no tooling, set-ups, or change-overs. Moreover, objects can be built just in time when and where they are needed. The capability unlocks business performance in a highly sustainable manner by reducing inventory, freight, and waste. 3D printing's value is not limited to complex objects.

On-site creation of investment castings or construction molds can supplement traditional manufacturing techniques.

3D printing is not just for prototypes and mock-ups. Many sectors already use the technology for finished parts and products. The aerospace industry, for example, has led the charge on additive manufacturing. Jet engine parts such as manifolds require more than 20 pieces that are individually manufactured, installed, welded, grinded, and tested into a finished product. The 3D printed alternative is easier to build and service and also reduces overall system weight. Medical devices use 3D printing to customize and personalize everything from dental crowns to hearing aids to prosthetics.

The potential doesn't end there. More fantastical use cases are starting to become a reality, such as mass customization of consumer goods, including personalized products ranging from commodities to toys to fashion, with "print at home" purchase options. Even food printers are entering the market, starting with chocolates and other sugar and starch staples, but moving toward meats and other proteins. Organs, nerves, and bones could be fully printed from human tissue, transforming health care from clinical practice to part replacement—and even life extension. Leading thinkers are exploring self-organizing matter and materials with seemingly magical properties. One example is already here: a plane built of composites with the ability to morph and change shape, ending the need for traditional flaps and their associated hydraulic systems and controls.

The enterprise implications are many—and potentially profound. First, organizations should take an honest look at their supply chain and market offerings—and identify where the technology could enhance or replace these offerings. As we discussed in the *Digital engagement* chapter, intellectual property and rights issues will emerge, along with new paths to monetize and disrupt. Finally, business leaders should embrace the democratized creativity the technology is unleashing. Companies can use 3D printing to drive faster product innovation cycles, especially where it can push the boundaries of possibilities based on materials science and manufacturing techniques.

Inspired by lectures given by ***Avi Reichental****, co-chair for nanotechnology and digital fabrication, Singularity University*

Avi Reichental currently serves as faculty co-chair of the additive manufacturing program at Singularity University. He has been the president and chief executive officer of 3D Systems since September 2003.

Advanced computing

Advances in raw computing power and connectivity are frequently the building blocks of our annual tech trends report. Core lessons that have guided us through the Internet revolution remain true today, and are steering us toward exponential advances in the future of computing.

The first lesson is the importance of early adopters and how they personally and commercially kick-start industries and adoption. Early adopters have an insatiable demand for improvement and for the doubling of performance. Moore's Law forecasts how many transistors per dollar could be put onto a chip wafer. Engineering curiosity and scientific prowess have fueled many advances in the field. Nonetheless, to build growth and feed customer demand, companies continue to invest in seismic performance improvements because they know there is a demand for products that are twice as good.

The second lesson is an open, hackable ecosystem with a cost contract that encourages experimentation through its lack of incremental accounting for network usage. From the system kits of the PC revolution to the open source movement to today's Arduino and Raspberry Pi hobbyists, a culture of innovation and personal discovery is driving advances in open groups instead of proprietary labs. Lessons and learnings are being shared that accelerate new discoveries.

The third lesson is that the magical ingredient of the Internet is not the technology of packet switching or transport protocols. The magic is that the network is necessarily "stupid," allowing for experimentation and new ideas to be explored on the edges without justifying financial viability on day one.

On the computing side, we are at a fascinating point in history. Rumblings about the end of Moore's Law are arguing the wrong point. True, chip manufacturers are reaching the theoretical limits of materials science and the laws of physics that allow an indefinite doubling of performance based on traditional architectures and manufacturing techniques. Even if we could pack in the transistors, the power requirements and heat profile pose unrealistic requirements. However, we have already seen a shift from measuring the performance of a single computer to multiple cores/processors on a single chip. We still see performance doubling at a given price point—not because the processor is twice as powerful, but because twice the number of processors are on a chip for the same price. We're now seeing advances in multidimensional chip architecture where three-dimensional designs are taking this trend to new extremes. Shifts to bio and quantum computing raise the stakes even further through the potential for exponential expansion of what is computationally possible. Research in the adjacent field of microelectromechnical systems (MEMS) and nanotech is redefining "hardware" in ways that can transform our world. However, like our modest forays into multi-core traditional architectures, operating systems and software need to be rewritten to take advantage of advances in infrastructure. We're in the early days of this renaissance.

The network side is experiencing similar exponential advances. Technologies are being developed that offer potentially limitless bandwidth at nearly ubiquitous reach. Scientific and engineering breakthroughs include ultra-capacity fiber capable of more than 1 petabit per second[11] to heterogeneous networks of small cells (micro-, pico-, and femtocells[12]) to terahertz radiation[13] to balloon-powered broadband in rural and remote areas.[14]

Civic implications are profound, including the ability to provide education, employment, and life-changing utilities to the nearly five billion people without Internet access today. Commercially, the combination of computing and network advances enable investments in the Internet of Things and synthetic biology, fields that also have the ability to transform our world. Organizations should stay aware of these rapidly changing worlds and find ways to participate, harness, and advance early adoption and innovation at the edge. These lessons will likely hold true through this exponential revolution—and beyond.

Inspired by lectures given by **Brad Templeton**, *networks and computing chair, Singularity University*

Brad Templeton is a developer of and commentator on self-driving cars, software architect, board member of the Electronic Frontier Foundation, Internet entrepreneur, futurist lecturer, and writer and observer of cyberspace issues. He is noted as a speaker and writer covering copyright law, political and social issues related to computing and networks, and the emerging technology of automated transportation.

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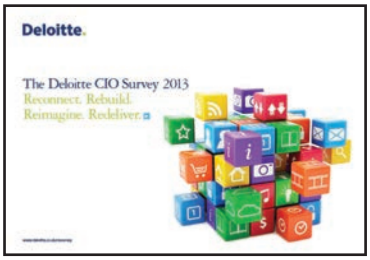

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