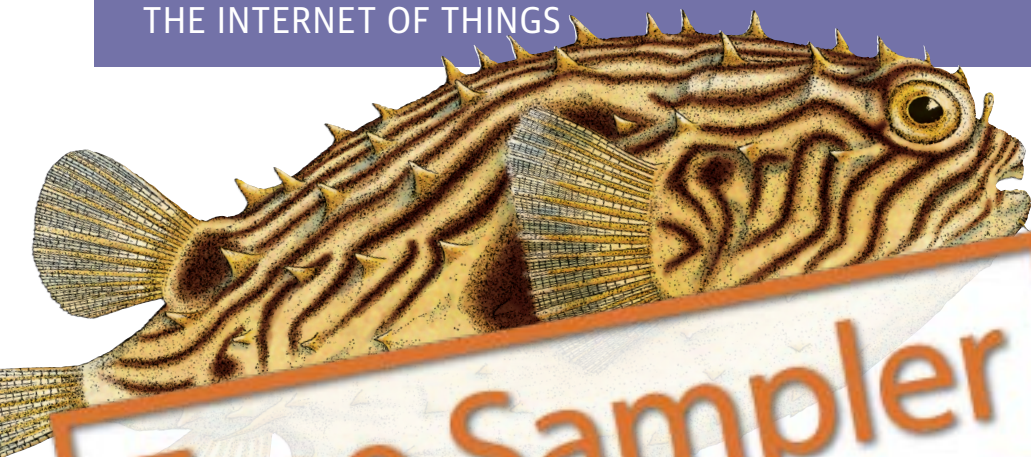


Designing for Emerging Technologies

UX FOR GENOMICS, ROBOTICS, AND
THE INTERNET OF THINGS



Free Sampler

Jonathan Follett, Editor
Foreword by Saul Kaplan

Designing for Emerging Technologies

The recent digital and mobile revolutions are a minor blip compared to the next wave of technological change, as everything from robot swarms to skin-top embeddable computers and bio printable organs start appearing in coming years. In this collection of inspiring essays, designers, engineers, and researchers discuss their approaches to experience design for groundbreaking technologies.

Design not only provides the framework for how technology works and how it's used, but also places it in a broader context that includes the total ecosystem with which it interacts and the possibility of unintended consequences. If you're a UX designer or engineer open to complexity and dissonant ideas, this book is a revelation.

"If you're looking for insights into how to design the future today, look no further."

—Dan Saffer

Author of Microinteractions

"This book is a must-read for anyone involved in innovative product design, new business creation, or technology research for near future applications. The wide collection of essays offers a wild ride across multiple disciplines."

—Carla Diana

Creative Technologist and author

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Designing for Emerging Technologies

UX for Genomics, Robotics, and the Internet of Things

Edited by Jonathan Follett

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Designing for Emerging Technologies

Edited by Jonathan Follett

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Designing for Emerging Technologies

JONATHAN FOLLETT

A Call to Arms

Since the dawn of technology, humanity has lived with both its benefits and burdens. The fire that cooks our food also burns our hands; the mills and factories that produce our clothes often pollute our water and air; the computers that process our data sometimes crash and send our mission-critical records into oblivion. From the Agricultural to the Industrial to the Information Revolution, humanity has enjoyed great advantages from technology, but we have suffered the consequences of flawed thinking regarding its use, resulting in wasteful consumption of our world's resources, problems for our environment, and social disruption. Humanity enters the new millennium struggling with the challenges we've created for ourselves in areas from energy to infrastructure, transportation to healthcare, and manufacturing to agriculture. To address these challenges, we will no doubt turn once again to technology: in the coming century, we'll be able to hack our DNA, embed computers in our bodies, and print replacement organs. The question is, what will we do when we find ourselves with the capability to do just about anything we can dream of?

To explore that question—at least from a design perspective—let's consider the implications of four significant emerging technologies whose growth, maturation, and widespread commercial adoption has the potential to disrupt the current economic order:

- A networked, intelligent world connected by the Internet of Things (IoT)
- More efficient and effective manufacturing, healthcare, and disaster relief aided by advanced robotics
- Custom, just-in-time manufacturing, driven by additive fabrication/3D printing
- Medicine, food, and fuel created by altering the code of life itself, through genomics and synthetic biology

Through the lens of these disruptive technologies, we'll look at what designing products, services, and experiences for people might require and examine some of the high-level user experience (UX) tenets practitioners might consider when approaching the design for such new fields.

Today, we're on the cusp of a significant technological period, not unlike the Second Industrial Revolution that occurred in America from the end of the Civil War until World War I, when major discoveries and inventions completely transformed the economic, social, and political fabric of the United States. During this particularly prolific era, inventors, innovators, and scientists such as Alexander Graham Bell, Thomas Edison, Henry Ford, and Nikola Tesla introduced the world to technologies that would define modern life in the twentieth century. These included the light bulb, the telephone, and the mass-produced automobile, among many others. The light bulb and basic electrical service provided the cornerstones of the electric age, while the telephone started a communication revolution, and the automobile began an era of personal transportation that would alter the landscape of America itself. Historically, this period provides a powerful example of the systemic disruption that occurs when multiple technological innovations emerge, mature, and reach popular adoption along roughly the same timeline. Just as the inventions of the Second Industrial Revolution transformed the United States on almost every level, robotics, additive fabrication, the IoT, and synthetic biology similarly have the potential to define and shape our next era.

As these technologies evolve, they will influence humanity's progress as a species, making the tumult of our current Information Revolution look like a minor blip by comparison. Although the miracles of our age are many, computers, the Internet, and mobile devices primarily serve to *accelerate* human communication, collaboration, and commerce. Without dismissing their importance, we observe that many existing models of interaction have been enhanced, rather than transformed, by moving from the physical to the digital realm—becoming cheaper, faster and, perhaps, better in the process. Email is an accelerated version of the postal service, e-commerce, a more convenient and efficient version of the brick-and-mortar store, and so on. Conversely, in technologies such as synthetic biology and additive fabrication, we can see the potential to remake our current order in substantial fashion, with the formation of entirely new industries and the birth of new markets.

A May 2013 McKinsey Global Institute report titled “Disruptive technologies: Advances that will transform life, business, and the global economy,” identifies the global markets ready for disruption and describes the potential economic value of this transformation. Genomics has the potential to alter the \$6.5 trillion healthcare and \$1.1 trillion agriculture industries through products such as personalized medicines and genetically modified foods. Additive fabrication/3D printing and advanced robotics will upend the global manufacturing industry—affecting the \$6 trillion in labor expenditures and \$11 trillion in global manufacturing GDP, respectively. And, the IoT will disrupt the manufacturing, healthcare, and mining industries to the tune of \$36 trillion.¹

Design for Disruption

Let's look briefly at the disruptive potential of each of these emerging technologies—the IoT, advanced robotics, 3D printing, and synthetic biology—and the need for design thinking in their formation.

1 James Manyika, Michael Chui, Jacques Bughin, Richard Dobbs, Peter Bisson, and Alex Marrs. “Disruptive technologies: Advances that will transform life, business, and the global economy.” May 2013; McKinsey Global Institute Report (<http://bit.ly/1CJ2q8v>).

THE IOT, CONNECTED ENVIRONMENTS, AND WEARABLE TECHNOLOGY

The IoT is a popular shorthand that describes the many objects that are outfitted with sensors and communicating machine-to-machine. These objects make up our brave, new connected world. The types and numbers of these devices are growing by the day, to a possible 50 billion objects by 2020, according to the Cisco report, “The Internet of Things: How the Next Evolution of the Internet Is Changing Everything.”² Inexpensive sensors providing waves of data can help us gain new insight into the places in which we live, work, and play, as well as the capabilities to influence our surroundings—passively and actively—and have our surroundings influence us. We can imagine the possibilities of a hyper-connected world in which hospitals, factories, roads, airways, offices, retail stores, and public buildings are tied together by a web of data.

In a similar fashion, when we wear these sensors on our bodies, they can become our tools for self-monitoring. Combine this capability with information delivery via Bluetooth or other communication methods and display it via flexible screens, and we have the cornerstones of a wearable technology revolution that is the natural partner and possible inheritor of our current smartphone obsession. If we consider that the systems, software, and even the objects themselves will require design input on multiple levels, we can begin to see the tremendous opportunity resident in the IoT and wearables.

ROBOTICS

In 2013, Google’s purchase of eight robotics companies (which are to be consolidated into a new division led by Andy Rubin, the former head of its successful Android operating system) was publicly heralded as an inflection point for the robotics industry. Not coincidentally, the stocks of competitors such as iRobot rose dramatically.³

2 Dave Evans. “The Internet of Things: How the Next Evolution of the Internet Is Changing Everything.” April 2011; Cisco White Paper (<http://bit.ly/1CJ2sNE>).

3 John Markoff. “Google Puts Money on Robots, Using the Man Behind Android.” December 4, 2013; The New York Times (<http://nyti.ms/1CJ2tkR>).

More so than any other emerging technology, robotics has captured the imagination of American popular culture, especially that of the Hollywood sci-fi blockbuster. We're entertained, enthralled, and maybe (but only slightly) alarmed by the legacy of *Blade Runner*, *The Terminator*, *The Matrix* and any number of lesser dystopian robotic celluloid futures. It remains to be seen if robot labor generates the kind of societal, economic, and political change depicted in the more pessimistic musings of our culture's science fiction. Ensuring that it does not is a design challenge of the highest order.

In the near term, robots are ideal for taking care of jobs that are repetitive, physically demanding, and potentially hazardous to humans. As such, immediate opportunities for advanced robotics lie in areas where human labor is still intensive, such as manufacturing and logistics.

3D PRINTING

Additive manufacturing—more popularly known as 3D printing—is a process of creating a three-dimensional object by printing one miniscule layer at a time, based on a computer model. This flexible technology can use a wide variety of substrates including plastic, metal, glass, and even biological material. Custom production using additive manufacturing techniques promises to disrupt many industries, from construction to food to medicine. Possibilities for this technology range from immediately practical applications such as printing new parts just-in-time to fix a broken appliance; to controversial, uncomfortable realities, including generating guns on demand; to hopeful and futuristic methods, perhaps the ability to create not just viable human tissue, but complete, working organs, which could be used in transplants or for the testing of new drugs and vaccines.

Today, additive manufacturing is already changing architecture and construction. In April 2014, WinSun, a Chinese engineering company, reported that it can construct 10 single-story homes in a day by using a specialized 3D printing technology that creates the main structure and walls using an inexpensive combination of concrete and construction waste materials.⁴

4 "China: Firm 3D prints 10 full-sized houses in a day." April, 25 2014; BBC News (<http://bbc.in/1CJ2r1E>).

In the field of health, the work of roboticist Easton LaChapelle represents the change made possible by additive fabrication in medical-device prototyping and production processes. The 17-year-old wunderkind has created an ultra-light, fully functioning prosthetic arm whose parts can be 3D-printed for about \$500. Traditionally manufactured prosthetic arms that are currently available can cost upward of \$80,000. LaChapelle's prosthetic arm is controlled using an EEG headset, which measures brainwaves and communicates with the arm wirelessly via Bluetooth.

At the Business Innovation Factory BIF9 conference in Providence, Rhode Island, held in September 2013, LaChapelle demonstrated his invention and discussed his amazing progression through the design and prototyping phases. The first generation of the product LaChapelle created was a robotic hand, made of Lego bricks, surgical tubing, and five servo motors. He created the second-generation robotic arm by using 3D-printed parts and a Nintendo Power Glove. Now in its third generation, the arm is made almost entirely of 3D-printed parts, and most dramatic of all, it has human strength. While LaChapelle has not made the leap from prototype to a manufacture-ready device, it's easy to imagine the potential for disruption in the market it represents.

From a process standpoint, LaChapelle's methods in designing and engineering the prosthetic demonstrate the speed at which ideas can move from a designer's imagination to becoming something real and testable. Even though prototyping has always been a part of the designer's toolkit, additive fabrication makes it possible to apply the same rapid and flexible process of ideation, creation, testing, validation, and iteration to physical products that used to be reserved for the realm of digital development.

GENOMICS AND SYNTHETIC BIOLOGY

In April 2003, the publicly funded Human Genome Project completed the sequencing of the entirety of our human DNA, providing the blueprint for building a person at a price of \$3 billion. At the time, this scientific achievement was heralded as one of the greatest in history, with far-reaching implications for health and medicine. Then-President Bill

Clinton, in announcing the working draft sequence of the Human Genome in 2000, said “Without a doubt, this is the most important, most wondrous map ever produced by human kind.”⁵

Fast forward just slightly more than a decade, and the cost of sequencing a human genome has dropped to roughly \$1,000—an exponential reduction in price far exceeding what Moore’s Law would predict. A host of companies are racing to introduce technology to make even more rapid and inexpensive sequencing possible. With the widespread affordability of this sophisticated test quickly becoming reality, genomics can provide the map for a new wave of personalized therapies: highly targeted drugs for fighting cancer, cardiovascular disease, diabetes, and other hereditary illnesses.

As with genomic sequencing, the price of DNA synthesis continues to drop. It now approaches 25 cents per base pair or less via services such as GenScript, DNA 2.0, and others. Writing the code of life is the cornerstone of the science of synthetic biology; the intentional design and engineering of biological systems will make incredible things possible. In his book *Regenesis*, George Church, geneticist, Harvard professor, and perhaps the most well-known scientist in this field, outlines some of the inventive solutions offered by this future potential, including bio-fuels, targeted gene therapies, and even virus-resistant human beings. In Church’s expansive vision, we see a future in which humans have the capability to design nature itself, changing the fabric of biology and human evolution.⁶

If advanced robotics, additive fabrication, synthetic biology, and other emerging technologies extend humanity’s grasp, making it possible for us to achieve our goals in manufacturing, health, energy, and other industries rapidly and efficiently, they also will place their own set of demands upon us. The fields of graphic design, industrial design, and software UX design have all evolved in response to the unique demands of new technologies. It’s a classic human characteristic to relate to and interact with our latest tools. Graphic design makes information

5 “Breaking News—President Clinton, British Prime Minister Tony Blair Deliver Remarks on Human Genome Milestone.” June 26, 2000; CNN.com Transcripts (<http://bit.ly/1CJ2xky>).

6 George Church and Edward Regis. *Regenesis: How Synthetic Biology Will Reinvent Nature and Ourselves*. 2012; Basic Books.

depicted in printed media clear, understandable, and beautiful; industrial design makes products elegant, usable, and humane; and UX design makes the interaction with our digital products and services efficient and even pleasurable.

Historically, bridging this gap between man and disruptive technology has not been an easy task. In addition to the positive outcomes of the Industrial Revolution, the political, societal, and economic change across the globe also engendered negative responses by people whose lives and livelihoods were displaced. Most famously, the Luddites in England sabotaged machines in the factories, preferring to destroy the technology they felt would ruin man's existence, rather than proceed forward in concert with it. Mass production similarly had its tensions with traditional craftsman—from woodworkers to painters to architects—who responded by creating the influential Arts and Crafts movement in the late 1800s. And, in the literature of the time, industrialization faced one of its most enduring critiques in Mary Shelley's *Frankenstein*, which articulated most eloquently the idea that science left unchecked and pursued for its own sake was not to be trusted. We, too, can expect that the road to adopting the emerging technologies of our time will be subject to societal tensions and negative reactions, critiques, and counter-movements, which is all the more reason for designers to involve themselves early.

Eight Design Tenets for Emerging Technology

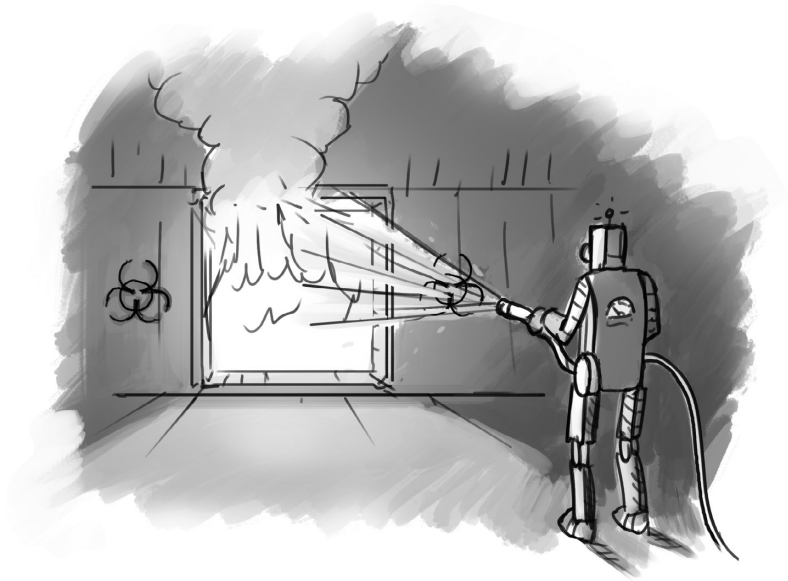
As we face a future in which the definition of what it is to be human might be inexorably changed, we will need design to help frame our interactions with technologies, from skin-top embeddable computers to bioprinted organs to swarming robots, which often seem to be racing ahead of our ability to process and manage on an emotional, ethical, and societal level. Designers have an opportunity to help define the parameters of and sculpt the interactions between man and technology, whether we're struggling with fear and loathing in reaction to genetically altered foods, the moral issues of changing a child's traits to suit a parent's preferences, the ethics guiding battlefield robots, or the societal implications of a 150-year extended lifetime. At its best, not only can design provide the frame for how technology works and how it's used, it can also situate it within a broader context: incorporating system thinking, planning for a complete technological lifecycle, and evaluating the possibility of unintended consequences.

Our field of practice will be transformed, as well, and we must prepare for it by moving from design as facilitation, shaping the interface and workflow, to design as the arbiter, driving the creation of the technology itself and applying our understanding of interaction, form, information, and artistry to new areas. To balance those asking, “How can this be done?” we should ask, “Why should we do this, to what end, and for whose benefit?” We must move from being passive receptors of new technology to active participants in its formation. As design thinkers and practitioners we’re called to be explorers. And, although it’s true that not every designer will want or be able to follow this path, those who do will have an opportunity to contribute in significant fashion.

Today, design work is changing at an unprecedented pace, and we are all too aware of the need to constantly evolve our skills to match the demands of the marketplace. With this uncertainty comes opportunity: the design positions of the future are not yet defined. Just as there was no industrial, graphic, or interaction designer at one time, so too the designer of emerging technologies has, at least for now, a broad canvas to explore. How we bring our current skills to bear on new problems, how we determine new subjects to learn, and how we integrate with burgeoning new industries will all play a part in the way our emerging design practices form.

What competencies will be most important for the designer in these new areas? What approaches will be most effective for managing the disruptive power of emerging technologies? What thinking processes will help the designer negotiate the technical, social, and ethical complexities that emerging technology will inevitably present? As a first attempt at answering these questions, the tenets that follow articulate some high-level guidelines for creative thinking and process development, drawing broad-based inspiration from related professional fields, including architecture, art, ethnography, engineering, and most of all, user experience. Although these tenets are certainly also applicable to knowledge work in a general sense—for the scientist, technologist, or entrepreneur—we will consider them in the context of design for emerging technology.

1. IDENTIFY THE PROBLEMS CORRECTLY



The gap between the problems we face as a species and the seemingly unlimited potential of technologies ripe for implementation begs for considered but agile design thinking and practice. Designers should be problem identifiers, not just problem solvers searching for a solution to a pre-established set of parameters. We must seek to guide our technology, rather than just allow it to guide us.

On the cover of the November/December 2012 issue of MIT Technology Review, the shortcomings of the past decade's technological achievements are expressed in the damning headline dramatically superimposed in white type over the bemused portrait of astronaut Buzz Aldrin: "You Promised Me Mars Colonies. Instead I Got Facebook." The subhead elaborates tellingly: "We've stopped solving big problems. Meet the technologists who refuse to give up." The accompanying article "Why We Can't Solve Big Problems"⁷ details some of the current limitations in American culture, finance, and politics that, since the Apollo moonshot, have relegated big thinking and technical aspirations to the sidelines. The author, however, concludes the following:

⁷ Jason Pontin. "Why We Can't Solve Big Problems." MIT Technology Review, October 24, 2012 (<http://bit.ly/1CJ2zJ9>).

It's not true that we can't solve big problems through technology; we can. We must. But all these elements must be present: political leaders and the public must care to solve a problem, our institutions must support its solution, it must really be a technological problem, and we must understand it.

We are on the cusp of a new technological age, saddled with the problems of the previous one, demanding that as we step forward we do not make the same mistakes. To do this, we must identify the right challenges to take on: the significant and valuable ones. Chief among our concerns must be the environment, not only in reducing the carbon we release as a result of consumption and seeking new sources of energy, but also in understanding the effects of a growing global population, against the backdrop of limited resources. We must also improve human health and consider the ramifications as humans live longer lives. And, we must find new ways to manufacture goods and produce food and clean water for a planet currently with 7.2 billion inhabitants—a population that is projected to explode in the next 35 years by an additional 2.4 billion, reaching 9.6 billion by 2050, according to the UN report, “World Population Prospects: The 2012 Revision.”⁸ Recognizing these major challenges for humanity in the twenty-first century and seeking proactive solutions, even in significant areas such as the environment, energy, health, manufacturing, agriculture, and water usage, will not be an obvious or easy task.

We can see an example of this in the tragic events of the Fukushima meltdown. On March 11, 2011, a 9.0 magnitude earthquake and subsequent tsunami damaged the Fukushima Daiichi nuclear reactors in Japan. Over the course of 24 hours, crews tried desperately to fix the reactors. However, as, one by one, the backup safety measures failed, the fuel rods in the nuclear reactor overheated, releasing dangerous amounts of radiation into the surrounding area. As radiation levels became far too high for humans, emergency teams at the plant were unable to enter key areas to complete the tasks required for recovery. Three hundred thousand people had to be evacuated from their homes, some of whom have yet to return.

⁸ United Nations, Department of Economic and Social Affairs, Population Division (2013). World Population Prospects: The 2012 Revision (<http://esa.un.org/wpp/>).

The current state of the art in robotics is not capable of surviving the hostile, high-radiation environment of a nuclear power plant meltdown and dealing with the complex tasks required to assist a recovery effort. In the aftermath of Fukushima, the Japanese government did not immediately have access to hardened, radiation-resistant robots. A few robots from American companies—tested on the modern battlefields of Afghanistan and Iraq—including iRobot’s 710 Kobra (formerly Warrior) and 510 PackBot were able to survey the plant.⁹ The potential for recovery-related tasks that can and should be handled by advanced robotics is far greater than this. However, for many reasons, spanning political, cultural, and systemic, before the Fukushima event, an investment in robotic research was never seriously considered. The meltdown was an unthinkable catastrophe, one that Japanese officials thought could never happen, and as such, it was not even acknowledged as a possible scenario for which planning was needed.

The Fukushima catastrophe inspired the United States Defense Advanced Research Projects Agency (DARPA) to create the Robotics Challenge, the purpose of which is to accelerate technological development for robotics in the area of disaster recovery. Acknowledging the fragility of our human systems and finding resilient solutions to catastrophes—whether it’s the next super storm, earthquake, or nuclear meltdown—is a problem on which designers, engineers, and technologists should focus.

In the DARPA competition mission statement, we can see the framing of the challenge in human terms.

History has repeatedly demonstrated that humans are vulnerable to natural and man-made disasters, and there are often limitations to what we can do to help remedy these situations when they occur. Robots have the potential to be useful assistants in situations in which humans cannot safely operate, but despite the imaginings of science fiction, the actual robots of today are not yet robust enough to function in many disaster zones nor capable enough to perform the most basic tasks required to help mitigate a crisis situation. The goal of the DRC is to generate groundbreaking research and development

⁹ Marina Koren. “3 Robots That Braved Fukushima.” *Popular Mechanics* (<http://bit.ly/1CJ2DZu>).

in hardware and software that will enable future robots, in tandem with human counterparts, to perform the most hazardous activities in disaster zones, thus reducing casualties and saving lives.¹⁰

The competition, so far, has been successful in its mission to encourage innovation in advanced robotics. In the competition trials held in December 2013, robots from MIT, Carnegie Mellon, and the Google-owned Japanese firm, Schaft, Inc., competed at a variety of tasks related to disaster recovery, which included driving cars, traversing difficult terrain, climbing ladders, opening doors, moving debris, cutting holes in walls, closing valves, and unreeling hoses.

2. LEARN CONSTANTLY



Designers will need to understand the implications of science and technology for people. To do this effectively, we must be able to immerse ourselves in new technical domains and learn them quickly. Just as our understanding of and empathy for people allows us to successfully

¹⁰ “DARPA Robotics Challenge.” DRC. <http://www.theroboticschallenge.org/> (accessed June 10, 2014)

design with a user's viewpoint in mind, understanding our materials, whether they be pixels or proteins, sensors or servos, enables us to bring a design into the world. To achieve this, designers need to be early adopters of technology, learning constantly.

The ability to quickly learn new materials and techniques has always been one of the most important of a designer's core competencies. However, the speed at which this is expected and at which technological change occurs is the critical difference today. *How* we learn will soon become as important a consideration as *what* we learn. To prepare designers for the new roles that emerging technology will bring, schools will need to develop curricula that emphasize continuous learning as a core competency and provide tools and methods to enable it.

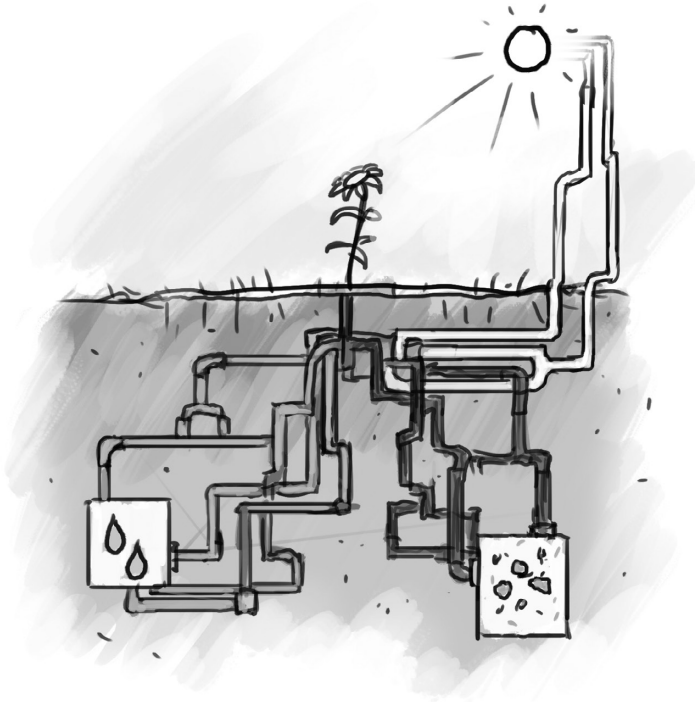
AIGA, the professional association for design, and Adobe Systems, Inc., the design software giant, released research, "Defining the Designer of 2015," based on the input of 2,500 designers and a variety of experts and focused on the future of the field.¹¹

In order to fulfill the expectations placed upon designers in the future, they will need to employ a set of skills that include some beyond today's typical scope. No single designer is likely to have all the skills required, yet this research revealed the range of competencies that a studio or design department, among its full complement of staff, will need in order to meet the demands of the future.

Although the AIGA/Adobe survey results focus largely on communication-related design, it acknowledges that among the competencies needed by the designer of 2015, the need for "understanding of and ability to utilize tools and technology" and the "ability to be flexible, nimble and dynamic in practice." Ultimately, designers will need to be lifetime learners.

11 "Defining the Designer of 2015." AIGA. <http://www.aiga.org/designer-of-2015/> (accessed June 10, 2014)

3. THINK SYSTEMICALLY

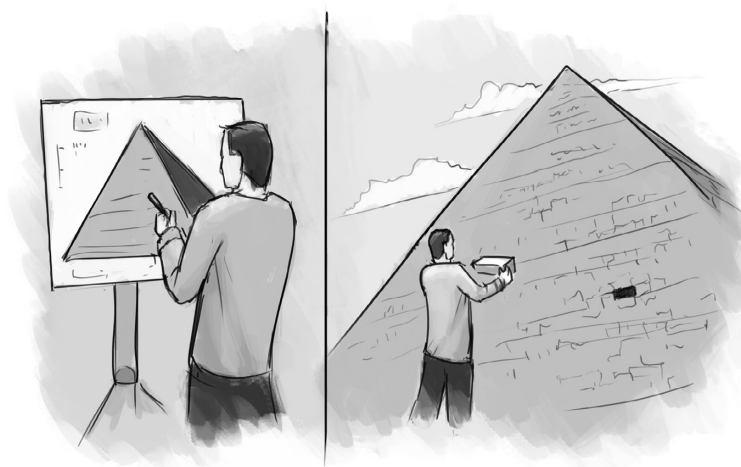


Increasingly, designers will also need to be system thinkers. As we consider the fields of advanced robotics, synthetic biology, or wearable technology, the design of the ecosystem will be just as important as the design of the product or service itself.

A good example of such a product is Mimo, a next-generation baby-monitoring service that goes far beyond the usual audio and video capabilities in soothing the anxieties of new parents. A startup company led by a group of MIT engineering grads called Rest Devices has created an ingenious baby “onesie.” It’s a connected product that delivers a stream of data including temperature, body position, and respiration information, ensuring that mom and dad are fully versed in the minutiae of their offspring. What at first glance might seem like the enablement of over-parenting paranoia, could, in fact, also provide valuable scientific data, particularly given that crib death or SIDS (Sudden Infant Death Syndrome) is a phenomenon that is still not fully understood.

From a design perspective, a company such as Rest Devices has a range of needs typical of those startups in the budding wearable technologies industry. The onesie itself must be designed for both functional and aesthetic elements—a mixture of industrial design for the “turtle” on-body device that houses the sensor and the fashion design of the garment itself. The mobile software application that provides the data interface requires interaction design and visual design—not to mention the UX design of the total system, which must be optimized for setup and navigation by nervous parents. Whether one person or many provide these different design skills for Rest Devices, it’s clear that at every point at which people touch the technology, there is ample opportunity for the interaction to be carefully examined and optimized in relation to the entire ecosystem. In this way the Mimo is a good example of the first wave of wearable technology. Like the Nike FuelBand, the Fitbit, and even the Recon heads-up ski display, these wearables represent technology embedded into the infrastructure of our lives in a way never before seen. But the magic of the consumer experience of these products is only possible through the design of a complete, and hopefully seamless, ecosystem.

4. WORK AT A VARIETY OF SCALES



Designers should be able work at a variety of scales, from the aforementioned overall system view, to the nitty-gritty details. Moving between these levels will be important, too, as each one informs the other—the macro view informs the micro, and vice versa.

At the highest level, designers can work proactively with politicians and policy makers to effectively regulate new technology. As one example of this, in September 2013, the FDA released final guidance on mobile medical apps, which was crafted with input from industry experts. From bioethics to industrial regulations governing the use of robotics, designers will want and need to have input into the realm of policy. Just as free markets cannot exist without effective and enforceable contract law, so, too, technological advancement cannot exist without sensible, effective, and enforceable regulation with a long-term view. Designers will need a seat, not just at the computer or the lab bench, but at the policy-making table, as well.

At Involution Studios, an experience design firm, we've worked with healthcare industry clients on emerging technology projects such as genomics research software and connected medical devices. As one depiction of how design thinking can be utilized at the organizational level, one engagement we recently completed for the Personal Genome Project (PGP) at Harvard University exemplifies how design research tools and techniques can help cutting-edge organizations focus on human-centered problems.

Founded in 2005 by George Church, the mission of the Personal Genome Project (PGP) is to sequence and publicize the genomes of 100,000 volunteers for use by the scientific community in the improvement and management of human health and disease. When Involution first engaged with the PGP, however, everyone on the team saw the organization functioning slightly differently, with different objectives.

It was clear that the volunteer members—those who were donating their genome and medical histories—were the type of people who were willing to take on great risk to help advance scientific discovery. The PGP had done a good job of educating their members on the possible perils that could come with publishing their genomic data for the world to see. However, the members received little to no feedback on whether their information was being used by the scientific community, how it was being used, or the potential impact of their contributions. Because members could reclaim their contributions at any time, the PGP needed to find a way to better nurture these relationships so that the project could continue striving toward its goal of 100,000 participants.

Involution and the PGP collaboratively mapped the organization's ecosystem to better visualize how it was functioning. "It was time for us to step back and talk about what that overarching goal was, and we did that through this workshop. It was very helpful," said Jason Bobe, executive director of the PGP, who believes the workshop gave his team members a forum to tease out their big ideas as well as their roles within the organization. As a result of sketching, brainstorming, and mapping exercises, the PGP team members were able to see the risks and benefits of their organizational model through the lens of the many different users they were serving. "We had a team where we had a bunch of ideas about what we were doing, but we didn't have a cohesive, shared understanding of how we were going to do everything we wanted to do," said Bobe. With Involution's help, the team was able to uncover multiple challenges that were holding the PGP back. The result from the workshop was significant: a complete reimagining of the PGP's organizational model, separating member recruitment efforts from data collection and sequencing, and truly focusing on member relationships.

5. CONNECT PEOPLE AND TECHNOLOGY



Design should provide the connective tissue between people and technology. The seamless integration of a technology into our lives is almost always an act of great design, coupled with smart engineering; it's the "why" that makes the "what" meaningful. It is through this humane expression of technology that the designer ensures a product or service is not just a functional experience, but one that is also worthwhile. We must consider the outputs of these technologies—what people need and want. The designer should ask: "Why are we doing these things? How is humanity represented against what's possible with technology?" It is the designer's duty to be a skeptic for the human side of the equation.

For instance, as robots take a greater role in the fields such as manufacturing by automating repetitive and dangerous tasks, as well as augmenting human abilities, we can see that even though there are many benefits, there remains a question as to how such robotic optimization can coexist with meaningful work for people in the long term. At first glance, the combination of collaborative robotics and agile manufacturing seems to be one potential answer to this problem. Rethink Robotics' Baxter, Yaskawa Motoman's Dexter Bot, and Universal Robotics' UR are examples of collaborative robots designed with human-like characteristics, flexibility regarding the tasks they can execute, and ease of programming, opening up new possibilities for working in tandem with human workers on the factory floor. In this model, human labor is augmented by, not replaced with, the robotic technologies.

Advanced collaborative robotics could readily provide the flexible systems required to meet the demands of agile manufacturing. A key advantage to robotic manufacturing is its adaptability: robotic production lines can be easily modified to accommodate shorter-run, customized products. We could soon see robots replace expensive dedicated industrial machinery made for specific production processes, which can be extremely difficult to repurpose when changes to a process are required. As a part of this agile manufacturing paradigm, robots with the ability to work in collaboration with human beings—in factories, warehouses, and other industrial settings—will be a critical component. Human workers will be responsible for programming, monitoring, supervising, and otherwise interacting with a robotic workforce that is repurposed regularly to handle the creation of custom, short-run production.

6. PROVOKE AND FACILITATE CHANGE



It is not only the designer's responsibility to smooth transitions and find the best way to work things out between people and the technology in their lives; it is also the designer's duty to recognize when things are not working, and, rather than smooth over problems, to provoke wholesale change. Technological change is difficult and disruptive. Even today, there are countless examples of technologies outpacing the frameworks for controlling them, resulting in a sense of unease in people about the seemingly unprecedented and unchecked advances, from digital surveillance encroaching on our privacy to genetically modified foods filling our grocery stores. Designers can start the discussion and help lead the process of transformation.

As one illustration of this, despite the seemingly unlimited potential of genomics, or perhaps because of it, the tension between those who wish to move the science forward and those cautioning restraint is palpable. Take the example of 23andMe, a company that provides inexpensive personal DNA sequencing. In November 2013, the United States Food and Drug Administration (FDA) shut down the service for

supplying medical interpretation of the DNA data in the reports the company issued to its customers.¹² Here's the notice that appeared on the 23andMe website:

At this time, we have suspended our health-related genetic tests to comply with the U.S. Food and Drug Administration's directive to discontinue new consumer access during our regulatory review process. We are continuing to provide you with both ancestry-related genetic tests and raw genetic data, without 23andMe's interpretation. ... We remain firmly committed to fulfilling our long-term mission to help people everywhere have access to their own genetic data and have the ability to use that information to improve their lives.

The FDA's action brings into question the future regulatory environment that scientists, entrepreneurs, designers, and engineers could encounter in the realm of personalized medicine. The regulator's dilemma for emerging tech is that the rules governing familiar industries might not apply to technology likely to be disruptive to those industries. In the case of 23andMe, regulators must balance the benefits of customers learning about diseases they carry or are at risk for with the dangers of false positives, misuse, or misinterpretation of the data. 23andMe is disruptive because it provides personal genomic testing at a low price point. It also ventures into territory never before seen by an industry familiar with expensive testing regimes typically administered in a reactive, rather than proactive, manner.

In December 2013, the Presidential Commission for the Study of Bioethical Issues released its report, "Anticipate and Communicate: Ethical Management of Incidental and Secondary Findings in the Clinical, Research, and Direct-to-Consumer Contexts." This document provides guidance on how to manage the issues of incidental and secondary findings.

How clinicians, researchers and direct-to-consumer companies manage incidental and secondary findings will likely touch all of us who seek medical care, participate in research, or send a cheek swab to a company for a peek at our own genetic make-up," said Amy Gutmann,

¹² Chris Welch. "FDA orders 23andMe to halt sales of DNA test kit." The Verge. <http://bit.ly/1CJ2GEt> (accessed June 10, 2014)

Ph.D., Commission Chair. “The reality is that we might find out more than we bargained for. Yet practitioners are getting conflicting advice about how to manage such findings across contexts and modalities such as genetics, imaging, and biological specimen testing. We all need to know how to better manage health information we did not expect.”¹³

As designers, we need to be engaged in proactive, society-wide conversations such as this so that we can help define safe boundaries and people-centric policies ahead of time, rather than trying to figure things out—and spend time defending our industries’ very existence—after the horse has left the gate.

7. WORK EFFECTIVELY ON CROSS-DISCIPLINARY TEAMS



The challenges inherent in much of emerging technology are far too great for an individual to encompass the requisite cross-domain knowledge. For this kind of work, then, the team becomes paramount. It is a multidisciplinary mix of scientists, engineers, and designers who are best positioned to understand and take advantage of these technologies. And, it is crucial that these creative disciplines evolve together.

13 “Bioethics Commission on Incidental Findings: Anticipate and Communicate.” December 12, 2013; Presidential Commission for the Study of Bioethical Issues (<http://bioethics.gov/node/3186>).

From such collaborations new roles will be created: perhaps we will soon see a great need for the synthetic biological systems engineer or the human-robot interaction designer. This cross-pollination of science, design, and engineering is already happening at organizations such as the Wyss Institute at Harvard, whose mission is to develop materials and devices inspired by nature and biology. Wyss structures itself around multidisciplinary teams. Forward-thinking design firms such as IDEO have also added synthetic biology to their established practices of industrial and digital design.

As an example of this cross-pollination, in a presentation, “Life is what you make it,” given at a Friday Evening Discourse at The Royal Institution of Great Britain in London, esteemed scientist and Imperial College professor Paul Freemont described how biological design could take its cues from computer software engineering, using an abstraction hierarchy for biological design.¹⁴ In the design of complex systems, an abstraction hierarchy makes it possible for engineers to focus on solving the problems at hand because they don’t necessarily need to understand the complexity of the lower levels of the hierarchy. In software development, for example, engineers can code in Java or C++ and not need to understand the machine-level code that ultimately executes the program. In the coming revolution in biological design, such an abstraction hierarchy will offer bioengineers the capability to operate similarly.

Although programming might be an apt analogy for that manipulation of nature, there are fundamental differences between the writing of computer code and genetic code. Even if we know the outcome of the genetic code we write, the environment into which it is released is far more complex than the controlled operating system of a computer or mobile device. There is so much unknown about biological systems that prototyping and testing will be critical steps for responsible innovation. Even though designers won’t necessarily need to become genetic engineers to contribute to the field of synthetic biology, they’ll need to understand the materials just as deeply.

¹⁴ Paul Freemont. “Life is what you make it.” November 29, 2013; The Royal Institution, Friday Evening Discourse. (<http://bit.ly/1CJ2Mfj>).

At Boston University, the Cross-Disciplinary Integration of Design Automation Research (CIDAR) lab is creating bioCAD tools such as Clotho, an open source software framework for engineering synthetic biological systems. The larger goal for Clotho—named for the Greek goddess of Fate who was responsible for spinning the thread of human life—is to create standardized data, algorithms, and methodologies for synthetic biology. Other software tools such as Genome Compiler and Gene Designer aim to improve the process of genome creation from design to quality assurance to fabrication. At the intersection of software design and genome design, these tools for automating aspects of the synth bio process are cross-disciplinary efforts.

8. TAKE RISKS, RESPONSIBLY



To find our way forward as designers, we must be willing to take risks—relying upon a combination of our education, experience, and intuition—which can be crucial to innovation. We must always keep in mind both the benefits and consequences for people using these new technologies, and be prepared for mixed results.

The Glowing Plant Kickstarter project is a good example of such inspired risk taking in action. There is perhaps no technology more fraught with perceived peril than genomics and synthetic biology. Seeing the opportunity to both inspire and educate the public, a team of biochemists started a project to generate a bioluminescent plant, which they touted as “the first step in creating sustainable natural lighting.” Financed on the crowd-funding website Kickstarter, the Glowing Plant project generated so much grassroots excitement that it raised \$484,013 from 8,433 backers, far exceeding its initial goal of \$65,000.

However, soon after the Glowing Plant project finished its campaign, Kickstarter, without any explanation, changed its terms for project creators, banning genetically modified organisms (GMOs) as rewards for online backers.¹⁵ Glowing Plant, with its project financing already in place, might be the last example of crowd-funded synthetic biology for a while. Although this incident, in and of itself, might seem minor, it’s worth remembering that Kickstarter is the primary resource for crowd-funding in the United States. Removing this financial option for synthetic biology startups, in a seemingly arbitrary decision, will have a chilling effect on future innovators.

The results of the Glowing Plant crowd-funding project illustrate the promise and perils of designing for such a disruptive technology as synthetic biology. How do we evaluate the risk and reward, in this case, knowing the outcome? Even though the team initially received immense grassroots enthusiasm and financial backing, they also caused the Kickstarter ban, as an established corporate entity reacted with fear. During this transition time between fear and acceptance, designers of genetically modified organisms, like the team behind the Glowing Plant project, will continue to push the envelope of what companies, regulators, and the government find acceptable. It’s safe to say

15 Duncan Geere. “Kickstarter bans project creators from giving away genetically-modified organisms.” August 2, 2013 (<http://bit.ly/1CJ2QvH>).

that until synthetic biology is better understood, policy decisions such as this ban will continue to happen. It might be that a willingness to push forward and to take risks will be important to making the transition, to reach public acceptance and ultimately help move the technology forward.

Changing Design and Designing Change

People are less interested in the science and engineering, the mechanisms that make emerging technologies such as advanced robotics, synthetic biology, and the IoT possible, but they are deeply concerned with the outcomes. As these technologies emerge, grow, and mature over the coming years, designers will have the opportunity to bridge human needs and the miraculous technological possibilities.

It will be a great and even intimidating challenge to involve design early in the process of defining new products and services, but it will be critical as we establish the practices of the twenty-first century—from the design of technology policy, to systems, to tactical interaction frameworks and techniques. Policy design will involve advising regulators and politicians on the possibilities and perils of emerging tech; system design will demand clear understanding of the broader interactions and implications that surround the immediate details of a product; and framework design will benefit our day-to-day tactical work, providing a foundation for designers and design practice to come. What all of these technologies will create, as they evolve together, remains to be seen. But, the most interesting discoveries will be at the intersections.

Understanding new technologies, their potential usage, and how they will impact people in the short and long term will require education and collaboration, resulting in new design specializations, many of which we have not yet even considered. In the coming years, as the boundaries between design and engineering for software, hardware, and biotechnology continue to blur, those who began their professional lives as industrial designers, computer engineers, UX practitioners, and scientists will find that the trajectory of their careers takes them into uncharted territory. Like the farmers who moved to the cities to participate in the birth of the Industrial Revolution, we can't imagine all of the outcomes of our work. However, if history is any indicator, the convergence of these technologies will be greater than the sum of its parts. If we are prepared to take on such challenges, we only have to ask: "What stands in the way?"

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