DESIGNING REALITY

How to Survive and Thrive in the Third Digital Revolution
Imagine: The year is 1965. Gas is thirty-one cents per gallon. The Beatles have just released the album *Help!* The Watts riots are raging in Los Angeles. *The Sound of Music* is leading at the box office. Digital Equipment Corporation introduces the PDP-8, the first computer to use integrated circuit technology, for eighteen thousand dollars.

You’re sitting in a packed coffee shop in San Jose drinking a cup of joe (venti half-sweet no-foam caramel macchiatos have yet to be invented). The only open seats are at your table. A group enters, talking animatedly. They’re all holding the latest issue of *Electronics* magazine and are clearly bubbling over with excitement. One of them asks if they can sit at your table. Sure, you say.

You listen in as the group—researchers, it turns out, at a nearby semiconductor company—talk excitedly about an article in the magazine. What they’re saying seems completely far-fetched. They’re talking about how, one day, computers will be small enough to fit in a pocket or be worn like a watch. How these “personal” computers will be as powerful as a mainframe computer. How, in the near future, all these computers will be connected, enabling anyone, anywhere, to access, manipulate, and share information with anyone, anywhere.

The more they go on, the more their vision of the future sounds fantastical. After all, computers are enormous machines filling entire rooms and run by leading research institutions and big companies. They’re expensive and require highly trained operators. The idea that computers could fit in a pocket or be connected seems like something out of Arthur C. Clarke or *Dick Tracy* or *The Jetsons* and not any near-term reality that you need to pay attention to. You can’t help but express your skepticism to your tablemates.
The researchers pause and nod as if they’ve heard this skepticism before. What has made them so excited isn’t just that computer technologies are increasing in performance, but that they’re doing so at an exponential rate. That kind of change, they explain, can be hard to see in the early phase, before the change becomes so explosive that it is obvious to everyone. And yet, they argue, all the signs of accelerating computing performance are there—if you know where to look. And they insist they know where to look. They’re brimming with confidence. You’re both skeptical and intrigued. Fine, you say. Where, exactly, should you look?

Encouraged, the researchers begin to explain. First, they say, look at the very nature of digital technology—specifically, what enables digital technologies, unlike most everyday technology, to accelerate at an exponential rate. They compare digital computers to another recent invention, the Xerox machine. Unlike a computer, they explain, a Xerox machine employs an analog process. If, for example, you wanted to make an exponential number of Xerox copies of a document, you’d feed the first copy into the machine and make a copy. You’d then feed the two copies back into the machine to make four copies, then eight, then sixteen, and so on. By the time you get to thousands of copies, let alone a million or a billion of them, most of the copies would be nothing more than a garbled mess because of the accumulated imperfections in the copying process—the information they contained would be lost.

This is not the case with digital technologies, they explain. Digital messages are converted into symbols (ones and zeros). By adding an ongoing process of error correction to the system, a digital machine can double the number of these messages repeatedly without losing any information. This, the researchers explain, is the essence of digital. It enables billions of digital messages to be manipulated and shared with no loss of clarity. Further, the error correction is so cheap that the messages have almost no marginal cost of reproduction. This basic science, they argue, will drive revolutionary changes throughout society.

One of the researchers then opens a copy of *Electronics* magazine and shows you the article they are all excited about. It is written by a man named Gordon Moore, head of research and development at Fairchild Semiconductor, where they work. You’re amused at the article’s wonderfully direct title: “Cramming More Components onto Integrated Circuits.” In the article, Moore makes the case that the number of components on an integrated circuit has been doubling annually and that he expects the trend to continue for at least ten years. The researchers are excited because this trend is essential to computers’ ability to become smaller, cheaper,
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and faster—and it’s happening at an accelerating pace. If Moore’s prediction is right—if computing performance does continue to double during the next ten years, then by 1975, computers will be a thousand times faster. Considering this trend, Moore predicts the development of “such wonders as home computers—or at least terminals connected to a central computer—automatic controls for automobiles, and personal portable communications equipment.” He goes on in the article: “The electronic wristwatch needs only a display to be feasible today.” You were right to think of Dick Tracy and the Jetsons; that is exactly what Moore is predicting.

The researchers continue to explain. The increasing power of computers makes other digital technologies possible and more powerful as well. For example, one of the researchers is working on a contract from the Department of Defense’s Advanced Research Projects Agency to show how computers can communicate over long-distance data networks. Another researcher points out that they are developing computers that will eventually be able to defeat humans at difficult games like chess. These developments, along with many others like them, will intersect and build on each other, laying the foundation for enormous change across every sector of the economy, as well as for culture and society in general.

As your tablemates continue, you become convinced that this is indeed something you need to pay attention to. The exact timing may be unclear, but you realize that you may have just been given a truly unique opportunity to see around the corner into a radically different future. Now you just have to decide what to do with this knowledge.

If you are an entrepreneur, you will probably begin thinking about the potential for new, disruptive business opportunities. If you are the leader of an existing business organization, you are likely to try to use the technologies to gain competitive advantage and to shed or transform parts of your business destined to become obsolete. If you are a leader of a public institution, you might begin to assess how these powerful technologies will reach everyone, not just the fortunate few—how they might be leveraged to enhance the public good and mitigate potential harm. Regardless of who you are, you will consider how these new technologies will have an impact on your personal and professional life. At the very least, it is clear: a digital revolution is coming.

MISSED OPPORTUNITIES

In fact, over the last half century, two digital revolutions have come to pass, more spectacularly than Moore himself predicted. The first digital
revolution was in communication, taking us from analog phones to the Internet. The second digital revolution was in computation, bringing us personal computers and smartphones. Together they have fundamentally changed the world.

As early as 1965, the signs of the coming digital revolutions were there for anyone to see. And yet most of the world missed them. As a result, few were prepared for the deep economic, social, and cultural impacts of the first two digital revolutions. Moore’s prediction, now known as Moore’s Law, didn’t just last for the ten years he first projected; it has held for fifty years. And computers are now approximately a billion times as powerful as they were in 1965, and they do fit in your pocket and on your wrist.

The technology has continued to advance at an exponential pace, but individuals, organizations, and institutions have largely been playing catch-up, struggling to keep pace. The struggle is at all levels of society—individuals whose lives are increasingly mediated by digital technologies; organizations whose operating models are constantly being disrupted by accelerating technologies; and institutions, such as government, education, and law, that are struggling to maintain stability amid constant change.

The deeper these technologies penetrate society, the greater the struggle for society to keep pace. The best time to shape the destiny of transformative, accelerating technologies is early, before changes have become both widespread and entrenched. This is when the embedded assumptions in the technology and the initial market instantiations are in the early stages of formation and still negotiable. The revolutions in digital communication and computation have enabled unprecedented productivity, generated enormous wealth, and catalyzed remarkable changes in everyday life. But a great many people have also been left behind.

Today, more than a half century after the publication of Gordon Moore’s paper, over half the planet still has no Internet access altogether, while billions more have limited or unreliable access. In much of the world, a combination of growing income and wealth inequality, technological unemployment, and social polarization, driven by digital echo chambers and “always-on” social media, are ripping at the very fabric of society. Many people feel a deep-seated longing for a simpler, more meaningful and less turbulent future.

The negative aspects of the first two digital revolutions are not simply accidents. Nor were they driven by some unseen hand. Decisions made (and not made) and priorities set (and not set) early on, as the technologies were being developed and introduced to the market, have had lasting
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We built breakthrough digital communication capabilities, but we failed to build in cultural norms, feedback loops, and algorithms that could have reinforced civil discourse. We created incredibly efficient new models of digital commerce, but have also introduced new threats to privacy and security. We value the advances made possible with digital automation, even as we struggle with the impacts of lost jobs due to technology.

It would have been impossible, of course, to foresee and forestall all the negative consequences of the first two digital revolutions. However, by waiting decades to prioritize helping individuals, organizations, and institutions co-evolve with the technology, we have missed great opportunities to proactively create value and mitigate harm as the technologies were developing. In 2015, President Obama declared that “high-speed Internet is a necessity, not a luxury”—like electricity or water. That was a half century after the publication of Moore’s paper. Imagine if developing a culture of digital inclusion, digital and programming literacies, and digital civility was a shared public-private priority starting in the mid-1960s. Imagine if there had been as much social innovation shaping the impact of the technology as there was innovation in the science and technology itself—so that both the social and the technical systems had more effectively co-evolved.

We largely missed this opportunity with the first two digital revolutions. But we now have another chance. It comes with the third digital revolution—in fabrication.

THE THIRD DIGITAL REVOLUTION

The third digital revolution completes the first two revolutions by bringing the programmability of the virtual world of bits into the physical world of atoms. Since that physical world is out here where we live, the implications of the third digital revolution may be even greater than those of its predecessors. This revolution is built on the same fundamental science of digital, only now it enables both bits and atoms to be exponentially manipulated. Just as communications and computation went from analog to digital, resulting in personal computers, mobile phones, and the Internet, the digitization of fabrication offers the promise of personal fabrication, enabling individuals and communities to produce and share products on demand, wherever and whenever something is needed.

The similarities between digital fabrication and digital communication and computation are striking. Much like the early mainframe computers,
most serious digital fabrication today is done with enormous machines run by highly trained operators at leading research institutions and big companies. Soon, however, the power that lies in these enormous machines will become accessible to anyone—just as the computer you carry in your pocket has the power of what was once a mainframe computer. We can already see around the corner into a future where anyone can turn data into things and things into data, and can share this information across an Internet of bits and atoms.

As with the early stages of the first two digital revolutions, this vision seems, well, fantastical. And yet, not only is this vision theoretically possible, we are already on an exponential path to it becoming a reality. Fab labs, community-based labs where individuals can access powerful tools for digital fabrication, have been doubling in number every year and a half, since the first lab was established in 2003. Like the early years of the first two digital revolutions, however, the exponential nature of the third digital revolution is not readily apparent to the casual observer. As inventor and futurist Ray Kurzweil points out in his book *The Singularity Is Near*, “exponential growth is deceptive. It starts out almost imperceptibly and then explodes with unexpected fury—unexpected, that is, if one does not take care to follow its trajectory.”

*Designing Reality* is about taking care to follow the exponential trajectory of digital fabrication. It aims to help you use this knowledge to both prepare for and shape the third digital revolution. In small and possibly big ways, everyone has agency to contribute to this revolution. We do not need to wait a half century for future political, educational, and philanthropic leaders to realize that fab access and literacy is a necessity, not a luxury. We are still in the early stages of the third digital revolution. Research priorities are being formulated, core technologies are developing, and the organizations and institutions essential to universal fab access and literacy are emerging.

Every new technology has inherent attributes that affect the capabilities and behaviors of people using the technology. Digital technologies enable rapid duplication, manipulation, and propagation of content. This property has been central to the transformation of virtually every sector of the economy, how we spend our leisure time, and how we connect with each other. Over the past few decades, we have seen the economic and social impact—both positive and negative—of our ability to duplicate, modify, and share music, videos, blogs, news, email, text messages, and other digital material at virtually no additional marginal cost. This capability is inherent in the very nature of the technology.
Digital fabrication shares some, but not all, of the attributes of digital communication and computation. In the first two digital revolutions, bits changed atoms indirectly (by creating new capabilities and behaviors); in the third digital revolution, the bits will enable people to directly change the atoms. This difference is not yet literally at the atomic level (for most people), but it does mean the ability to use digital design interfaces to modify the physical world. Despite the enormous changes brought on by the first two digital revolutions, much of the physical world around us—roads, houses, appliances, transportation, food—have remained remarkably the same. But in the third digital revolution, the very nature of how the physical world around us is constructed will change. Across the global network of fab labs, we can already see a steady stream of innovations around cost-effective models for individuals and communities to make clothing, furniture, toys, computers, and even houses and cars through designs sourced globally but fabricated locally. These capabilities will continue to improve over time, with exponentially better, faster, and cheaper digital fabrication technologies.

The third digital revolution taps into a deeply held human desire to make things. As Dale Dougherty, founder of Make magazine, points out in his book Free to Make, “making engages us fully and deeply as human beings, and it satisfies our creative souls,” and helps us “see ourselves as confident, capable and creative individuals.” Whether it is a machinist at home in a basement workshop, a farmer at a fab lab in rural India, or a twelve-year-old kid at a Maker Faire DIY gathering, making things is deeply satisfying and inspires hobbyists, artists, inventors, engineers, and enthusiasts.

We can see the early signs of the transformative power of digital fabrication in the work of fab pioneers from around the world. Throughout this book, we will meet people like Blair Evans from the Incite Focus fab lab in Detroit. Blair has developed a thirty-acre parcel of land on Detroit’s East Side and is boldly exploring new social and economic models where everyone can choose to “work and spend less, create and connect more.” Building personal and community self-sufficiency is not a new idea, but Blair and his colleagues are showing how digital fabrication platforms can accelerate self-sufficiency when the platforms are used to collaboratively produce practical goods, from food to furniture.

This increasing ability to make what one consumes at a personal or community level will help address one of the greatest challenges emerging from the first two digital revolutions—the number of jobs being replaced by technology. Some estimates project that as many as half of all jobs
could eventually be automated because of advancements in artificial intelligence, robotics, and other rapidly accelerating technologies. These losses are not just blue-collar jobs such as factory work or truck driving, but also white-collar jobs ranging from paralegal work to radiology, and even computer programming. There is debate as to whether new jobs, associated with the new technologies, will make up for lost ones. Even if this emerges (and that is by no means certain), there will be gaps between the loss of old jobs and the emergence of widely accessible new ones. The toxic blend of technologically driven unemployment, income and wealth inequality, and constant change driven by digital technologies, have left many people feeling unmoored and angry, driving nationalist movements throughout the world. These are big challenges, yet the increasing democratization of manufacturing could lead to a more appealing future where personal and community self-sufficiency is combined with global interdependence and knowledge sharing—grounded in capability rather than fear. It could help break down the false dichotomy of globalization and local self-sufficiency, and help transcend political divides.

The foundation for a more sustainable and enriching future is happening not only at a personal and community level, but also on a city and country scale. Another fab pioneer we will meet, Tomas Diez, from the Barcelona fab lab, is leading a global Fab City movement. At the tenth annual global convening of fab labs, the mayor and the chief architect of Barcelona made a bold commitment. They pledged that in forty years, Barcelona would replace its global supply chains with sustainable local production—becoming a city able to make what it needs. This declaration is not a throwback to the craft era, but rather a vision for a postindustrial city where bits that travel globally can manipulate atoms that stay locally to empower cities to become sustainable. Following the Barcelona declaration, several other cities and a few countries, from Santiago to Shenzhen, from Boston to Bhutan, have signed on. Tomas describes the Fab City movement: “We need to reinvent our cities and their relationship to people and nature by re-localizing production, so that cities are generative rather than extractive, restorative rather than destructive, and empowering rather than alienating.”

We also introduce fab pioneers working in indigenous communities from Alaska to the Amazon. These innovators are using advanced technologies to keep alive ancient practices for local self-sufficiency and community building. Providing more effective tools to use local materials to collaboratively solve local challenges taps into a deep desire on the part of many people in both traditional and modern societies to be more
connected to nature and the physical world around them. Even the most ardent proponents of digital technologies recognize the risk of being sucked into ever-more-enticing social media and immersive virtual worlds. We see anxiety about this risk in the Silicon Valley execs who send their children to “tech-free” schools and in the broader trends such as digital-free holidays and initiatives like the National Day of Unplugging. The third digital revolution can help drive us toward a more healthy balance of time spent in the digital world of bits and the “real” world of atoms.

These aspirational visions will only be urged into existence if we engage and inspire individuals, create the needed organizations, and transform the inherited institutions. The first steps are in recognizing that we are, indeed, on the cusp of a third digital revolution and in understanding its trajectory. The signs are all there, and Designing Reality will show you where to look. It will show you how we know the third digital revolution is happening, why it’s happening, and, crucially, how you can prepare for and help shape it as it happens.

When exploring exponential technologies, we can very easily fall into either a dystopian vision of the future, where humans have little agency as the technology runs amok and robots steal all our jobs, or be lulled into a techno-utopian vision of the future, where we can just sit back and technology will solve our problems. Both these extremes are continually reinforced in popular media. As we have seen with the first two digital revolutions, the reality is much more textured. The benefits and risks of accelerating technologies are very real, with deep impacts on many lives, but we have the agency, individually and collectively, to shape these impacts now.

We can all help bend the arc of the third digital revolution to create a more self-sufficient, interconnected, and sustainable society. Such a transition will not happen overnight. There will be continued employment for work that cannot be replaced, along with new jobs that leverage these digital fabrication technologies. As individuals and communities increasingly make what they consume, emerging models will challenge our conceptions of work—providing new options for balancing how we will live, learn, work, and play. Making this blend of societal arrangements benefit everyone won’t be easy. Yet, if we see a billionfold increase in the capability and reach of digital fabrication technologies over the next few decades, we can realize the vision of working and spending less while creating and connecting more. We could build on the Fab City vision of a society that is “generative rather than extractive, restorative rather than destructive, and empowering rather than alienating.”
Designing Reality is written around two broad themes that are together essential for realizing the power and promise of digital fabrication: understanding the technology powering the third digital revolution, and advancing the social systems that must co-evolve with the technology.

TECHNOLOGY

Your guide for understanding the technology is Neil Gershenfeld, director of the Center for Bits and Atoms (CBA) at MIT. Neil has been working at the frontier of digital fabrication for two decades and has a track record of seeing around the corner into the future of digital technologies. His 1999 book, When Things Start to Think, anticipated and helped shape what became known as the Internet of Things. His 2005 book Fab described the emergence of fab labs and the maker movements, introducing many people to the power and promise of digital fabrication.

Now, in Designing Reality, Neil shows how these trends have added up to a third digital revolution that can be seen today after a decade of the spread of the technologies for digital fabrication; how it can be historically understood through the alignment of all three digital revolutions; and how it can be seen in the future in an evolving research roadmap. He shows how the hype surrounding 3D printing is just the tip of a much bigger story, leading up to a Star Trek–style replicator that can make (almost) anything, including itself. It will do this by digitizing not just the designs of things but also the construction of the materials that they’re made of.

Neil opens in Chapter 1 with the story of the accidental origin of the fab lab movement from his How to Make (almost) Anything class at MIT. He then provides a tour of how community fab labs are being used across the global network, highlighting how today’s digital fabrication processes are already empowering people. From the northern tip of Norway to the southern tip of Africa, from rural villages to sprawling cities, community-based fab labs have sparked an outpouring of innovation, providing early indications of the power and potential of digital fabrication.

From the present, Neil then explores in Chapter 3 the history of the core scientific foundations of the third digital revolution. He explains how these go back four billion years to when life evolved the machinery for molecular manufacturing and how the underlying principles of reliability, modularity, locality, and reversibility serve as the core ideas that unify digital communication, computation, and fabrication. He highlights the
historical lesson that the implications of these processes could be seen and used long before the technology had reached its final form.

Neil anchors this section with an introduction to Lass’ Law, an analogue to Moore’s Law for digital fabrication. The law is named for Sherry Lassiter (aka Lass). Along with leading the Fab Foundation (the nonprofit that supports the fab lab network), Lassiter manages outreach for CBA. As the pile of fab lab requests on her desk grew, she first noticed that the number of fab labs was doubling roughly every year and a half.

When Neil wrote *Fab*, he neither planned for nor envisioned this exponential growth. At the time, CBA had only recently launched the first few fab labs. For Neil, the year 2003 was the equivalent of 1959, the start of the data points that Gordon Moore had plotted. Now, after more than a decade of the number of fab labs doubling—along with continued advancements in the research roadmap and a growing fab ecosystem—we can predict a likely exponential trajectory for digital fabrication performance and reach.

As with Moore’s Law after its first decade, we can extrapolate this exponential growth. At the time, CBA had only recently launched the first few fab labs. For Neil, the year 2003 was the equivalent of 1959, the start of the data points that Gordon Moore had plotted. Now, after more than a decade of the number of fab labs doubling—along with continued advancements in the research roadmap and a growing fab ecosystem—we can predict a likely exponential trajectory for digital fabrication performance and reach.

This brings us to Neil’s Chapter 5, a roadmap for the future of digital fabrication. He opens the chapter with an inventory and a description of the current tools in a fab lab. He then outlines four distinct stages: community fabrication (powered by computers controlling machines), personal fabrication (based on machines that can make machines), universal fabrication (marking a transition to digital materials), and ubiquitous fabrication (with programmable materials). Each of these stages represents an exponential improvement in digital fabrication performance.

Much as the core elements of the first two digital revolutions were visible in the labs of the mid-1960s, when Gordon Moore wrote his article, all the core elements of the third digital revolution are visible in research labs today. The question is, how long it will take for them to emerge from the lab and impact society? And will we be ready?
SOCIETY

Your guides for exploring how social systems can effectively co-evolve with the accelerating technologies of the third digital revolution are Joel Cutcher-Gershenfeld and Alan Gershenfeld. Joel is a professor in the Heller School for Social Policy and Management at Brandeis University and past president of the Labor and Employment Relations Association. He has researched and facilitated large-scale systems change in the auto industry, the aerospace industry, health care, biomedicine, and the non-profit sector. Joel is a macro social scientist with a track record for advancing theory and practice in negotiations and high-performance work systems. He is now pioneering new models for multi-stakeholder alignment within and across levels: workplace, enterprise, community, industry, national, and international levels.

Alan is president and co-founder of E-Line Media, a “double-bottom-line” company (committed to both positive financial returns and meaningful social impact), harnessing the power of digital media and games to help people understand and shape their world. In his work at E-Line and in his former roles as a studio head at Activision and board chair for Games for Change, he has worked on social-impact media projects with NSF, DARPA, USAID, the White House Office of Science and Technology Policy, the Smithsonian, PBS, the Gates Foundation, the MacArthur Foundation, and others that have collectively engaged and empowered millions of people all over the globe.

Both Joel and Alan have been collaborating with Neil in the fab lab movement since the launch of the first lab, where Joel and his oldest son volunteered for many years. Joel also helped launch a fab lab in Champaign-Urbana, Illinois, and has led the application of new stakeholder alignment methods across the fab network. Alan has researched sustainable business models for fab labs, and E-Line has worked on a DARPA-funded video game exploring the future of digital fabrication, in collaboration with the Fab Foundation and CBA. In conducting research for this book, Joel and Alan have visited fab labs throughout the world, interviewed dozens of fab pioneers, and surveyed hundreds of stakeholders.

Neil explores the technology roadmap and offers tools and techniques for leveraging the technology; Joel and Alan explore the social roadmap and offer methods and mind-sets so the social systems can co-evolve with the technical systems. In Chapter 2 Joel and Alan also open by observing
the current global network of fab labs. But unlike Neil, they don’t only present exhilaration and empowerment; they also highlight the tensions and challenges that permeate the fab network. Despite the promise of personal fabrication and individuals’ ability to make what they consume, digital fabrication is still a long way from being a reality for most people. There are significant challenges around fab access, literacy, and the cultivation of an ecosystem that ensures truly democratized technologies. A close look at these challenges is essential if we are to address them. Observing disconnects throughout the fab ecosystem provides a window into the embedded underlying assumptions and conflicting values. Today, the benefits of fab labs come more from the process of making than they come from the result, because of the difficulty of mastering current workflows. Over time, this balance will need to change if the impact of digital fabrication is to move beyond just the cultivation of new skills and dispositions to increasingly make what we consume.

Like Neil, Alan and Joel then turn to the past. In Chapter 4, they highlight how Moore’s Law is as much a social construct as a technical one. Moore’s Law was never a law of physics, but rather an observation that became a core business strategy for a company, an industry benchmark, and finally a galvanizing framework for better, faster, cheaper digital technologies. The chapter illustrates how the interweaving of social and technical change is not new—how the modern social sciences, that is, the study of human societies and relationships, began in reaction to the rise of the industrial revolution. And yet, because the social sciences began by reacting to technology, the dominant practice in this field is the observation of technology rather than its co-creation. Taking a more proactive stance begins with understanding rates of change for individuals, organizations, and institutions, which takes on new meaning in a world of accelerating technologies. This points to the key roles of rate limiters and rate accelerators to positive social change, as well as lessons learned from the first two digital revolutions in harnessing the power of digital platforms and emergent ecosystems to effectively co-evolve technical and social systems.

Joel and Alan conclude with specific guidance for shaping the future of digital fabrication (Chapter 6). They describe eight aspirational scenarios, jointly created with fab pioneers across five continents. In these scenarios, social systems and technical systems co-evolve in transformational ways. To shape the future, we need mental maps for not just possible futures, but for preferable ones. To help transform these preferable futures
into reality, Joel and Alan offer a framework for fostering new mind-sets and applying effective methods so that everyone can find meaning, purpose, and dignity in the third digital revolution.

*Designing Reality* brings the perspectives of science, technology, social science, and humanities to the third digital revolution—through three brothers who are not only observers of the revolution but also active participants in helping guide it. Each brother brings a different lens to the book. Like all lenses, each brother’s clarifies some things and makes other things less clear. Their disagreements have been even more important than their agreements as they came together to write this book. The same is true any time very different sectors or domains need to collaborate around complex, rapidly changing technology to accomplish collective goals—collaboration that the third digital revolution demands.

This is a unique historical moment: we can foresee the likely trajectories, and it is still early enough that we can shape the technology before it shapes us in ways we will regret. The stakes are high. If our projection is correct, the third digital revolution will have as much impact as, if not more impact than, the first two digital revolutions. We will soon be facing a torrent of new opportunities and challenges that go to the very heart of how we exist. Literacy scholar James Paul Gee from Arizona State University summarizes the opportunity and challenge in his essay “Literacy: From Writing to Fabbing”:

Fab could create a world with yet deeper inequalities than we currently have, a world where only a few engage in the alchemy of turning ideas into bits into atoms and back again. The rest will live in a world where the stuff of life and the world—objects, cells, materials—are owned and operated by only a few. Fab is a new literacy and we have as yet no real idea how it will work out. But it is a special and, in some sense, final one.

How many of us will get to be homo fabber? Humans have always been the ultimate tool makers. Soon the tools for world making will be cheap enough to be in the hands of everyone, should we want to make that happen. Will we, as a species, make a better world or a worse one when some or many or all of us become god-like creators, calling worlds into being? Fab is to literacy what fire was to human development: a tool that can light the way or burn it down.
Will we light the way or burn it down? We have the agency, individually and collectively, to tip this balance. As digital fabrication becomes increasingly democratized, we’ll have the ability to leverage bits to manipulate atoms to improve lives. We will be able to design reality, both metaphorically and literally.