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CHAPTER 1

Introduction: Guiding Technology's Promise

In the 1960s when today's explosion of high technology first began, we were wowed by the "ape" scene in the classic movie, *2001: Space Odyssey*. The scene dramatically captures the fundamental power of technology to drive human progress, a power we are rediscovering daily. It is one of the great icons of the Information Age.

In the movie, an ape discovers that an old bone makes a great club. For the first time ever, one of our ancestors has created a tool. He can use it to break things. Defend himself. Kill his enemy. After affirming this novel idea, the ape raises his club to deliver a blow previously well beyond his power, and the swelling music announces that a crucial watershed has been reached. Technology has arrived, initiating the upward march of human history. During the next few million years, this pivotal force allowed mere apes to make the long journey to our present world of biogenetic engineering, quantum computers, and space exploration.[1] That is the power of technology.

We know that technology flows out of creativity, knowledge, and inspiration, which may explain the significance of the black monolith in *Space Odyssey.* This second great icon points to another major theme in *Technology's Promise* – the rising role of consciousness. I don't know what the author of the movie, Arthur C. Clarke, had in mind, but the monolith strikes me as the quintessential "black box" containing vast powers shrouded in mystery. It is a fitting metaphor for consciousness.

Within the last decade or so, a mere nanosecond in evolution, an even greater barrier has been breached as sophisticated information systems begin to close this evolutionary cycle. Today knowledge – the very heart of scientific progress – is being harnessed on a massive scale.[2] The decoding of the human genome, for instance, was only possible using supercomputers to decipher the 3 billion bits of information in DNA.

This historic step can be understood as a "virtuous cycle" of continually increasing scientific knowledge driven by the Information Technology (IT) Revolution. Figure 1.1 illustrates how IT improves

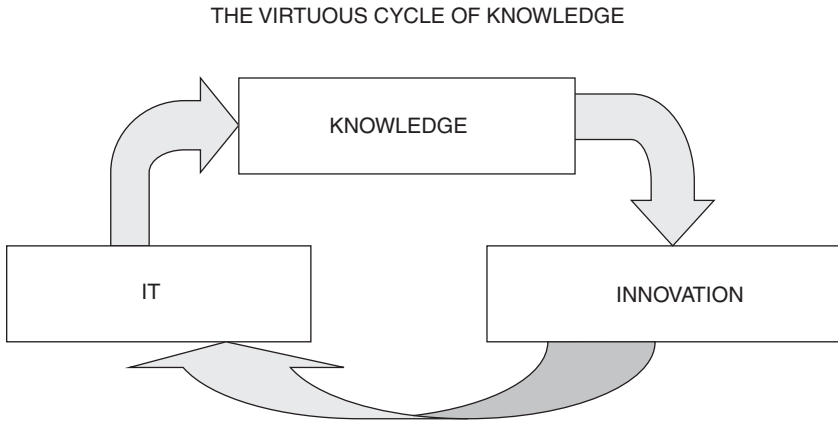

Figure 1.1 The Virtuous Cycle of Knowledge

our ability to acquire knowledge → which then allows more widespread commercial innovation → which in turn improves information systems again → on and on in a spiral of transformation.

This is not simply another scientific advance, but a breakthrough in the process of science and industry itself. Scientific research and commercial innovation are growing in power and speed as the ability to amass knowledge drives technological progress as never before. Some scientists, like Ray Kurzweil, think of it as a "singularity" in which the pace of technological change leaps dramatically during the next 20 to 30 years.[3] Although many think this will cause computer power to surpass human abilities, our discussion of consciousness in Chapter 9 will show that this is likely to prove illusory.

The virtuous cycle of knowledge is opening up dramatic new fields of discovery that are interwoven to build on each other. A central breakthrough is the way the IT Revolution transforms everything – science, economics, culture, and even awareness. We are also discovering that information lies at the heart of life, as exemplified in the way the DNA molecule encodes the information defining each organism. Closely related is the increasing ability of nanotechnology to bond atoms in ways that form a variety of tiny structures, and the role of observation (information again) in governing the unusual behavior of atomic particles in quantum physics.

The emerging scientific perspective, then, sees the world as an intimate interplay between atomic matter, biological life, and information. Some call it the "molecular" age, because it focuses on how information processes organize matter and living organisms at the fundamental

scale of the molecule.[4] Many contend that this power to control matter and information is roughly akin to playing God. Craig Venter, the scientist who helped decode the human genome, is now creating synthetic life in his lab.

The growing power of science explains why we are seeing breakthroughs everywhere. As the evidence presented in this book will show, we can now realistically envision renewable energy replacing oil, medical control over the genetic process of life, computer power becoming cheap and infinite, mobile communications at lightening speeds, robots serving as helpers and caregivers, and much more to come. The technology revolution is still at an early stage, and it presents great dangers as well as benefits. But its potential for using knowledge to solve technical problems is so great that it is limited only by imagination and will.

Although the benefits should be vast, we must remember that technology can be easily misused and it often produces disastrous unforeseen consequences. The automobile made modern society possible, but its costs include traffic congestion, air pollution, energy crises, and some 40,000 highway deaths/year in the U.S. alone. If the auto were a new technology that had to be authorized by the U.S. Congress, it is not at all clear that cars would pass muster without severe regulations.

Some think this is a deterministic view, whereas technology is merely an enabler that allows people to make their own decisions. That is certainly true, but it is a serious mistake to downplay the enormous power of technological forces that can sweep away everything in their path. A business owner may dislike IT systems, yet he/she will probably need to use them to survive in a competitive marketplace. We always have freedom, then, but it is constrained by technological imperatives.

The coming upheaval is almost certain to present massive challenges we are not yet equipped for. The world is changing so much and so quickly that most people do not grasp what we are getting into. We lack even the concepts to begin understanding.

THE TECHCAST PROJECT

This revolution in technology will affect all sectors of society, alter the way people work and live, and restructure the world. Little wonder that it is challenging our best minds today. In the pages ahead, I hope to demonstrate that it is possible to understand these changes more insightfully using a carefully organized system of study. For many

years I have conducted the TechCast Project at George Washington University and at my own company, TechCast LLC, to forecast emerging technologies.

People everywhere sense the world is passing through great technological change, but they lack convenient, reliable information. TechCast fills this need using a sophisticated website (www.TechCast.org) that scans the literature and surveys 100 high-tech executives, scientists and engineers, academics, consultants, futurists, and other experts around the world to forecast breakthroughs in all fields. (See Appendix for list of experts) No forecast is perfect, of course, but we think this approach provides what I think of as "the best possible answers to tough questions." Results are automatically calculated and distributed over the website to corporations, governments, and others – anywhere in the world, on any prominent technology, in real time.

Our studies show that technological advances, their adoption patterns, and social impacts follow well-defined cycles that can be forecast rather accurately. This is possibly the most complete forecasting system available covering the entire span of technological innovation.[5] Figure 1.2 highlights the TechCast results, showing forecasts for 61 leading technologies organized into seven fields. We will

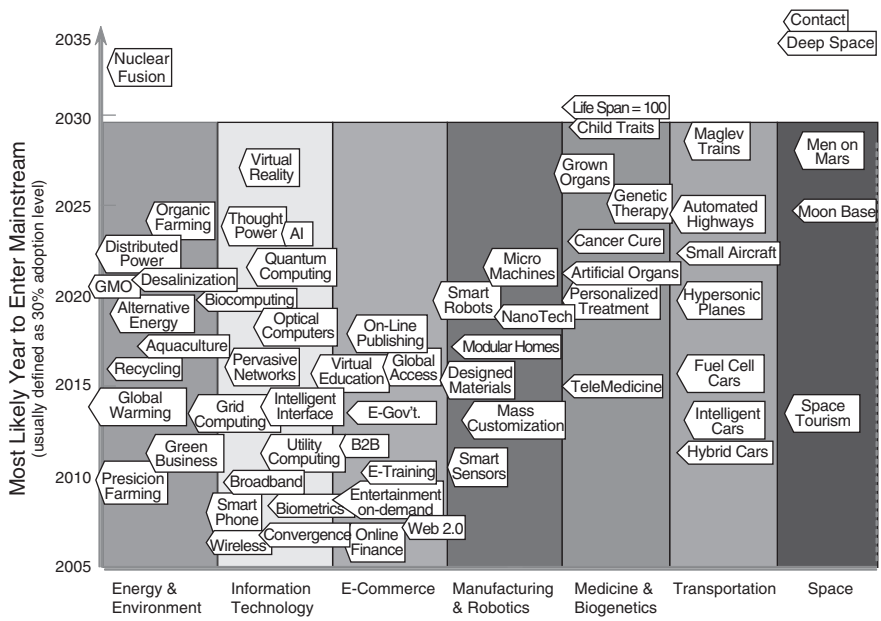

Figure 1.2 Summary of Forecast Results

examine details of these breakthroughs in later chapters, but this overview demonstrates that dramatic advances are underway. They will transform our lives in the years ahead.

The world constantly struggles with huge uncertainty, so how can we justify attempting to forecast such controversial events? There is a long record of distinguished forecasts that proved remarkably accurate. H.G. Wells anticipated a computerized world long before others had an inkling. Jules Verne foretold landing on the moon and atomic submarines, with remarkable accuracy. Arthur C. Clarke defined communications satellites more than a decade before the launch of Sputnik. Peter Drucker described knowledge work in the 1970s. There are many other fine examples, which show that well informed, imaginative judgment can produce remarkably prescient forecasts.

True, we are constantly assailed by predictions that prove naïve. Think back to the common fear in the 1960s that automation would leave us with excessive leisure and nothing to do! We were also told to expect nuclear power "too cheap to meter," a "paperless office," and the stock market to hit 30,000 on the Dow about the year 2000. How can we sort out half-baked ideas from sound forecasts?

The TechCast process is not based on imagination, prophecy, or speculation but on the scientific method. It is empirical in nature, gathering the best background data available and organizing it into a careful analysis of each technology. Experts are taken through these analyses online and instructed to enter their best estimate of when each technology is most likely to enter the mainstream, the potential size of the economic market, and their confidence in the forecast. The experts are not all world-renown, but they represent the leading edge of collective knowledge about technology. To keep the analysis intellectually honest, we make a point of including opposing trends that hinder technology, such as political obstacles, high costs, social resistance, or other barriers. Comments from the experts and new data are used to update the analyses periodically. These forecasts are not snapshots in time but the result of a continual tracking process that improves as technologies "arrive."

Because the TechCast method is basically a system for pooling knowledge, the field of Knowledge Management (KM) offers a useful perspective for understanding the rationale underlying our approach. From the KM view, TechCast is a "learning system" conducted by a "community of practice" to "continually improve" results and approach a "scientific consensus." One of the most vivid experiences of this work is seeing how pooling the tacit knowledge of 100 good minds and cycling through all this information can create forecasts that are remarkably prescient and reasonable.

TechCast has used this method for 15 years on a variety of studies. On average, the forecasts of when a given technology will arrive vary by +/– three years.[6] Some technologies vary widely because they are controversial, while others show little variance because they are well understood. We have recorded arrivals of several technologies roughly within this likely error band of three years. The results are more compelling when considering the fact that the expert panel changed over this time, as did the prospects for various technologies and other conditions. "Prediction markets" have demonstrated remarkable accuracy recently using the same method, but they put teeth into the process by requiring experts to bet real money on their judgments.[7]

This work also holds up well when conducting studies for other purposes. On one consulting assignment, we conducted two parallel studies to forecast energy technologies, one using a group of energy experts and the other using a group of general experts. The forecasts compared almost exactly, usually within one to two years.[8] The method was also used to anticipate the emerging system of business and economics emerging for the Information Age at least a decade before its arrival.[9] In another case, we anticipated a "global information network for science, commerce, and communication" before anyone knew it as the "Internet."[10]

It is often thought that methods like this are subjective, whereas quantitative methods are more precise. However, quantitative methods also involve uncertainty because they require underlying assumptions that often are doubtful. The TechCast method subsumes quantitative forecasts into the background data and allows the judgment of experts to resolve the uncertainty that remains. Experts may have their own bias, naturally, but it is usually distributed normally, washing out in the aggregate results. If the present level of uncertainty is defined as 100%, we have found that this process reduces uncertainty to about 20 to 30%. Our clients say there is nothing else like it.

TechCast can be compared to a stock market. Stock markets basically manage knowledge about capital, and now we need systems for managing knowledge about technology.

A VIRTUAL TRIP THROUGH TIME

The next few pages offer a quick summary of our more intriguing conclusions from each chapter. Think of it as taking a virtual trip through time in order to grasp where we are headed. In Part I, we focus on the conceptual breakthroughs underlying each technological field, the painful dilemmas they provoke, and a simple but compelling story of

how each is likely to change the world. Part II addresses the social implications of the Technology Revolution: restructuring business and other institutions, the challenge posed by artificial intelligence (AI) to human intelligence, and four scenarios on a trip through time.

These chapters also examine the critical issues that must be overcome along the way. The mounting crisis in energy, environment, and climate change caused by the spreading of industrialization throughout the globe. The hijacking of IT by terrorists to subvert the system itself. The moral dilemmas posed by the powers of biogenetic engineering. The need to restructure business and other institutions for a knowledge-based world. And the impending shift in human identify as robots and AI take over many of the tasks that have consumed our time.

Each field of technology is summed up in a bubble chart to highlight emerging capabilities that are especially critical, interesting, or strategic. These are breakthroughs with profound scientific implications, big commercial potential, and great social impacts. They can be predicted with high confidence and are immediate enough to take seriously. In other words, they are most likely to affect you, your organization, and your community. All situations are different, but we strive to tease out implications throughout the book to help corporations, governments, and individuals anticipate these profound changes and react with constructive strategies.

In short, the approach is to subsume all available knowledge – driving trends, opposing obstacles, critical issues, and expert forecasts into an accurate strategic assessment. Throughout the text, highlights are drawn from the website to flesh out these ideas, and endnotes offer other sources. References for all these facts and other data are available at www.TechCast.org. Here's a summary of the chapters:

PART I FORECASTS OF THE TECHNOLOGY REVOLUTION

Chapter 2 Transition to a Sustainable World

We start by showing that industrialization is likely to cover most of the globe at about 2030, producing a three- to five-fold leap in the demand for energy and other scarce resources, in pollution levels, global warming, and other aspects of the industrialization-energy-environment crisis. The modernization of China and India alone will double or triple these problems.

Our forecasts show that some of these issues are likely to be resolved over the next 10 to 15 years. Corporations are now moving to green business practices because the inevitability of this transition has made environmental management a competitive advantage, spurring a huge boom in anything green. The issue of global warming is likely to be addressed seriously about 2012, and alternative energy should make a good-sized dent in the use of carbon fuels about 2020.

This chapter concludes that the industrialization-energy-environment crisis actually is a great opportunity in disguise. The transition to a sustainable world will produce an enormous new industry to manage the Earth. It may even serve to unify people after centuries of ethnic, sectarian, and tribal conflict.

Chapter 3 Globalization Goes High-Tech

Chapter 3 will show that the old, smoking factories of the Industrial Age are yielding to intelligent manufacturing systems operating virtually to produce almost anything cheaply, quickly, and customized to order.

Research in materials and nanotechnology is making it possible to design almost any type of product, and mass customization can deliver an endless stream of sophisticated goods customized for each individual. Driven by the logic of cheap labor and new markets, these changes promise to bring material abundance to poor nations over the next few decades, eliminating much of the poverty that blights the planet.

The tension in this emerging world of plenty, however, will be mounting demand for scarce resources like oil, massive loads on the environment, and more clashes between diverse cultures, as in the conflict between the West and Islam.

Chapter 4 Society Moves Online

Advances in broadband, wireless, and AI are inexorably moving life online as computer power becomes cheap, ever-present, and intelligent.

Our forecasts show that today's rapid growth of online entertainment, e-tailing, virtual education, and other such e-commerce services will soon dominate modern economies. Over a longer term, optics, quantum physics, and nanotechnology offer the hope of continuing the gains in computer power when silicon chips are unable to further improve performance (Moore's Law).

Within a decade or so, we could simply speak to high-fidelity images on large wall monitors while working, shopping, learning, and conducting almost all other social functions. You might buy something by simply talking with an onscreen robot that greets you by name, knows all the merchandise and displays it on demand, answers questions, and has infinite patience – the perfect salesperson.

Chapter 5 Mastery Over Life

A variety of breakthroughs in medicine and biogenetics is likely to provide mastery over the process of life itself.

Artificial organs are being developed to replace almost all bodily functions, including parts of the brain, and stem cell research is increasingly able to repair organs. Life extension techniques are expected to raise average life spans to 100 years within a few decades, and possibly beyond the biblical 120 years. Just as the Industrial Age mastered most aspects of the physical world, the Knowledge Age is now making it possible to master the biological world. Yes, it sounds too good to be true, but so did the notion that men could fly, much less travel to the moon.

We also explore how this progress presents social and moral dilemmas that will have to be resolved. How will we make difficult medical choices about stem cell research, designer babies, life extension, euthanasia, and other sensitive matters?

Chapter 6 Faster and Farther

Travel is being reinvented to manage an explosion of global commerce. We will describe the emergence of the "intelligent car," maglev trains floating between major cities on a cushion of air at 400 mph, and Mach 10 hypersonic aircraft that could reduce flying times around the globe from 30 hours to 3 hours.

It may seem that information systems could replace travel, but information forms a virtual world that parallels the physical world. People will always want to visit each other, handle the merchandise, and hammer out tough decisions together. The need for physical contact is inexhaustible, and some studies show that growing virtual contact only makes face-to-face relations more necessary.

The physical and virtual worlds coexist in parallel dimensions, so travel will likely grow alongside the movement of information. Thus, we forecast there will be no rest for the weary road warrior.

Chapter 7 The Final Frontier

Space tourism is likely to become common in one decade, and we are likely to see the establishment of a permanent moon base and a manned landing on Mars in about two decades.

But the ultimate challenge of deep space travel to distant solar systems awaits fundamental breakthroughs in our understanding of physics. The distances of deep space are so enormous and our capabilities so puny that it will take long, intense research to discover ways to traverse them.

Our estimates suggest the needed scientific breakthroughs are likely to arrive about 2050, which coincides with our forecasts for deep space travel. Forecasting anything that far off seems foolhardy, but it is compelling that a variety of sources suggest travel to other star systems is likely about this time.

PART II SOCIAL IMPACTS OF THE TECHNOLOGY REVOLUTION

Chapter 8 Shifting Structures of Society

Here we explore how this technological upheaval is restructuring business, government, medicine, education, and other institutions as a knowledge-based world alters the basis of economics and leadership.

Financial investment powered the Industrial Age when capital was needed to build manufacturing capability. But today speed, agility, knowledge, collaboration, and innovation are the critical factors needed to survive a world of creative destruction, fickle clients, transient workers, and shifting social values. That's why corporations are constantly in flux, scandals like Enron highlight ethical failures, government is struggling to redefine itself, education is going virtual, and rising medical costs are unsustainable.

We will see that two main trends are driving institutional change. Hierarchies are dispersing into "self-managed teams" able to manage complexity by harnessing the knowledge of ordinary people. And the old focus on profit is yielding to a "corporate community" of collaborative partnerships among employees, clients, business alliances, investors, and the public. These two major trends represent a synthesis of the Western ideals of free enterprise and democracy, offering the possibility of resolving the political impasse between right and left that grips the U.S. and much of the world.[11]

Chapter 9 An Age of Consciousness

Here we explore what follows information and knowledge. Chapter 4 shows that the Information Age is likely to mature about 2020, so what's next? Just as the agrarian economies yielded to manufacturing, which is now being eclipsed by services and information, the knowledge economy eventually will run its course as well.

Services have been automating for years (ATMs, airline kiosks, etc.) and wealthy nations now fear that even knowledge – once thought immune to export – is moving off shore to lower-paid people in developing nations. Various forms of AI are spreading, like the intelligent agent that answers your phone calls, smart computers, and cars that talk to us. All-purpose robots are so well developed that the Japanese and Koreans expect to be selling equivalents of R2D2 to families by about 2010.[12]

This "automation of mental work" poses one of the most fascinating issues of our time – *Is there a fundamental difference between machine intelligence and human intelligence?* Despite the fact that about 90% of us are utterly convinced that human thought surpasses sheer information, could we all be wrong? Everybody once accepted the Flat Earth model of the world for millennia. Is science poised for another great revolution demonstrating that we are fundamentally not much more than wet computers? Or will this critical issue force us to accept a domain of consciousness and human spirit as the new frontier? This chapter explores some of the most challenging and fundamental questions now before us.

Chapter 10 Scenarios

We conclude by integrating all forecasts across fields in vivid, decade-by-decade scenarios to explore how this wave of innovation is likely to unfold – a sort of surrogate for time travel.

2010 should see even greater advances in information systems and e-commerce, making most of the world smarter, faster, and fully wired. By 2020 AI will permeate our lives and permit huge advances in telemedicine, virtual education, and e-government. About 2030, industrialization is likely to reach most developing nations, enabling as many as five billion people to live at modern levels. But intercultural conflict, weapons of mass destruction (WMD), and threats of environmental collapse will pose an historic crisis of maturity that challenges basic worldviews. By 2050, this crisis of maturity is likely to be resolved with the emergence of a modernized global society,

somewhat like a far larger and more diverse version of the U.S. or E.U. Local wars, ecological disasters, and other troubles will continue but limited to the normal dysfunctions of any social system.

We then move across these scenarios to outline the larger path of civilization's progress. The agriculture, manufacturing, and services stages have largely been completed in modern nations, and we are now passing rapidly through the knowledge phase toward some form of global consciousness. I will show that this movement through ever more powerful stages of development comprises a great "life cycle of evolution," somewhat like the individual human life cycle but vastly larger and longer.[13] Today's crises, and their eventual resolution, can be better understood in the context of this great arc of civilization now approaching the brink of global maturity.

GUIDING TECHNOLOGY'S PROMISE

Whenever I discuss this, I hear great skepticism because people see no way out of today's dilemmas. Friends often advise me not to be "so optimistic." They are afraid it will damage my credibility. However, mere optimism is blind hope without justification. The views presented in this book recognize that the world must mature if it is to survive, and the evidence assembled here presents an entirely plausible path forward. In fact, our forecasts describe the most likely outcome, rather than mere possibilities. They are justified on empirical grounds, rather than wishful fantasy, and they may be overly conservative. There are no guarantees, of course, but they offer a reasonable basis for the type of vision needed to meet today's challenges. Without such aspirations, nothing would change. We would remain captives of today's world.

Everything I have learned tells me that the next stage in social development will focus on building some higher-level system of governance organized around a global community. Within the past two-hundred years, civilization has advanced from farming the soil, to manufacturing goods, to managing global organizations, and now to harnessing knowledge. Some of our individual forecasts may prove wrong, but the broad direction seems to lead beyond knowledge to a new global consciousness, as many others have foreseen.[14] This hardly means the future will be a utopia, as war, economic failures, and political stalling are not about to disappear. But with a modicum of hard work, luck, and heightened awareness, this wave of techno-

logy promises to produce a coherent form of global order about 2050, and possibly sooner.

The key to understanding this transition lies in seeing that technological evolution comprises a natural life cycle of the entire planet, much like the life cycle of any organism although infinitely larger. Just as the Industrial Revolution was powered by the need to overcome poverty, and the IT Revolution is crucial for managing complexity, the world is today in the throes of a "mental revolution" to resolve the global crisis of maturity. Think of the similar crisis every teen faces in shedding the baggage of youth to become a responsible adult. Whether a teenager or an entire civilization, the challenge is much the same – grow up or die.

Things look especially bleak today because that's the normal situation facing any system struggling through maturity – a teenager, a nation, or a global civilization. Those who have raised youngsters quickly learn about the mercurial anguish that is normal in such transitions. Our present experiences are rooted in the past, however, so they are not a feasible basis for thinking about the global transition, any more than the experiences of childhood allow us to anticipate adulthood. Nobody plans these passages; they are natural events in the cycle of life.

Today, the rise of a global civilization possesses a life cycle all of its own that is unfolding very rapidly. The lightning-fast spread of information and knowledge, at the very time the world is unifying into a global network of economic systems, has provoked a series of mental shifts to address the challenges ahead. We have accepted women in power, transformed planned economies into free markets, and begun to protect the environment. Now the really tough challenge of shifting consciousness lies ahead. Although the transition to global maturity could reach critical mass any time, the evidence suggests that it is most likely about 2030 when conditions become critical.

People tend to place such prospects in the distant future, if they accept them at all. But the power of IT systems is now hastening advances as never before, accelerating the passage to a coherent world order in our lifetimes. A 50-year-old today is likely to witness the global crisis of maturity at 70 years of age and the emergence of a global order at the age of 90. As Chapter 7 notes, life extension should raise average life spans to 100 years by about 2030, so these are realistic goals. Even an 80-year old today could easily live to see the crisis of maturity. This is not merely an intellectual exercise, therefore, because most of us will witness this highpoint in civilization.

The technology revolution is fraught with risk and clouded with uncertainty. Yet by carefully studying these possibilities, we can better fulfill the great promise held out by technological advancement. The physicist Freeman Dyson called technology "a gift from God." That gift is growing rapidly now and raising very provocative hopes and fears, much like a teenager getting ready to drive off in the family car for the first time. Yes, he could have an accident, but with the guidance of parents, the experience should help him grow into a competent adult. To avoid squandering the enormous gift of technology's promise, I hope this book can help guide it to success.

Notes

1 Halal, "The Life Cycle of Evolution: A Macro-Technological Analysis of Civilization's Progress" *Journal of Future Studies* (August 2004) Vol. 9, No. 1, pp. 59–74.
2 See William E. Halal, *The Infinite Resource: Creating & Leading the Knowledge Enterprise* (San Francisco: Jossey-Bass, 1998).
3 Ray Kurzweil, *The Singularity is Near* (NY: Penguin Books, 2005).
4 Mihail C. Roco and William Sims Bainbridge, *Converging Technologies* (Arlington, Virginia: National Science Foundation and Department of Commerce, 2002).
5 Publications on technology are popular now, but we are not aware of others that provide such comprehensive, authoritative forecasts. Some of the best recent works include David R. Howell, *The Global Technology Revolution 2020* (Santa Monica, CA: RAND Corporation, 2006), The UN Millennium Project conducted by Jerome Glenn and Ted Gordon; and the trends provided by Marvin Cetron of Forecasting International. However, none of these sources contain actual forecasts.
6 Halal, William E. *et al*. The GW Forecast of Emerging Technologies. *Technological Forecasting & Social Change* (1998) Vol. 59, pp. 89–110.
7 Justin Wolfers and Eric Zitezwitz, "Prediction Markets," *Journal of Economic Perspectives* (Spring 2004) 18:2 pp. 107–126.
8 Laitner, John. *Energy Impact of Emerging Technologies* (Washington, DC: Environmental Protection Agency, 2004).
9 Halal, *The New Capitalism: Business and Society in the Information Age* (NY: Wiley, 1986).
10 See "The GW Forecast of Emerging Technologies," *Op. Cit*. and "Emerging Technologies," *The Futurist* (Nov–Dec 1997); reprinted in O'Meara *et al*. (eds) *Globalization and the Challenges of a New Century* (Indiana University Press, 2000).
11 See my special issue of *On-the-Horizon*, "Institutional Change" (2005).
12 Halal, "The Coming Conflict Between Science and Spirit," *Thinking Creatively in Turbulent Times* (2004).
13 Halal, "The Life Cycle of Evolution," *Op. Cit*.
14 Among the most prominent of these modern day prophets is Willis Harman, author of *Global Mind Change* (Indianapolis, IN: Knowledge Systems, Inc., 1988).

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