33 OPEN, COLLABORATIVE INNOVATION IN THE 21ST CENTURY

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There have been many turning points in history. One of the most prominent in my mind is the Industrial Revolution, characterized by new technologies that enabled us to reorganize the production of goods and services. It is pretty clear that we are in the early stages of a similar historical turning point. While no one knows for sure what future generations of historians will call this new period we are entering—perhaps the Knowledge Economy—we can certainly identify the forces at work around us.

I believe that there are three interrelated and very profound such forces. First is the digital revolution, led by continuing advances in information technologies. Second is a business revolution, which is a product of those advances in IT. And third is a societal revolution, born of the Internet and other open standards that are enabling collaborative innovation on a global scale. Each of these revolutions is very powerful in its own right, but they are converging like weather fronts and creating the conditions for a "perfect storm" of innovation.

IT is to our era what steam power was to the industrial revolution: a huge catalyst for change at many, many levels. We see it all around us. The environment is going digital all over the world, in emerging economies as well as advanced ones. Think of iPODs, DVDs, and digital TVs in entertainment and voice-over-IP in communication. Mobile devices and cell phones have become extensions of ourselves. Software is almost as important to planes and automobiles as gasoline. IT is being embedded in everything, giving our physical world, in effect, a fourth dimension—a digital dimension.

Simultaneously, these inexpensive digital technologies are being aggregated into tremendously powerful supercomputers like Roadrunner, the first petaflops supercomputer developed by IBM for the U.S. Department of Energy and installed at Los Alamos National Laboratory earlier this year. A petaflop is a 1 followed by 15 zeros. That is how many calculations per second Roadrunner can perform. When talking about peta-

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flops, the numbers are so large that it is hard to comprehend what they mean. We are almost into numbers of astronomical dimensions.

The advent of petaflop supercomputing will enable major advances in applications of all sorts, in medicine, science, engineering, and business. It will help us explore the major challenges associated with climate change, making it possible for scientists to test global climate models with far higher accuracy than has been possible so far. We can expect advances in a wide range of application of critical importance to society, such as the development of biofuels, the design of more fuel efficient cars, personalized genomics-based medicine, and the ability to better understand and manage the behavior of our global, integrated—and increasingly unpredictable—digital economy.

Los Alamos researchers have already started to use Roadrunner in a project called Petavision that simulates extremely complex neurological processes. Such applications are critical to help us better understand the structure of the brain, which hopefully will lead to breakthroughs in treating major disabilities like Alzheimer's, autism, and schizophrenia.

Since the beginning of the industrial era, business and other institutions have constantly adapted processes to take advantage of new methodologies and technologies. But today's process adaptations are taking advantage of sophisticated architectures and computing infrastructures, resulting in the wholesale integration and refashioning of business processes across the enterprise and beyond. Perhaps more profound, companies are beginning to use rigorous, engineering-like methodologies to identify the processes in which they have unique expertise and efficiencies of scale, so they can determine which are strategic and give the firm, in a phrase, "economies of expertise."

Business operations and processes can be viewed more as components, and each function—be it finance, manufacturing, or human resources—can be treated as a separate service. At the same time, open standards are making the underlying IT applications so flexible that a company can take apart and recombine those services more quickly to address changing needs. That flexibility frees a company to focus on what it does best and to pursue its comparative advantage.

In a historic departure from conventional one-to-one relationships between businesses, this new-found flexibility and focus herald the emergence of collaborative, interconnected industry ecosystems composed of diverse centers of expertise around the world. What holds true for business processes is just as true for all processes across industry ecosystems.

This business process revolution, combined with the rapid growth of services in the economic mix, is giving rise to a much more disciplined, more scientific approach to business. Historically most scientific research has been geared to manufacturing, once the dominant force in the world's economy. Now, industrial and academic research facilities are beginning to apply more scientific rigor and engineering discipline to the practices of services in order to train people in business and information technology, and also the human factors that go into a successful services operation.

Many leading universities have begun exploring and investing in this area, working in tandem with thought leaders in the business world to establish Services Sciences, Management and Engineering as a new discipline. The University of California at Berkeley, for example, has implemented a Services Science curriculum with help from IBM Research—much the way the first Computer Science department was founded at Columbia University over 30 years ago, also with help from IBM. Quite a number of

other universities around the world have already embraced Services Sciences or are considering doing so.

The dynamism propelling this business revolution is collaboration on a global scale—between businesses, between industries, and between economies; between companies and all their stakeholders; and between governments and their constituents. It is giving rise to a truly societal revolution.

I believe that when those historians I mentioned try to assess this societal revolution—this new, as yet unnamed era—they will be compelled to focus on the mid-1990s, when the Internet burst upon the larger society. That is when open standards really began to come into their own, and offer the promise of near-universal connectivity, a promise that is being fulfilled year by year.

Around a billion people are already connected to the Internet via personal computers. Billions more will do so over inexpensive mobile devices in a few years. Trillions of sensors will be connected to the Internet in the not too distant future. Online commerce keeps growing and is now counted in the trillions of dollars.

The need to support these billions of mobile devices and trillions of sensors is giving rise to "cloud computing." I think of clouds basically as Internet-based networks made up of a very large number of servers and storage components. They contain vast amounts of information, and provide a variety of services to large numbers of people—to their mobile devices as well as their PCs. The users of clouds only care about the services and information they have access to, not about the underlying details of how the cloud works.

In my opinion, two key factors take cloud computing into a qualitatively different dimension. One is massive scalability. I believe that the kinds of advances that we have become used to in the world of supercomputing are now coming to the more general purpose computing world. A number of new applications are emerging that will likely grow by two to three orders of magnitude over the next decade.

The other factor is the much higher quality of experience that cloud applications provide to their users. Cloud applications are very different from classic IT applications, whose intrinsic complexities are barely hidden from their users. You truly want users of cloud applications to just be able to access them in the most natural and simplest way possible. Cloud applications should be able to provide a really high quality of experience to massive numbers of users without missing a beat. They should significantly improve the way people deal with the many tasks and devices that surround them in their everyday life—at work, at home, on-the-go, and wherever they happen to be.

What are some of the workloads in the horizon that will likely grow at prodigious rates and require a human-like quality of experience? Quite a few, I believe: real-time information access and analysis, such as RFID-based supply chains, transportation management and security systems; myriads of new consumer applications in entertainment, healthcare, payments and financial services; social networks and virtual worlds involving large numbers of people interacting with each other; support of billions and billions of new mobile devices and sensors; and so on.

Ever since the advent of the Internet, open standards have been increasingly finding their way into all aspects of IT, integrating systems, information, and people on a truly historic scale. And it's not over yet. Information technology is becoming increasingly pervasive and generating prodigious amounts of information, and colossal amounts of processing power to turn that information into useful knowledge in real-time. Couple that with the open-standards-based Internet that facilitates communication worldwide and

it's no wonder that a global, infrastructure—the very nature of which is collaborative—is emerging and moving society into a new era.

Already we are seeing the emergence of open, collaborative innovation as a serious mode of economic production that has arisen because large numbers of individuals can now organize themselves for productive work. This challenges the long-held notion of the "firm" as the only way to organize work that creates value. Indeed, social networks are creating all kinds of new communities, and all that information out there is very likely to transform the way companies deal with each other and with individuals—employees, customers, partners, shareholders, and others.

We don't know how this new marketplace will evolve—any more than people in the 18th century could foresee the full impact of industrialization on business, economies, and nations. But I think we have enough evidence to say with some confidence that open, collaborative approaches are not transient, as we see an increasing number of open communities working together in areas like Linux, Grids, cloud computing, and application development tools. What is different today is that for the first time, in large part because of the Internet, we have the capacity to "self-organize" into groups fluidly and globally. And that promises a much more diverse, exciting—and very innovative—marketplace.

Collaborative innovation must be at the heart of all the policies that shape the direction of a nation's economy and be at the center of the national agenda. Designing and implementing the right mix of policies to spark innovation will no doubt be a challenge, but it's a challenge no one can ignore with impunity. Technology and open standards have us at the brink of a new era. We are connecting all of society's institutions—governmental, educational, commercial—across a global IT infrastructure.

The name of this new era will be devised decades from now by historians with the perspective of time. But we can say this with some certainty: Those future historians will be investigating an era when we experienced, not merely a new round of innovation, but a new style of innovation—one that pools the most fertile minds in the world, and frees them to create the 21st century.