

Summary

RAND has undertaken a three-year effort, sponsored by the National Intelligence Council, to study some of the key changes expected worldwide as a result of the continuing information revolution. A first conference in a series was held November 16-18, 1999 in Washington, DC, concentrating on potential political, economic, and social consequences of this revolution, with special attention focused on differential impacts possible in differing countries, regions, and cultures of the world.

A second conference in this series, reported on here, was held May 10-12, 2000, in Pittsburgh PA. It concentrated on technical trends in the information revolution, focusing in particular on the resulting new artifacts and services that might become widespread during the next 20 years, thereby affecting individuals, organizations, nations, and cultures worldwide.

In one sense, it is easy to “predict” the future, at least over the next 15-20 years: computing will get faster and cheaper, communication bandwidth will increase, interesting new devices (beyond cellphones and handheld personal information managers, or perhaps a merging of the two) will emerge. And so on. And yet, many previous attempts to forecast future technology developments have been woefully lacking, if not just plain wrong. Twenty years ago, circa 1980, essentially no one predicted the explosive development of the World Wide Web – indeed, although a precursor of the Internet was a fairly robust technology, there was no HTML, nothing like today’s “chat rooms,” and no 500-megahertz multi-gigabyte laptop computers, or cell phones. So the “faster/cheaper/ smaller” mantra only hints at future developments, it certainly doesn’t predict them. Conversely, projections often appear naively optimistic in retrospect. (As one participant put it, “If it’s 2000 already, why doesn’t my car fly?”)

This conference attempted to get beyond Moore’s Law (an expected doubling of the density of integrated circuits on a silicon chip every 18 months or so), to ask about specific artifacts, devices, and services that might be developed, with attention to those likely to have differential impacts on various countries, regions, and cultures of the world. The conference was designed to illuminate the assumptions underlying various predictions and estimates, so that these could be examined for mutual consistency and likelihood.

We structured the conference in part by distinguishing among developments in technology, artifacts, and services.¹ We view *technology* as the idea or intellectual property behind an artifact or product that embodies it, such as wireless communication technology *per se*. An *artifact* is a device (such as a cellular telephone) embodying one or more technologies. *Services*, similarly, result from the application of technology, but in the form of capabilities offered to users, usually in a form resulting from storage, access, and manipulation of information. A website that helps you locate the nearest CD music store might be such a service.

Below we list the major topic areas and findings resulting from the conference deliberations, under the headings of technology, artifact, and service developments. We indicate for each the report sections in which more information is available on these subjects.

Some clear technology developments

It is widely believed that the exponential growth in computing power that has been seen for decades now will continue for at least another 10-15 years, reaching the limits of silicon technology by about 2015. That trend underlies many of the other developments that are expected.

There will be a convergence of voice and data communications, and a quantum jump in bandwidth during the next two decades. These developments will be characterized in first-world economies by:

- Seamless data, voice, video sharing
- Universal connectivity
- Application convergence through Internet Protocol (IP)
- Widespread wideband wireless
- Optical, multiwave lines and switches, allowing bandwidths of thousands of gigabits/sec

A white paper on communication technology developments provided to conference participants by Professor David Farber, Chief Technologist, Federal Communications Commission, is included in this report (Appendix A).

Machine-accessible common-sense knowledge will become available to various computer applications, especially in bounded domains of discourse. It will aid a variety of applications, most particularly on the World Wide Web – such as

¹ A similar distinction, but one varying in some aspects, was described in the proceedings of the first conference in this series. See Hundley (2000), section 10.

helping to provide “sensible” answers to browser queries and other forms of user-computer dialog.

Machine translation (MT) among key natural languages is a long-sought goal. Its availability, for example, would allow the informational riches of the Web – currently predominantly in English – to be accessed by persons whose only language is Arabic, Japanese, Chinese, or Spanish (for example). The general MT problem is unlikely to be “solved” in the next 20 years, but it was stated that “you can have any two of the following three desiderata: high quality, general purpose, fully automatic.” For many purposes and limited domains of discourse, this will be good enough for useful applications.

There are very strong synergies developing between bio-, nano-, and material technologies. Beyond semiconductors, on-chip integration of logic and other components will likely include chemical sensors and components, electro-optical devices, and biological components as well as microelectromechanical systems (MEMS). The results, especially for sensor technology – and when combined with wireless communication developments – will be revolutionary, with an expected cornucopia of new devices and applications.

Future technology developments are discussed in more detail in Sections 2 and 3 of this report.

Some clear artifact developments

Given developments in underlying computing and communication technologies, we expect to see a multitude of diverse, powerful, inexpensive sensors and other devices capable of (limited-distance) wireless communication. Among them are tiny video cameras, MEMS microphones, accelerometers, gyros, GPS receivers providing location information, smell sensors, food spoilage sensors, biosensors, and polymer-based sensors. These devices will provide vastly increased coupling between the physical world and the cyber world, allowing information systems to react much more comprehensively to (changes in) their environment.

Computing and information systems will become much more ubiquitous, with convergence of wireless telephones, personal digital assistants (PDAs), radio, voice and e-mail messaging, smart home appliances, etc. Precursor devices in this trend are the Palm VII and the RIM BlackBerry. Developments in such small, portable, personal devices along with sensing technology will make wearable computers increasingly important informational aids. Aiding in these developments will be protocols such as WAP (wireless application

protocol) and the Bluetooth radio protocol for short-range wireless communication.

Section 4 of this report provides further discussion of developments in informational artifacts.

Some clear services developments

There is a major shift underway in business emphasis, from products to services. Increasingly, businesses see specific products as elements or components of a broader service that the firm provides to customers. Information technologies are central to this new business model.

Because of the conference's interest in artifacts and services with the potential to have major effects on differing regions and cultures worldwide, there was considerable interest in the state-of-the-art of machine translation of human languages, provided as a service on the Internet and Web. This technology, along with automatic voice recognition, could have profound effects in making information for education and entertainment available around the world. The emphasis was not on perfection in these services, but rather on the availability of "good enough" translation and voice recognition to allow access to Web resources by speakers of a variety of languages, and on freeing the user from keyboard-dependent interfaces through voice recognition. With this combination of technologies, one can imagine kiosks at which a question can be voiced, and the riches of the Internet used to provide a spoken or displayed answer. It may even be reasonable to imagine that kiosk containing a small satellite dish by which Internet and other informational services are accessed, and solar cells and auxiliary batteries by which it is powered as a self-sufficient informational platform.

Services available from such a kiosk might – at least initially – be tailored to certain specialized areas, such as farming, weather reports, market prices for agricultural products, and so on. In that manner, the complexities of translation and voice recognition might be "good enough" for effective usage. (Conference attendees were told, for example, of high-quality, automatic language translation now being performed for the limited domain of Caterpillar tractor manuals.)

There was discussion of robust, global information utilities serving a wide variety of needs. As is increasingly the case, entertainment will likely lead the way, with business-to-business (B2B) e-commerce as a strong second force.

As these information utilities grow, they will become backbones supporting increased lifelong learning and specialized training.

The breakout group on future IT services concentrated on four areas of “final” (end-user-related) services: health care, education, entertainment, and supply-chain management. These are considered to be selected examples of services areas, certainly not a definitive list.

Health care services will increasingly be influenced by “telemedicine,” in which some or all of the services will be IT-mediated. The opportunity to access information and actual care from a vastly expanded set of providers will confront both patients and health-care professionals with a bewildering array of choices. This in turn may generate new dynamic brokering services. Although telemedicine is likely to increase the gap between rich and poor societies (e.g., because high, reliable bandwidth is often required), some benefits will accrue to poorer countries, for example from their improved access to information and training. The group felt that such developments as a “smart stretcher” being investigated by the U.S. military might prove important to countries short of trained medical personnel.

In educational services, the greatest impact of the continuing information revolution is likely to be in lifetime learning and specialized training. Other important changes will occur in post-graduate education. It was felt that university undergraduate studies and K-12 education will be less affected over this time period due to a variety of social, political, and other factors, but may be dramatically affected somewhat later.

Entertainment will continue to be a powerful driver of IT developments in the next 15-20 years. Among the artifacts and services expected to play a large role are:

- Multi-person computer-based games
- Web-mediated physical activity, such as interactive games requiring strenuous physical responses
- Ubiquitous web-cams providing entertainment, communication (improved interpersonal interaction at a distance) and intrusive surveillance
- Interactions with people of different cultures, aided by translation programs
- The ability to view athletic events from almost any vantage point
- Video glasses that place images directly before a viewer’s eyes
- E-books.

IT-enabled supply-chain management and the general control of production processes were considered as drastically reducing the advantages that accrue to

cheap labor, possibly ending the flight of manufacturing to the developing world. The key to highly effective production control services may be in devising better ways to allow humans to visualize and to understand intuitively the workings of very complex systems.

The above examples of IT-enabled services depend on a number of enabling services. Ones considered especially important were security, validation, payment, and dynamic brokerage. The importance of secure Internet and Web services is clear. “Validation” is closely related: it refers to the importance of being able to trust that you are communicating with an intended party, and that the information received and transmitted is to be trusted.

Payment schemes such as “micropayments” will be increasingly important in allowing e-commerce services to charge small amounts (less than the cost of processing a credit card payment) for small services performed, such as reading a document, or downloading a small file. “Dynamic brokerage” refers to a decentralized capability for matching highly specific requests from customers for packages of services with suitable offers of these services from a wide range of suppliers. This requires creating of a standard vocabulary for articulating requests for services, and for describing services offered.

Further discussion of services is provided in section 5 of this report.

Markets

Much of the discussion at the conference was deliberately related to “technology push.” Yet participants understood that markets play a critical role in determining which of the *possible* artifacts and services become *actual* and widespread. The group discussing market factors created lists of “filters” that new developments must pass through in order to become actualized. Such filters include: the availability of supporting infrastructure; market demand factors like ease of use, entertainment value, and affordability; and availability of funding.

It was also noted that market criteria play differing roles in various regions of the world. The group created the chart (Table S.1) as showing examples of market criteria by region, although its content is not based on any serious analysis. It is meant as a framework that might be filled in more accurately and carefully by regional and technology experts working together.

Table S.1: Examples of Possible Regional Market Drivers and Limiters

	Drivers	Limiters
North America	time savings improves health	backward compatibility
Europe	educational value time savings improves health	social concerns; backward compatibility
North Asia	fashion, image educational value	government policy; backward compatibility
Mideast		social concerns
South(East) Asia	creates expertise empowerment educational value	lack of capital, infrastructure, and human expertise
Africa	creates expertise empowerment fulfills basic life needs	lack of capital, infrastructure, and human expertise
Latin America	creates expertise	lack of capital, infrastructure, and human expertise

This group's discussion also distinguished between the market for invention, and that for innovation. Each was characterized as relatively distinct from the other. How IT-related products emerge from basic research, through revolutionary change, into breakthrough products, and gradual evolutionary change – or don't do so successfully – depends to a large extent on the “market” for invention, and for innovation, within a society.

Further discussion of market factors affecting the development of IT artifacts and services is in section 6 of this report.

“Beyond cyberspace”

One breakout session labeled its topic “beyond cyberspace.” This label was meant to cover such subjects as: What will happen when information technology is ubiquitous and permeates social space? What will happen when IT becomes part of the background rather than a locus of emerging foreground trends?

The discussion of this group focused on four domains of human concern: work; political processes and governance; education; and crime.

It is clear that manual labor is increasingly being replaced by knowledge work. Among the effects noted were that, “We’ve turned the Taylor model on its head. Knowledge workers know more than the managers do now, and knowledge workers have so much mobility that they control the viability of the corporation.” The group foresaw increasing use of “collaborative networks” across different physical environments and time zones. It is possible that there will be more “componentization” of software systems and knowledge-based jobs, making it possible to issue bids for all kinds of work. The main task left to the corporation would be to assemble the results as they came back from bidders. But would work then become less meaningful? If so, with what consequences?

Another work-related effect of the IT revolution discussed was the reorganization of industries, especially focused on a trend toward disintermediation of work, with the likely result that new classes of intermediaries will emerge from this restructuring. There are also many issues brought to the fore by IT developments involving the migration of workers across national boundaries. Some mass migrations, especially of knowledge workers, are possible – with unclear effects on the “steady state” of the world.

The discussion of political processes and governance ranged over possible challenges to national sovereignty, government’s services to its citizens, and electoral politics. It was felt – as others have noted – that internationalization of markets and the fluidity of the labor force further contribute to the marginalization of the nation state. In addition, nation states increasingly share *de facto* power with large multinational corporations and nongovernmental organizations.

Among various trends involving government, it appears that regulatory agencies are especially at risk of not keeping pace with developments, given IT-enabled fluidity and fast-paced changes in markets and financial systems. In addition, some traditional government services (e.g., the postal service) are competing with private services (e.g., FedEx, UPS, e-mail providers).

Ubiquitous information technology will increase the pressure for “e-voting.” The rationale for representative government will be challenged by advocates for direct democracy. One participant characterized e-voting as the “death of deliberation.” A number of “micro-elections” on various special measures and single-issue initiatives may in fact increase voter apathy. There are many social and political factors to be considered in this arena.

This group also discussed IT and education, as did some other groups. The basic conclusions were similar to others’: distance learning and post-secondary education would likely be most affected, and increase in the corporate

education sector would be evident. Participants also believed that technical advances – such as those mentioned above in language translation and voice recognition – may well yield small, inexpensive IT devices that could be distributed on a one-per-child basis to spread appropriate education throughout developing countries.

The topic of IT-affected changes in crime was briefly discussed. Ubiquitous IT will significantly reduce physical crime, both because of greatly increased surveillance from inexpensive sensors, and due to DNA tracing and other advanced analytic techniques. An unintended consequence may well be the shifting of crime to the IT world, where new kinds of extortion and digital retribution may become possible. The cat-and-mouse game between cybercrime and cyberforensics will continue.

Other societal effects of ubiquitous IT technology are discussed in section 7.

Some tensions arising from these developments

A number of individual and societal tensions arise from the developments outlined above.

As one example, participants believed that ultra high-speed all-optical communication networks will be a highly disruptive technology. It is possible that many present-day leaders in computer and communications industries will be threatened with extinction.

There are major battles to be waged between advocates of “open” versus “closed” worlds of protocols and standards. It is unclear where the balance will be found.

Among the many social tensions are increasing threats to intellectual property rights, for example from new business models such as that exemplified by Napster and Gnutella. Threats to individual privacy will increase. And it is likely that many of the new IT artifacts and services will in fact, as is often the case, primarily benefit those with the resources to obtain and exploit them.

What comes next?

This document reports on the second of a planned series of conferences. The conferences to date have considered some political, economic, and social consequences of the information revolution, and key technical trends. Among the topics requiring further work are: better, parameterized models of the

information revolution, and discussion of which models are appropriate for which countries and regions of the world; more study of the information revolution in Latin America; better quantitative projections of future IT penetration throughout the world; and a better understanding of “proximity” in the information age – an understanding of which societal activities will cluster geographically and which will disperse.

We also anticipate holding two more major international conferences, preferably in Europe and Asia, to expose and vet our results before a wider international audience, and thereby to broaden and deepen our models of the future course of the information revolution throughout the world.