3. The Technology Underpinnings for the Information Revolution

Speakers: Robert Anderson and Larry Press

Rapporteur: C. Richard Neu

The next session of the conference was devoted to a discussion of potentially important technological developments during the next twenty years, and remarks regarding "information revolution demographics"--who is being affected by the information revolution and how.

Information Technology Trends

The first speaker began by noting that we can be certain that some important technological trends will continue. Computers will continue to get faster, smaller, and cheaper, for example. Wide bandwidth will become increasingly available. The really challenging questions, however, have to do with how businesses and societies will make use of these technological "raw material" to create applications, products, and services that will change people's lives.

Forecasts of such things have been wildly off the mark in the past, and considerable humility is required in this sort of exercise. Nonetheless, this speaker suggested, it is worth thinking about possible future "inflection points"--the moments that mark dramatic changes in the ways that technology is used. He also warned against focusing too intently on hardware or software trends. True "inflection points" are created by the interaction of technology and society. It wasn't the automobile itself that has turned out to be so important, for example. The changes that have really mattered, he argued, have been the growth of suburbs, the isolation of "nuclear" families in suburban houses physically distant from other generations of the same family, the dependence of industrialized nations on a few Middle Eastern oil producers, and so on.

The speaker identified a number of likely advances in *hardware* that may contribute to important inflection points. The most dramatic and socially significant advances in computing power may be those that arise from the

internetting of millions of computers, in effect making the capacity of supercomputers available to anyone with a modem. Some alternatives to current silicon-based electronics may also hold promise for information processing and storage in specialized applications. Among those that might prove workable in the next twenty years are: photonics, DNA computing, nanotubes, quantum computing, and holographic memory devices.

The continuing miniaturization of silicon-based electronics may lead to a proliferation of small and inexpensive sensors during the next twenty years--with possibly profound social and life-style consequences. The speaker suggested that we may see:

- Ubiquitous miniature television cameras linked to the Internet;
- Smart house, offices, businesses or even cities that would "know" where you are and what you are doing;
- Small sensors with "insect-like" capabilities to crawl, hop, or fly;
- Combinations of information technology and bio-technology to create sensors to detect certain chemicals, drugs, smells, etc. or perhaps to create "body area networks" that monitor and report on a variety of health status indicators.

Significant advances in *software* may be made possible by more automated programming techniques or through "genetic programming" that allows programs to "evolve" in order to solve complex problems. Early efforts to reverse-engineer human sensory organs and parts of the human brain are also showing some promise.

Knowledgeable observers have been (prematurely) forecasting dramatic developments in *artificial intelligence applications* for years. The forecasts may soon be proven correct, the speaker suggested, if only because we will be to apply immense amounts of computing power to these very difficult problems. The applications with the most potential for changing the way people live may be:

- "Good-enough" speech recognition;
- "Good-enough" text understanding to enable effective language translation;
- "Good-enough" pattern recognition to allow automated monitoring of, say, television images;
- And much more capable information retrieval capabilities--perhaps advanced 'bots to search many available sources.

Continued development of communications links may make possible coordinated actions on a massive scale as tens of thousands of Net users organize and coordinate actions--for good or ill. There is every reason to expect that e-commerce will continue its recent growth, increasing competition and squeezing the margins earned by middlemen. Increased "mining" of data generated in everyday life transactions is already proving valuable to some businesses and worrying to some who fear the loss of personal privacy.

Advanced communications technologies may allow rapidly configurable collaborative environments--virtual laboratories, institutes or universities. Also possible may be realistic real-time interactive gaming and simulation environments, allowing much expanded "experience" with complex procedures and situations.

This speaker concluded his remarks by suggesting that the most far-reaching consequences of the information revolution might arise from the fact that it enables other revolutions--especially a revolution in biotechnology.

General discussion of this topic was deferred until after the next presentation.

Information Revolution Demographics

These remarks were followed by some comments on "information revolution demographics"--who is being affected by the information revolution and how. The second speaker noted two principal themes for his remarks: 1) Connectivity to and use of the Internet is spreading very rapidly, but 2) very large disparities in access and use persist.

Almost every country in the world today has some Internet connectivity, he noted. But in many countries, access is very restricted--to small numbers of individuals working in favored institutions in the capital city. Also, bandwidth available for international communication is very limited in many developing countries. The speaker noted that some countries have a total capacity for international Internet communications that is less than is typical for a medium-sized U.S. firm with a T1 line. High-speed connectivity today exists almost exclusively between the United States and Europe and between the United States and Asia. There are very few high-speed links to or among developing economies. About half of all Internet users today are in the United States and Canada.

Internet hosts are heavily concentrated in the United States, Western Europe, and in some parts of Asia. The distribution of the hosts is roughly in line with

relative standards of living throughout the world. The number of Internet hosts per capita in a country, for example, shows a strong correlation with the Human Development Indicators monitored by the United Nations Development Program (UNDP).

The last few years have, of course, seen a rapid growth in the number of Web servers. Interestingly, there has been even faster growth in the number of *secure* Web servers. English is by far the dominant language of the Web, and it is even more dominant on secure Web pages.

The speaker warned against thinking about Internet diffusion only in terms of the number of users in a particular country. He suggested six dimensions that characterize the extent of Internet development in a country:

- pervasiveness: a measure based on users per capita and the degree to which non-technicians are using the Internet.
- geographic dispersion: a measure of the concentration of the Internet within a nation, from none or a single city to nationwide availability.
- sectoral absorption: a measure of the degree of utilization of the Internet in the education, commercial, health care and public sectors.
- connectivity infrastructure: a measure based on national and international backbone bandwidth, exchange points, and last-mile access methods.
- organizational infrastructure: a measure based on the state of the ISP industry and market conditions.
- sophistication of use: a measure characterizing usage from conventional to highly sophisticated and driving innovation.

This speaker concluded with a proposal for much more extensive data collection on the use of the Internet, computers, and other information technologies and communications technologies worldwide.

Discussion

The general discussion of this presentation and the preceding one on technology trends began with a question about what, if anything, made information technology different from other advanced technologies. For example, the questioner noted, worldwide patterns of Internet usage are not obviously different from the patterns of clean water, vaccinations, high-quality housing, and many other indicators of standards of living. The second speaker responded that it is largely "a matter of faith"--widely believed but certainly not proved--

that information technology is unique in the possibilities it offers for changing societies. Another participant argued that the Internet is different from other advanced technologies in that its rate of mass adoption has been much faster than any previous technology.

Another participant noted that in both of the preceding presentations we had heard much about *quantities* of information or communication, but almost nothing about the *quality* of this information. The author of the presentation on technology trends suggested that there is probably little to be said about the quality or content of information and communications. The market will out. These media will carry and process whatever information users desire to be carried. Technology, he argued, is neutral with regard to quality.

Another participant noted that correlations between Internet usage and economic factors may be spurious. In many countries, she argued, there is excess capacity within national telephone systems. The real constraints on Internet access and usage, she suggested, are governmental and regulatory. Another participant noted the importance of institutional and legal barriers to Internet use in some countries. The presenter of the material on Internet demographics agreed with these observations, but warned against believing that simple deregulation would be a cure-all.

Other participants pointed to the need for much finer-grained analyses of Internet usage. Our traditional socio-demographic categories may not be adequate for these analyses, one suggested. For example, some of the heaviest and most sophisticated users of the Internet are young people with very low current incomes but access to Internet services through their schools, employers, or families. Another contested the notion that Internet diffusion has proceeded faster than had the diffusion of other technologies; television, he asserted, reached a mass audience more quickly than the Internet has. He also suggested that in some countries and for some demographic groups, the Internet may be substituting for other, still underdeveloped information technologies, and that consequently the diffusion of Internet technology is something of a special case. He also pointed out that the business models of firms that offer Internet technology and services are different in important ways from the business models of firms offering other technologies and services. Until we understand these business models and their implications, we will not fully understand what drives or retards diffusion of the Internet. Yet another participant noted that treatment of intellectual property rights may also have much to do with the way in which the Internet is utilized in different countries.

Near the end of the discussion, a number of participants expressed some impatience with the concentration on who uses the Internet and how much. They argued for more attention to the political and social consequences of using this or any other information technology. In this connection, another participant introduced terminology that proved useful throughout the rest of the conference. He distinguished between "technology"--the know-how or understanding that allows us to accomplish particular ends--and the "artifacts"--the actual applications--that we build with our technology. He argued that the artifacts will be of much greater political and social consequence than will the technology itself.