PART 6

Information Technology: Backbone of the Knowledge Economy

The expanding global reach of the Internet and the growing economic impact of electronic commerce have raised a number of intriguing challenges. Governments find themselves balancing a number of bifurcated policies—the need to protect intellectual and privacy rights while ensuring enough freedom to foster innovation and the need to regulate commerce and enforce existing laws while allowing the open trade of goods and ideas. The following six chapters provide perspectives on the role of government participation in electronic commerce, information technology R&D, and database publication. Also considered are the effects of information on publishing, research and education.

In Chapter 19, Elliot Maxwell from the U.S. Department of Commerce, discusses the policy issues stemming from the vigorous growth of electronic commerce. He illustrates the importance of electronic marketplace pointing out that e-commerce "is going to be a trillion-dollar activity in three of four years." President Clinton issued the report, *Framework on Global Electronic Commerce*, in 1997, outlining five principles for guiding e-commerce policies. The government will face the difficult tasks of enforcing consumer protection laws, maintaining privacy, and monitoring content regulation, while supporting and enforcing a "predictable, minimalist, consistent, and simple legal environment for commerce."

IBM's Irving Wladawsky-Berger, a member of the President's Information Technology Advisory Committee, outlines the roles of the government and private sector in advancing the IT revolution. He identifies the part the government has played in the development of the Internet, from its beginnings as DARPANET and NSFNet, to today's community of "200 million people worldwide." He believes "if high-tech, long-term IT research is to be done, the university and research communities—funded by the government—must do it." Wladawsky-Berger says that government must assume the role as the primary source of funding for advanced IT research at the front-end, while maintaining a subtler role of "restricting itself to indirect actions like continued deregulation."

In Chapter 21, Martin Blume, editor-in chief of Physical Review, details the changes that have occurred to the journal, and to electronic publishing in general with the advent of the IT revolution. Among these changes are the evolution of preprint to E-print, the publishing of books on CD, and the online publishing and distribution of papers. Blume says, "In addition to putting the current issues online we have also put online all of our journals back to 1985. This totals 100,00 articles." He also identifies new challenges posed by online publishing, such as the process of peer reviewing E-prints, and protecting intellectual property rights, international copyrights and licenses.

Jonathan Band of Morrison & Foerster, and Fujitsu Limited's Makoto Kono, provide Chapter 22. The authors chart the current debate surrounding database protection bills H.R. 354 and H.R. 1858, the protections now afforded database publishers, and the consequences these bills may have for the economy. The authors believe that the database bills "will head the database industry, and arguably the economy as a whole, in dramatically different directions." They caution towards balance, and warn that "drastic change to information policy will hinder the expansion of the Internet, impede research, and stifle entrepreneurship and innovation."

Larry Smarr of the National Center for Supercomputing Applications at the University of Illinois at Urbana-Champaign describes how the emergence of grid information infrastructures will affect the manner in which research and education are conducted. Advancements in infrastructure technology have led to the creation of grids—high-speed research networks—which will connect research institutions and allow the rapid transference of vast amounts of data. "The Grid is not just a supercomputer, but rather a network of computers, sensors for input, with results output to the Web." Smarr ends his chapter on a cautionary note, referencing the results and recommendations of the report from the President's Information Technology Advisory Committee. An excerpt from this report follows in Chapter 24.

This report, *Information Technology Research: Investing in Our Future*, finds that investment in technology has slowed in both the public and private sectors, and "federal support for research in information technology is seriously inadequate." The committee recommends that in addition to increasing spending on technology R&D, the federal government should focus on long-term IT research in software, high-end computers, and scalable information infrastructure. The report also recommends upgrading the knowledge base of and skills of the U.S. workforce, because "trained people are not just a byproduct but rather a major product of publicly supported research."

19 Policies for the Emerging E-Commerce Marketplace

Elliot E. Maxwell

I would like to briefly summarize the policy issues arising from the emerging electronic commerce marketplace.

Why should we care about e-commerce? One reason is the enormous impact electronic commerce is having on businesses and on our economy as a whole. Electronic commerce was a term that people did not even use ten years ago. Now it is an idea we cannot avoid. Companies that we now associate with electronic commerce, such as Amazon.com and eBay, are only several years old. It is quite remarkable that the public consciousness has been affected so dramatically and so quickly.

Electronic commerce is going to be a trillion-dollar activity in the next three or four years. What is even more striking is that the pronouncements we were making no more than nine months ago are outdated. In May of 1998, the Electronic Commerce Working Group issued a report for the Department of Commerce titled *The Emerging Digital Economy*. We optimistically projected at the time that electronic commerce would total perhaps $300 billion by the year 2002. By November 1998, when the President received our first annual report, the figures had grown dramatically. Now people quite confidently predict a trillion-dollar market in the next several years.

But the most important reason why we should care about electronic commerce is that it is changing our lives. It is changing the kinds of businesses we interact with and how they interact with us. It is changing how those businesses organize themselves. It is changing how they

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deal with their suppliers. It really is a sea change in the way we think about the world.

Governments first started to wrestle with questions of electronic commerce policy in 1996. In December 1996, the U.S. government issued a draft report, and for the first time in its policy making process, it accepted public comments over the World Wide Web from all around the world. In July 1997, the President issued the report titled *Framework for Global Electronic Commerce*, which is now available at www.commerce.gov.

Also in1997, the European community and the Japanese Ministry of Industry and Trade issued policy documents about e-commerce. The very broad agreement about electronic commerce and the Internet in these documents is quite striking given the different legal and cultural traditions.

One point of agreement was that electronic commerce and the Internet were potential engines for economic growth with important societal benefits. Also, the Internet was seen as a global institution. In terms of policy, the global nature of the Internet is a very important issue.

Even more striking in all of these papers was the notion that the private sector should play a key role. In fact, what has happened since 1993 or 1994 with respect to electronic commerce and the Internet was largely the result of the work of the private sector, not the government. Governmental action spurred the development of the technology that enabled electronic commerce, but the real growth of electronic commerce has been the result of private-sector leadership. This emphasis on private-sector leadership is one of the five crucial principles in the *President's Framework on Global Electronic Commerce.*

The second principle set out by the President was that government should avoid undue restrictions on electronic commerce. Too much control could "smother the baby" by not allowing new technology and new practices to emerge, not allowing innovation to thrive. "Undue" is a key word because the government is involved whether by enforcing consumer protection laws, or funding advanced R&D, or providing that electronic contracts can be enforced.

Third, where government involvement is needed, its aim should be to support and enforce a predictable, minimalist, consistent, and simple legal environment for commerce. People should be able to understand the rules, and the rules should be kept to the minimum required to accomplish an important social purpose. They should be enabling as opposed to restrictive.

Fourth, governments should recognize the unique qualities of the Internet. Often, in policymaking we look for the historical analogy, we turn toward the regulations and laws that are in place, and we try to apply them to the next "new thing." We need to ask ourselves how the rules would work in this unique environment, rather than simply applying them as they are written. How can we accomplish the important aims of existing laws in the cyberspace environment using the technologies and the capacity to innovate in this space?

Finally, the President noted that electronic commerce over the Internet should be facilitated on a global basis. The Internet and electronic commerce would be far worse off if treated as if bound by a nation's borders. If every nation made its own set of rules a genuine global medium would not emerge.

There was a surprising amount of agreement about governmental action but there are lots of barriers to making this work in a global environment. Among them are the very different legal regimens and cultural traditions, including the different ways different countries view the role of government.

For example, we are now engaged in discussions with the Europeans about privacy policy. Much of the difference between us rests on quite different views about the relationship between the citizenry and the government. Traditionally, (this is a gross exaggeration, but please allow it for purposes of illustration) laws involving privacy rights have been, in the U.S., first aimed at protecting citizens from their government. In many other countries, the government is viewed quite differently, as the principal protector of the citizenry. Therefore, the question of rights is not about rights vis-a-vis the government but of rights that may be infringed by institutions, including businesses. This type of thinking dramatically changes how one might look at regulating electronic commerce activity.

Another impediment in trying to think about the Internet on a global basis is a kind of mercantilist view that if the United States succeeded in growing e-commerce here it would be to the detriment of e-commerce success in Europe or Japan. Reports by other governments said, "We have to form our Internet policy, so that we won't be left behind. We don't want jobs to be created in the United States, rather we want them created in France or in Germany or in Japan." The issue of economic competition among regions can potentially frustrate the development of policies that facilitate on a global basis.

The Policy Structure for an Electronic Commerce Infrastructure

Telecommunication Infrastructure

A number of what I call infrastructure policies have to be addressed in parallel, not in series, to make electronic commerce work for the benefit of individuals and businesses. First, not in priority but belying of my telecom background, is the question of access to bandwidth. Most people connect to the Internet from homes or small businesses through dial-up modems. We are starting to see higher bandwidth connections for these users through cable modems, DSL technology, and others, but it is still a very, very small percentage. There are approximately 100 million U.S. households. At the end of 1998, it was estimated that about 300-500,000 households had cable modems and about 30,000 had DSL modems. So one-half of one percent of households have access to higher bandwidth. When lots of homes and businesses have access to higher bandwidth it will fundamentally change the experience of using the Internet, and will offer new tools to the innovative people creating electronic commerce.

International Market Openings

The second infrastructure question is one of market opening. On a global basis, people who offer connections to the Internet must be able to reach their potential customers. Internet service providers in Peru and in Poland must get the functionality they need in the telecommunications market. The best way of accomplishing this is moving from a monopoly environment in telecommunications to a competitive environment. Pricing structure must change so rates are reasonable. It means giving people access to particular kinds of connectivity. Fair terms for interconnection must be available. We are now starting to see national administrations around the world changing their views. They are liberalizing, privatizing, and actively working toward lowering rates for Internet access. They are trying to jump-start their connectivity and the connectivity to the Internet.

Legal Framework/Authentication and Security

The third issue is the legal framework for electronic commerce. Everyone has signed a contract at one time or another. Contracts in the U.S., by definition, require a reduction to writing and a signature, and in some cases, some method of authentication. But what if we want to form electronic contracts? We cannot think about it in the same way. If every electronic contract that you formed over the Internet had to be reduced to writing, sent back and forth for your signatures, and filed away, electronic commerce would slow to a crawl. We need to change our laws to allow for electronic contracts and at the same time to address security and authentication. How do you know that the person to whom you sent information is the person you intended to send it to? How do you know that the information you received was from the person whose name is on it? How do you know that the information was not changed? A legal framework has to be built so that people have confidence in using electronic commerce. That means confidence in the identity of the person they are communicating with, confidence in the security of the medium they are using, and confidence in the integrity of the communication. We will need to bring all our creativity to these subjects to benefit from technological development, such as new means of authentication, and protect ourselves from new threats to privacy and security. Without consumer confidence, electronic commerce will not grow.

Taxation

Taxation is another infrastructure issue. When Congress passed the Internet Tax Freedom Act in October 1998, it called for a commission to examine a series of questions and report back to the Congress in April of 2000. How do you, or do you, tax remote sales? Under certain circumstances, States and localities can tax remote sales, but they have to determine where the online companies are located, where the transaction took place, and whether there is sufficient nexus between the activity and the state or locality that seeks to tax it. We have a model in remote sales such as catalogue sales, but it may not be the model to be applied.

So how should we think about taxation? Should all kinds of sales be treated the same way? What is the impact on states and localities that raise a fair percent of their revenue from sales taxes? What does it mean for the bricks and mortar businesses that may have to pay everywhere if they are physically everywhere? What does it mean for the cyber merchants, who are virtually everywhere and physically beyond the taxing authority? What would taxation due to the growth of electronic commerce? The taxation question is an important one and contentious.

Tariffs and Customs

Tariffs and customs also need to be considered. How should we think about the tariffs on material in an electronic form that crosses a national border? At the moment, if I send a CD across a border there is a customs duty based on the values of the physical medium. In this case the value of the physical medium is very low, but the value of the information on that disk may be quite high. But what happens if we send the same content electronically? It is not presently subject to customs duties.

The World Trade Organization now has a temporary moratorium on tariffs on electronic material delivered electronically and we support an indefinite extension of this moratorium. But, just as state and local governments are interested in taxing electronic commerce, other countries may well be attracted to duties on electronic.

Electronic Payment Systems

Another issue is electronic payment systems. An effective and efficient system is necessary for e-commerce to thrive. We have been lucky to have a well developed credit card system to use, but many potential users do not have credit cards and credit cards are not particularly useful for micro-payments. For the government there are issues about money laundering, particularly given the anonymity possible on the Internet. We must also consider the creation of new forms of money, and their impact on traditional currencies. What, for example, is this is going to mean for governments that have strictly controlled their currencies?

Security and Reliability

Another infrastructure issue is security and reliability. In 1991, when telecommunication networks crashed on both coasts, there were immediate congressional hearings. There were mandates to the Federal Communications Commission to take care of this problem. In response, a Network Reliability Council was established. More recently we have seen people being unable to trade on E*TRADE or Schwab because of network failures. As more business and mission-critical activities go online, and more people incorporate the Internet into their daily lives, what will be the impact of network failure? Will we think about reliability as we think about the reliability of our desktop? (Well, it crashed again. But that's okay because I'll just reboot). Or is the analogy going to be the telephone system? (I'm not going to tolerate telephone system failure). Perhaps the penalty for the success of the Internet will be an increasing focus on reliability? If this is so, will the government have any role?

Universal Access

An additional infrastructure issue is universal access. Presently, about 94.5 percent of households have access to a telephone (which compares unfavorably to 98 percent of households that have color television sets). Unfortunately, the number is tied to income: 99 percent of households with incomes over $75,000 have access to a telephone, while 75 percent of households with incomes under $7,000 have such access. Telecom penetration varies considerably by racial and ethnic background, and by geography. There are similar but even more striking examples of disparities in access to computers and the Internet documented in Commerce Department reports.

Much can be done using community access centers. The Administration has worked very hard to connect schools and libraries to the Internet and to find ways of providing community technology centers as access points. But we will have to wrestle with the issue of a possible digital divide and what that means for our society. What kind of differences are tolerable for our society given the growing importance of access to information technology and the Internet?

Research and Development

The last infrastructure issue is research and development (R&D). What is the role for the government in R&D related to electronic commerce and to the underlying technologies? The government's role in the past has had an incredible impact in this area, extending beyond the creation of the Internet. For example, when people go on the Internet and use a search engine, or use a browser to navigate the Web, they are probably using instruments, that were developed using federal funds. The research that has been supported has had enormous societal returns, but we will always need to ask where the government should direct its funding.

Policy Structure for Electronic Commerce Activities

Consumer Protection

There are also issues that I call "applications issues," that involve the transactional consumer interest such as the relevant consumer protection issues. We take for granted that the government has a role in consumer protection with laws against fraud and misrepresentation. The government has the same role in protecting consumers on the Internet. The difficult question, though, is what rules should operate around the world and how the rules should be optimized for the particular environment of electronic commerce because this particular environment has some quite unique characteristics.

Can you imagine an environment in which, if you are about to purchase something, you have a pop-up window that says, "This is what happens if you need to return it; these are your means of redress if you are not satisfied"? We do not do that in the real world or in the catalogue world. This electronic environment has some special capabilities that we need to consider. Consumer protection needs to exist in this space, but we must think about how we can accomplish the purpose of our existing consumer protection rules while utilizing these new capabilities. Perhaps we can even strive to create an environment that is even more consumer friendly.

Many people went shopping over the Internet in the 1998 holiday season. Unfortunately, some of the data after the holiday season showed a lowering of consumer confidence in e-commerce than before. Why is that? Some e-tailers were overwhelmed, swamped by the demand. From the standpoint of the Commerce Department we were glad there was demand. But some retailers did not let their customers know that they had run out of goods. They did not let people know that they had cancelled their orders. That was wrong, not only from the standpoint of building a business, but it was also a violation of existing rules that apply to all telemarketers. Some of these people were violating rules that they had not taken the time to understand. It is critical for businesses to obey such rules in order for people to feel confident in using the Internet.

Privacy

Privacy is another applications issue. In a survey of Web sites about 18 months ago, the Federal Trade Commission discovered that only 14 percent had their privacy policies posted. The On-Line Privacy Alliance and others have worked very hard with the major providers of e-commerce to make sure that privacy policies are posted and that people understand them. In fact, organizations like BBB*OnLine* and TRUSTe provide third-party verification of those policies. These privacy policies need to provide notice so that people know what is going to happen with their information and provide choice so consumers can decide if they want to have their information used that way. Internet users must have some redress mechanism if the information is misused. If self-regulation is to work in the privacy world, good privacy policies must be broadly used and they must reflect fair information practices.

Content Regulation

A third applications issue is content regulation. In the United States we tend to think about this issue in terms of pornography, but there are other important topics, such as sedition in China and hate speech in Germany. A prosecution is currently taking place in Germany because CompuServe had hosted a Web site that showed Nazi regalia. It was not a German-based site, but German law forbids the display of these items. The German prosecutorial authorities have sought to hold CompuServe responsible. What happens if a Chinese authority tried to act against a dissident group hosting a Web site based in the United States? Or consider someone in California operating a site that, by contemporary community standards in California, is not pornographic. But what happens if an attorney general in another state wants to shut it down because the site is available to people in another state whose standards would not accept it? How do we think about these content issues? How we deal with the special needs of minors?

The Administration sought to provide more and more tools to people so they can control their own communications. But these current issues are contentious, as you can see in the press at any moment.

Intellectual Property

The fourth applications issue is intellectual property. How do you accomplish the protection of intellectual property in this digital environment where you can make perfect copies and send them out to millions of people for a cost that is staggeringly low? Bills before Congress seek to implement treaties that emerged from the World Intellectual Property Organization negotiations. We are also facing conflicts in this area between the traditional needs of the academic and research community, people who seek to have access to information, and the desire of content creators to get the greatest economic rewards for their creations so as to spur creativity. These tensions will continue to exist and will be an important part of the policy discussions in the world for electronic commerce.

Regulation of Like Services

A fifth applications issue is regulation of like services. If you go to broadcast.com you can “watch” dozens of television stations that are being transmitted over the Internet. You listen to hundreds of radio stations the same way. In its physical world location, each one of these stations is subject to rules as a regulated broadcaster. Should those rules apply to the location where you are when you receive that station over broadcast? Should Internet telephony companies be regulated like local telephony companies as they are offering a like service?

Jurisdiction

The last issue, the question of jurisdiction, is perhaps the hardest issue. Almost all the above issues raise it. When we started policy discussions about the technical management of the Internet and trying to privatize the domain name system, the first response was to let the Internet community decide it. But who is the Internet community? How does it vote? Where does it go to vote when it makes these decisions? How should one allow people who have stakes in these issues to participate in their resolution? What role is there for governments? What role for multilateral institutions? Who chooses which rules apply and interprets them?

What happens if I have a retailer headquartered in California, a server in New York, a customer in France, and the delivery in India? Who gets to make the rules about what is allowed or banned? What kind of advertising can you do? What return policy for goods is applicable? And what about telemedicine—who will set standards for the practice of medicine? What about architects delivering blueprints? What about people who are engaged in other forms of professional services? How do we reach agreement about who is going to make the rules and which rules apply? Unless we can resolve these issues we are going to find people reluctant to offer their goods and services on the Internet. Think of the business owner who says, "I won't participate in electronic commerce if I don't know which one of 200 jurisdictions' consumer protection rules might apply." Think of a consumer who does not want to necessarily be bound by the rules of the location of the seller because he or she does not know what those rules are. So there are questions of who chooses which rules, who interprets the rules, and how they are enforced underlying all of these other issues.

This is an enormously vibrant and exciting time. AAAS members were present at the birth of electronic commerce, and we all have some stake in what policies emerge and how successful they are in striking the balance between enabling the growth of electronic commerce and preserving the fundamental values we have as a society. I hope AAAS members and the communities they represent become engaged in these policy debates because they are debates about the shape of our future. It is a new medium, we have a wonderful opportunity to make choices and we need all the help we can get.

20 Government and Private Sector Roles in the IT Revolution

Irving Wladawsky-Berger

Whether one is directly involved in the information technology (IT) industry or simply dependent on its products, we are caught up in an information revolution that is transforming society at large. At the heart of this revolution is the vision of a society exploiting information technologies to connect people with business, with government, with information of all sorts, and—perhaps most important—with each other.

I would like to offer some reflections on government's role in this revolution vis-à-vis the private sector as well as the academic and research sectors. The revolution is evident in the frenzy of connectivity all around us. One IT consultant estimates that 200 million people worldwide will be connected to the World Wide Web in 1999, and a half-billion by 2003. More than 200 million devices—everything from set-top boxes to screen phones—will be connected by the end of this year, and almost three-quarters of a billion devices will be connected by 2003.

Consumers are spending ever more billions of dollars via the Web, while estimates of worldwide business-to-business Internet revenues for 2003 exceed $1 trillion. Meanwhile, companies are reducing paperwork, cutting costs, and saving hundreds of millions of dollars just by sharing information with key suppliers and employees. My own company sold more than $3 billion worth of goods and services online last year, and its current electronic commerce volumes are running at roughly $1 billion per month.

It is not just business, either. Education, health care, research, government—practically all of society's institutions are using the Internet

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to empower students, teachers, patients, citizens, and constituents. Even the IRS has enabled millions of Americans to file their tax returns over the Internet, once again reaffirming T. S. Eliot's observation that "April is the cruelest month." But despite all its momentum, our revolution is not a spontaneous phenomenon. Connecting the whole country, the hemisphere, and even the world is hard, deliberate work.

The wholesale transformation that our revolution envisions is easily among the more ambitious enterprises our country has undertaken. The Manhattan Project, the Apollo landings, and the Strategic Defense Initiative seem simple compared with the complex scientific and social changes involved in connecting and transforming all of society.

Such a monumental task requires that the major participants in the revolution—the university and research communities, private industry, and especially government—be partners in pursuit of the vision. Together, we are trying to build something both very complex and very wonderful.

Our guiding principle must be pragmatism. We must be true to that brilliant depiction of Americans as a "nation of tinkerers"—a people focused intensely on what works. That focus on the workable must inform all our efforts, but especially the policies and practices of government.

Government must encourage and promote the revolution and at the same time beware of ill-advised laws or regulations that can distort the marketplace, divert vital resources, or deflect the course of some promising research project. Our information society has the feel of a very complex, mysterious, and exciting ecosystem in which each element is connected to and influences every other element, and ultimately the life of the whole.

The government's role of enabling that ecosystem to grow and flourish is akin to that of a very wise gardener. The garden needs to be tended, the soil cultivated and fertilized as necessary, and the proper seeds planted. The garden then needs a watchful eye to make sure that weeds and pests are properly dispatched. But beyond that, the gardener must be pragmatic and be content simply to let the garden grow, and let all its various parts achieve their natural balance and productivity in the ecosystem. The right relationship has to exist between the gardener and the garden. One does the tending, the other the growing.

This is the kind of pragmatic posture we on the President's IT Advisory Committee took when we outlined the areas essential to establishing the information age in the United States. If you have read our report, you know we called for a substantial increase in IT research and for close attention to the major social issues that would accompany the transformation of our society to the information age.

Government has a role to play in just about every aspect of the transformation—sometimes a more prominent role, sometimes less. Take research, for example. Everyone agrees that long-term, strategic research is essential to the future health of the IT industry and to all the other businesses and the millions of people in the United States who depend on it directly or indirectly. The real issue is the division of labor: What roles should government, academia, the research community, and industry play? The most instructive example might be the Internet itself.

More than a quarter-century ago, you could not find a business in the United States with an interest in linking four universities' host computers together. The U.S. government, on the other hand, had a compelling interest in establishing a system of communication that would withstand a nuclear attack. DARPA went ahead with the project, and so the Internet was born.

Over time, researchers at the national labs and universities connected and began sharing information and applications. And most important, they began enhancing existing technologies and standards and developing new ones.

Today, according to some estimates, that modest original Internet has grown from four hosts to more than 40 million. It connects roughly 180,000 networks and supports well over four million World Wide Web sites. The real spurt stared five or six years ago when businesses began to realize that, through the Internet, they could connect all their islands of automation internally, and reach out to millions of existing and prospective customers all over the world. And as all the new Internet companies have demonstrated, you did not need the resources of a Fortune 500 company to accomplish it.

In building the original Internet and extensions like the NSFNet, government responded to a need that no one in the private sector had any incentive to satisfy. Government seeded the initial efforts and continued to nurture it over time. Universities and researchers developed it further. Now the business community is transferring its commercially useful fruits to the marketplace.

That is precisely the model of the right relationship between government, academia, research, and industry as we continue to move our nation into the information age. The IT industry is fully prepared to invest in research and development, but in this most competitive marketplace in the world, the lion's share of those funds must flow toward product development—and most of what remains flows toward company-specific, near-term applied research.

Only a small number of companies can afford to invest in research with a five- or ten-year payoff. The vast majority of companies do no long-term research. IBM is the exception in our industry, not the rule. Thus, there is a widening gap between the growing numbers of IT applications and users in the marketplace—the demand, so to speak—and the fundamental research that has traditionally supplied the underpinnings—the seed, as it were—for IT technologies, infrastructures, and applications.

So if high-risk, long-term IT research is to be done, the university and research communities—funded by the government—must do it. That is the only way to maintain our nation's competitive advantage, ensure the prospect of long-term economic growth, and in the process train a new generation of researchers to preserve and extend our technological primacy.

Beyond long-term research, government can hasten the coming of the information age by showcasing the new, complex technologies that underlie its own applications. The Department of Defense has done this through the years—the Internet being a case in point. The Accelerated Strategic Computing Initiative (ASCI) program is another example of government—in this case, the Department of Energy—leading the design of very powerful parallel supercomputers for its own applications.

Certainly the government is working to leverage the potential of IT, but to date it lags behind the American business community. That is not surprising. At IBM we learned that such transformations are tough and take time.

Organizations resist change. A concerted effort is needed to master all the technical challenges, and to break through the even tougher cultural barriers. The Department of Defense, for example, is beginning to face this era of transformational change in its approach to warfare. It is shifting from the traditional model of warfare based on platforms like tanks, ships, and planes to a network-based warfare that can potentially deliver to the U.S. military the same efficiency, responsiveness, and innovation it has brought to American business. The intelligence community, too, is trying to create a more networked, collaborative, environment among its major agencies and mission partners to provide a richer, more comprehensive intelligence picture to the warrior.

Beyond those agencies, which are usually found in the vanguard of new technologies, are the sweeping, inclusive nature of Internet-based applications and the variety of government agencies that can help build them. The Department of Health and Human Services, for example, should lead in telemedicine. Distributed learning technologies are absolutely indispensable for the Office of Personnel Management. Security and authentication technologies are absolutely indispensable for the Social Security Administration and the IRS. In many of these areas, management tools can make substantial contributions in data handling as well.

While it is clear to all of us on the President's advisory committee that government has the preponderant role to play in long-term strategic research, it is equally clear that the profound transformations arising from the information revolution are raising very important societal issues—issues like access, learning, and privacy. Government's interest in each is very real. How it should act in each case varies. With technology prices plummeting, the marketplace itself will provide near-universal access over time.

So, government should probably adopt a more subtle role, restricting itself to indirect actions like continued deregulation and offering access at government facilities or kiosks in public spaces. Research on new wireless technologies will also significantly help in providing high bandwidth connectivity for everyone. When it comes to education and learning, on the other hand, government at all levels should unquestionably take a strong leadership role—implementing policies that raise educational achievement across the board and that prepare our society for lifetime learning.

But of all the byproducts of the IT revolution, the growing concern for privacy is among the more critical. How well we protect personal information online will determine whether the Internet will achieve the success we all hope for. Privacy is not a cut and dried issue. What is and is not private changes from person to person. For one person the scope of privacy is very narrow; for another, it is very broad. For some people privacy is negotiable, and they may be willing to trade information about themselves in return for something of value.

Ask the average person how to assure personal privacy online and you will probably get a reflexive resort to government control. Certainly a pervasive regulatory regime could assure the public that nothing improper would happen to their personal information by making sure that nothing at all would happen to their personal information—nothing bad, certainly, but nothing good either. At the other extreme is the laissezfaire solution, which might suffice in a perfect world. But, as the Founding Fathers knew, human nature is far from perfect.

So, somewhere between those two poles lies the answer—some balance between legitimate government action and the rewards and sanctions of the marketplace. Frankly, I am inclined to find the balance much closer to the marketplace. After all, when the economy is networked, global, and competitive, consumers can impose sanctions and punish a company much faster and more effectively than can government.

But of all the participants in the networked economy, members of the business community especially need to establish themselves as worthy stewards of privacy. That is one reason IBM announced recently that we would advise only at Web sites that posted their privacy policies.

The great majority of the business community recognizes that its real interest lies in maintaining the trust and confidence of their customers—and therefore in respecting the privacy of personal information. That is why any government privacy policy should provide maximum latitude for stringent self-regulation—the kind of discipline that business is already adopting.

The 80 global companies and major trade groups of the Online Privacy Alliance, for example, have created guidelines for privacy policies and an enforcement framework with real teeth. Many Alliance companies are working with "seal programs"—independent third parties like the Better Business Bureau's BBBOnLine, and TRUSTe—that monitor a company's compliance with its privacy policy and confer, as it were, a seal of approval.

Industry has made real progress. According to one observer, when someone visits a Web site this month, there is a 90 percent chance that it will be operating under the guidelines of the Online Privacy Alliance. And beyond government and in industry is the individual empowered by increasingly sophisticated software tools.

Clearly, the less government obtrudes on the marketplace, the greater will be the flow of Web transactions delivering goods and services, health care, government services, financial services—indeed, everything that is dependent on online trust. And flowing from that will be new opportunities, new business, and new jobs in all sectors of the economy.

In the history of our country, few partnerships have been more fruitful than the collaboration between government, academia, the research community, and the IT industry. It has made us the world's unquestioned leader in information technology and the pioneers of the information age. Certainly, government played a leadership role throughout the process; and in some cases, leadership meant playing the dominant role as it did in starting the Internet. In other cases, the role has been less direct—such as seeding and cultivating research in the universities or collaborating with industry through the national labs.

As government defines its proper role vis-à-vis industry, the universities, the research community and the IT industry, it must constantly ask: "What will work best?" Unless we are talking about truly long-term, strategic research, what will work best are policies that permit each part of the ecosystem to pursue its natural course—the free intellectual ferment of the university and research communities, for example, and the creative chaos of the marketplace.

The really hard work for the gardener is in the beginning. After that it is up to the garden and the elements.

21 The *Physical Review* and Electronic Publishing

Martin Blume

The scientific journal *Physical Review,* which was founded in 1893, started out very slowly. The United States was a backwater of physics at that time and distribution of scientific knowledge was slow. Scientists needed a journal that would be used in the United States for the distribution of physics results.

A number of significant papers appeared in that journal even in the early days. Ultimately *Physical Review* became, and still is, one of the premier physics journals in the world. The number of significant scientific results published in this journal has increased significantly, but the percentage of papers that are significant has probably not changed from the beginning. This is pointed out very frequently. Today we publish close to 100,000 pages every year using paper technology.

We are now in a period of centennials. *Physical Review* had its centennial in 1993, X-rays in 1995, radioactivity in 1996, the electron in 1997, and radium in 1998. The American Physical Society, which published subsequently to the founding of *Physical Review,* celebrated its centennial in 1999.

The publishers of *Physical Review* celebrated its centennial by putting out a collection of significant articles that appeared in the journal over the years. The book was about seven centimeters thick. It contained a number of summaries of the different fields of physics, as well as a selection of papers in each of those fields chosen by a panel of experts. The difficulty arose when the experts could not confine themselves to 200 papers. In fact, they had 1,000 papers. It sounds strange to talk about 1993 as the distant past, but electronically it is. In 1993, they put

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in the back of the book a CD that contained all 200 papers published in the book itself, plus the other 800, plus all the ancillary material.

The founders of *Physical Review* would have been astonished at the physics that had been done in those 100 years, but they would have been quite comfortable with the journal as it was published in 1993. It was still a paper journal, but with a slightly different color. There were many more papers, but overall the format and the way of distributing the information would have been completely comfortable for the founders 100 years ago. The CD, however, would have astonished them.

What information was contained in that 100th anniversary volume? The papers that appeared there have, in fact, changed our view of the universe and the way we live. Some of the early papers discussed the Millikan oil drop experiment, the Compton effect and Compton scattering, and the Davidson-Germer effect, which showed that electrons are waves. A paper that appeared in the 1980s on the Higgs mechanism was one of the reasons that physicists wanted to build the supercollider here and why we are participating in the Large Hadron Collider elsewhere. A paper by J. Robert Oppenheimer and Hartland Snyder was the first place where the idea of black holes was announced. A famous paper by Einstein, Podalsky, and Rosen discussed whether quantum mechanics is a complete theory. And the invention of the transistor was announced in *Physical Review*. Some papers have led to Nobel Prizes.

All scientists need places where they can talk to one another in detail. *Physical Review* was described a few years ago in the *New York Times* as one of the most opaque and unreadable journals in the world. My predecessor, Editor-in-Chief Ben Bederson, wrote a very nice letter to the *Times*, which was published, pointing out that every technical journal is opaque, but it has to be understandable to other scientists. For example, Richard Feynman had a reputation, correctly, as a fine communicator. Yet it astonishes people to look at the density of equations in his papers in *Physical Review*. This density is necessary because it has to be boiled down later on. If you explain only in words it will not work. So we say proudly that our journal is opaque, but it is understandable to other physicists.

The distribution of this knowledge and of the journals is very important. Scientists want to distribute their knowledge as quickly as possible. Early on the idea of the preprint came about.

As the electronic era dawned, the preprint evolved into E-prints. E-prints are now very much with us and are very important. Scientists can distribute their papers by submitting them to various E-print servers, the most famous of which is Paul Ginsparg's at Los Alamos. In this way they can distribute the knowledge very, very quickly. E-prints also provide something of a relief valve because people sometimes want to put out very controversial ideas. These ideas can be distributed through E-prints. The difficulty with E-prints is the same difficulty with preprints. They are not peer-reviewed and they are not edited.

Of course, peer review is not an absolute certification. It does not say that something is right. It always disturbs me when I hear reporters stating that this was published in a peer-reviewed journal. They say it as if this were a mark of honor, indicating that this is something that is, therefore, absolutely correct. The only thing we can say for peer review is that it states that this paper is worthy of other scientists' attention. It may well be wrong; it may well be erroneous. After all, peer review cannot be an absolute. Verification has to be done in the marketplace of scientific ideas.

In 1988, Val Fitch of Princeton was president of the American Physical Society. He commissioned a report on the possibilities of distributing scientific results electronically. This was before the E-print archives were established. Stewart Loken of the Lawrence Berkeley Laboratory chaired that committee. In 1991, he put out a very prescient report, which was given with a title that is very common right now, 20/20. Obviously you want to have good vision for the future. The 20/20 report gave a number of possibilities for electronic distribution, which were supposed to be implemented by the year 2020. At the time of the report some of the relevant technology was bitnet, e-mail, anonymous FTP, and the gopher distribution of the results of scientific research. The report considered these and also had a glimmer of using the Internet in other ways, but the World Wide Web did not really exist then. (The browsers were just coming into play at that time and they have made a significant change). We have seen that everything predicted for 2020, amazingly, has already taken place. (Because of the prescience of that report I have asked Stewart Locan to form another committee to reconsider the situation. I want that committee to think about future developments and to predict where we may end up going).

How did we start with electronic publication and distribution? The first thing you think of is taking what you were going to put out in print and putting it online. This has been called "shovelware" by one wag. You just take whatever is there, shovel it online, and that is it. It is a very smart way to start electronic distribution, but it is a very dumb way to proceed. When you do this, consider the problems of *Physical Review*. We received 23,000 submitted articles for submission last year. And we have to put out our journals on a timely basis. We, therefore, have to do two things at once. We have to continue to put out the journal on paper (paper will not go away for a long time) and, at the same time, we have to move very rapidly. This is particularly true for physics journals because physicists are very comfortable with electronic media. The members of the American Physical Society will simply push the publications to the limit and make sure that we are as close to the forefront as possible. Otherwise they will go elsewhere. They will take their very good work and publish it elsewhere. We do not want that to happen.

We also believe in the importance of peer review in putting out the journals. That has to be worked into the electronic distribution as well.

You can do many other things besides just putting an article online and letting that take the place of the paper article. You have to consider the additional information that can be included electronically, including multimedia and movies. Mathematical physicists can put up a program that is actually executable so results can be duplicated and tested. There has been significant expansion of what you can do.

In addition to putting the current issues online we have also put online all of our journals back to 1985. This totals 100,000 articles. An important policy question here has to do with intellectual property. Scientists are now being pressured to hold on to the copyright and to give a license to publish to the publishers. If we had been doing this and had only a limited license that made no mention of new technologies, we would have been faced with getting 100,000 permissions in order to put all of these articles online. We probably would not have done this simply because of the effort. We could not have possibly have tracked everyone down. As a consequence, I believe the scientific community would have been that much poorer. This is one example of how intellectual property questions come in.

We also see the possibility of keeping a license that says we can do whatever we want with the articles we publish in the future as if we have the copyright, with any technology now known or to be invented. One of the difficulties with this is that it is not, according to the lawyers we have consulted, necessarily enforceable abroad. Only one-third of the society's papers come from the United States; two-thirds come from elsewhere in the world. In fact, more papers come from Western Europe than from the United States, and it is there that some of these copyright laws might come into play.

One of the things that also would have astonished the first editors of *Physical Review* is that our online archive goes back only to 1985. All we have to do now is fill in the gap between 1893 and 1985 and we will have a complete collection. In total shelf space we are more than halfway there. But the journal continues to grow very rapidly. (A story variously attributed to different famous physicists says that if they extrapolate the growth of the journal *Physical Review* to the middle of the next century, the speed of expansion on the shelves of libraries would, in fact, exceed the speed of light. But this would not violate relativity because no information would be exchanged).

Many things will happen as a result of having all of the journals online. In looking ahead to the future we also have to consider other scientific journals. We want to have a seamless web of scientific journals. If you have a reference in one journal you should be able to click on that and go to the other journal where the reference is. This is already a possibility. The Physical Society established a link manager where all you have to know is the reference. When you put the reference in, it goes to our program, which calculates where the article is now and takes you to the abstract of that article. If you have a subscription it also gives you the article itself. The European Physical Society and the French-German journal *European Physical Journal* have started linking to us in this way.

It is very important to be able to move rapidly around the world. There are two ways in which you can do this. One is to establish mirror sites of your journals in other parts of the world. This has certain advantages. It is very easy to do if it is not something for which you need access controls. But it raises taxation questions. A value-added tax can be put on electronic subscriptions in some countries in Europe. At the same time, the print is not taxed. Therefore our journals are distributed with electronic access given along with the print to avoid the value-added tax.

When first conceived, the Internet belonged to academia and to researchers. One of the problems that we see now is the heavy use, as people go online to shop, play video games, etc. Academic use is very much on the back burner. It is very important for intellectual discourse that there be some sort of dedicated links that would work strictly for academia.

With the Physical Society we have gone to another way besides mirror sites. We also have pipelines. We work with a company called Digital Island based in Honolulu that has links to different parts of the world. We can go from Honolulu to Paris in one hop. We use this to distribute our work.

You can also do searches on articles. Searching will be very important in the future. I often look through the online archive, simply typing my name into the references part of the link and finding all of the articles that refer to my papers. This is a very interesting exercise. A new search engine that we are working on will have special capabilities. It will, in fact, enable us to distribute the journals free, since the money we make on its sales will pay for everything we need. That search engine will find every paper that does not refer to you but which you should have. That is not too farfetched with a little artificial intelligence.

The implications of globalization are also very great. The development taking place right now in the electronic world parallels in many ways the revolution in personal transportation that occurred in the 50 or 60 years after the 1893 founding of *Physical Review*. The horse and buggy, which was the main form of personal transportation in 1893, was gradually replaced with the automobile. At the same time the highway system was developed, with pavement, four lanes, and, ultimately, limited access. Our publishing situation right now is at the stage where the horse and buggy is being replaced with an automobile that looks like a buggy but has an internal combustion engine. After all, that is what the first cars looked like. Only when the automobile was designed from the ground up did it reach its full potential.

As far as the roads are concerned, we are looking at a paved but not limited-access highway in many parts of the world. In other parts of the world we see either dirt paths or no roads at all. We have to take significant care to make sure that our colleague physicists in electronically remote parts of the world are served, and that they have access to the journals on the same rapid basis that other people do.

We are in the process of removing some of the horse manure left over from the horse and buggy era. We hope that this will not be replaced with the air pollution that has come with the cars.

Coming from Long Island, I have a particular fear. We have a nice limited-access highway, the Long Island Expressway, known affectionately as the world's longest parking lot. In fact, we can imagine the electronic super highway becoming a toll version of the Long Island Expressway, something to be seriously avoided.

I chair a committee of the International Union of Pure and Applied Physics. Its purpose is to address a number of international issues. One of the issues is international Internet availability and reliability for scientific publications. Every time you build a new highway the traffic increases disproportionately and you run into difficulties. We are going to have to work on that to ensure that scientists can continue to work on the Internet. Another issue is linking, mirroring, and cross-publication searching for journals of different publishers. A third issue is the availability of publications in electronically remote areas. Long-term availability and archiving of electronic publications are two particularly significant parts of this issue. I mentioned the CD that we put out in the back of the 100th anniversary volume just five years ago. That CD consisted of TIF images and some special software that enabled you to read them. It was readable only on a PC. It was not readable on a UNIX machine or on a Macintosh. I recently got a new PC with Windows98. I installed that special software and my PC promptly crashed. I tried again and it crashed again. It does not crash on all versions of Windows98 but it certainly did on that one.

We have to keep our electronic archives readable in the future. A few of us have been around long enough to have IBM punch cards with a particular computer program that we ran 25 or 30 years ago. It is very hard to get them read now. A few museums have punch card readers, and you could do it there, or perhaps some remote places still use punch card readers in one way or another. I would not have a problem if I had simply translated the punch cards and put them on tape and put that into a computer. The program was FORTRAN, which would probably run somewhere (but even that might have to be updated). We had to update the CD because of all the noise we made about our promise to keep things update-able.

The same thing is going to have to be done by publishers in the future to maintain the important elements of the archive. Paper is paper. It is there and that is what you have. But things can become unreadable electronically. They translate into something illegible. Long-term availability issues are very important.

Another issue is peer review and E-print archives. We want to maintain peer review, but the E-print archives are important. People can submit their articles to *Physical Review* from the E-print archive at Los Alamos. We will actually link to Los Alamos if there is a paper that is referred to and appears only in the E-print archive. People can download it and see it.

Finally, we have international intellectual property questions, which have been touched on. All of that is significant to us. The most important priority, of course, is that we want the scientific enterprise to continue to prosper. I personally want to see the most important papers published and distributed through *Physical Review*. I hope that will continue to be the case.

22 The Database Protection Debate in the United States

Jonathan Band and Makoto Kono

Two database protection bills are now pending before the U.S. House of Representatives: H.R. 354, introduced by Howard Coble (R-NC), and H.R. 1858, introduced by Thomas Bliley (R-VA). These bills differ significantly in approach and scope. This memorandum summarizes the background to the debate, compares the two bills, and discusses the possible global ramifications of legislation in this area.

The Status Quo

Historically, America's basic information policy has been that facts reside in the public domain. This allows a second-generation publisher to extract facts from an existing compilation for reuse in its own compilation. Facts are viewed as the building blocks of knowledge that everyone is free to use and reuse.

Nonetheless, a database publisher has several ways of protecting his investment in collecting facts. First, the publisher can rely on copyright. Copyright protects the original selection, coordination, and arrangement of the facts in a compilation, but not the facts themselves. Thus, copyright usually prevents the wholesale copying of a database—which typically contains at least a minimal amount of original expression—but not the extraction and reuse of individual facts.

Second, the publisher can rely on contracts. Many databases, particularly online databases, are distributed subject to license agreements

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under which the licensee—the user—agrees not to re-disseminate the information.

Third, the publisher can rely on state common law misappropriation. Under this doctrine, the collector can prevent competitors from copying "hot news" or other time-sensitive information (see *NBA v. Motorola Inc.*, 105 F.3d 841 (2d Cir. 1997)).

Fourth, the publisher can rely on technological measures. These measures are particularly effective with respect to online databases, where the publisher can limit the user's access to relatively small amounts of information at any one time. These limitations impede the copying of the database as a whole. Technological measures now receive legal protection under the recently enacted Digital Millennium Copyright Act (DMCA). The DMCA created a new chapter 12 to the Copyright Act, which prohibits the manufacture and sale of devices that are designed to circumvent technological protection measures.

The Feist Decision

Until 1991, the collector could rely on yet another legal doctrine: "sweat of the brow." In a few circuits, courts interpreted the Copyright Act as preventing the copying of facts in a compilation in which there were no original elements in selection or arrangement. Courts in these jurisdictions thought it was unfair and unwise to afford no protection to the efforts of people who assembled plain vanilla directories. It is important to note that sweat of the brow was largely a stop-gap measure; courts typically applied it to compilations which lacked any expression and which were copied in their entirety.

In 1991, however, the Supreme Court in *Feist v. Rural Telephone,* 499 U.S. 340 (1991), found the sweat of the brow doctrine unconstitutional. A unanimous court held that under the copyright clause of the Constitution, copyright protection could extend only to expressive elements in compilations, and that effort without creativity could not convert facts into expression. Notwithstanding the loss of the sweat of the brow doctrine, the database industry in the U.S. has continued to grow—largely because of the protection afforded by copyright, contract, state common law, and technology, as discussed above. Nonetheless, some database publishers have sought to restore the protection afforded by the sweat of the brow doctrine.

EU Database Directive

This effort gained significant momentum in 1996, when the European Union adopted its Database Directive. Under this regime, a second-generation publisher could not extract or reuse a qualitatively or quantitatively substantial part of a first generation database, even if the second publisher did not extract or reuse any protectable expression. The Database Directive's *sui generis* protection is available only on a reciprocity basis. That means a non-EU publisher can receive the heightened level of protection only if the publisher's country of origin afforded an equivalent level of protection. In other words, if the U.S. does not enact database legislation on par with the Database Directive, then U.S. publishers cannot receive this added protection in Europe.

There is, however, a loophole in this reciprocity requirement. If a non-EU publisher has a subsidiary operating in the EU, then databases distributed by the subsidiary would be able to receive the heightened protection.

In response to the EU Directive, Congressman Carlos Moorhead (R-CA) introduced H.R. 3531 in the 104th Congress. H.R. 3531 would have established a *sui generis* database protection regime even more stringent than that of the Directive's; H.R. 3531 had a 25-year term of protection, while the Directive established a 15-year term of protection. H.R. 3531 died with the end of the 104th Congress without further discussion.

Additionally, the EU and the U.S. Patent and Trademark Office suggested that a database treaty modeled on the EU Database Directive be placed on the agenda of the 1996 World Intellectual Property Organization (WIPO) Diplomatic Conference. At the beginning of the conference, however, discussion of a database treaty was deferred because too many other items relating to the Copyright Treaty and the Performances and Phonograms Treaty needed to be resolved. Moreover, representatives from other regions contended that discussion of a database treaty was premature.

H.R. 2652

In the 105th Congress, database protection reappeared in the form of H.R. 2652, which was introduced by Howard Coble, Chairman of the House Subcommittee on Courts and Intellectual Property. Although the legislation was styled as a misappropriation bill based on a tort rather than an intellectual property right, the substantive tests were almost identical to those of H.R. 3531. H.R. 2652 received support only from a limited number of large database publishers such as Reed Elsevier (the Anglo-Dutch owner of Lexis-Nexis) and Thomson (the Canadian owner of West).

Value-added publishers and the science, education, and library communities argued that H.R. 2652 was unnecessary—that copyright, contract, common law misappropriation, and technology provided databases with adequate protection. Moreover, these opponents contended that the database industry was healthy and that there was no market failure that required legislative correction.

Nonetheless, H.R. 2652 passed the House twice—once as a stand-alone bill, and the second time as part of the House's version of the Digital Millennium Copyright Act. At this point, the Department of Commerce, the Department of Justice, and the Federal Trade Commission all registered serious concerns with the bill. In the House-Senate conference on the DMCA in the closing days of the 105th Congress in October 1998, the database portion was dropped.

H.R. 354—The Collections of Information Antipiracy Act

On January 19, 1999, Chairman Coble introduced H.R. 354, which is very similar to H.R. 2652. Under H.R. 354, a person cannot (i) make available to others (ii) a substantial part (iii) of a collection of information gathered or maintained by another person through the investment of substantial resources (iv) so as to cause material harm to the primary or related market for a product or service containing that collection of information. Additionally, one cannot extract a substantial part of a collection of information so as to cause material harm to the primary market for the collection of information. The goal of the legislation is to protect the investment in databases by restoring the sweat of the brow doctrine and by ensuring protection for U.S. publishers under the EU Database Directive through the establishment of a comparable regime here.

Many of the specific problems identified by the critics of H.R. 2652 exist in H.R. 354 as well. According to these critics, H.R. 354 goes far beyond preventing database piracy, and prevents legitimate reuse of information for socially valuable purposes. Specifically, given the ambiguity of the term "substantial part," the second-generation publisher is at risk whenever he extracts any information from an existing database—he has no way of knowing what the first publisher, or a court, will consider "substantial."

Further, most, if not all, value-added databases will harm a "related market" for a product containing the first collection of information. Indeed, the market for a value-added database almost by definition is a related market for a product containing the collection of information. H.R. 354 contains a "reasonable use" provision not found in H.R. 2652, but its terms are so vague as to provide little comfort to most value-added publishers.

Another concern identified by opponents of H.R. 354 is sole source databases. For many database markets, there is no feasible way for another person to collect the information independently. This may be because the information is historical, and thus can be found only in an existing database; or because the publisher has a special relationship with the producer of the information. The protection afforded by H.R. 354 guarantees these publishers monopoly prices.

A final major concern is that, notwithstanding the 15-year term limit, H.R. 354 as a practical matter confers perpetual protection for databases. This is particularly the case with dynamic online databases, where the second publisher has no way of knowing for which portions of the database protection has expired.

For these reasons, the opponents of H.R. 354 believe it will inflict serious harm on many sectors of the economy that rely heavily on access to information. Financial publishers such as Bloomberg and Dun & Bradstreet have concluded that it will increase the cost of the information they incorporate in their products. Similarly, scientists feel that H.R. 354 will destroy the culture of sharing information that is so integral to scientific progress and has maintained U.S. scientific competitiveness for many decades.

In March 1999, the Intellectual Property Subcommittee held a hearing on H.R. 354. The Subcommittee "marked up" the bill in May, 1999, and a few days later the full Judiciary Committee adopted it with no substantive debate.

H.R. 1858—The Consumer and Investor Access to Information Act

On May 19, 1999, Tom Bliley, Chairman of the House Commerce Committee, ranking member John Dingell (D-MI), and the chairmen and ranking members of the Telecommunications and Finance Subcommittees jointly introduced H.R. 1858, the Consumer and Investor Access to Information Act. H.R. 1858 targets the parasitic copying of databases, without prohibiting reuse of information to create new kinds of databases. Specifically, this bill prohibits a person from distributing a duplicate of someone else's database in head-to-head competition with the first database.

By establishing a narrower prohibition than H.R. 354, H.R. 1858 does not prevent reuse of information in innovative databases. It deals with the sole source database problem by prohibiting misuse of the new protection. It eliminates the chilling effect of frivolous litigation by vesting enforcement authority in the Federal Trade Commission rather than private parties. H.R. 1858 also has a more comprehensive exemption for online service providers than does H.R. 354.

This narrow approach has widespread support among financial publishers; the science, education and research communities; Internet companies; and large corporate users of information. They believe that this bill successfully balances concerns about database piracy with the need to use previously gathered information as a foundation for new products.

The Telecommunications and Finance Subcommittees held hearings on H.R. 1858 during June 1999. Those hearings highlighted the difference between the two bills, and emphasized that the Judiciary Committee and the Commerce Committee view the issue of database protection from different perspectives. The Judiciary Committee is more concerned with protecting the publishers' investment, while the Commerce Committee is more concerned with ensuring the availability of information necessary for commercial activity.

H.R. 1858 was marked up in the Telecommunications and Finance Subcommittees in July 1999. It was considered and passed by the full Commerce Committee in early August, 1999. It is now up to the Rules Committee and the House Republican Leadership to decide how to proceed with these two competing bills.

Senate Action

On January 19,1999, Orrin Hatch (R-UT), Chairman of the Senate Judiciary Committee, placed a statement concerning database protection in the Congressional Record. He attached to his statement, for discussion purposes, three alternative bills: an early draft of H.R. 354; an early draft of H.R. 1858; and a draft his staff had produced during the

105th Congress based on H.R. 2652. To date, none of these bills has been formally introduced in the Senate.

Further, John McCain (R-AZ), Chairman of the Senate Commerce Committee, introduced S. 95, also on January 19, 1999. While the other bills discussed above increase protection for databases, the McCain bill heads in the opposite direction. It prohibits any limitation on "the dissemination by any medium of mass communication" of stock trading information.

The stock exchanges, particularly the New York Stock Exchange and NASDAQ, have signaled support for H.R. 354. Financial publishers such as Bloomberg, as well as stock brokerages such as Charles Schwab & Co., fear that the exchanges will use broad database protection like H.R. 354 to increase the price of the live feeds of stock quotes, and otherwise restrict the downstream use of this information. S. 95 resolves this dispute by making stock information even more available than it is currently. (Although S. 95 targets only stock trading information, Senator McCain has indicated that he is interested in the broader database issue.)

Administration Position

The Clinton Administration has concluded that there is a gap in existing protection for databases that needs to be filled. It has raised specific concerns with the language of both H.R. 354 and H.R. 1858. With respect to H.R. 354, the Administration believes that its scope is too broad. It believes that only acts of commercial distribution should be prohibited, and not acts of extraction without further dissemination to the public. It has continuing concerns regarding perpetual protection and sole source databases. It also believes the definitions of terms such as "related markets" need to be tightened. The Administration stressed that these concerns needed to be addressed in part to ensure that the legislation did not run afoul of the First Amendment of the Constitution. The Department of Justice in particular fears that restrictions on the use of information could violate the fundamental right of free speech.

The Clinton Administration also voiced concerns with respect to H.R. 1858. It felt that some terms were too broadly defined, and could result in overprotection. At the same time, it felt the absence of a private cause of action would result in underprotection. It strongly applauded H.R. 1858's focus on commercial misappropriation.

To date, the Clinton Administration has not signaled its preference for one bill over the other. This is not surprising given that the debate between the two bills has evolved in some measure into a political battle between two very powerful Congressional committees.

Federal Trade Commission Position

On July 1, 1999, the Federal Trade Commission (FTC) issued testimony concerning H.R. 1858. The testimony stated that H.R. 1858 successfully addressed many of the concerns the FTC had raised in 1998 with respect to H.R. 2652, the predecessor to H.R. 354. The FTC testimony identified a few areas where the language of H.R.1858 was ambiguous, particularly in the misuse section. The FTC also questioned whether it had sufficient resources to enforce H.R. 1858's prohibitions.

International Dimensions

Reciprocity Under the EU Database Directive

Proponents of H.R. 354 argue that H.R. 1858 does not offer comparable protection to the EU Database Directive and therefore will not lead to reciprocal protection under the Directive. The Administration has publicly stated that the U.S. should decide for itself what level of protection is appropriate for databases, and not worry about comparability with the Directive. Underlying this position is the realization that reciprocal protection is the outcome of a political process involving negotiations between the U.S. and the EU. In other words, the substantive merits of comparability are a minor, if not insignificant, factor in this political process.

WIPO Deliberations

As noted above, the WIPO in 1996 decided not to consider a database treaty at the Diplomatic Conference. Since 1998, the WIPO has held two sessions of the Standing Committee on Copyright and Related Rights to study the subject, and database protection was on the agenda of regional meetings cosponsored by the WIPO during the summer of 1999. While currently there seems to be no significant momentum to deliberate the database protection issue in the WIPO, it is likely that WIPO will pursue a database treaty after the U.S. enacts the legislation. This is because the U.S. at that time probably will join together with the EU in placing great pressure on the WIPO to consider a database treaty very seriously. A database treaty will prove controversial because the developing world will view it as yet another stratagem by the developed world to impede the developing world's progress.

Conclusion

The database bills pending in Congress will head the database industry, and arguably the economy as a whole, in dramatically different directions. While H.R. 354 will grant first-generation publishers a new weapon against piracy, it will also provide them with unprecedented control over downstream competition. At the other end of the spectrum, S. 95 indicates that the database debate imposes risk on first-generation publishers. Congress may very well decide to deprive them of some of the protections they now have. As noted above, many database publishers are de facto monopolists, and Congress is appropriately suspicious of monopolies in the Information Age. In between these two extremes, the H.R. 1858 provides an incremental increase of protection to first-generation publishers against pirates without constraining legitimate activities by second-generation publishers.

Balance in this area is critical. Information is the oxygen of the new economy; drastic changes to information policy will hinder the expansion of the Internet, impede research, and stifle entrepreneurship and innovation. As Chairman Hatch recently stated, the U.S. Congress will consider the database issue within the context of the "national Internet policy."

The EU adopted the Database Directive with relatively little public participation. The database debate in the U.S., by contrast, involves all stakeholders, including database publishers, Internet companies, commercial users, libraries, universities, science organizations, and a range of financial institutions. Accordingly, the discussion of this issue is far more robust in the U.S. and far more likely to produce a balanced result. Therefore, we encourage you to closely monitor U.S. developments if there is no such discussion in your country.

As the debate proceeds in the U.S. and abroad, certain threshold questions must be kept in mind:

- Is additional protection truly needed?
- If so, what is the harm that needs to be addressed?
- Is the legislation designed to cure this harm drafted narrowly enough so as not to have unintended negative consequences?

Furthermore, discussion of the database protection issue should reflect other fundamental domestic policies such as future development of the economy and technology.

23 The Emergence of Grid Information Infrastructures

Larry L. Smarr

The information technology revolution is going to affect everything about research and education. What is emerging in many people's minds is a transformation similar in impact to previous infrastructure transformations, such as the birth of the electrical power grid. In that era, we went through a series of science and engineering experiments (real world test beds with competing standards such as Edison and Tesla fighting over DC versus AC), similar to what we have today in the battles over various flavors of operating systems or web browsers. Eventually, over the course of decades, the marketplace settled these disputes and what rapidly developed was a ubiquitous electrical technology infrastructure.

One rarely thinks about the subcomponents of the electrical power system anymore (unless it fails). But the subcomponents of the information technology system are still in development. We are a long way from having ubiquitous information delivery. The goal should be "where there is air, there are bits." But the wireless revolution is only beginning, even though a lot of the fixed fiber and cable are in place.

While such historical analogies are useful, the information technology system is fundamentally different from the other aspects of technology that change society, which are typically linear in nature. This modern infrastructure system is driven by an unrelenting exponential. Most people, even scientists, have a hard time understanding how radical such

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exponential change is. When an exponential sweeps through a preexisting threshold, it changes the impossible into the routine.

As an example, when I founded the National Center for Supercomputing Applications (NCSA), our first supercomputer cost $10 million. We had to dig a trench to the Illinois Power electrical substation to run it. There were only four other such supercomputers available to the National Science Foundation (NSF) funded academic research community. Today, the exponential of Moore's Law has enabled the average PC laptop to have more memory and to run faster than that 1985 supercomputer. This move from the very elite edge of science to mass consumption is happening on time scales of ten to fifteen years.

At public meetings in the early 1980s, I can remember telecom company representatives telling the National Science Foundation that the Federal Government had no business funding the creation of a general Internet for academics like we have today. They said that would be an unacceptable interference by the government in the private sector. So the government said, "Fine. But surely you don't mind if we hook up the five new NSF Supercomputer Centers with a national backbone network of 56 kilobits per second, do you?" And I recall the telecom representatives responding, "Well, let's see. No, there's no revenue there. Sure, you can do that. It won't harm anything." Well that NSFnet supercomputer backbone led directly to the regional and local networks that created the NSFnet that was finally commercialized a few years ago to form the global internet we all live on.

The point is that government research at the edge of the marketplace can make huge changes when you are dealing with an exponential driver. For the ten years prior to the creation of the NSFnet backbone, the Defense Advanced Research Projects Agency (DARPA) supported researchers to create the ARPANET testbed and the TCP/IP protocols, which define today's Internet. This seminal work set off the exponential which the NSFnet backbone picked up, quickly growing from 56 kilobits/sec to 1.5 megabits per second to 45-megabits/sec to today's NSF vBNS backbone of 2.4 gigabits/sec. Applications enabled started with rudimentary email, remote logon, and file transfer, but grew more complex as the greater bandwidth allowed the graphical Web to come into being, now followed by the digital video explosion.

The World Wide Web emerged in a similar pattern to the internet. Research on how to hyperlink physics articles led Tim Berners-Lee, a physicist at CERN, to develop the protocols for the World Wide Web. In 1993 NCSA staff developed the graphical web browser NCSA Mosaic and the open source web server NCSA HTTPd, making them available for free to several million users worldwide. As more web servers went up to host content, there were more things to look at which led to more downloadings of the browsers, setting off exponential growth. Once again, this rapidly (in this case less than two years, rather than the ten with NSFnet) led for a need for commercialization. Many of the NCSA Mosaic developers left to help found the technical core of Netscape, while Microsoft licensed Mosaic to create Internet Explorer. Similarly, Apache built their open source server software based on the NCSA web server code and created the most widely used server today. Again the NSF funded supercomputer centers played an intermediate transformational role between the protocol development and early experiments and the final mass market commercialization.

Perhaps we can get a glimpse of the future information infrastructure by observing what scientists are doing now, namely creating a ubiquitous digital infrastructure in which to carry out science and education. Because of the volume of data that science deals with this infrastructure must have very high speed networks, appropriate levels of computer power distributed throughout the Net, and large data caches strategically positioned. Effectively, academic scientists are saying that we need to do this because trying to live in the filled commercial pipes of the Internet is not the way to get science done very quickly.

Of course, with this vast increase in data, we have to be able to analyze and visualize the data, using virtual reality technologies. Furthermore, every modern digital scientific instrument has a host computer with it. With a high speed networking card, such local instruments can become shared global superinstruments. Finally, given that scientific research and education is a collaborative activity, researchers are creating digital video mediated electronic meeting rooms and teleclassrooms.

In order to systematically explore this new digital workspace, the National Science Foundation has undertaken a bold experiment called the PACI Program (Partnerships in Advanced Computational Infrastructure). About 280 universities have faculty and students using one of the remote NSF supercomputers over the last couple of years, with almost 1,000 projects. As a result of the national PACI competition, NSF established two leading edge centers: the San Diego Supercomputer Center at UCSD and NCSA at UIUC. Roughly 50 partnering universities are connected to these leading-edge sites by the NSF vBNS and Internet2 high speed networks. The PACI programs involve computer scientists, computational scientists, deployers and supporters of infrastructure, and people in education. They have formed (there is not even an English word for it) an interlocking web of virtual partnerships. As we would say in the Midwest, these folks are working together to raise a "cyberbarn."

The "cyberbarn" that the PACI program is building will be a prototype of the commercial 21st century infrastructure, termed a Grid. Just as with the NSFnet, these Grid experiments are not the commercial broadband Internet, but may directly lead to new services on it. This high speed research network is much faster than the commercial broadband network (enabled by cable modems and DSL) that you keep hearing about which will roll out commercially to your home and business over the next five or ten years. It is also being used intensively right now. NSF funds it to see what kind of applications will emerge in this futuristic information infrastructure, which has a thousand times the bandwidth of the ubiquitous modem based network of today. Why do we care about this experiment? Because it all comes back to the exponential growth-in ten years, by Moore's law, you will get somewhere between a 100- and 1,000-fold increase. What PACI is experimenting with now, by 2010 it will be in your living room. The fact that our country and the world are getting an early view of what this is like will drive the marketplace in terms of preparing for it.

NSF has also funded a digital port-of-entry to the United States, the STARTAP, in Chicago at the Ameritech Network Access Point. At that interconnection point, the NSF funded grids link with the grids that the other agencies are funding, as well as research networks from many different foreign countries. A lot of experiments emerging in this next phase will be inherently global in extent.

It is instructive before we explore the new world of the Grid, to recall why the supercomputers from which they sprang were so important to some researchers. Supercomputers like radio-telescopes are national facilities with unique capabilities. They enable projects that cannot be done anywhere else. Through peer review, anyone with a good idea can get access to them. That's why NSF has traditionally built such national facilities.

We can see an example of why you might want to use a supercomputer from a breakthrough calculation done earlier this year. Atmospheric phenomena are excited on many different space and time scales. Getting only an overall view (like on the TV news) is not enough. The Center for Analysis and Prediction of Storms (CAPS) program, which is a NSF Science and Technology Center located at the University of Oklahoma, has been using supercomputers to predict on a much finer level grid, for example a few kilometers (compared with current National Weather Service computational grids of 20 or 30 kilometers). You will not see this today on the evening news, but if these PACI experiments work out perhaps you will benefit from this routinely in five to ten years.

A year ago we started a pilot of this approach by dedicating one of NCSA's largest supercomputers to the CAPS group during the week-long American Meteorological Society meeting in January 1999. Every morning the CAPS team ran simulations of the weather faster than real time. Where severe weather shows up they used nested grids to resolve features as a variety of spatial and temporal scales. Because of the parallelism of the supercomputer they were able to carry out multiple runs in which they made variations in the uncertainties in the initial data. This "ensemble computing" created much more accurate forecasts. They also improved regional forecast accuracy by the use of data on velocities of the atmospheric water obtained from the new NEXRAD Doppler radars in Oklahoma.

Eventually we would like to run high resolution local forecasts on regional supercomputers and tie them all together into a national or global low-resolution forecast with this high-speed Grid linked into the Doppler radar system. Already the results of these weather forecasting experiments are being distributed over the World Wide Web. In fact, the FAA and some airlines are now using the results of these experiments to reroute planes away from severe storms.

So what we see here is a glimpse into a more general transition from using stand alone supercomputers to using the Grid to enable scientific research. The Grid is not just a supercomputer, but rather a network of computers, sensors for input, with results output to the Web. It is a grid-based, not just a supercomputing-based, approach to computational science.

The Grid is also transforming the way we hold meetings. It may be a while before large groups like the AAAS can meet on the Grid, but smaller groups are doing it now as experiments on the Access Grid. The Alliance just opened an ACCESS facility next to NSF building in Arlington, Virginia. We recently had a remote lecture from a scientist at Argonne National Laboratory to an audience at the ACCESS center. On the right-hand side of the floor to ceiling screen were the power points and on the left-hand side was a video window in which the speaker looked larger than life. The speaker could see the audience and they could see him. And the audience could ask questions and he could respond.

Furthermore, he was only one of a half dozen sites simultaneously linked, all mutually seeing and interacting with each other.

Within a few years you will see similar services coming over broadband to in-home high-definition television (HDTV), with life-like human figures will be projected using digital video. Alliance researchers are already adding interactive real time virtual reality capabilities to the Access Grid. And, of course, the entire World Wide Web of information is digitally available to bring into these virtual discussions, lectures, and group meetings. The PACI program is setting up a series of prototype ACCESS centers across the country as cyberports into the Grid. With our long range government funding we are focusing on driving applications from science and education.

As a young theoretical astrophysicist, I had always assumed that almost all scientists were theorists. It was pointed out to me that in fact, maybe only five or ten percent of academic scientists are theorists and all the rest were experimentalists or observers. So until Grid technology impacts experimentalists it will not really impacted science as a whole. This critical phase is still in the very early stages. For instance for years the San Diego Supercomputer Center has worked with one of the largest electron microscopes in the country, linking it through the network to high-power visualization software and to supercomputers to turn batch observations into interactive ones. This effectively creates a "super instrument" that is available from anywhere on the Net.

The Alliance has a partner experiment, the Berkeley-Illinois-Maryland Array, which has as its "lens" our supercomputer at NCSA. This millimeter array synthesis telescope, which is located in a high desert site in California, sends data across the network to the NCSA SGI Origin supercomputer. Then the result, which is 2000 images of an object in the sky, each taken at a different millimeter wavelength spectral line, is stored as a data cube in a digital library on the Internet. You can interactively rotate the image and zoom in and out to see details inside the cube. Here we see the practice of science actually beginning to be impacted by the Web.

What I have found most peculiar about this whole emergent global cyber-enterprise is that scientists, the people who invented the Web, do not use it nearly as much as nonscientists. In the average household (with only 1/000 of the bandwidth of a university researcher), citizens are using portals which have pages individually customized just the way the user wants them. People spend hours a day on the web trading stocks, researching purchases, chatting with friends, and buying goods and services. They are coming to *live* on the web. As I visit universities around the country I find that your typical scientist is way behind the Web power curve compared with the typical home cyberpioneer. We have to figure out how to get the scientists to actually use the results of this revolution they created.

Another big change that is coming has to do with the human computer interface and in particular, how we visualize massive datasets. Two-dimensional megapixel screens may be acceptable for personal PCs, but if your dataset was generated by a high performance computer with 1,000 times as much computing power as a PC, then the PC screen is clearly not going to be adequate for analysis of the data. For instance, if you have computed the details of a complex physical/biological environment, how are you going to represent that other than the way the real environment is represented? It must be three-dimensional and time dependent. That is why people have been creating virtual reality theatres and large screen displays. Furthermore, you can create virtual worlds and then link them over the Internet. That is, you see your remote colleague as an avatar, a software representation of that person, in the appropriate place in the shared virtual space where they are standing. The computer also knows where hands and eyes are pointing, so the avatar has a moving head and hand. You jointly go into this virtual space with other scientists, essentially like living with talking ghosts, and then you do your science.

A pioneering example of this cyber-modality is the Alliance Environmental Hydrology Application Team. NCSA and University of Illinois researchers are investigating the Chesapeake Bay with their colleagues at Old Dominion University. ODU has an ImmersaDesk (a one-wall CAVE) that is linked over the highspeed NSF vBNS to NCSA's Power Wall (which is a 4-screen high-resolution device), a walk-in CAVE and to a desktop. We are able to bring the various scientific and technical specialists that are needed, including computer scientists who help develop and drive the software, into this single collaborative environment.

This may sound like science fiction, but it has already been used for several years by industry. Caterpillar, an NCSA Strategic Industrial Partner, used their computer-aided design databases for earth moving equipment as the data source for the CAVE. The equipment, which may not have physically been built yet, appears as a full three-dimensional object which can be driven through the Peoria Proving Grounds or a Siberian rock quarry, all created by realtime texture mapping of photographs of those environments. By linking up CAVES and/or televideo from Germany to Houston to Peoria to Urbana, Caterpillar can bring together experts in design, manufacturing, maintenance, and customer support to make joint decisions about design choices.

-The level of research innovation in universities is possible because of the strong support of the Federal Government, such as the National Science Foundation for long-term basic research. With the PACI program, the NSF has also moved to fund “reduction to prototype” of information technology research results. The Federal Government is the only part of our society that is able to fund the 5-, 10-, 15- year-out research. Industry is not able to do that because of the quarterly focus on share holder value. The recent report by the President’s Advisory Committee on Information Technology made this point strongly. It also pointed out that the Federal Government’s support for long-term high-risk IT research has actually been pulled back over the last few years. For instance, we are seeing an under-investment in IT research compared to what we had with DARPA in its heyday.

Given that 30 percent of the real GDP growth in the last ten years has come from information technology related activities and yet today only one out of 75 of the federal R&D dollars goes into information technology research, the Federal Government has done some soul-searching since the PITAC report came out. Rarely has the Federal Government reacted as quickly with a budget request in response to a study as it did with the PITAC report. This is particularly important because of how quickly this information revolution is moving.

The PITAC report looked in an integrated way at the Internet, supercomputers, virtual reality, database, software, and so forth. Based on this study, the report chose four areas as priorities for research: software; scalable information infrastructure; high-end computing; and, for the first time, socio- and economic-impact studies. With the FY00 actual budget and the FY01 budget request, the Federal Government proposes to roughly double its investment in long-term information technology research, adding another $1 billion a year to what is currently funded. We can expect to see this proposal treated in the traditional bipartisan manner of a national initiative that will be supported by all parties.

This is a good response by the Administration and I expect a strong support in Congress. But there are a few potential roadblocks we need to be worried about. The AAAS analysis of the R&D funding environment in Congress points out that our country may have prematurely celebrated the end of the deficit era. There is some questionable bookkeeping involving how the federal government is treating trust funds as income rather than long-term debt. We still have the discretionary caps on the books and heretofore the political will has not been there to remove them. We must get the universities involved in a new style of R&D which is appropriate to the information industry rather than the manufacturing industry. Finally, we must train a large number of young people who are going to carry the innovations of the universities the next set of companies. If we do not do this we will never meet the kind of growth rate that it will take for our country to avoid stalling out in this information revolution. These are all serious barriers, but there are encouraging signs that most of them will be dealt with. If so, then we are on the verge of an even greater speed of transformation of the information infrastructure than we have seen in the past. This will allow our country to continue its global leadership in creating the information infrastructure needed for 21st Century commerce, research, and education.

24 Information Technology Research: Investing in Our Future

President's Information Technology Advisory Committee

Executive Summary

Information Technology will be one of the key factors driving progress in the 21st century—it will transform the way we live, learn, work, and play. Advances in computing and communications technology will create a new infrastructure for business, scientific research, and social interaction. This expanding infrastructure will provide us with new tools for communicating throughout the world and for acquiring knowledge and insight from information. Information technology will help us understand how we affect the natural environment and how best to protect it. It will provide a vehicle for economic growth. Information technology will make the workplace more rewarding, improve the quality of health care, and make government more responsive and accessible to the needs of our citizens.

Vigorous information technology research and development (R&D) is essential for achieving America's 21st century aspirations. The technical advances that led to today's information tools, such as electronic computers and the Internet, began with Federal Government support of research in partnership with industry and universities. These innovations depended on patient investment in fundamental and applied research.

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We have had a spectacular return on that Federal research investment. Businesses that produce computers, semiconductors, software, and communications equipment have accounted for a third of the total growth in U.S. economic production since 1992, creating millions of high-paying new jobs. Government-sponsored University research programs have supported graduate education for many of the leaders and innovators in the field. As we approach the 21st century, the opportunities for innovation in information technology are larger than they have ever been—and more important. We have an essential national interest in ensuring a continued flow of good new ideas and trained professionals in information technology.

After careful review of the Federal programs this Committee has concluded that Federal support for research in information technology is seriously inadequate. Research programs intended to maintain the flow of new ideas in information technology and to train the next generation of researchers are funding only a small fraction of the research that is needed, turning away large numbers of excellent proposals. Compounding this problem, Federal agency managers are faced with insufficient resources to meet all research needs and have naturally favored research supporting the short-term goals of their missions over long-term high-risk investigations. While this is undoubtedly the correct local decision for each agency, the sum of such decisions threatens the long-term welfare of the nation.

The Nation needs significant new research on computing and communication systems. This research will help sustain the economic boom in information technology, address important societal problems such as education and crisis management, and protect us from catastrophic failures of the complex systems that now underpin our transportation, defense, business, finance, and healthcare infrastructures. If the results are to be available when needed, we must act now to reinvigorate the long-term IT research endeavor and to revitalize the computing infrastructure at university campuses and other civilian research facilities, which are rapidly falling behind the state of the art. If we do not take these steps, the flow of ideas that have fueled the information revolution over the past decades may slow to a trickle in the next.

To address these problems, the Committee estimated in its Interim report in August 1998 that the Federal government should increase its support for information technology research by a billion dollars per year by FY 2004. Since that time the Committee has sought comments from the community regarding its preliminary findings and recommendations, and convened several panels to review those recommendations. This effort produced a more detailed model for the costs of the research programs and other activities needed to address the problems identified in our report. As a result of these activities, the Committee has further refined the findings and recommendations presented in its Interim Report, and adjusted its funding recommendation accordingly. The Committee now recommends that the Federal government increase annual funding for information technology R&D over the five-year period from FY2000 to FY2004, as follows:

Recommending Funding Increases for Information Technology R&D ($ in millions)

Area	FY00	FY01	FY02	FY03	FY04
Software	112	268	376	472	540
Scalable Information Infrastructure	60	120	180	240	300
High-End Research	180	205	240	270	300
High-End Acquisitions	90	100	110	120	130
Socioeconomic	30	40	70	90	100
Total	**472**	**733**	**976**	**1192**	**1370**

These increases are in addition to the programs in existence in FY99. The full report provides additional details on these budget recommendations, including discussions of the method used to produce them.

Although there are unmet needs across the entire spectrum of research activities, priority for increased funding should be on long-term, high-risk investigations. In addition to increases for research itself, the Federal government must also ensure that the research community is equipped with the state-of-the-art facilities needed to carry out advanced projects. Finally, Federal budgets must continue to ensure that advances in information technology work to benefit all Americans and that all Americans have the education and training needed to prosper in a world that will increasingly depend on information technology.

To be successful, the expanded Federal research program we propose must be effectively managed. Current cross-agency coordination mechanisms are working well, but they suffer from the lack of well-defined responsibilities for ensuring that key areas are not overlooked. There has been no agency with the primary responsibility for ensuring that long-term, high-risk research is protected from the pressures that arise in mission agencies. Ideally there should be an agency charged with leading the organization of a fundamental information technology research program appropriate for the 21st century.

The Administration's proposed Federal budget for FY 2000 demonstrates a commitment to sustained growth in information technology research through its initiative, *Information Technology for the Twenty-First Century (IT2).* This commitment is an important first step in what must be a continuing effort on the part of the Federal government to increase research dollars and to create a new management system designed to foster innovative research. But the effort cannot stop here. Further increases and continued oversight are needed to remedy the shortfall in long-term research investments that has accrued.

Findings and Recommendations

Federal information technology R&D investment is inadequate. Measured in constant (non-inflated) dollars, support in most critical areas has been flat or declining for nearly a decade, while the importance of information technology to our economy has increased dramatically. As a result, the Nation is gravely underinvesting in the long-term, high-risk research that can replenish the reservoir of ideas that will lead to innovations in information technology in generations to come.

Federal information technology R&D is too heavily focused on near-term problems. Much of the Federal investment in information technology R&D is being funded by mission agencies. In the face of the enormous increases in information technology problems to be addressed, funding agencies have had to prioritize their investments. Inevitably, priority has been given to short-term, mission-oriented goals over long-term research. This reflects the situation in the private sector as well. As a result, investment in long-term, high-risk research has been curtailed. This trend threatens to interrupt the flow of ideas that has driven the information economy in this decade and threatens efforts to solve nationally important problems.

Recommendation: Create a strategic initiative in long-term information technology R&D. To address these problems the Committee recommends that the President create a strategic initiative to support long-term research in fundamental issues in computing, information, and communications. The initiative should increase the total funding base by $1.37 billion per year by FY 2004. The Federal funding agencies should use the resulting budget increases to encourage research that is visionary and high-risk. To do this, they will need to diversify modes of research support and increase the duration of projects. The goal should be to recapture in the universities and research labs much of the excitement that existed at top-rated departments in the past.

Priorities for Research

Four areas of the overall research agenda particularly need attention and must be a major part of a strategic initiative in long-term research and development:

Software

The demand for software has grown far faster than our ability to produce it. Furthermore, the Nation needs software that is far more usable, reliable, and powerful than what is being produced today. We have become dangerously dependent on large software systems whose behavior is not well understood and which often fail in unpredicted ways. Therefore, increases in research on software should be given a high priority. Special emphasis should be placed on developing software for managing large amounts of information, for making computers easier to use, for making software easier to create and maintain, and for improving the ways humans interact with computers. Specifically, the Federal program should:

- Fund fundamental research in software development methods and component technologies.

- Support fundamental research in human-computer interfaces and interaction.

- Support fundamental research in capturing, managing, analyzing, and explaining information and in making it available for its myriad of uses.

- Make software research a substantive component of every major IT research initiative.

Scalable Information Infrastructure

Our Nation's dependence on the Internet is increasing. While this is an exciting development, the Internet is growing well beyond the intent of its original designers and our ability to extend its use has created enormous challenges. As the size, capability, and complexity of the Internet grows, it is imperative that we do the necessary research to learn how to build and use large, complex, highly-reliable, and secure systems. It is therefore important that the Federal government:

- Fund research on understanding the behavior of the global-scale network and its associated information infrastructure. This should include collecting and analyzing performance data and modeling and simulating network behavior.

- Support research on the physics of the network, including optical and wireless technologies including satellites, cable, and bandwidth issues.

- Support research to anticipate and plan for scaling the Internet. Support research on middleware that enables large-scale systems.

- Support research on large-scale applications and the scalable services they require.

- Fund a balanced set of testbeds and research infrastructure that serve the needs of networking research, research in enabling information technologies and advanced applications.

High-End Computing

Extremely fast computing systems, with both rapid calculation and rapid data movement, are essential to provide accurate weather and climate forecasting, to support advanced manufacturing design, to design new pharmaceuticals, to conduct scientific research in a variety of different areas, and to support critical national interests. Although they achieve remarkable performance in some cases, the current scalable, parallel, high-end computing systems are not well suited to many nationally important, strategic applications. To ensure that U.S. scientists continue to have access to computers of the highest possible power, funding should be focused on innovative architectures, hardware technologies, and software strategies that overcome the limitations of today's systems. Without major increases in funding in these areas, the realizable performance of new machines will fall far short of their potential. We specifically recommend that the Federal program should:

- Fund research into innovative computing technologies and architectures.

- Fund R&D on software for improving the performance of high-end computing.

- Drive high-end computing research by trying to attain a sustained petaops/petaflops on real applications by 2010 through a balance of software and hardware strategies.

- Fund the acquisition of the most powerful high-end computing systems to support science and engineering research.

- Expand the National Science and Technology Council (NSTC) Computing Information and Communications (CIC) High-End Computing and Computation (HECC) Working Group's coordination process to include all major elements of the government's investment in high-end computing.

Socioeconomic Impacts

Information technology will significantly improve the flow of information to all people and institutions in the Nation, and could be a powerful tool for democratization. Our National well-being depends on understanding the potential social and economic benefits of on-going advances in information technology. However, problems are arising from the increasing pace of information technology-based transformations. To realize the promise of the new technologies, we must invest in research to identify, understand, anticipate, and address these problems. We must develop concrete objectives and comprehensive metrics through which to assess the ongoing transformations brought about by the integration of information technology into our lives. We must conduct careful research on the impact of the transformations against the objectives, and develop appropriate policies to deal with the knowledge we gain from the research. The Federal government should:

- Expand Federal initiatives and government/university/industry partnerships to increase information technology literacy, access and research capabilities.
- Expand Federal research into policy issues arising from information technology.
- Fund information technology research on socioeconomic issues.
- Expand the participation of underrepresented minorities and women in computer and information technology careers.
- Create programs to remove the barriers to high bandwidth connectivity posed by geographic location, size, and ethnic history of research, educational institutions, and communities.
- Accelerate and expand education in information technology at all levels—K-12, higher education, and lifelong learning.
- Strengthen the use of information technology in education.

Management and Implementation of Federal Information Technology Research

Building a Federal IT program suited to the needs of the Nation in the 21st century will require new management strategies, new modes of research support, and new implementation strategies. This new approach is demanded by the reality of Federal budget constraints, the need for more long-term cross-disciplinary team research, and the need to maintain a small, efficient, and coordinated research management process. It is essential that the Federal systems responsible for managing and implementing the new IT program be positioned to review the entire information technology research budget, to restore the balance between fundamental and applied research, to encourage long-term and high-risk collaborative research projects, and to employ a systematic review by participating Federal agencies and the private sector.

To achieve these goals, we recommend that the existing Federal information technology management and implementation structure be enhanced as follows:

- Strongly encourage NSF to assume a leadership role in basic information technology research. Provide NSF the necessary resources to play this role.

- Designate a Senior Policy Official for information technology R&D.

- Extend the HPCC program coordination model to all major Federal information technology R&D activities.

- Diversify the modes of research support to include more projects of broader scope and longer duration, placing a renewed emphasis on research carried out in teams.

- Fund collaborations with applications to drive information technology research, but take measures to ensure that research remains a primary goal.

- Fund centers for Expeditions into the 21st Century.

- Establish a program of Enabling Technology Centers that will drive research by examination of critical applications areas.

- Establish an annual review of research objectives and funding modes.

The Government's Essential Role

While the importance of information technology to the future of the economy and the government is clear, it may not be immediately obvious that government investment is needed to ensure continued progress. The PITAC members from industry were unanimous in their opinion that it is not feasible for the private sector to assume responsibility for long term, high-risk research, in spite of the success of the information technology industry. Their opinion is found in the attached sidebar.

We believe that the Federal Government must retain and expand its role in leading long-term fundamental research in information technology. Advanced Government services and national security depend on it. The benefits to our Nation and society will be huge. A loss of international leadership in information technology would be economically devastating.

We cannot rely on industry to fund the needed research because they necessarily focus, in view of economic realities, on the short term. Industry cannot and will not invest in solving problems of importance to society as a whole unless such investments make sense from a business perspective.

The rationale for funding long-term information technology research goes far beyond economic benefit and national security needs. Enormous societal gains can be reaped from advances in information technology. Only through research on a scale substantially greater than is being carried out today, can we build an infrastructure that will be available, affordable and usable by all citizens—one that can support the compelling "transformations" discussed in the next chapter of this report.

Federal investment in information technology directly supports the education and preparation of our young people for careers in information technology research, and the training of workers who need to upgrade their skills to keep pace with a changing marketplace. Trained people are not just a byproduct but rather a major product of publicly supported research. These trained professionals are critical national infrastructure, and will create and develop new ideas, form a talent pool for existing business, and launch new companies.

The benefits that the transformations described in the next chapter of this report can have for our Nation's future are extraordinary. A networked society can reach out to all its citizens, and can bring our Nation closer together and address many societal issues. While it cannot resolve all these issues, information technology can give us leverage toward their solution.

But the realization of the positive transformations we will describe in the next chapter of this report is not guaranteed. The realization of each transformation will depend on the results of aggressive, well-managed Federal research programs. Long-term Federal investment in information technology research is necessary to incubate ideas to the point of clear commercial viability, and to develop methods of measuring and tracking our progress toward realizing our positive vision.

Conclusion

In both the public and private sectors today, U.S. investments in technology R&D have slowed to a relative trickle. American businesses, in an ever-shrinking and more highly competitive world, have devoted less and less of their precious resources to long-term R&D, directing their efforts instead to reducing costs and getting new products into the pipeline today at the expense of the future. The Federal government has mirrored this trend because of dramatically increasing pressures on the research and development budgets, with only modest increases in funding levels. Funding agency managers have responded by making the natural and correct decision to favor the short-term needs of their missions over the need for long-term research in information technology. The U.S. Government's lead in research in high end computing and computation—so crucial to keeping our military edge in the competitive era of the Cold War—seems to have come down along with the Berlin Wall.

As a result, the once robust technological edge the U.S. has enjoyed over the rest of the world is actually built on an increasingly fragile technological substructure. If the trend away from long-term research continues, the flow of bold new ideas that has fueled the information economy in this decade is likely to slow to a trickle by 2010. To keep its competitive edge, the United States must rededicate itself to cutting edge high-tech research and development—or risk being overcome by nations with a clearer plan and a stronger view of the future. This is a risk the Nation cannot afford to take.

The initiatives proposed in this report would represent a major step toward restoring long-term Federal research in information technology to levels that will ensure continued prosperity and new technological solutions to national problems in the next millennium. The time to act is now and the Federal government has a unique role to play in supporting research in this critical area. The Brooks/Sutherland report stated this well:

> Very few companies are able to invest for a payoff that is 10 years away. Moreover, many advances are broad in their applicability and complex enough to take several engineering iterations to get right,

> and so the key insights become 'public' and a single company cannot recoup the research investment. Public investment in research that creates a reservoir of new ideas and trained people is repaid many times over by jobs and taxes in the information industry, more innovation and productivity in other industries, and improvements in the daily lives of citizens. This investment is essential to maintain U.S. competitiveness.*

This committee strongly recommends that the Federal government embark upon the kind of leading-edge, visionary research necessary to continue the revolution that has transformed the lives of our citizens in ways not thought possible just thirty years ago. The recommendations of this committee also stress the needs to: 1) to upgrade the knowledge base and skills of our workforce, so that our citizens will be prepared to face a new century fully prepared for the technological challenges that are yet to come; and 2) to give all American the opportunity to participate in the information age, so that our citizens will be able to fulfill its promise. These steps, if taken now, will bring handsome returns to the Nation over the coming decades.

*Brooks, Jr., Frederick P., and Sutherland, Ivan E., co-chairs. *Evolving the High Performance Computing and Communications Initiative to Support the Nation's Information Infrastructure.* Prepared by Committee to Study High Performance Computing and Communications: Status of a Major Initiative. Washington, DC: National Academy Press, 1995.