Renewing U.S. Telecommunications Research

Statement of
Jack Keil Wolf, Stephen O. Rice Professor, University of California at San Diego; Vice President, Technology, QUALCOMM Inc.;
and
Member of the
Committee on Telecommunications Research and Development
National Research Council
The National Academies

before the
Committee on Commerce, Science and Transportation
U.S. Senate

April 24, 2007

Good morning, Mr. Chairman and members of the Committee. My name is Jack Wolf. I am professor of electrical and computer engineering at the University of California at San Diego and Vice President, Technology at QUALCOMM. I served as a member of the Committee on Telecommunications Research and Development of the National Research Council that authored the report *Renewing U.S. Telecommunications Research,* issued in August 2006, on which you have asked me to testify. This study was requested by the National Science Foundation.

The National Research Council is the operating arm of the National Academy of Sciences, National Academy of Engineering, and the Institute of Medicine of the National Academies, chartered by Congress in 1863 to advise the government on matters of science and technology.

I will start with an overview of the study's key findings before turning to our recommendations.

The modern telecommunications infrastructure—made possible by research performed over the last several decades—is an essential element of the U.S. economy and society. Telecommunications research has yielded major direct benefits such as the Internet, radio frequency wireless communications for cellular systems and wireless local area networks (which have enabled modern mobile voice and data communications), optical networks (which have revolutionized communications by providing extraordinary communications bandwidths at very low unit cost), and voice over IP (which provides voice communications with enhanced flexibility and efficiency). It has also had important spinoffs, from transistors to lasers to the UNIX computer operating system.

Telecommunications has expanded greatly over the past few decades from primarily landline telephone service to the use of fiber optic, cable, and wireless connections offering a wide range of voice, image, video, and data services. Yet it is not a mature industry, and major innovation and change—driven by research—can be expected for many years to come. Promising opportunities for future research include enhanced Internet architectures, more trustworthy networks, and adaptive and cognitive wireless networks.

As our report concluded, the U.S. position as a leader in telecommunications technology is at

risk because of the recent decline in domestic support for long-term, fundamental telecommunications research. The risk is magnified by the long period of time—as much as a decade or even longer—that it can take to translate a fundamental discovery or big new idea into a commercial product or service or to educate and train a new researcher.

The recent fast pace of innovation, the array of new ideas to be pursued, and the substantial investment in telecommunications by other nations are all indications that telecommunications remains a high-value sector in which the United States should strive for continuing leadership. The importance of maintaining U.S. leadership is underscored by telecommunications' critical contribution to U.S. leadership in information technology in general, its important contribution to improving productivity in nearly all industries, and its role in national security and homeland defense.

Indeed, without a continuing focus on telecommunications R&D, the United States will increasingly be forced to purchase telecommunications technology and services from foreign sources. Risks include (1) U.S. dependence on foreign sources of technology to meet critical defense needs; (2) loss of exclusive or early access to state-of-the-art communications technology; (3) loss of know-how to employ state-of-the-art technology; (4) opportunities for other nations to introduce security holes into equipment and networks; and (5) loss of technical capability for cyberdefense.

Strong competition is emerging from Asian and European countries that have identified telecommunications as a strategic area for economic development and that are making substantial investments in telecommunications R&D. Equipment vendors in a number of countries (such as China) now compete strongly with U.S. firms and have been very successful in emerging markets.

Telecommunications products and services generally have become commodities over time as multiple firms acquire the know-how to supply similar, competing products, and such competition has benefits in terms of lower prices for goods and services. To maintain leadership—or even a strong position—in telecommunications in the face of pressures from lower costs overseas for labor and other essentials requires that U.S. firms constantly focus on achieving high-value innovation as a foundation for developing new, non-commodity products and services.

For example, notable benefits have accrued to the United States as a result of its leadership in defining the Internet's design. However—by virtue of its very success—the existing Internet architecture has become difficult to change. Despite many potential avenues for significant improvements in areas ranging from security to real-time audio and video transmission, research and development has become largely incremental in nature. Moreover, the current architecture is largely a commodity, and firms from other nations will become increasingly able to deliver competitive products and services. Research aimed at defining future architectures promises particular benefits because U.S. firms will be positioned to offer new kinds of services and not just incremental improvements to existing ones.

Sustaining a base of researchers and research institutions is critical to the long-term health of a research discipline. Without adequate research funding, it will be hard to attract new students to the field, retain foreign students in the United States, provide critically needed support for postdoctoral researchers, or attract and develop new faculty and industrial researchers.

Nevertheless, as the report notes, research support has fallen off in recent years. Prior to the restructuring of the telecommunications industry that began in 1984, the Bell System's research labs played a vital role in long-term, fundamental telecommunications research for the United States. Stable research funding was provided that amounted to a tax levied on the service revenues of the Bell operating companies. Post-restructuring, industrial support for such research has declined, become more short-term in scope, and become less stable.

It is notoriously difficult to compile definitive data on support for industry research and development, but the general shape of the situation became clear in testimony to the study group. Industry support for telecommunications research has decreased (as measured in dollars, numbers of researchers, and publications), and the work that is funded now has become increasingly short-term in focus—evolutionary rather than revolutionary—at a time when global competitors of the United States have placed a priority on long-term research in this area. Anecdotal reports indicate that basic research scientists in industry are being shifted to development work and that publication by industry

researchers in telecommunications journals has decreased.

The diverse array of competing telecommunications firms—telephone, cable, Internet, and wireless that have emerged—have for the most part left research to equipment vendors, which have themselves increasingly focused on short-term goals. As a result, telecommunications research is increasingly being done at universities rather than industry, and outside rather than inside the United States.

Another consequence of changes in the industry structure with implications for innovation is that the diversity of players in today's telecommunications industry makes it more difficult to design and deploy major, end-to-end innovations. Multiple visions are now being pursued by various segments of the telecommunications industry, and although an increased diversity of players provides more fertile ground for new ideas, it also makes widespread deployment of good ideas more difficult. Moreover, no single entity is able to appropriate the results of long-term, fundamental research or to comprehensively address the engineering and standardization issues associated with end-to-end solutions that must span multiple service providers and multiple sectors of the industry. As a result, vendors tend to favor incremental improvements to today's networks over more fundamental and high-risk research that seeks major advances in new or enhanced end-to-end applications and services and the architectural innovation that supports them.

The National Science Foundation and the Defense Advanced Research Projects Agency have been the two primary sources of federal telecommunications R&D support. NSF, long a supporter of telecommunications R&D spanning a range of topics, is currently emphasizing new approaches through such efforts as the Networking Technology and Systems (NeTS) program and the Global Environment for Network Innovations (GENI) experimental facility being planned by NSF in collaboration with the research community. DARPA, which funded a number of important telecommunications advances in the past (including elements of the Internet itself), has been generally shifting its emphasis toward more immediate military needs and giving less attention to long-term telecommunications research.

Despite these significant investments over the years, federal funding of long-term research did not increase sufficiently to compensate for the decline in industry support for long-term research. Because of the Bell System's ability to fund and conduct so much research in-house the federal government historically did not emphasize support for academic research in telecommunications and university researchers themselves tended to concentrate on research areas more amenable to work by individual investigators or small research groups, such as semiconductors, communications theory, and signal processing, leaving to industry research related to the design and operation of large-scale communications networks. Notable exceptions to this pattern, such as computer networking research supported by the Defense Advanced Research Projects Agency and National Science Foundation (which led to the Internet), illustrate the enormous potential payoff from government-supported and university-based research on new architectural ideas.

Long-term concerns similar to those now faced in the telecommunications sector prompted the establishment of research organizations for the semiconductor and power industries, with the implicit or explicit participation of government. Indeed, the current situation in telecommunications is somewhat analogous to the crisis faced by the U.S. semiconductor industry in the 1980s, when international competition and decreased R&D funding threatened that industry's long-term viability. In response, the Semiconductor Research Corporation and SEMATECH were formed. Their work is widely credited with having played an important role in the recovery, renewed leadership, and long-term viability of the U.S. semiconductor industry. Notably, there have been no parallel systematic efforts—either government- or industry-led—for telecommunications.

I will now turn to the committee's key recommendations.

Our report's first major recommendation reflected the view that a strong, effective telecommunications R&D program for the United States will require a greater role for government-sponsored and university research, and more funding of long-term research by industry. To underscore the seriousness with which the study committee viewed the challenge, we made a bold recommendation, that the federal government establish a new research program with the objective of

stimulating and coordinating research across industry, academia, and government. This proposed research program, called the Advanced Telecommunications Research Activity (ATRA) , was envisioned as a hybrid of activities of the sort historically associated with DARPA (which through the ARPANET program managed a research portfolio, developed a vision, and convened industry and academia to build what would become the Internet) and SEMATECH (which brought the semiconductor industry together, initially with some federal support to complement industry dollars, to fund joint research, development, and roadmapping activities).

ATRA's mission would be to (1) identify, coordinate, and fund telecommunications R&D, (2) foster major architectural advances, and (3) strengthen the U.S. telecommunications research capability. Key suggested steps for implementing ATRA are (1) establishment of mechanisms for carrying out project-based research; (2) establishment of advisory committees with high-level industry participation; (3) exploration of the need for R&D centers; and (4) establishment of a forum for key parties to discuss critical technology development issues.

Our report urged that telecommunications research funding should be consistent with the vital role played by telecommunications in the U.S. economy and society and with the direct contributions made by the U.S. telecommunications industry to the nation's economy and security. The study committee recognized, however, that budgets are often a zero sum game, and that a bold proposal of this sort would have been quite difficult to implement in the budget environment at the time its report came out. Moreover, we were not charged with making budgetary recommendations nor examining tradeoffs between research needs in telecommunications and other areas of science and technology research—nor did we in any case believe that increased investment in telecommunications research should come at the expense of other areas of scientific or engineering research. But our report points to telecommunications research as an area where investment is critical.

For more on the broad case for investment in science and technology, I would refer you to the National Research Council's recent report *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future.* I am hopeful that the present budget

environment, in which significantly increased investment in scientific research is being contemplated, offers new opportunities for supporting an initiative in telecommunications.

As for where within the federal government the ATRA program could fit, there are multiple options, each with its own set of tradeoffs, and our report provides several of these. For example, ATRA's proposed mission would align with that of existing agencies within the Department of Commerce, and NSF has developed mechanisms for joint academic-industry engineering research, albeit more focused and on a smaller scale.

Even with the establishment of an ATRA research program, NSF and DARPA would remain key contributors to U.S. telecommunications research efforts. Both have successful research management cultures that complement each other and the activities envisioned for ATRA. NSF has significant strengths in supporting basic research, training researchers, and building research communities that can play an important role in strengthening the U.S. research base in telecommunications. NSF's commitment to supporting research in this area has been evident, and NSF has a number of opportunities for sustaining such attention, including making efforts to attract and develop young research talent in telecommunications. DARPA is well known for a culture of focused programs with active program management and significant industry participation. In considering investments in telecommunications research, DARPA should consider the telecommunications capabilities attainable by potential U.S. adversaries by virtue of the burgeoning commercial telecommunications sector overseas and the risks associated with the United States having to rely on communications components and systems that are increasingly being developed overseas.

Second, the report also recommends that all segments of the U.S. telecommunications industry increase their support for fundamental research, possibly taking advantage of the avenue provided by participation in joint, cooperative research activities organized by ATRA. Indeed, the committee recommended that industry should provide a significant fraction of total R&D funding for ATRA, which would support researchers from academia and industry and provide industry with a way

to pool funds, spread risk, and share beneficial results.

Moreover, effective expansion of federal support of telecommunications research through ATRA will require participation from both service providers and equipment vendors to help identify the most critical research needs together with complementary industry investments in research. ATRA can play an important role in facilitating mechanisms to enable service providers to pool research support.

Mr. Chairman and members of the committee, our report contemplates a multifaceted, reinvigorated telecommunications research program. Our recommendations envision an enhanced and multifaceted role for government-sponsored and university research in telecommunications as well as additional investment by the telecommunications industry in more work of a fundamentally high-risk character, and thus a strengthening of the nation's telecommunications research institutions and programs, industry, and infrastructure.

You can find more information about these and related studies on the Web site of the Computer Science and Telecommunications Board of the National Research Council at http://www.cstb.org.

Thank you. That concludes my comments. I would be happy to take any questions you may have.