



# **Toward Universal Participation in the NII**

## **Phase 2 of a National School Network Testbed**



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## Introduction

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Over the last two months a broad partnership of educators has come together to address a challenge from the Vice President to “connect all of our classrooms, all of our libraries, and all of our hospitals and clinics [to the National Information Infrastructure (NII)] by the year 2000.” Our partnership contains over 1000 schools, within nearly 500 school districts and 19 states. It also contains science museums, informal education centers, universities, research and development groups, publishers, and network service providers that are building state-of-the-art applications of networking in education. The proposed Phase 2 of the National School Network Testbed will be a tool of this partnership and a place in which multiple infrastructure experiments, pilot studies, and field tests of new education network services can be undertaken. Through this collaboration we will attempt to provide an empirical basis for public policy and guidance for public and private investment.

Our partnership wants to go well beyond the Vice President’s challenge to achieve not just universal connection but universal *participation*. We are united in a desire to bring the NII to bear on the complex tasks of educational innovation and systemic reform. For this, the NII cannot simply be a delivery vehicle for video programming and database services. It is critical that the NII engage the active participation of all students, teachers, administrators, and members of the community, with students actively involved in their own learning, teachers becoming life-long learners in their professions, and parents and community more integral to the education process. The fundamental premise of this partnership is that in order to scale up participation in the *national* information infrastructure, we have to build the *local* information infrastructure of the school and community in such a way that all participants can be active constructors of services in classrooms, school district offices, and community learning centers.

This proposal is to fund part of the work of Bolt Beranek and Newman Inc. (BBN), the University of California, Irvine, and the Global SchoolNet Foundation in supporting the partnership in this endeavor and in conducting core research and development. The letters of commitment from 68 partners attached in Section I illustrate that this core work is a small part of what will be happening in the Testbed and grows directly out of the needs and contributions of the partner organizations as well as the findings from Phase 1. For example, while the Science Learning Network seeks to extend the rich informal learning environments of science museums to larger audiences, Internet-connected schools throughout the country seek both to access these resources and to make their own contributions to them. The Testbed will support the complementary goals of these and the other partners.

The research conducted by BBN and nine partner organizations in Phase 1 of the Testbed, which forms the basis for the current proposal, clearly points to the need for tools and services that support multiple functions at the local level in a way that is fully integrated with the work of the school and the goals of innovation and systemic reform. A single R&D project or network application, however compelling, cannot by itself justify the cost of an infrastructure that allows participation. The infrastructure must serve the local need to access multiple resources. A student working at a classroom computer may access tools and services provided by national organizations, by the school district, by the school, and by other students in the classroom. The *local information infrastructure*, the LII, must support multiple uses, impacting all areas of the curriculum while providing professional development opportunities, new approaches to administration, and greater community access.

The Testbed partnership represents multiple network infrastructure-building experiments including, for example, district-wide networks, “wired cities,” and home dialup services. It also represents a

full range of organizations and activities from commercial information services to systemic reform initiatives. While the partnership is heterogeneous, the agenda of the work proposed here is narrowly targeted at building the LII so that schools and their communities can participate in the NII as full contributors to it and, thereby, justify their networking investments.

The Testbed partnership is a joint effort to understand these requirements for the LII. This can only be done where the same LII is used for multiple purposes and where there exist LIIs built on multiple kinds of underlying network infrastructures. Thus, the work of the Testbed itself will be to:

- Set up a Testbed Exchange that will coordinate the work of the partners, provide technical and training support, develop an evaluation framework as a basis for cost-benefit assessments, and work to get the very best network applications operating within multiple local infrastructures. The Exchange will have a narrower focus than other network information centers (NICs) in its emphasis on building the local base for the national infrastructure, but will use established NICs as its broader dissemination vehicle.
- Conduct research and development on tools and services that can address the requirements of the LII. BBN has made considerable progress already in designing a set of LII tools and services that assist teachers and students in integrating a range of local and remote network services and activities into the work of the school. The New American Schools Development Corporation-funded Co-NECT schools as well as other Phase 1 Testbed schools will soon be testing a prototype of this system. While not the only such system operating in the Testbed, these tools, with additional work, will provide a proof-of-concept for the core tools and services needed for an LII.

BBN, University of California, Irvine, and the Global SchoolNet Foundation bring an unparalleled capacity to provide these fundamental services to this partnership. BBN is a world leader in networking technology and as a co-developer of the original ARPANet has been a leader in the Internet community from the beginning. BBN also builds on three decades of work in the application of advanced technology to education and brings to the Testbed a major school design project, the Co-NECT School, which constitutes a laboratory for the R&D on LII tools and services in the context of an intense, systemic reform agenda. BBN's management of the Phase 1 Testbed has proven the capacity of its senior staff, Martin Huntley, Susan Bernstein, Denis Newman and Beverly Hunter to develop the partnerships necessary to reach very broadly to practitioners, policy makers and other researchers with information, technologies and frameworks for getting the NII to school. Henry Becker of UC Irvine, who will lead the evaluation efforts, is a nationally known researcher with vast experience in assessment of educational technologies and a commitment to cost effective approaches. Al Rogers of the Global SchoolNet Foundation has been recognized as an educator of the decade by the National Educational Computing Conference for his career-long commitment to participation by students and teachers in network projects. NSF funding to provide services, support and technology to the Testbed partnership will assure that the substantial investments by the partners themselves as well as by many government agencies, including NSF, NTIA, and the U.S. Dept. of Education will be optimized through collaboration and synergy. The Phase 2 Testbed will be a significant step toward the participation of all classrooms in the NII.

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## Background and Rationale

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### Report on Previous Research: Phase 1 of the National School Network Testbed

The rationale for this Testbed grows directly out of the work of the Phase 1 partners over the last year and a half, during which approximately 50 schools and other educational organizations (including school district and state education department offices) in Massachusetts, New York, and California participated in eight projects. Network uses included collaborative classroom investigations, modeling and visualization technologies, informal science environments, staff development, student investigations and scientific sense-making, administrative applications, and others. Phase 1 research partners included the American Association for School Administration, Center for Children and Technology, Education Development Center, Graham and Parks School, Massachusetts Corporation for Educational Telecommunications, Ontario Institute for Studies in Education, Ralph Bunche School, UC San Diego, and University of Illinois.

The goal in Phase 1 was to understand how elementary and secondary schools can achieve universal access to network resources. Massively scaling up school networking will require widespread buy-in from many sectors. We knew that unless a technology proves to be a cost-effective approach to solving perceived problems, it will not be widely implemented. So, in particular, we wanted to know what potential and demonstrable benefits will appeal to the interests and needs of diverse influential groups, including parents, school administrators, teachers, public officials, and industry. The central tasks of Phase 1 were to determine the feasibility of using Internet technologies in elementary, middle, and high schools as well as district and state education offices and to understand better the cost and benefit factors of that technology at these different levels of the educational organization.

On the basis of our earlier study of the “Local Infrastructures for School Networking” (Newman, Bernstein, Reese, 1992), we conjectured that the type of network connection that allows students and teachers to use network application software on desktop computers – programs such as *NCSA Mosaic*, *Eudora*, *GINA*, and many other graphical user interfaces to Internet tools and services – would be a critical factor in scaling up to universal access. As the earlier study described, what these programs have in common, beside greater ease – indeed, greater pleasure – of use over the more common text-based terminal-host software, is that they require a real Internet-protocol connection, what we call “Internet-from-the-desktop.” This connection can run over a dialup telephone line or a high-speed dedicated line, but the critical feature is that the desktop computer is assigned an Internet address and becomes a peer with every other computer on the Internet, whether it is a large university computer used as a server for databases, bulletin boards or email or a portable computer dialing into the network from a teacher’s home. These desktop programs are often called “clients” because they request services from another machine or “server” – thus, client-server computing. Phase 1 was a feasibility study because, when we began it, these kinds of connections were very rare in schools. Our 1992 study identified only about a dozen, but by 1994 the number of schools with full Internet connectivity has increased dramatically. All participants in Phase 1 had this Internet-from-the-desktop level of connection.

Three reasons led us to believe that Internet-from-the-desktop may be a technical key to universal implementation. First, while it is more expensive than the older technology, it offers greater ease of use, making it more accessible to the masses of teachers and students who have so far not participated in networking. Second, Internet-from-the-desktop makes it possible for a school system to gradually scale up access and participation. A school can move smoothly from, for example, dialup access to a remote server, to using a district server accessed via dedicated lines, to a server located at the school accessed through a local area network (LAN). Third, students and

teachers in the school can interact directly, flexibly, and simultaneously with any number of projects, network services and virtual communities without going through a centralized host that acts as a gatekeeper. Thus, the same connection can serve multiple purposes for students, teachers, and administrators, potentially lowering the costs for any one purpose.

While not the only kind of server to operate in the Testbed, the Copernicus Internet Server, developed by BBN, has been a critical element in demonstrating the feasibility of providing schools with the capability of managing their own Internet services. The Testbed goal was to find an inexpensive alternative to the difficult-to-administer Internet server typically managed by University or corporate information services departments. The version of the server developed and deployed in Phase 1 is built on a PC (Intel 80486) hardware platform and a low-cost Berkeley UNIX operating system. It integrates email, news, gopher and World Wide Web, WAIS, and FTP services, along with a custom management component. The *Copernicus Manager* is the key innovation in the Copernicus server. This software makes it easy for non-specialists to administer services on the Copernicus server, including creation of personal email accounts, mailing lists, and news groups (bulletin boards) through a Macintosh (soon to be *Windows*) program called *Kepler*. *Kepler* is a desktop client program similar to other client programs used to access Internet services and thus extends the same familiarity and ease of use found in client-server computing. The success of the Copernicus system provides a model for future systems.

At the recent meetings of the American Educational Research Association, Newman (1994) presented an analysis of data from twenty Phase 1 researchers and practitioners. These are the findings that most directly influence the agenda for Phase 2:

- The Internet-based client-server technology was very attractive to participants and was easy to learn. The Copernicus Internet Server demonstrated the feasibility of managing Internet services in school and district settings. We found in several of the projects, however, that there is a systematic need for onsite support due to the inherently distributed nature of the systems. Simply at a technical level, providing more networking power to local desktop systems requires considerable set up and configuration. This is in large measure because PC operating systems are not designed to handle multiple people sharing the same machine or using different machines at different times. For example, the Community of Explorers project finds that a single network-connected machine is often used by several teachers; the Shadows project and Co-NECT schools find that students and teachers may use different machines at different times; the InternNet participants moved between a networked lab situation and a personal computer at home. Our technology development component in Phase 2 will address this issue of reducing the support costs of the technology through tools and services that make it straightforward to set up an LII for the kinds of complex interdependent tasks that are called for in applying networking to the larger, reform goals towards which the Testbed partnership is moving.
- The CoSN/FARNET conference of educators, including Testbed participants, that met in October, 1993, reached consensus on the need to link network use to broader systemic reforms. Our Phase 1 analysis reached the same conclusion and noted that the cost effectiveness of any application of networking must be calculated in relation to larger goals, and current methods, for reform of education. Too often, we think of network applications as add-on activities that bring their own costs and benefits. However, the commitment to and resources for larger reform efforts, such as, introducing a new curriculum framework, are much broader in scope than the networking component alone. Once a commitment is made to the staff development required for the larger reform, the cost of networking can be weighed against its effectiveness in accelerating or expanding the reform effort. In Phase 2,

the Testbed must move beyond single purpose network uses and into systemic reform efforts in order to understand the value of networking.

- The broader conclusion that begins to emerge from our Phase 1 work is that we must understand networking in terms of an infrastructure that can have multiple uses: from curriculum to administration to community access. It is currently very common for administrative and curriculum networking to use separate networks. It is not just the applications or projects that have to be conceptualized in systemic terms; the tools and services as well as the “wires” have to be understood as a very general investment that cannot be allowed to be captured by one purpose (e.g., curriculum or administration). The cost-effectiveness of networking must be considered in relation to the costs of a general infrastructure just as the benefits come from not just the sum of the individual projects, but the systemic changes in the organization that can occur when students, teachers, and administrators are empowered by an open system of communication.

The first year report of the Phase 1 Testbed lists the dissemination activities including papers, discussions and workshops which have been presented at major national conferences such as NECC and Tel-Ed, at policy workshops organized by CoSN, and regional meetings such as California CUE. Articles have appeared in publications ranging from *Communications of the ACM* to *Fortune* magazine. Testbed staff have contributed to national policy discussions of the Office of Science and Technology Policy, the U.S. Education Department, The White House (NCC-TET, 1994) and many state and district-level discussions. The Copernicus Gopher/Web server is publicly available on the Internet and points to partner projects around the country from the California Department of Education to the Ralph Bunche School in New York City.

## Goal and Rationale for Phase 2

As we turn to Phase 2, the partnership is much larger but the agenda is actually more focused, drawing on the findings from Phase 1. We have amended the title of our proposal from Phase 1’s, “Toward Universal Access to Math and Science Resources” to “Toward Universal *Participation* in the NII”, because we now realize that the mechanisms for scaling up require active participation, not just access. We continue to emphasize that the local infrastructure is currently the weak link. Thus, the Phase 2 partnership will address the following question:

**Can we construct and manage communications networks and information services to support educational innovation on a *local* level in such a way that taxpayers, governments, and private industry will view their benefits and cost-effectiveness as warranting the investment needed to support them on a large scale?**

This question brings together two essential elements, *constructable resources* in the *local information infrastructure* (LII) as the key to universal participation. Together, they form the fundamental rationale for the Testbed and are the basis for the following conjectures to be addressed in the Testbed:

- Wide distribution of the capability to produce value on the NII is a key to universal participation by schools. As more students, teachers, and administrators have the opportunity to actively construct educational value from the vast raw materials of the NII by constructing their own local resources, they add new value to the networking infrastructure. The more valuable the information and services available on the NII, the more schools and communities are likely to invest in additional connectivity, adding to the NII’s growth. It is important that we investigate this potential immediately because constructability is not as straightforward to implement as the so-called interactive “video-on-demand” and shopping

systems that may otherwise come to dominate the NII and that have far less to offer education.

- User-constructability is essential for supporting the reforms in math and science instruction that are at the heart of most NSF-funded educational projects. These are based on constructivist principles, an approach to learning and development in which students and teachers are active learners and “doers” of math and science, not passive recipients of information. The potential for providing educational value consistent with the pedagogy of the active learner requires that students and teachers participate as developers, not just recipients, of network services. Our conjecture is that a networking infrastructure designed to support these reforms can extend this constructivist approach, having an enormous multiplier effect on efforts to improve education.
- Service providers that are remote from the school and community can support user-constructable services, but if the infrastructure is to handle millions of new participants, management responsibility will have to be widely distributed. While national or regional resources (computational, information, and human) can serve as the basis for educational networking when participants number in the tens of thousands, local organizations, schools, and school districts will have to participate in the construction and management of these resources when participants begin to number in the millions. Our conjecture is that the LII can be the locus of integration for hundreds of services, projects, and communities no matter where their participants are located. The day-to-day management and local tailoring of this LII can be handled locally.
- Local infrastructures continue to be the weak link in the chain and a topic that few other groups are addressing directly. At the same time, however, school systems are beginning to build LIIs at an accelerating rate. While *Education Week* (West, 1994) reports widespread understanding that the “last mile” problem is nowhere near being solved, the National School Network Testbed partnership contains many school systems and communities that are right now building intra-school and intra-community networks. Since early work with school LAN systems (Newman et al 1989; Newman, 1990) and more recent analyses of the local infrastructures used in school networks (Newman, Bernstein & Reese, 1992; Newman, 1993a, 1993b), BBN has been addressing this problem. We believe that there is now sufficient grass-roots experience with integrating local and wide area networks to gather a group of partners to invent solutions to this problem, solutions that will support the partnership’s shared goals for systemic educational reform.

To address these conjectures, we must put in place a diverse partnership that encompasses a large number of network initiatives – especially those that address systemic reform. To see whether the LII can be the locus for the integration of many projects, the Testbed will allow the partners to go beyond piloting a single technology application, a single approach to staff development, or a single way of organizing network-based science instruction. While many of the projects and services will be discrete entities, we will be particularly interested in LII-supported efforts to bring these together into a coherent whole as part of larger reform efforts.

The Testbed must also encompass a large set of LIIs. We cannot base our conclusions on a school system with one kind of infrastructure or one set of goals. We need to look across urban and rural settings and include a range of levels of experience. The Testbed will include “wired cities” as well as rural schools connected by ordinary phone lines. The partnership includes local organizations (schools, districts, and communities) that are investing their own resources to solve their own problems – not just sites equipped for research purposes.

By encompassing a rich set of network applications within a wide range of local information infrastructures, the partnership can answer the question we set for ourselves both with respect to our immediate practical concerns of building the infrastructure and, more generally, in a way that will inform decisions at all levels of government and industry. We are at an important juncture. While school reform calls for an NII that supports locally constructable resources, major investments are being planned in an NII with a focus on delivery of programming and services. Unless, over the next few years, we are able to demonstrate the value and cost effectiveness of local constructability, the NII may be dominated by commercial delivery programming and services. The National School Network Testbed partnership will enhance and bring together many initiatives at federal (e.g. NSF, NTIA, Department of Education), state and local levels in demonstrating the alternative while attempting to solve the fundamental problems of scaling up to universal participation.

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## The Partnership

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In planning Testbed Phase 2, we have discussed participation with individuals representing 120 organizations, many of which represent dozens or hundreds of schools. A significant proportion of these organizations and schools would not on their own compete for NSF grant support; hence participation in the Testbed enables them to play a contributory role nationally that they would not otherwise perform. Collectively, these organizations are working on all aspects of educational reform across all institution types. Here are some examples:

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| <ul style="list-style-type: none"> <li>• <b>Teacher preparation</b><br/>Council of Independent Colleges<br/>TeacherNet at CSU Long Beach</li> <li>• <b>Teacher enhancement</b><br/>Global SchoolNet<br/>Arizona State University<br/>Geometry Forum<br/>Poway School District, CA</li> <li>• <b>School restructuring</b><br/>Coalition of Essential Schools<br/>Co-NECT Schools (NASDC)</li> <li>• <b>Home-school connections</b><br/>Indiana's Buddy System</li> <li>• <b>Alternative assessment</b><br/>Allegheny/Schools Partners</li> <li>• <b>Community involvement</b><br/>Fifth Dimension – UCSD<br/>Lexington, MA</li> <li>• <b>Informal education</b><br/>Exploratorium<br/>Harvard's Arnold Arboretum<br/>Franklin Institute's Science<br/>Learning Network</li> <li>• <b>State systemic initiatives</b><br/>Massachusetts<br/>California</li> <li>• <b>Urban initiatives</b><br/>Washington, D.C.</li> <li>• <b>Rural initiatives</b></li> </ul> | <p>Sweetwater, WY</p> <ul style="list-style-type: none"> <li>• <b>Curriculum reform</b><br/>Middle-School Mathematics<br/>through Applications Project</li> <li>• <b>Voc-tech education</b><br/>Minuteman Tech<br/>MIT's Lincoln Lab<br/>National Center for Research in<br/>Vocational Education</li> <li>• <b>Educational administrators</b><br/>AASA<br/>Stevens Institute</li> <li>• <b>Gender equity</b><br/>Center for Children and<br/>Technology<br/>National Coalition of Girls'<br/>Schools</li> <li>• <b>Underserved groups</b><br/>Onondaga Nation School<br/>Gallaudet University</li> <li>• <b>Scientist-school linkage</b><br/>Earthwatch<br/>Geometry Forum</li> <li>• <b>Educational publishing</b><br/>Scholastic<br/>Chancery Software</li> <li>• <b>Digital libraries and<br/>information services</b><br/>AskERIC</li> </ul> | <ul style="list-style-type: none"> <li>Eisenhower National<br/>Clearinghouse<br/>CNIDR<br/>InterNIC</li> <li>• <b>Educational services and<br/>laboratories</b><br/>NW Regional Lab<br/>OCM BOCES</li> <li>• <b>Industry roles</b><br/>Digital Equipment<br/>New American Schools<br/>Development Corp.<br/>Pacific Bell</li> <li>• <b>National education and<br/>infrastructure policies</b><br/>Chief State School Officers<br/>CoSN</li> </ul> |
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These organizations are employing telecommunications networks and creating information services for a wide range of applications, including:-

- collaborative design in engineering (Cornell's SYNTHESIS)
- telementoring (Center for Children and Technology, EDC)
- scientific visualization (Northwestern's Collaborative Visualization)
- multimedia (OCM BOCES)
- collaborative inquiry (TERC)
- information retrieval skills (Wilson High School, Portland)
- environmental monitoring (York Schools, ME)
- curriculum building and sharing (Co-NECT, Coalition of Essential Schools)
- professional development (Teaching Teleapprenticeships-UIUC)

Our partners, although remarkably diverse, share a common spirit of constructivism and a quest for equity. Sweetwater County School District #2 in rural Green River, Wyoming exemplifies this spirit. The following are excerpts from their email messages:

“First goal: construct a community wide educational network system where all learners can access local, regional, national and global information and become actively engaged in research...The district students are installing twisted pair Ethernet cabling to every classroom, hubs and routers at every school...[In] a project with the Wyoming State Fish and Game Department and Los Alamos National Labs...learners are active participants in range, wildlife, and land use studies. We envision learners, equipped with global positioning devices, gathering data over time on climactic variables; air and water pollution; plant and animal populations; human use and impact...Learners will use the local data, along with satellite images and other topographical information, to study mathematical relations, develop population simulation models, make population projections...Students will operate a “help desk” with dial-in lines...students will pilot new configurations and system changes...students will manage the POP3 mail server that will provide electronic mail boxes for every student in the district and every interested learner in the community...We envision our planning, installation and implementation as a scaleable model for network expansion into small rural communities...a workable way for communities to find the critical mass needed to support internetworking [and] to justify the costs...Schools are in a position to provide the time and effort to keep the system running while providing valuable real world learning experiences for students.”  
(Jim Rogers)

Out of the 120 organizations under discussion, 68 letters of commitment are included in Section I of this proposal. The following are the criteria we are using in selecting partners for the Testbed:-

- the organization must have an educational reform purpose
- it must have a commitment to building technological infrastructure for networking to support learning and teaching
- it must have the intention of providing full Internet access and participation to its constituents (and nearly all do have at least one building with full Internet connectivity and are looking to expand from that)
- it must seek to empower its constituents to be not just consumers of information but also contributors to the information infrastructure
- it must be willing to share concrete products and processes with the larger Testbed community (either for free or on a for-fee basis)

- it must be willing to share evaluation data and findings with the larger Testbed community
- it must bring financial support for its information infrastructure activities.

The Testbed partners from whom we currently have letters of commitment represent the following numbers of institutions: over a thousand elementary and secondary schools; close to five hundred school districts; ten regional school district collaboratives; four state education agencies or statewide organizations; several vocational-technical schools and community colleges; six private schools; many colleges and universities; ten science centers and museums; several thousand homes; four educational publishers; five business/industry organizations; and over twenty educational research organizations and service providers. This partnership is making substantial investments in their own infrastructure, staffing, and staff development, estimated conservatively at \$122M. In addition, BBN, UC Irvine, and Global SchoolNet Foundation are contributing \$2.9M in cost sharing for this work.

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## The Testbed Exchange

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The first task of this project will be to establish and operate the Testbed Exchange, a distributed support, research, and information exchange facility that will both directly serve the partnership and provide the Testbed with a proactive interface to the wider NII community. The Exchange will be organized as a number of “Desks,” each with a human specialist responsible for gathering, organizing, structuring and constructing data resources and pointers to same, for tracking developments in the area within and outside the Testbed, and for proactively ensuring that Testbed partners take advantage of and contribute to the Desk. Each Desk is responsible for the research function in its area of operation.

Exchange Desks will reflect the structure of our agenda focusing on the local information infrastructure (LII) with a central Desk concerned with that fundamental issue and supported by a Desk concerned with the applications that ride on top of the LII and a Desk concerned with the connectivity that supports the LII. A fourth Desk will be concerned with Support issues, a fifth with Evaluation issues, and a sixth Desk will proactively forge links to other information agencies such as the InterNIC and AskERIC.

- LII Desk will help Testbed participants with tools and techniques, and be a locus for research around local management and construction of network resources. This Desk will be responsible for determining the functional requirements for tools and services that are designed to support the LII. It will evaluate formative experiments conducted by partners on such tools and services and feed that information back to the partnership. This Desk will communicate primarily with partner organizations and individuals responsible for onsite support of LIIs and with partners designing network applications. Martin Huntley of BBN will be responsible for this Desk.
- Projects Desk will focus on the uses to which Testbed partners put the LIIs. Of concern here are the individual projects as well as the systemic efforts toward school change and innovations such as project-based learning, portfolio assessment, and community involvement. This Desk will proactively broker between projects and school systems that are prepared to undertake the project. It will bring applications that are addressing the same issue together in order to share approaches to effective use of LII tools and services. The desk will also develop ways that the larger NII community can participate in Testbed projects and make this information available via the Reference Desk. This Desk will communicate primarily with practitioners in partner sites and with current and potential developers of network applications. Beverly Hunter of BBN will be responsible for this Desk.

- Connectivity Desk will evaluate connectivity models, funding models and realities, emerging roles of municipalities and metropolitan area cable and other “highway” builders. This Desk will work with the commercial builders and operators of the NII and will evaluate major new initiatives to assure that the Testbed partnership is informed of opportunities to build their LIIs on a firmer base. It will address security issues and evaluate the security needs of Testbed LIIs. This Desk will communicate primarily with partner school systems and communities that are building network infrastructure and with the network and communications industry that is building the NII. Susan Bernstein of BBN will be responsible for this Desk.
- Support Desk will develop and broker staff development services, evaluate the cost effectiveness of approaches to staff development, and assess the support requirements of network technology as well as its use in providing support. The Desk will compile materials for use in staff development, design and implement a range of formal and semi-formal training opportunities emphasizing locally constructable resources, and gather data on issues involving teacher support and training. This Desk will communicate primarily with the LII Desk and its clients. Al Rogers of the Global SchoolNet Foundation will be responsible for this Desk.
- Evaluation Desk will be responsible for the overall evaluation activities of the Testbed which are described in more detail below. It will develop an evaluation framework and assist partners in gathering data to assess, for their uses, the cost-effectiveness of different LII options. The desk will serve as a coordinator for data collected on Internet service use by automated tools and mechanisms built into servers deployed on the Testbed. It will coordinate research efforts that cut across the specific issues of the other desks. The work of this desk will be especially important for independent evaluation of the cross-project synergies that the Testbed is intended to foster. This Desk will communicate primarily with partners that are conducting application and infrastructure building projects. Henry J. Becker of UC Irvine will be responsible for this Desk.
- Reference and Dissemination Desk will be responsible for developing a distributed database (such as gopher/Web or other mechanism) that will incorporate information about the products and processes of the Testbed projects for both partners and others who are participating in the NII generally. This facility will be maintained in a form that will be easily integrated into the information services of agencies and organizations such as the InterNIC, AskERIC and CoSN. This desk will be responsible for assuring that partners participate in national and regional conferences and other opportunities for informing the public of the findings from Testbed projects. This Desk will communicate primarily with the other Desks and with information services outside the Testbed and will be the resource of first and last resort for questions about the Testbed.

The Exchange will be overseen by a Testbed Advisory Group representing the member organizations. A smaller steering committee will be convened to give consistent feedback and recommendations on the construction and conduct of the Exchange. This group will communicate regularly and gather once a year for a face-to-face planning meeting.

The Exchange will be more than a clearing house for information. It will address research questions of its own, help design support infrastructures, serve as broker for resources and new partners, and be a vehicle for dissemination to the community beyond the Testbed. It will also set the Testbed development priorities to assure that participating projects have the tools they need.

The Exchange will put in place an organization and its automated tools that can support an expanding Testbed membership, and create a shared “place” for the formulation and investigation of a range of important research questions by the Testbed partners. A variety of communications

tools will be used by the Exchange, including telephone, fax, U.S. mailings, and email as well as gopher/WWW, ftp, listserv, WAIS, and desktop videoconferencing. New tools and techniques for the automation of information construction and dissemination will be continually researched and deployed.

A fundamental premise of the Testbed Exchange is that its functions will be developed to become a self-sustaining operation underwritten by industry and state-level partners by the end of the funded period. Specifically, it will from the start provide distributed services which can be spun off when they achieve critical mass and will work with Testbed partners to have them take over specific Desks.

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## **Developing the Technology to Support Local Information Infrastructure**

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Several of the proposed Testbed partners have over the past two years been attempting to create LIIs for their schools, school districts, and virtual communities. In this process, they have encountered technical obstacles that make it difficult or too expensive for them to build the kinds of local educational projects and information services they want to create. In the proposed Testbed effort, we will develop three technology components to support local information infrastructure:

- Support for local construction of information services by people who are not technical specialists
- Organizing information access for several people who share one computer
- Tools for monitoring and analyzing system use and ensuring security

This development work will build upon both the progress made with the Copernicus system in the Phase 1 Testbed and upon the tremendous progress being made in client programs such as *NCSA Mosaic*, *Eudora* and other graphical user interfaces to Internet services. The Testbed development will address the fact that the construction and management of the underlying network services that make these client programs useful are still largely the domain of technically proficient system operators. The idea that these services can be constructed by non-specialists is still new, but, as we have argued, unless participants in the LII can control these resources it will be impossible to *scale up* while maintaining the principle of the active learner.

Copernicus servers are not the only ones of their type to be used in the Testbed, nor are they required for Testbed participation. Nevertheless, in efforts to make the Copernicus technology more readily available to Testbed partners and the rest of the Internet community, BBN will continue, independent of NSF funding, to port and unbundle elements of the Copernicus system and to explore distribution partnerships. We are beginning a re-implementation of *Kepler* for Windows. The Copernicus system itself is being ported to the Digital Alpha OSF/1 and the Sun platforms and we expect these versions will be available in the fall of 1994. More significantly, we are working on unbundling the Copernicus management layer from the other services so that sites that already have servers can license just the management system. BBN is in discussions with system integrators and Internet service providers to develop appropriate partnerships for the widespread distribution and support of the technology for end-users as well as other developers. For some partners, we will develop joint development agreements in which we license the source code so that they can port the system to servers that BBN has not yet addressed. BBN will continue selling the Copernicus server and maintenance agreements providing support, directly to schools and other end-users, but, for the first year of the Testbed, will roll any revenues beyond costs from Testbed partners back into sustaining development – essentially creating a cooperative that benefits from the development through maintenance upgrades.

The technology development agenda is based on the requirements of the partner projects that will be operating within the Testbed and will be continually adjusted to address those requirements as the work of the Exchange LII Desk continues to refine them over the first two years of the Testbed. The current requirements come from the Ralph Bunche School, Co-NECT School, CoVIS, TeleCSILE, Community of Explorers and TERC partners and the development that has been accomplished on the Copernicus and related systems as part of the Phase 1 Testbed and internal BBN development.

In support of this goal, there will be three tracks of development over the three years of the Testbed. Each will begin with a narrower focus on specific issues in supporting partner projects and transition to addressing large scale implementations in the second and third years.

### **Track 1: Constructability of Tools and Services**

The first set of tasks focus on the primary objective of the Testbed, support for local construction of services. BBN development of client-server management capability on the Copernicus Internet Server is a first cut at this functionality. Current functions include management of email accounts, newsgroups, and Gopher/Web servers. Building on this base, we will work with partners on the following tasks.

- File servers are used on the school local area network to support software such as word processors, databases and modeling environments. Integrating these local services with Internet services into a coherent part of students' and teachers' experience of the local information infrastructure will assist their curriculum work. This task will build on BBN's progress in integrating the management of Copernicus and AppleShare and Novell file servers via an extension of the *Kepler* interface, enabling students and teachers to easily create individual and project workplaces on the file servers incorporating access to all network services (year 1).
- Following the approach of having Copernicus manage *external servers*, the Testbed will support the CoVIS project by integrating access to the Collaboratory Notebook database, which resides at a central location, with the management of local servers in the school research sites, simplifying the local management of collaborative projects that involve the Notebook and other services such as email. The approach will be extended to *other partner services* as appropriate (continuous through years 1-3 as required by partners).
- The Testbed will assist partners and other members of the Internet community to add services and tools to the Copernicus server. This includes the TERC "telecollaboratives" server which provides data accumulation for distributed projects; *GINA* authentication allowing users to be authenticated when using California State University's Graphical Interface for Network Access; and Whois++, a directory service. We will continue to work on setup and distribution of locally initiated news groups and other mechanisms for conferencing used by many of the partners. By building the management of these services into the Copernicus system, schools will more easily sponsor their own telecollaborative projects, register new users as *GINA* users, and set up local directories (continuous through years 1-3 as required by partners).

The goal of this track of development is to support the local construction and management of network services. We expect the LII to support many kinds of projects and by opening the way to easier management of multiple projects, we can begin to develop a more general requirement for new user-constructable services and build prototypes of them.

## **Track 2: Organization of Access from Client Machines**

Phase 1 Testbed research has shown that client-server software brings greater ease-of-use but requires considerable on-site technical support especially in the set up and configuration of desktop systems. Schools present an additional challenge for network applications since machines are seldom assigned to a particular person. Personal computers are not well designed for these typical school situations and the second track of Testbed development will attempt to lower the level of on-site support.

- Simplified installation procedures will be developed for collections of Mac and Windows Internet client software commonly used in Testbed sites. These will allow a single networked machine to be shared by multiple people, by providing workplaces located on AppleShare and Novell file servers containing necessary configuration files for each user (years 1-2).
- We will develop a mechanism for managing and distributing multiple projects. Any one person in a school will participate in several different local work groups or virtual communities. An individual will also use many different local and remote network information services and may participate in several projects. We will develop “workplace templates” that a person can use on their computer to organize and manage all the different services and projects they are using. These templates will also be distributable over the network, providing a mechanism for sharing projects and curriculum units (years 2-3).

## **Track 3: Monitoring and Security**

With very large scale implementation of LII technology, security and monitoring become of increasing concern. Tools will be developed that are simultaneously useful to the Exchange's Evaluation Desk, to R&D projects, and to the people responsible for managing and operating the LIIs such as school or district technology coordinators who need to assess the value and effectiveness of their own services. At the same time, this track will be sensitive to concerns for privacy of communication. The Testbed development will address the following areas:

- The Testbed will develop monitoring mechanisms and procedures for analysis of quantitative information through instrumentation of the Copernicus servers. This will allow automatic collection of quantitative data on, for example, access to server resources and use of email (but not information on the content of the communication) (year 1). These monitoring and information tools will be deployed widely in partner sites for use in managing the LII as well as to provide an enriched data source for analysis and assessment (year 2).
- The Testbed will also use existing components such as help-desk systems to build a distributed information system that will be used by the Testbed Exchange (year 1).
- To extend the monitoring and data gathering functions, the Testbed will track emerging use of agent software (e.g. intelligent agents, knowbots) and intelligent data analysis tools in networked environments, and will test, adapt, distribute, and deploy such tools as they become available. (2-3)
- Through its Connectivity Desk, the Testbed will investigate requirements for security and evaluate products such as “firewalls” for use by LIIs. It will also investigate reverse firewalls which can reduce access from within the LII to unwanted remote resources and will develop mechanisms by which teachers can monitor outgoing communication, a requirement expressed by Phase 1 project partners for elementary school use of Internet communication (years 2-3).
- The Testbed will work with ARPA-funded and other partner projects that are developing electronic commerce, and with Testbed publisher and service provider partners, to implement

appropriate methods for paid subscription to services, for example SCHLNet, which currently charges a modest fee for the distribution of bulletin boards to local servers (year 3).

We will continue to base development on principles of open architecture, interoperability, and the integration of publicly available software. By the end of the three years as a result of this program of development we expect that the technology for supporting local information infrastructure will be very widespread both within the Testbed organizations and throughout the nation.

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## Evaluation and Assessment

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The evaluation component of the Testbed will be managed by the University of California, Irvine which will be responsible for the Exchange's Evaluation Desk and will:

- Carry out analytic, comparative studies of K-12 Internet-based projects
- Provide support for partner evaluation efforts
- Conduct studies that assess the effectiveness of the project's operative components

### Analytic Studies

Three analytic studies will address important issues of scaling, connectivity, resource utilization, and instructional and curricular reform regarding "Internet-from-the-desktop" for K-12 schools and classrooms. They will do so by collecting and analyzing survey data from Testbed partner schools and organizations as well as using other data provided by Testbed partners and data automatically generated via the servers. A baseline study will focus solely on Testbed partner schools while the other two will also incorporate samples of non-Testbed telecommunications-using K-12 schools (schools that did not meet Testbed criteria including Internet-from-the-desktop) in order to compare a wider range of school telecommunications efforts. The three studies are:

- **Baseline study.** A moving census of Testbed schools as they join the Testbed will provide baseline information about their previous involvement in technology, technical expertise, hardware and software initially used for connectivity, expected level of participation by various teachers and student groups, plans for technology development within the school, orientation towards instructional and curricular reforms, characteristic teaching patterns and instructional practices, and nature of the student clientele.
- **Effects study.** A major survey incorporating samples of schools in all Testbed partner projects as well as non-Testbed telecommunications users. The survey will sample teachers within sampled schools in order to study the following three sets of issues:
  - **Connectivity.** How different levels of Internet accessibility – including types of connections, numbers of connections and locations of connections – affect utilization, curriculum reform implementation, and teacher and student competence and productivity.
  - **Utilization.** How different conditions across project and school participants – including physical connectivity, teacher technical expertise, support from projects and districts, and project organization – affect utilization of various Internet resources, including construction tools provided.
  - **Instructional and curricular reform.** How different conditions across project and school participants – including connectivity, teacher technical expertise, teacher interest and understanding of reform ideas, and project organization – affect how students and classes use Internet resources.

- **Scaling study.** This study will integrate diverse sorts of information from inside and outside the Testbed in order to understand the problems of and strategies for “scaling up” the infrastructure to include hundreds of thousands of classrooms worldwide. For example, how will increased numbers of participants increase opportunities for successful information search? How will it also exert pressure on the availability of scarce resources such as adult expertise? How will scaling up affect the characteristics of the overall participant population (e.g. the type of clientele served, their role as producers or consumers of information, and their technology base)? How will it affect the quality of the contributions, the ease of locating relevant material or communities of common interest, and the value to users of the materials and ideas obtained? How will institutionalization of the mechanisms for contributions evolve, and how will investment in the infrastructure evolve in order to permit large numbers of participants from the K-12 arena? Who will pay for school investments in its local network infrastructure, for a district’s high-speed Internet connection, or for a service provider in support staff?

Answers to these questions cannot come from surveys of participants alone. But systematic aggregation of attitude data, behavior data, expenditure data, and statements about policy from schools, districts, infrastructure suppliers, and information providers can play an important role in building our understanding. This study will undertake small, targeted surveys as needed, but will primarily rely on assessing other sorts of information (the other research within the Testbed effort, news articles and public statements, budget and policy documents, and other scholarly and scientific research) in order to provide a comprehensive assessment of how the problem of scaling will best be solved.

### **Management of the Evaluation Desk**

In taking on responsibility for the Evaluation Desk, UC Irvine will have broad responsibilities for supporting Testbed partners including the following activities:

- Leadership in encouraging and assisting projects to undertake their own evaluations, for example, by helping them to specify goals for such evaluation, and helping them to select among methods for accomplishing it.
- Technical support for undertaking evaluations: This includes providing evaluation tools, expert advice on research design, and technical advice to partner projects attempting their own evaluations. Specifically, the support includes recommended questionnaire items and formats, interview protocols and procedures, and sampling and evaluation designs.
- Support to Testbed partners for consolidating and using the automated data collected by the Copernicus servers.
- Coordination with other Testbed Exchange desks on research questions that cut across their purview.

The Evaluation Desk will also facilitate the development of separately funded efforts to conduct evaluations of specific partner projects beyond the comparative analytic studies conducted as part of this contract. The Evaluation Desk will be responsible for working with the results of partner evaluations of their specific projects in order to draw general conclusions about the benefits and cost-effectiveness of the LIIs and associated technologies.

### **Testbed Effectiveness Studies**

The study of Testbed operative components will include two surveys of partner schools and an initial observational examination of eight selected sites. Their purpose is to provide informative feedback about the adequacy of functioning of the Testbed Exchange Desks.

The surveys and observations of Testbed participants will complement information that each desk would normally obtain about its users and contributors. Such surveys provide information about schools and teachers that have not begun participating or have chosen not to participate in a given Testbed Exchange Desk activity. Unrecognized needs and problems will surface in such surveys and observations enabling the Desks to proactively improve their services (including the Evaluation Desk itself).

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## **Dissemination**

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The Testbed Exchange and particularly the Reference and Dissemination Desk is a mechanism for reaching a very broad audience. The Internet community is well equipped to receive, indeed interact, with that information. The Testbed will also continue our Phase 1 approach to preparing articles for publication in scholarly journals and books, trade magazines, and distribution of technical and position papers. Our bibliography lists some of the recent papers.

We will remain active participants in conferences and working groups such as NECC, Tel-Ed, AERA, National School Board Technology conferences, Internet Engineering Task Force, and national and regional conferences addressing both technical and policy issues. The Testbed will remain pro-active in reaching administrators, legislators, school board members, and industry through our partners such as the Council of Chief State Officers, American Association of School Administrators, New American Schools Development Corporation, and other similar organizations.

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## **Work Plan and Future Phases**

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### **Growth of the Partnership**

Phase 2 of the Testbed will be a three year project. During year 1 the partnership will continue to grow and the LII technologies and technologies for tracking and managing the Testbed will be put in place. The second year will be characterized by a more stable operation and collection of data within the Testbed. There will be "controlled growth" through the inclusion of new sites within the member districts or organizations that are partnering with current members. The third year will involve assessment and renewed expansion of the Testbed in order to test the scalability of approaches.

Once a year, the Testbed will convene a conference which will coincide with a major national conference such as Tel-Ed which many of the partners will be attending. This conference will be an occasion to address issues of broad concern in the Testbed and to involve new partners in the discussion.

The number of partner school systems in the Testbed, while quite large, will not encompass all schools with connections to the Internet. While the Reference and Dissemination Desk will begin immediately to provide resources and information to the entire Internet community, the Testbed members will to a large extent represent the early adopters and pioneers. The limited resources of the Testbed Exchange (except for the Reference and Dissemination functions) will be focused on the Testbed until the third year. As we begin the third year in the fall of 1996 the Testbed partnership will simultaneously begin to expand and transition to a phase in which more of the Exchange functions will be distributed among partners and the continued support of the research and development activities will transition to support by partner organizations.

**Management**

The Phase 2 Testbed will be directed by Dr. Martin Huntley of BBN who has been in charge of user support during Phase 1. He will have specific responsibility for the LII Desk and will oversee the Global SchoolNet subcontract and other consultants and will be responsible for convening annual meetings of the advisory board. Susan Bernstein and Denis Newman will continue as Co-PIs. Bernstein will have specific responsibilities for the Connectivity Desk and for supervision of the technology development. Newman will have broad responsibilities for reporting research findings, including work with Huntley on translation of the LII Desk findings into technology requirements and overseeing the UC Irvine subcontract. Beverly Hunter will take responsibility for the Projects Desk, for recruiting new partners and assessing the adequacy of the information flow from the Testbed to the wider range of stakeholders.



## SECTION D BIBLIOGRAPHY

- Barowy, William & Bernstein, Susan. *Building a New Kind of Computer Network for School Science*, 15th Annual Lesley College Computer Conference: Educational Technology for Schools, Lesley College, Cambridge, MA, May 8, 1993.
- Bernstein, Susan. *Internetworking and K-12 Schools*, a Birds of a Feather Session at InterOp/93 Spring, Washington, DC, March 11, 1993.
- Bernstein, Susan. A Testbed presentation at NYSERNet '93, New York, October 1, 1993.
- CoSN/FARNET Project. *Building Consensus/Building Models for K-12 Networking*, Washington, DC, October, 1993.
- Feldman, A. (1994) Collaborative Inquiry in Networked Communities. Paper presented in a symposium on *Issues in Computer Networking in K-12 Schools: A Progress Report of Four NSF Testbeds*, B. Hunter, chair, at the annual meetings of the American Educational Research Association, April 7, 1994, New Orleans.
- Franklin, Daniel. A Testbed presentation at the Works-In-Progress session of the USENIX Winter 1994 Technical Conference, San Francisco, January 17-21, 1994.
- Hunter, Beverly. "Linking for Learning: Computer-and-Communications Network Support for Nationwide Innovation in Education", *J. Science Education and Technology*, Vol. 1 No. 1 pp 23-33, 1992.
- Hunter, Beverly. "Internetworking: Coordinating technology for systemic reform", *Communications of the ACM* (May 1993), pp. 42-46.
- Hunter, Beverly. "NSF's Networked Testbeds Inform Innovation in Science Education", T.H.E. Journal, October 1993.
- Hunter, Beverly. "Collaborative Inquiry in Networked Communities", *Hands On!* 16 (2), TERC, Cambridge, MA, Fall 1993.
- Hunter, Beverly. *Learner and Teacher Contributions to the National Information Infrastructure*. Keynote address to Society for Technology and Teacher Education. Washington, D.C. April 1994.
- Hunter, Beverly. "Learning and Teaching on the Internet: Contributing to Educational Reform", chapter to appear in *Public Access to the Internet*, Keller, James (ed.), John F. Kennedy School of Government, Harvard University (in preparation).
- Huntley, Martin. *The global classroom: the Internet as a K-12 resource*. IEEE Social Implications of Technology Meeting, MIT, Cambridge, MA, April 12, 1993.
- Huntley, Martin. *Networking: What are the questions?* MassCUE Retreat for K-12 technology coordinators, Sandwich, MA, May 13-14, 1993.
- Huntley, Martin. *The benefits of the Internet in K-12 education*, K-12 Apple Update Seminar, Boston, June 23, 1993.
- Huntley, Martin. *Networking in K-12*, MassCUE conference, Worcester, MA, October 23, 1993.
- Huntley, Martin. *Connecting Schools to the Internet: New Tools for Learning Science*, MECC Conference on Educational Technology, Minneapolis, November 22, 1993.

- Huntley, Martin. *Internet from the Desktop: National School Network Testbed*, RIEMA/NEEMA Conference, Newport, RI, March 4, 1994.
- Huntley, Martin. *Report on the National School Network Testbed*, New England Conference on Technology and Education, MIT, Cambridge, MA, March 12, 1994.
- Huntley, Martin. *Real Internet Connections for Schools*, N.H. Society for Technology in Education Annual Telecommunications Conference, Concord, NH, March 18, 1994.
- Huntley, Martin. *Real Internet Connections for Schools*, Catching the Internet Wave, a Cisco Systems/Online Bookstore/NEARnet conference for school superintendents and administrators, Cambridge, MA, April 7, 1994.
- Huntley, Martin, Lowd, Beth, & Avots, Juliette. *Hands-on the Internet* (3 hour workshop), New Hampshire School Administrators' Association Technology Conference, Merrimack Education Center, Chelmsford, MA, November 30, 1993.
- NCC-TET The National Information Infrastructure: Requirements For Education and Training: An Agenda for Action. National Coordinating Committee on Technology in Education and Training. Washington, DC, March 1994.
- Newman, Denis. "School Networks: Delivery or Access", *Communications of the ACM* 36, 5 (May 1993), pp. 49-51.
- Newman, Denis. *Getting the NII to School: A Roadmap to Universal Participation*, a position paper of the National School Network Testbed, Bolt, Beranek and Newman Inc., Cambridge, MA, December, 1993.
- Newman, D. (1994) Costs and Benefits of Internet-from-the-Desktop: Observations from the National School Network Testbed. Paper presented in a symposium on *Issues in Computer Networking in K-12 Schools: A Progress Report of Four NSF Testbeds*, B. Hunter, chair, at the annual meetings of the American Educational Research Association, April 7, 1994, New Orleans.
- Newman, Denis, Bernstein, Susan, & Reese, Paul. *Local Infrastructures for School Networking: Current Models and Prospects* BBN Report No. 7726, 1992.
- Newman, Denis, Huntley, Martin, Barowy, William, & Bernstein, Susan. *The Copernicus School Network: Bringing Real Internet Connections to Schools*, International Conference on Technology in Education (ICTE), MIT, Cambridge, MA, March 21, 1993.
- Newman, Denis & Reese, Paul. *Making REAL Internet connections: Experiences from the National School Network Testbed*. Presentation at NECC, Orlando, Florida, June 28, 1993.
- Newman, Denis, Reese, Paul, Rhodes, Lew, & Huntley, Martin. *Bringing Real Internet Connections to Schools: Report on the National School Network Testbed*. Highlight Panel at Tel•Ed '93 Conference, Dallas, Texas, Nov. 11, 1993.
- Newman, Denis, Reese, Paul, & Huggins, A. (in press). "The Ralph Bunche Computer Mini-School: A Design for individual and community work", chapter to appear in Hawkins & Collins (eds) *Design experiments: Restructuring through technology*. Cambridge: Cambridge University Press, in preparation.
- NTIA (1993). *The National Information Infrastructure: Agenda for Action*. Washington: Dept. of Commerce, NTIA.
- Office of Educational Research and Improvement, (OERI ,1993). *Using Technology to Support Education Reform*. Washington, DC.

- Pea, R. (1994) The CoVIS Collaboratory: High School Science Learning Supported by a Broadband Educational Network with Scientific Visualization. Paper presented in a symposium on *Issues in Computer Networking in K-12 Schools: A Progress Report of Four NSF Testbeds*, B. Hunter, chair, at the annual meetings of the American Educational Research Association, April 7, 1994, New Orleans.
- Schofield, J. (1994) Common Knowledge: Pittsburgh--Implementing Network Connectivity in the Pittsburgh Public Schools. Paper presented in a symposium on *Issues in Computer Networking in K-12 Schools: A Progress Report of Four NSF Testbeds*, B. Hunter, chair, at the annual meetings of the American Educational Research Association, April 7, 1994, New Orleans.
- Stuve, M, Toth, E., Levin, J., & Newman, D. (1994) Evolution and preliminary results from two distributed communities of explorers. Paper presented in a symposium on *Organizing for Large-scale Electronic Network-Mediated Problem Solving* M. Waugh, chair, at the annual meetings of the American Educational Research Association, April 7, 1994, New Orleans.
- West, P. (March 2,1994) The Last Mile. Education Week. Washington: Editorial Projects in Education.

## SECTION I

### SPECIAL INFORMATION AND SUPPLEMENTARY DOCUMENTATION

“Documentation of collaborative arrangements of significance to the proposal through letters of commitment” (Grant Proposal Guide NSF 94-2, January, 1994, p. 10)

#### State Education Agencies

California  
Texas

#### Multi-school, cross-district

Lakes Region Network Consortium  
Lincoln Labs/Minuteman Voc Tech/Acton-Boxborough  
OCM Boccs

#### School districts

Bellevue Public Schools, Washington  
Champlain Valley Union High School  
Glenview School District, IL  
Guilford County, Greensboro, NC  
Mendocino Unified School District  
Poudre School District R-1  
Poway Unified School District, Poway, CA  
San Diego City Schools  
Sweetwater County, WY (SweetNet)  
Tempe School District No. 3  
Urbana District #116  
York Harbor, Maine

#### Individual schools

Gould Academy, Maine  
Graham and Parks School, Cambridge, MA  
Illinois Mathematics and Science Academy  
Ralph Bunche School, NY  
Rocky Mountain High School  
Wilson High School - Portland, OR

#### Communities networking

Lexington, MA - Lexington Information Network  
San Diego State University  
Sharing Place/Community Building at Talmar Wood

#### Colleges partnering with schools

Allegheny/Schools Partnership  
Arizona State University  
Cornell University (Interactive Multimedia Group)  
Council of Independent Colleges  
Northwestern University - CoVis  
Stevens Institute of Technology, Hoboken, NJ  
(CIESE)  
TeacherNet (California State at Long Beach)  
UCSD Teacher Education Program  
University of Illinois College of Education  
Vanderbilt University  
Washington State University, Vancouver

#### Research/support organizations with schools

AASA  
AskERIC  
Center for Children and Technology - EDC  
Co-NECT Schools  
Coalition of Essential Schools  
Community of Explorers  
Consortium on School Networking (CoSN)  
Corporation for Educational Technology  
Council of Chief State School Officers  
Earthwatch  
Eisenhower National Clearing House  
Fifth Dimension (UCSD)  
Geometry Forum, Swarthmore College  
Global SchoolNet Foundation  
Institute for Learning Technologies - Columbia  
Institute for Research on Learning - DesignNet  
Institute for Research on Learning - MMAP  
MCET (Mass. Corp. for Ed. Telecommunications)  
MUSE  
National Center for Research in Voc. Ed. (NCRVE)  
National Coalition of Girls' Schools  
New American Schools Dev. Corp. (NASDC)  
Northwest Regional Educational Laboratory

#### Science centers/museums with schools

Arnold Arboretum  
Exploratorium  
Science Learning Network (Franklin Institute et al)

#### Private companies with schools

Chancery Software  
Digital Equipment Corporation  
Open Systems Technology - Washington, DC  
Pacific Bell  
Scholastic