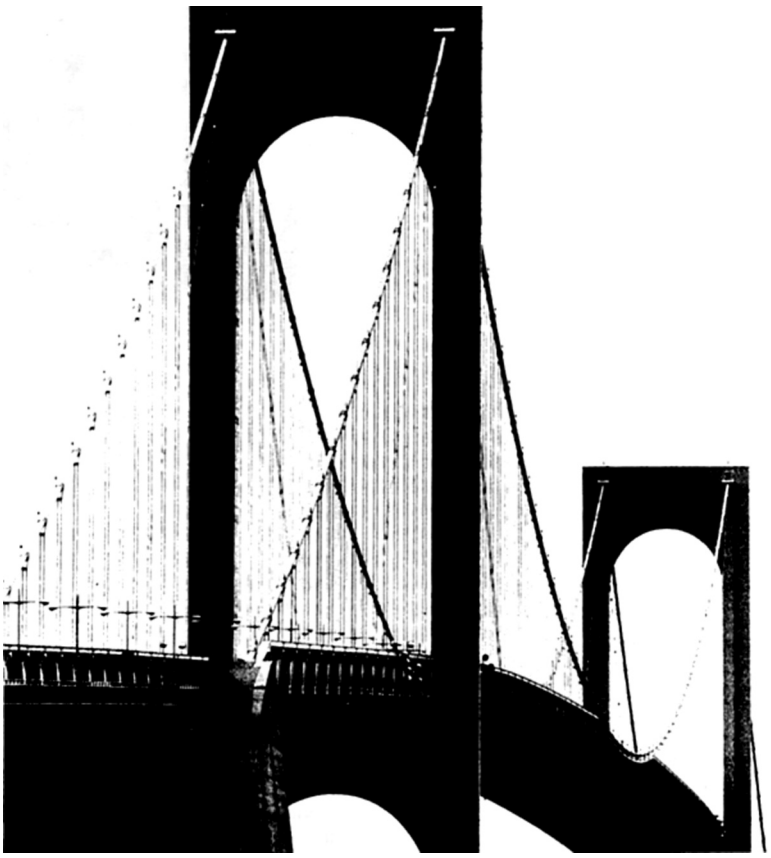

Making Connections

Building Penn's electronic future

Information Systems and Computing
University of Pennsylvania

1995 update
to
August 1994 long-range direction statement

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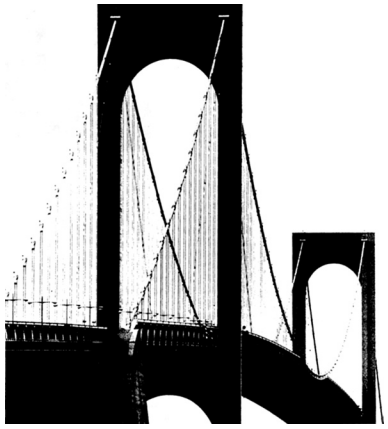

Abstract

This statement of direction moves Penn toward a future in which the University is greater than the sum of its parts. It is about making connections—connections to each other, connections to information, and connections among systems. It places Information Systems and Computing's vision of information technology serving people in the context of key trends in the field. It focuses on seven strategies:

1. Leveraged support
2. Academic computing initiatives
3. Ubiquitous networking
4. Business systems that work together
5. Corporate data accessible to decision makers
6. Architecture and standards
7. Cost savings

This document outlines a direction that puts these strategies into action. An information technology "architecture" provides the technical foundation. The organizational foundation for pursuing these strategies is changing. Penn's new President, Provost, and Executive Vice President have asked ISC and its campus partners to review the way computing is organized, staffed, and funded. Penn's schools and central groups will craft a campus-wide approach that builds on both local and central strengths.

Acknowledgments

The planning team benefited from the insights of many groups and individuals. It acknowledges with thanks the work of campus-wide initiatives including Project Cornerstone, Penn's Network Architecture Task Force, Office Systems Working Group (E-Mail Task Force), Distributed Computing Task Force, ResNet Steering Committee, and Committee on Electronic Publishing and Interactive Technologies. The planning team appreciates the thoughtful counsel of advisory groups including the ISC Administration Committee, ISC Academic Committee, Data Policy Committee, Network Policy Committee, Academic Computing Services Task Force, and Small Schools Group.

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An Acrobat (PDF) version of this document is available on Penn's WorldWideWeb (*URL: www.upenn.edu/isc/connections.html*) along with a free copy of Acrobat Reader, which will allow you to view and print the document.

This updated statement of direction is part of Penn's five-year planning effort. Your comments are welcome. To make suggestions or get more information, contact Linda May, Director of Planning, Information Systems and Computing, at may@pobox.upenn.edu or 215/898-0005.

Introduction

Penn exists in a society fueled by information. It performs its mission of teaching and discovery in a world of microchips and global networks. In this same world it competes with its peers for talent and funding.

Change is constant and rapid in information technology. Even so, the next few years will be a period of particular opportunity for Penn. The convergence of the information, entertainment, and consumer electronics industries will change the face of computing. New technologies underlie approaches to teaching and learning that are interactive and participatory. Investigators now command powerful individual computing resources while research teams routinely form across discipline and distance. Penn's administration is poised for dramatic restructuring, the result of candid self-examination and tough analysis. The University's challenge is to provide technical support for its people as they make Penn a more exciting, more efficient place.

Over the years Penn has created a structure that encourages its member units to take initiative and exercise great financial autonomy. At the same time the University has distinguished itself for successful interdisciplinary ventures. As the pace of technological growth on campus quickens, the structure for technological cooperation must be strengthened if Penn is to continue to prosper.

Computing power has declined in cost faster than any technology in history. Yet because information tools are becoming so indispensable, Penn and its units are spending heavily on them. Technology itself is not the only cost. Of key importance are the cost of making systems work together, the human cost of learning to use tools that are always changing, and the demand caused by rising expectations. Without coordinated effort to avoid redundant and incompatible technologies, Penn cannot get the best value for its money.

The fiftieth anniversary of the creation at Penn of ENIAC, the world's first general purpose electronic digital computer, falls in this planning cycle. The Office of Information Systems and Computing will work with its University partners to realize the promise of computing, in the birthplace of computing, to sustain and advance Penn's people and purpose.

Part One: Vision

Vision

Only connect! That was the whole of her sermon. Only connect the prose and the passion, and both will be exalted….

—E.M. Forster, *Howard's End*

ISC envisions an interconnected future in which the whole University is greater than the sum of its parts. Information technology will become an increasingly important vehicle allowing those parts to work together. Sometimes prosaic in itself, it will provide a common medium that carries much of the intellectual passion of Penn's mission. Penn has often emphasized four themes to shape its future: cooperation across disciplines and schools, undergraduate opportunity, international links, and ties to the community. All of these themes are about making connections. Information technology will help Penn make that future a reality.

Connections to each other. Collaboration will increase across disciplines, between students and faculty, and among work groups as information technology levels the obstacles of geographic isolation and temporal delay. PennNet will connect us as members of a richer, more broadly populated worldwide Internet. Scholarly exchange, both formal and informal, in electronic form will be routine, while collaborative learning and individualized instruction will come into their own. Administrative transactions will become more convenient features of daily life. Active participation in the Penn community will be possible on campus, at home, or on the road.

The transparent medium. ISC has a vision of information tools so widely available, so much easier to use, and so compatible with each other that they seem to disappear. While this vision will not be completely achieved in five years, we and our University partners will take important steps toward it. The Library's enormous resources of knowledge and expertise will be expanded through new electronic links and made available wherever they are needed. Students will interact with research data once available only to specialists. They will explore subjects in the media best suited to the material and to their own learning styles, drawn from a palette of text, sound, video, and still pictures. Researchers in more fields will use visualization tools to find patterns, understand relationships, and work with ideas as metaphors or images. New business systems will be more accessible and responsive, following the example of the popular PARIS system for course registration by telephone. Meanwhile, it's not enough just to install computers and cables. ISC will work with Penn's schools and administrative centers to integrate information tools successfully into the working lives of those who use them, providing guidance and help in exploiting new technology.

Data and systems that work together. Today the facts of Penn's business life are isolated. Without the ability to connect them easily, the daily work of faculty, students, and staff is made harder, our sense of community is weakened, and our shared history is diminished. This will change. Administrative systems throughout the University will work together and share a common base of data. Penn's leaders will make decisions based on information from many sources. Deans, for example, will easily be able to find out how many students are enrolled in a school's courses as soon as they are registered, and how those numbers compare with previous years. Enhancing the number and quality of such connections will allow Penn to build on the strengths of its decentralized structure and minimize its drawbacks—leaving the University and its units strong, flexible, and competitive.

Technology trends

Rapidly changing technology provides new materials for building the information future. Informing ISC's long-range plan are key trends—with a four- to seven-year time frame—summarized here. ISC will continue to track these evolving trends and align its activities to the emerging possibilities, as it advances its vision of connection, access, and integration.

Ubiquitous networking. Advances in tele-communications will turn computing into an "anytime, anywhere" activity. The nation's backbone networks for research and education will operate at gigabit capacities, with the help of Federal commitments to upgrade existing networks and fund research aimed, for example, at better ways to transmit data such as CAT scans and engineering blueprints. Almost all office computers will be physically connected by very high-capacity local area networks. The cable and telephone industries are racing to connect America's homes to the emerging web. Wireless technologies allowing mobile access without a physical connection will mature at a slower pace, catching up toward the end of the planning horizon. Ubiquitous, high-capacity communications are essential to most of the trends reported here.

Mobile computing. Mobile computing is the other half of the "anytime, anywhere" equation. Notebook computers will become very powerful and very common. Untethered scholars and professionals will carry only what they must and assume the infrastructure will provide the rest—network connections, common software, storage, printers, etc. Business systems will increasingly collect data at the source, as pen, rudimentary speech, and scanner input technologies mature.

Merging of computing and communications. Computing and communications have for years been converging as voice, video, and data all become digital. Telephone, cable, and software companies are exploring major joint ventures, spurred by competition to create the off-ramps and secondary roads of the "national data superhighway" envisioned by the Clinton/Gore administration. While it's too soon to tell how the race to wire America will end, it's possible that we'll all be watching our telephones and answering our televisions by the end of the decade as the boundaries between phones, TVs, and computers begin to disintegrate. "Narrowcasting" hundreds of specialized channels, interactive television, video phone calls, and customized news services with "tell me more" capabilities are predicted.

Multimedia for the rest of us. Multimedia—the mixing of text, video, still images, and sound—will become central to personal computing. As authoring tools get simpler and libraries of audio/visual clips become available, multimedia will become something you can make yourself as a homework assignment or conference presentation. Practical addition of

full-motion video to the mix awaits expected advances in data compression and faster processors for personal computers. Images and sound will make up an increasing proportion of the global Internet's online resources. Today's World-Wide Web, with its hypertext-linked words and images, is an early model.

The new textbook. Traditional survey text-books, with their three- to four-year development cycle, are likely to be edged out of the marketplace by customized books published on demand, course packs assembled from a variety of sources, and multimedia disks like Perseus, a CD-ROM from Yale University Press that contains 25 volumes of Greek text, a Greek dictionary, and 6,000 photos and drawings of artifacts and archeological sites.

Interoperation, integration. The ability to mix and match hardware and software from a variety of vendors will substantially improve as vendors come to the conclusion that their markets will be constrained otherwise. Hardware at almost all levels will increasingly become a commodity, with fewer and fewer differences among vendors. As with televisions today, brand will come to matter less than features. Paired with advances in data management tools and networking, this "open systems" approach will make it easier to integrate bodies of data. Administrators will reap the benefits of a larger business picture. Research communities can also begin creating bodies of integrated data—tracking related studies and building multiple-study databases, for example.

"User-centric" computing. Each person will stand at the center of his or her own computing universe, thinking and working in familiar ways instead of having to adapt to the technology. This trend runs throughout the technologies described below.

Client/server model. The client/server approach to computing will mature and dominate, as open systems standards and the necessary base of development tools emerge. In this model, the computing workload is split between "client" software running on desktop computers and complementary "server" software on larger remote machines. The desktop computer, with its familiar user interface, becomes a window to a set of data and computing resources that appear unified but can in fact be located almost anywhere. The network ties it all together. This flexible, modular strategy also breathes new life into the possibility of integrating data and systems by building many smaller applications that can communicate and cooperate.

More power in the user's hands. A range of powerful computing options will be available to individuals. More sophisticated notebook computers will be the only machines many faculty, students, and staff will need. Much of the research traditionally done on mainframes is already moving rapidly to workstations with advanced multimedia and numerical capabilities. Specialized servers on the network will provide additional capabilities such as high performance computing, printing, file storage, and electronic mail.

A switch in metaphors. Today's graphical user interfaces employ the metaphor of manipulating objects on a desktop. The desktop metaphor is likely to be replaced by the "agent" metaphor as the strategy of delegation replaces the strategy of making it easier for people to do things themselves. Swamped by information, people will turn increasingly to interfaces that "know" enough about their habits and preferences to help locate and filter that information. Individually tailored filters, based on artificial intelligence techniques, will be able to comb the network, for example, inspecting and understanding information regardless of the form in which it is expressed, selecting what is relevant. The filters might be instructed to deliver a percentage of more general information to preserve the pleasure of "browsing the shelves."

Computer support for collaborative work. More software will be written for the way many people actually work—collaboratively and in groups. Editing, collaborative writing, group brainstorming, conferencing, and other activities will be supported by real-time, multimedia technologies. Tools that let groups view and amend the same multimedia workspace will be common. As advances in telecommunications make computing an "anytime, anywhere" activity, groups can likewise exist anytime, anywhere.

Behind the scenes. As computing becomes a user-centered, highly networked activity, servers working behind the scenes are critical—and it's not yet clear where advanced server technology is headed. One likely direction is large mainframes that harness thousands of small processors working in parallel on the same task, for enormous power in modular increments. Another approach sets clusters of workstations on the same task, using the network to move data and instructions around. As networking technology advances, the workstation clusters are likely to rival the performance of the massively parallel mainframes.

The potential is extraordinary. So too are the challenges—rebuilding, transition, integration, flexibility, standards, capacity, and reliability. And the technical concerns are less formidable than the organizational, cultural, and financial ones. The following sections outline how we intend to face these challenges.

Sources: Project Cornerstone, the Network Architecture Task Force, ISC's Information Technology Forecasting Forums, briefings by major hardware and software vendors, literature review.

Part Two: Getting There

Penn's changing structure for computing

Penn's new President, Provost, and Executive Vice President have asked Information Systems and Computing and its campus partners to rethink the way computing services across the University are organized, staffed, and funded. This comprehensive effort will build on both local and central strengths to construct a campus-wide approach. Responsive services and cost efficiencies are the goals of the project.

Computing is decentralized. Computing at Penn is exceptionally decentralized, the result of responsibility-center budgeting and other practices that reflect Penn's culture. There is no "computer center" at Penn. Rather there is a wide range of computing services and facilities, all connected by PennNet. Most computing dedicated to instruction and research is administered by the schools. Some schools have diversified computing organizations that provide services ranging from desktop support and technology integration to educational technology, information systems, and institutional research. Other schools have only a few staff members that provide computing support.

Decentralization has both benefits and costs for Penn. It fosters creativity and places decision making close to those most directly affected. Decentralization can lead, however, to duplication of effort, inequalities among the schools, and islands of isolated data, technology, and expertise.

ISC's current role at Penn. The vision of the Office of Information Systems and Computing is one of technology serving people as they advance Penn's mission. Achieving that vision involves the efforts of many, both on and off campus. ISC acts to connect and integrate those efforts.

> *Mission.* The Office of Information Systems and Computing works to ensure the effective use of information technology to help Penn faculty, students, and staff achieve excellence.

Information Systems and Computing provides technology leadership for administrative computing, active brokering and advocacy for academic computing, and critical infrastructure and services in both areas. Unique among Penn's divisions, The Vice Provost for Information Systems and Computing reports to both the Provost and Executive Vice President.

Infrastructure—ISC provides PennNet, the campus network. It manages administrative data as a University asset and implements and operates many of the business systems that use this data.

Services—ISC supplements the computing support services offered by Penn's schools. It provides core services that cross organizations, require integration, or offer economies of scale. It offers services for local support providers. It negotiates contract arrangements to locate staff in school or administrative offices.

Direction and standards—With the Penn community, ISC sets technology direction and develops standards that foster communication, interoperation, and cost savings. ISC tracks emerging technology and helps coordinate pilot efforts across the University.

Coordination and brokering—ISC serves as broker, advocate, promoter, and partner. It brings together people with common interests and coordinates initiatives that cross organizational

boundaries. ISC provides forums for negotiating administrative data issues that require consensus.

Current ISC organization. Eight units currently make up ISC:

- Academic Computing Services—Information technology in the academic community
- Computing Resource Center—Computing support
- Communications Group—Documentation, news, promoting easier-to-use systems and services
- Data Administration—Data policies, standards, models
- Data Communications and Computing Services—PennNet and network services
- ISC First Call—Consolidated help desk
- Technology Learning Services—Computing skills training and learning resources
- University Management Information Services—Administrative computing systems, facilities management

Seven strategies

ISC's efforts will focus on seven strategies.

Leveraged support. Penn has witnessed dramatic growth in the use of information technology. Penn faculty, students, and staff are demanding support—from the mundane to the complex—and there's not enough support to go around. The University's comprehensive review of its computing support structure will be guided by the principle that Penn should expend effort where leverage is greatest. This means not only financial leverage, but leverage of skills and expertise: improving quality by placing tasks where they can be most effectively performed. Results of this review for ISC might include providing more services for local support providers, negotiating more contract arrangements to locate staff on-site in schools and administrative offices, and turning to outside contractors where they offer unique services or gains in efficiency. New systems and services will be designed to require less support in the first place.

Academic computing. In recent years computing has become ubiquitous on campus, outgrowing traditional distinctions among instructional, research, and more general uses. ISC's long-standing coordinating role in support of academic computing is also evolving. As part of Penn's comprehensive review of computing services, ISC and the schools will work together to create a campus structure that meets the needs of faculty and students. As that structure evolves, ISC will focus on two major trends—the shift from mainframes to networked workstations in research computing and the emergence of interactive multimedia and electronic publishing in education. ISC will increase its long-standing efforts to promote resource sharing, provide referrals, sponsor interest groups, and serve in other ways as broker and catalyst. We will expand our programs to negotiate discounts and site licenses for hardware and software used in instruction and research. We will continue to work with vendors to identify funding opportunities for Penn researchers and faculty.

Ubiquitous network. Many at Penn depend on PennNet to accomplish their daily work. To support the next generation of Library and business systems and to provide "anytime, anywhere" access to the expanding range of online resources at Penn and beyond, PennNet and its services will have to be upgraded, and in some areas completely redesigned.

The capacity and reliability of the campus backbone, its connection to the Internet, and support for remote access are the thrusts of the campus-wide Network Architecture Task Force. ISC is already wiring the residence halls (ResNet), upgrading Penn's Internet bandwidth (from 1.5 to 4 megabits per second), enhancing building links (from 1 to 10 Mbps), and deploying electronics to monitor network performance.

Network services are being improved as more powerful and easy-to-use software becomes available—most of which requires high-speed Ethernet connections and fairly advanced desktop computers. Task forces on electronic mail, distributed computing, local area networking, and campus-wide information systems (currently, PennInfo, Gopher, and World-Wide Web) are engaged with ISC in defining Penn's future in these areas.

Business systems that work together. A new generation of business systems that work together and share data will be put in place, beginning with the general ledger, purchasing, payables, and budget planning components of a new financial system. Penn's approach, known as "Project Cornerstone," involves streamlining—or "re-engineering"—business practices before acquiring the technology to support them. Rethinking Penn's business practices offers huge opportunities to do things better and more economically. Technology is one tool, among others, to make those changes possible.

The new Cornerstone systems will follow a "client/server" approach, taking advantage of the power and graphical user interfaces of today's personal computers. The Cornerstone systems will divide the computing workload between "client" software on desktop computers and "server" software on larger remote machines. The network will tie it all together. The new systems will share a common base of data and employ, for flexibility and ease of use, a relational database management system from Oracle Corporation. Local business systems using the same RDBMS will also be able to share Penn's corporate data. Sharing data across systems is a substantial economy. Shared data is likewise crucial to the continued viability of Penn's decentralized management structure. When each unit draws on a common data vocabulary, flexibility and innovation can flourish without conflicting with the interests of the University as a whole.

Management information. A "data warehouse," or query database, will make Penn's corporate data available to decision makers. The warehouse will pool data from existing and new business systems, make it consistent, and aggregate it in various ways. Programming skills will not be required to use the warehouse; desktop tools will support query, analysis, and reporting. A widely available online encyclopedia will contain data definitions, data models, and other "data about data." A vital component of Project Cornerstone, the warehouse will help bridge Penn's management information gap while the new Cornerstone systems are acquired over time.

Architecture and standards. Setting hardware and software standards is a strategy that strengthens the other strategies by fostering interoperation and cost savings. With the Penn community, ISC develops standards and undertakes the advocacy and education that are essential for standards to work in Penn's decentralized environment. Desktop hardware standards have particularly far-reaching implications for Penn. ISC recently issued "freshness dated" configuration standards for Macintosh and Windows computers, with ISC support guaranteed for four years from the date of publication.

ISC's approach is to embed standards in a framework—or "architecture"—for using information technology. With such a framework, Penn can break the cycle of choosing technology piecemeal to solve the problem of the moment. ("Direction 2000: information technology architecture," later in Part Two, contains details on networking, desktop capabilities, collaborative computing, scholarly information, and administrative systems.)

Cost savings. The strategies outlined here seek to hold down costs at the same time they improve services. Running throughout are the themes of economies of scale, standards, leverage, and support for streamlined business practices. The next section describes ISC's approach in more detail.

Controlling costs

ISC's clients are asking for quality, efficiency, and more control over their allocated costs. They want to pay directly where possible for services that are not infrastructure, with more choice about what they buy and when. At the same time, Penn is poised for a major review of the organization, staffing, and funding of computing services campus-wide. Specific targets and goals in the following areas will emerge from that restructuring effort:

Clear roles and responsibilities. Rationalize "who does what" from a University perspective, shifting some activities from central computing to schools and vice versa. Reduce gaps and overlaps, for more effective services campus-wide.

New funding models. Explore new funding models. ISC expects much of its funding to shift from an allocated-cost basis to a fee-for-service basis. This approach places the burden of cost-effective delivery squarely on ISC and the burden of informed choice on the end-user department. Both must come to agreement on the standards that guide these decisions. At the same time, a carefully defined set of core services will be funded by allocated costs in order to provide infrastructure and to seed strategic projects.

Campus efficiencies. Seek campus efficiencies through economies of scale, improved coordination, and other approaches.

Phase out services. Phase out services that are no longer cost-effective or whose value to Penn is declining; an example is the current move from asynchronous network connections to faster ethernet connections. Establish transition strategies and sufficient lead time for clients.

In addition, ISC will continue to pursue internal improvements and the University will continue to invest to lower costs in the long run:

Local efficiencies. Seek efficiencies in ISC operations and services. For example, ISC will eliminate redundancies, re-engineer processes, and find less expensive ways of doing things.

Apply strategic investments. Reduce long-term costs through strategic University investments. The University may choose to apply resources to infrastructure, new administrative systems, or emerging technology that lowers costs in the long run.

Direction 2000: information technology architecture

Three themes converge to shape an information technology direction for Penn. The first is a vision of an interconnected University greater than the sum of its parts. Next is the technology forecast explored in Part One.

The third theme is the strategy of creating a framework, or "architecture," for using information technology to meet Penn's academic and administrative needs. Some institutions focus on remaining nimble, assuming that technology changes too fast for them to plan ahead. Penn, on the other hand, has embraced an architectural strategy that allows its various units to move forward without fragmenting the whole. Such a strategy will help Penn upgrade its information technology infrastructure in rational steps rather than precipitous overhauls.

This section presents an information technology architecture for Penn in the year 2000. "Direction 2000" is grounded in Penn's principles for using information technology (listed in the Appendix). The architecture is informed by campus-wide initiatives on networking, administrative systems, Library services, office automation, and electronic publishing, among others. These projects and task forces will further define the architecture and the strategies for implementing it.

Architectural elements. Direction 2000 addresses five aspects of information technology, illustrated in the chart below. It places each person at Penn at the center of his or her own computing universe, interacting with systems and other resources from the familiar perspective of a richly featured personal computer. Penn's business systems, as well as its Library and other academic systems, will increasingly make use of "client/server" computing. Penn will deploy a more extensive, more reliable, higher-capacity network.

In the client/server approach, "client" software runs on desktop computers and complementary "server" software on larger remote machines. The desktop computer becomes a window to a set of data and computing resources that appear unified but are in fact distributed across campus and beyond. The network ties them together.

As the chart shows, Direction 2000 will be achieved over time. Some components are in place; others are in the planning stage. And some will evolve with Penn's needs and the opportunities of the marketplace.

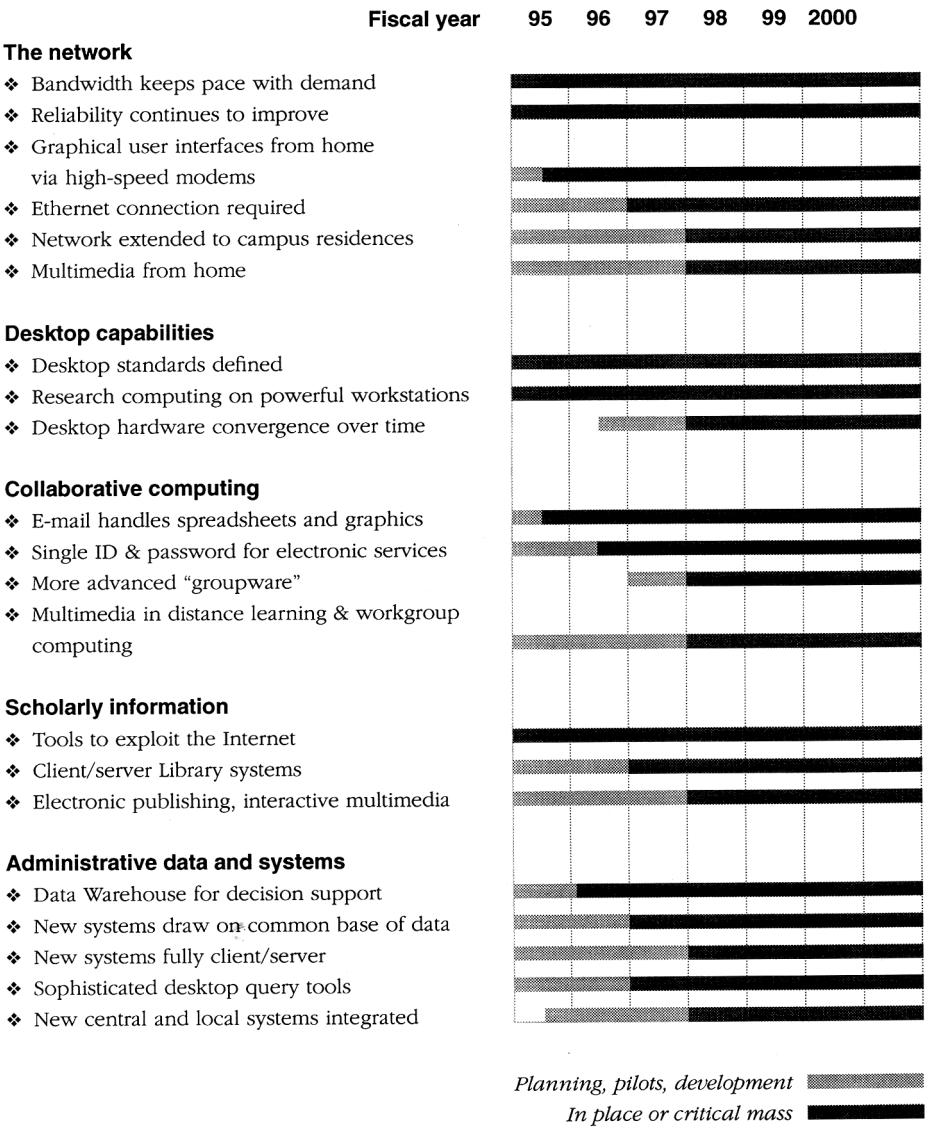
The network. As data and computing resources become more distributed, the network becomes more important. TCP/IP or its successor will continue to be Penn's primary enterprise-wide network protocol. This assures Penn's links to the scholarly community of the Internet and provides a solid foundation for client/server computing. AppleTalk and Novell IPX protocols will be transported to support workgroup activities, with a likely shift to TCP/IP as vendors move from proprietary protocols to the sturdier independent standard. Network capacity will stay ahead of demand. In the near term, all links between campus buildings and the PennNet backbone have been upgraded to carry at least 10 megabits/second and all networked workstations will have 10 megabit/second Ethernet connections. Higher speed networking (100 or more megabits/second) will be extended over time as the use of multimedia in instruction, research, and business applications grows. Penn will likewise expand the capacity of its links to the Internet as demand requires. Network reliability will be strengthened as monitoring systems are implemented and redundancy is increased.

PennNet (along with cable TV and new phone services) will be extended to all on-campus student residences. As remote access technology improves, networking from home and on the road will become more like networking at the office, with graphical user interfaces and multimedia capabilities. Penn is exploring strategies to extend connections capable of sustaining graphical user interfaces and multimedia network traffic to faculty, staff, and student residences in the three-state area. Penn is weighing the options of high-speed analog modems, ISDN digital telephony, cable TV, and services purchased from commercial Internet access providers.

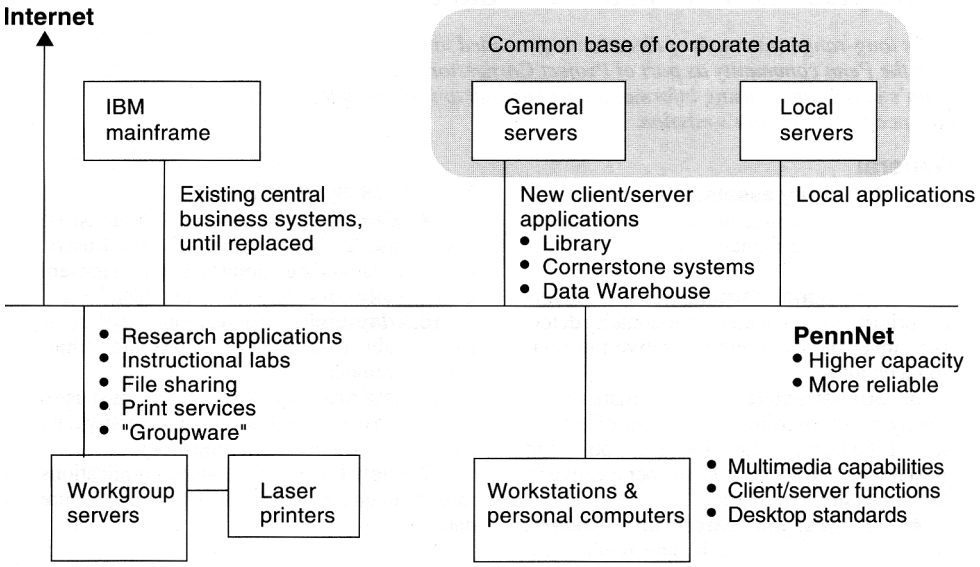
Desktop capabilities. With the University community, ISC sets desktop computing standards to help Penn hold training and support costs in check and to foster communication and interoperation. In the near term, computers running the Macintosh operating system and computers running MS-Windows will be ISC-supported general-purpose standards at Penn. ISC recently issued "freshness dated" configuration standards for both types of machines, with support guaranteed for four years from the date of publication. (Specifics can be found on Penn's World-Wide Web.) ISC will review desktop standards each

Direction 2000 Forecast

In the fast-moving world of information technology, it's difficult to predict timelines. The estimates in this chart will be reviewed each year in light of Penn's needs and priorities and industry trends.



Direction 2000—
an information technology architecture for Penn



year in light of University needs and industry changes. As new standards are issued, they too will specify "freshness dates."

Computing-intensive research will continue to move from mainframes and mid-range computers to a mixed environment of networked UNIX workstations. Faculty will choose systems that best meet their research and teaching needs, with networking standards to allow easy interconnection. Specialized servers on the network will provide additional capabilities such as high performance computing and file storage.

Desktop hardware platforms will converge over time, as the next generation of personal computers matures. The new computers will offer several software "personalities," or user interfaces within a single piece of hardware. To the user, the machines will feel like Macintosh, Windows, or UNIX computers and will continue to run software developed for those machines. The familiar user interfaces will make the more powerful computers as easy to use as current ones. As new object-oriented operating systems mature, the opportunity may arise for Penn to employ a universal operating system as well as universal desktop hardware—further containing support costs and improving compatibility.

The new machines, based on reduced instruction set computing (RISC) or other advanced designs, will offer dramatic speed and capability. Many faculty will find the machines well suited to their research, while the most computing-intensive work will continue to be done on specialized systems. Penn's new client/server applications will shift more and more functions to the desktop. Multimedia will become a significant aspect of personal productivity software, electronic mail, and business and academic systems. Innovative support strategies will provide the security people need to explore and exploit the capabilities of the new technology.

Collaborative computing. Scholarly collaboration, workgroup interaction, and distance learning will increasingly depend on computers and the network. Electronic mail that can exchange spreadsheets, formatted documents, and graphics will be in wide use at Penn within the year. Penn is exploring the feasibility of an institutional file system to give people access to their files from any networked computer—at home, on the road, or down the hall—and let them share files with others. With convenience come issues of security and privacy. Security is a major thrust of the newly formed Distributed Computing Task Force, as are infrastructure services to help Penn manage more cost-effectively the thousands of workstations connected to PennNet. For example, as campus-wide authentication is put in place, each person will need only one Penn identification number and password for electronic services.

More advanced "groupware" will increasingly employ multimedia technologies that make working together at a distance more like working together face-to-face. Penn's network, its desktop hardware standards, and its classrooms and meeting rooms are developing to meet the demands of such activities—from joint authoring of articles and joint drawing of engineering designs to seminars in which participants see and hear each other across continents.

Scholarly information. The Library's emphasis on electronic information will increase. It will make available a growing number of online academic resources including catalogs, indexes, abstracts, full-text documents, and images. Networked client/server applications are a key to the Library's goal of making academic information resources available whenever and wherever Penn scholars need them, while controlling the costs of delivery.

Penn's choice of network protocols makes it an integral part of the Internet. This world-wide collection of networks is experiencing explosive growth—in users and sources of information—literally by the day. Penn will continue to emphasize tools that help scholars identify, screen, and make effective use of the valuable resources in this crowded arena. Early examples of such tools are Gopher, Netscape, and World-Wide Web.

The economics of specialized markets are pushing publishers toward electronic distribution of academic information. Electronic journals are already common in some fields and textbooks printed on demand are no longer rare. Penn will participate fully in the development of this new publishing model. New publishing technology brings opportunities for creation as well as distribution of scholarly material. The ability to incorporate images and comparative examples and to link networked sources allows authors to communicate in novel and effective ways. With desktop hardware standards and a network that keep pace with the demands of multimedia, Penn will encourage the exploration of such new media as "diskbooks" and "netbooks."

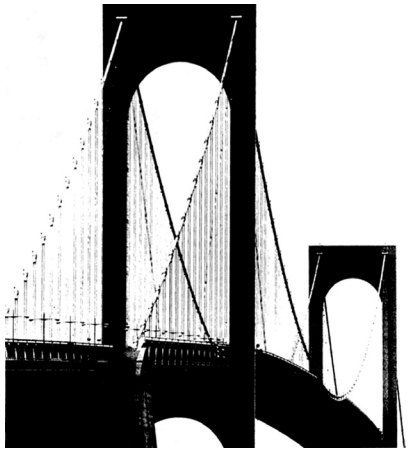
Administrative information and systems. With Project Cornerstone, Penn enters a new era of administrative computing. Over the next five to ten years, Penn's disparate business systems will be replaced by integrated, client/server applications and a "data warehouse" for management information. The new Cornerstone systems will take advantage of the productive power of graphical user interfaces and other features of desktop computers. For flexibility, they will employ a relational database management system (RDBMS).

The Cornerstone components will share data and work together:

- The first new systems—General Ledger, Purchasing, and Payables—have been acquired from Oracle Corporation, a major database and software vendor, and are expected to be in place in fiscal year 1996. A Budget Planning component is under discussion. These central systems will share a common base of data.
- A data warehouse, or query database, will make Penn's corporate data directly available to decision makers. The warehouse will contain selected data from existing and new systems—filtered, made consistent, and aggregated. Student and course data are in place, with sponsored project data to be added soon.
- A widely available data encyclopedia will contain data definitions, data models, and other "data about data."
- Local systems, housed on departmental servers, will be able to use central data and systems as needed.

Several technologies will help unify the whole. The first is Penn's network. The second is a common relational database management system. Penn has selected Oracle's RDBMS, which will underlie the central systems and Data Warehouse, and will be available to developers of local systems. The third is a common set of development tools. Builders of central systems will use the tools, which will also be available to local developers. The fourth is a common set of data query tools.

The new Cornerstone systems will be acquired over time, as the business practices they support are streamlined, or "re-engineered." Existing mainframe systems will continue to run on the mainframe until they are replaced.



Appendix:
Principles for Administrative Data & Technology

ISC's long-range statement of direction is grounded in these principles. Developed with the Penn community as part of Project Cornerstone, the principles articulate Penn's beliefs about using information technology to serve people as they advance the University's mission.

General

1. University assets. Information technology infrastructure, business applications, and data must be managed as University assets.

2. Functional requirements. University priorities and business functionality determine investments in administrative information technology.

3. Cost-effectiveness. Informationtechnology must contribute to the cost-effectiveness of the business functions it supports and must be cost-effective from the perspective of the University as a whole.

4. Policies, standards, and models. Policies, standards, models, and methodologies—based on the principles outlined here—govern the acquisition and use of data and information technology. Regular update and communication are required.

5. Investment criteria. Investment decisions (even those not to take action) must be based on business needs, cost-effectiveness, and con-sistency with standards and models.

6. Training and support. Penn must put sufficient effort into ongoing support of its information technology assets. Skills and experiences from across the University must be leveraged and communication channels opened.

University data

7. Accuracy. University administrative data must be accurate and collected in a timely way.

8. Security and confidentiality. University administrative data must be safe from harm and, when confidential, accessible only to those with a "need to know."

9. Ease of access. University administrative data must be easy to access for all groups of authorized users regardless of their level of technical expertise.

10. Multiple uses. Penn must plan for multiple uses of University administrative data, including operations, management decision making, planning, and ad hoc reporting.

11. Purposeful collection. A given set of data should be collected once, from the source, and only if there is a business need for the data.

12. Common base of data. A common base of data must be created to facilitate sharing, control redundancy and satisfy retention requirements.

13. Documentation. Detailedinformation about University administrative data must be created, maintained and made available.

Business applications

14. Ease of use. Applications must be easy to use for both novice and expert users. Interfaces should be similar enough to present a reasonably consistent "look and feel."

15. Adaptability. Applications must be easily adaptable to changing business and technical requirements.

16. Data sharing. Applications must use a common base of well defined University data and reference a common repository.

17. Ensuring data quality. Applications must help ensure valid, consistent, and secure data.

Infrastructure

18. Common communications infrastructure. Academic functions and administrative systems must share common data, voice, and video communications infrastructures.

19. Connections within the University. The communications infrastructure must be standardized to allow reliable, easy interaction among individuals, work groups, departments, schools, and centers.

20. Connections outside the University. The communications infrastructure must comply with national and international standards that allow reliable, easy interaction with those communities.

21. Hardware and software choices. Administrative hardware and software will be limited to a bounded set of alternatives. This applies to desktop computing, application servers, communications components, application development tools and data management tools

22. Emerging technologies. Penn must devote appropriate, coordinated effort to evaluating and piloting emerging technologies.

Organization

23. Data stewards. Data stewards are responsible for ensuring the appropriate documentation, collection, storage, and use of the administrative data within their purview.

24. Process owners. Process owners are responsible for developing and maintaining the standards, structures, and business applications that ensure the quality and cost-effectiveness of specific business processes.

25. Information Systems and Computing (ISC). Information Systems and Computing provides leadership, infrastructure, standards, services, and coordination that permit Penn to take full advantage of its information technology assets.

26. Schools and administrative centers. Schools and administrative centers are responsible for creating data and using information technology to meet the objectives of their organizations.