Creating the Electronic Design Studio:

Development of a Heterogeneous Networked Environment at Harvard's Graduate School of Design

Topic B. The New Design Studio

The migration of design education to reliance on computer-based techniques requires new ways of thinking about environments which can effectively support a diverse set of activities. Both from a spatial standpoint and a computing resource standpoint, design studios must he inevitably reconfigured to support new tools and reflect new ways of communicating. At Harvard's GSD, a commitment to incorporating computer literacy as a fundamental component of design education enables us to confront these issues through the implementation of a heterogeneous network imbedded in an electronic design environment. This evolving prototype of a new design studio, its development and its potential, will be the subject of this paper.

A new style design environment is built upon an understanding of traditional techniques, and layered with an awareness of new tools and methods. Initially we borrow from existing metaphors which govern our interpretation of the way designers work. Next we seek to extend our thinking to include allied or related metaphors such as the library metaphor which informs collections of software and data, or the laboratory metaphor which informs workspace groupings, or the transportation metaphor which informs computer-based communications such as electronic mail or bulletin boards" or the utility services metaphor which informs the provision of network services and equipment.

Our evaluation of this environment is based on direct feedback from its users, both faculty and students, and on subjective observation of the qualitative changes in communication which occur between and among these groups and individuals. Ultimately, the network must be judged as a framework for learning and evaluation, and its success depends both on its ability to absorb our existing metaphors for the process of design, and to prefigure the emerging metaphors to be envisioned in the future.

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Changing Studio Environments

There are many physical environments which harbor the process of design. We are familiar with the open studio plans adopted by many architecture firms and schools. Designers sit at drafting tables, arranged in rows. Small tackboards may screen these individuals from one another and serve to minimize distractions, but the overall effect is one of openness, designed to encourage communication between members of an architectural team. In theory, issues can be explored and resolved more readily if barriers to communication are reduced. Small and large sub-groups can form and reconfigure quickly to address architectural issues, since designers are constantly in visual contact with one another, and with the project materials, drawings, source information, samples, and the like. (fig 1)

fig 1 : Communications and media options in a traditional studio environment.

Within the traditional design studio, there are spaces to support a variety of communications, from the solitary concentration of the individual to the dialogues and exchanges of small and large groups. An atmosphere of open access encourages free-flowing ideas. A richness of resources provides opportunities to analyze history and tradition, and to evolve and test design concepts. The changing nature of the design studio, as it responds to the intrusion of computer technology and ultimately reconfigures itself to support computer-based methodologies, will be the subject of this paper. The electronic design environment developed at Harvard's Graduate School of Design will be employed as an example of an evolving prototype : the design studio in transition.

The studio as a setting for design and teaching demonstrates many important features. Walter Gropius' design for the Bauhaus buildings at Dessau in 1926 embodied very specific ideas about a physical environment which would be conducive to design and design education. While endeavoring to distinguish different elements of a complex building program including the School of Design, the Dessau trade school, dwelling and studio accommodations for students, and associated public facilities and private residences, Gropius evolved a multi-winged compound whose linkages and bridges connecting distinct wings underscored the nature of interdisciplinary communication.

During the last decade there has been a significant increase in the adoption of computer-based curricula by design schools throughout the world. While the scale of change varies widely from basic computing availability to CAD studios and required programming courses, the fundamental shift in applying computers to the core of the design process has proceeded rapidly.

Harvard Graduate School of Design

At Harvard's Graduate School of Design, the Lab for Computer Graphics and Spatial Analysis accumulated a history of computer-based design research exceeding two decades. More recent efforts, however, are focused on transforming the studio environment which supports the school's instructional component. Offering nine professional and post-professional degree programs in Architecture, Landscape Architecture, and Urban Planning and Design, the GSD maintains a student body of approximately four hundred and seventy-five graduate level students, fifty full-time equivalent faculty members, and a number of visiting faculty. The majority of the GSD's faculty, students and staff are housed in a single building, Gund Hall, on Harvard University's campus in Cambridge, Massachusetts.

Among courses offered to design students are several with a significant computing component, in particular a course in "Fundamentals of Computer-Aided Design" which is required for all professional degree students in Architecture and Landscape Architecture. This course, aimed at students in the second year of their professional studies, is primarily supported by Apple Macintosh™ computers, and employs a broad range of applications from word processing to image processing to 2D CAD to animation. The second half of the course enables students to investigate design theory concepts through Pascal programming exercises. A number of optional courses are open to students who have completed the "Fundamentals of CAD" course, namely "Introduction to Modeling", "Advanced Geometric Modeling", "New Metaphors in Design Practice", "Geographic Information Systems", a "Computer-based Studio", and additional seminars and workshops on related and current topics such as "Image Processing" and "Rendering Algorithms and Techniques". (fig 2)

The Daedalus network philosophy

To support these diverse courses, and to enable students to apply computers in independent research and design projects, the GSD has developed an electronic design environment called the Daedalus network. Initially a name given to an aggregation of computer hardware and software applied in instruction, the Daedalus network is now a pervasive resource which reaches the majority of faculty, students and staff of the GSD, providing a wide and growing list of services and capabilities. From its inception, the Daedalus network was conceived to be heterogeneous, that is, to represent the products of many vendors and to illustrate different computing strategies. We elected to employ products which were widely available to industry, and where possible, to select tools which represented an awareness of ad hoc and emerging industry standards. In addition, redundant tool selections were often made to satisfy needs for specific capabilities. For example, we consciously opted for four modeling packages which ran on different types of workstations, to provide students with a wide exposure to competing methodologies. By observing the commonalities and differences between methodologies, students gain insight into concepts, rather than emphasize the particulars of syntax. This philosophy of flexible standardization and redundancy ultimately translated into a network design approach of loosely coupled modules, components capable of linking together to provide additional functionality.

Spatial and technical components

Let us describe the components of the Daedalus network first in spatial terms. As in many educational environments, available space for new initiatives is an extremely precious commodity. Studio space is highly valued, given the size of the student body and the need for individual work areas for drafting, sketching and model building. Nevertheless, it is critical that the electronic design studio be located in proximity to the traditional design studio in order to reduce distinctions between traditional and computer-based processes. In

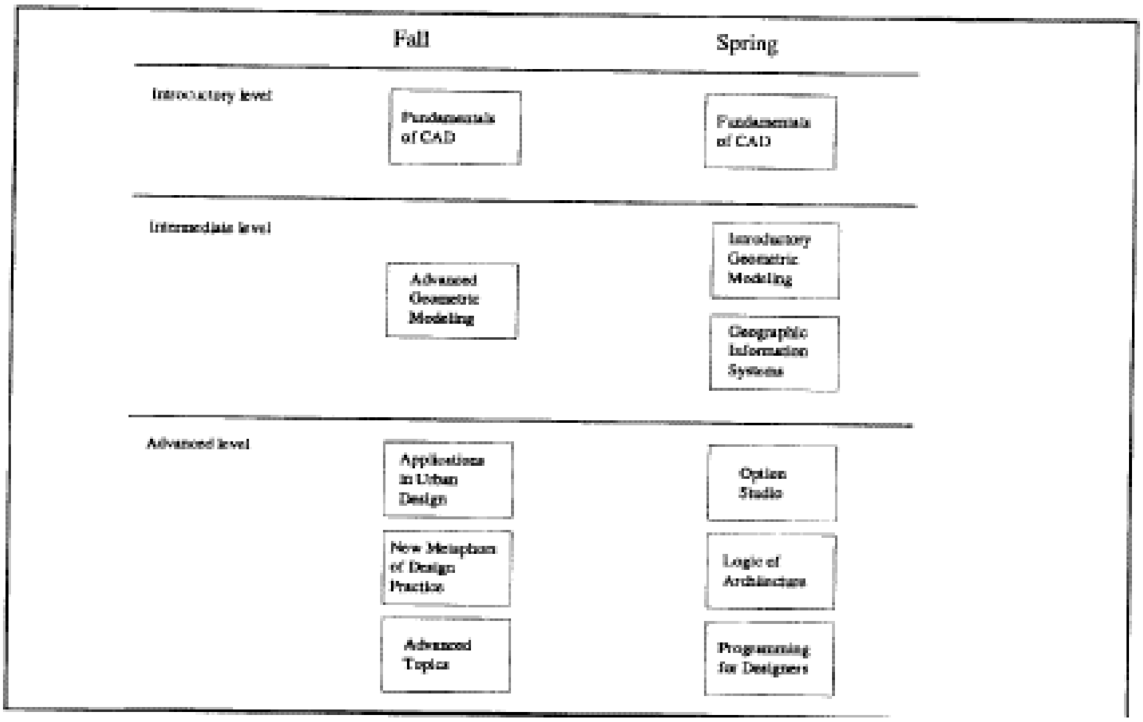

fig 2: Organization of computer-aided design offerings.

fact three such computer-based design areas, called "clusters", were introduced to two different floors of the Gund Hall open studio. (fig 4) Emphasizing economy and integration, standard drafting tables and chairs were outfitted with new computer systems by affixing personal computers and workstations with security devices. (fig 3) The computer clusters, while noticably different from the neighboring studio areas by virtue of their open and public nature, are occupied with the same enthusiasm that students evince for their private work areas. This differs markedly from the way other public areas are occupied, for example in the library, a more structured environment. While organized primarily for individual Computer use, clusters also support class groupings for training and demonstrations.

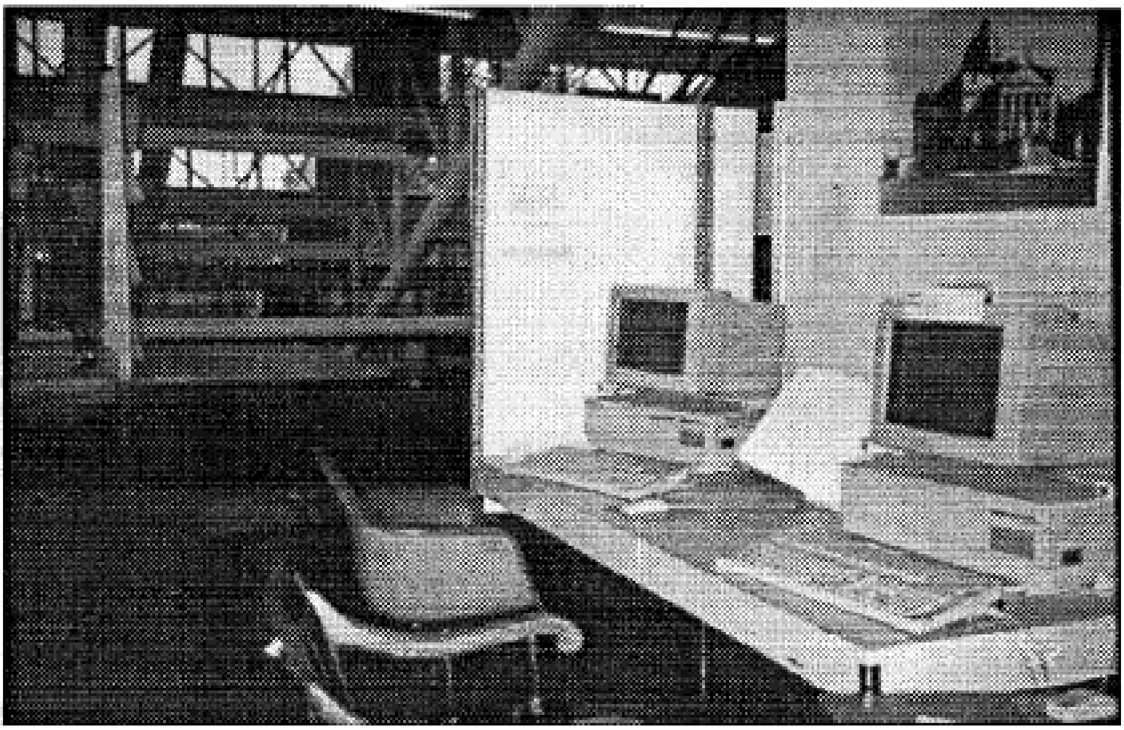

fig. 3 : Computer clusters are located in close proximity to traditional studio environments.

Each cluster is comprised of nine computers and a laser printer. Personal computers, workstations and laserprinters from Apple, IBM and compatible vendors, Sun, and Silicon Graphics are distributed throughout these three areas. In order to fit twenty-seven systems and three printers into these small studios, computers are arranged singly or in pairs atop drafting tables and standard height worktables. While the single computer per drafting table afforded a reasonable amount of space for working with a mouse, a tablet and a set of large drawings, smaller worktables with two systems were less roomy. This paired arrangement was suitable for smaller systems whose primary function was word processing or programming, not design applications where students worked from full size design drawings.

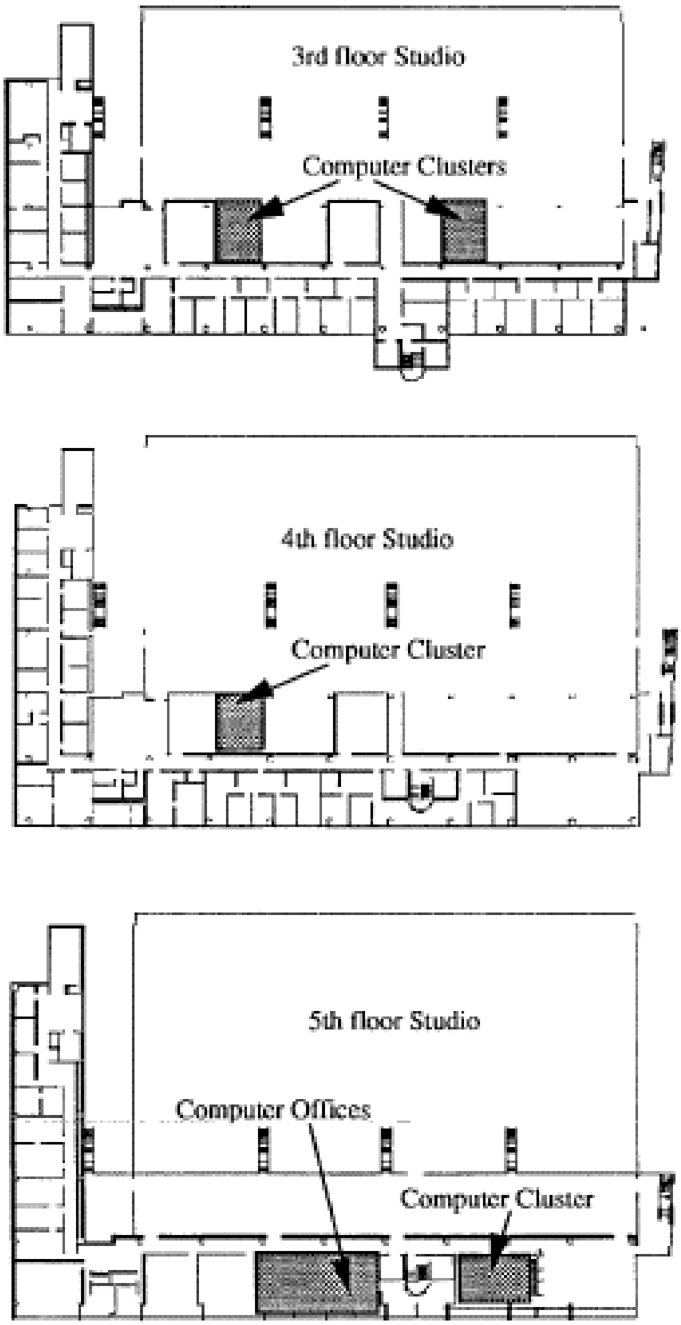

fig 4 : Graduate School of Design's computer clusters and staff offices

The grouping of equipment together into three small clusters, made necessary by space constraints in the studio, nevertheless afforded some important benefits. Networking is more efficient. High quality printing is located close at hand. One printer is shared between nine users, a reasonable and efficient ratio. More importantly, shared communications are often observed among the students who occupy each cluster. It is common for a user who has developed a computer difficulty to begin the problem-solving process by turning to his or her neighbors in the cluster. In this way a culture of interdependence and assistance develops around computer-based tasks. While opportunities exist for similar sharing around design tasks, the competitive and individual nature of the design process, compared to the quantitatively neutral atmosphere of computer-based tasks appears to smooth this process. (fig 5)

fig 5: Students employing studio-based workstations secured to drafting tables.

The major drawbacks of this approach result from ergonomic and physical differences between drafting or modeling-building activities and computer-based activities. The traditional studio is a flexible space which enables designers to work with a variety of media, paper, paint, cardboard, wood, perhaps even clay and plaster. These materials generate huge amounts of clutter and messiness, unfortunately quite unfriendly to computers sensitive to dust and temperature fluctuations. Great attention is paid to keeping computer clusters as clean as possible. Even so, systems, monitors and peripherals require frequent cleaning inside and out to remove accumulated dust. Lighting is a second issue, as the lighting provided for traditional design activities, a more generalized and even lighting based on fluorescent fixtures and daylighting, proves problematic for computer-based tasks. In order to eliminate glare and eye strain, many users prefer the removal of fluorescent fixtures in the computer clusters, and request task lighting at each workstation.

The requirements of specialized output and input peripherals make them unsuitable for location within studio clusters. A fourth cluster, located at a small distance from the main studio, provides a more controlled environment where printers, plotters, scanners, a digitizing tablet, a digital slide recorder, a milling machine and video interface / editing equipment are located. (fig 6) The computers necessary to drive this list of peripherals is quite diverse, representing each of our personal computer or workstation vendors. This cluster is well suited to applications training for small groups. Also, staff offices for computer support personnel are in close proximity to this fourth cluster, streamlining the provision of support to users.

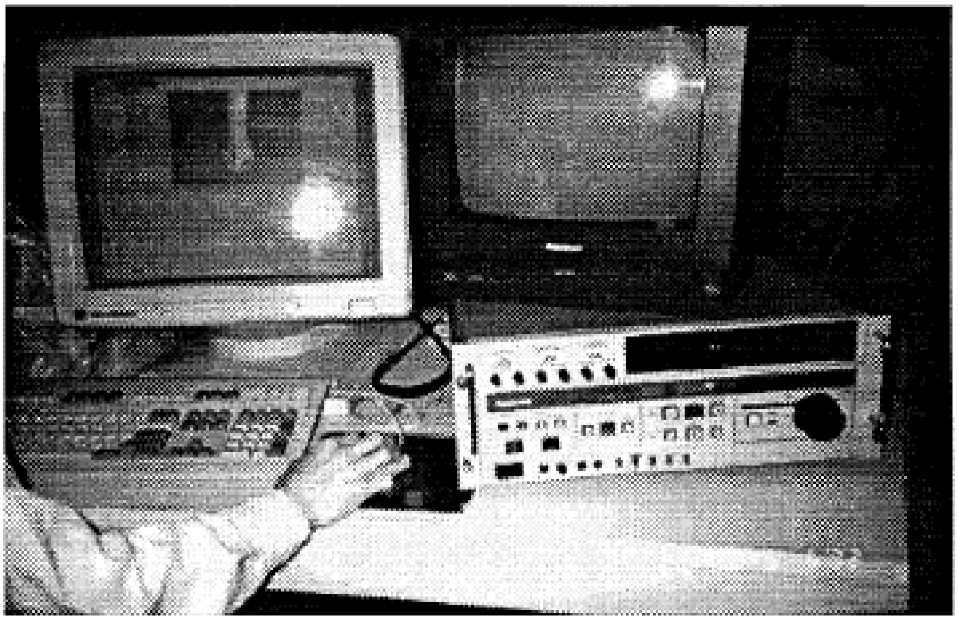

fig 6: Specialized equipment, such as this video animation system, is grouped in its own cluster.

The fifth major computer grouping consists of servers and computer resources staff workstations. The primary file server offers seven gigabytes of storage to network users. In addition, this server manages key aspects of the overall network. There are two mail servers on the network, personal computers whose sole function is to receive, store and forward electronic mail messages. Staff workstations include both personal computers and workstations, and are employed for a variety of functions including documentation, scheduling, communications, financed management, software development, and network and systems management. Computer equipment not included in one of these five clusters is distributed throughout faculty and staff offices and student work areas of the GSD. A majority of these systems are now connected to the Daedalus network, and the computer resources staff are responsible for supporting the entire user community of six hundred faculty, students and staff.

In fact, the most significant requirement for developing a thriving computer resource is a highly skilled and motivated technical staff. We are organized according to three specializations, user services, systems and applications, and networking. The user services team of two, with the assistance of a number of student employees, is responsible for providing first line support. This pair is heavily involved in equipment purchasing and installation, in coordinating user training, and in troubleshooting a universe of problems which users are likely to encounter. The two staff members who represent systems and applications provide programming expertise, administrative support to workstations and servers, and offer expertise in complex applications such as modeling, animation and video interface. The fifth staff member implements networking and communications products, connects individual users to the network, and supports a growing list of users and applications.

All computers and peripherals in each of the five clusters are connected to the network, which is based on the TCP/IP protocol. Through redundant network components, it is possible for users to connect using one of two methods, Localtalk or 10BaseT. Fiber cabling

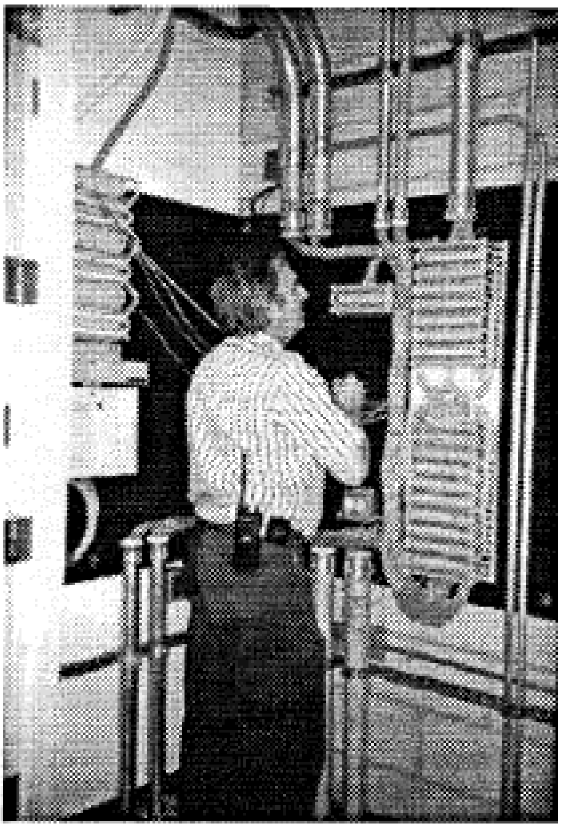

fig 7 : Network users are added incrementally in central networking closets.

is employed from floor to floor, and links our school to the fiber-based University network, Harvard's High Speed Data Network (HSDN). Twisted pair cables link each office and each studio drafting area with a central wiring closet on each floor. (fig 7) Within these closets users are patched, or connected, as needed. Depending on a particular user's request for a 10BaseT (ethernet) or Localtalk connection, one of two different cabling sequences is performed. A network gateway provides connectivity between 10BaseT and Localtalk users. There are approximately one hundred and fifty network nodes, including cluster machines, faculty, staff and privately-owned student computers. While some faculty and staff are yet to be added to the network, the largest potential for network growth lies in the sector of private student users who connect their own computers from their assigned drafting areas. (fig 8)

In many ways, the private student network represents, the most significant aspect of the network. In taking a firm stand against the uncontrolled growth in numbers of publically available GSD computer systems, we advocate growth in numbers of private students users.

fig 8 : Students have the option of attaching their own personal computers to the GSD network.

Thereby we hope to migrate beyond merely assuming computational skills on the part of our graduates, and progress toward a future where the computer will simply be one of many available tools which designers will employ with skill and judgement.

Network uses

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rum of applications. In the
arena of design exploration, the network supports a number of modeling packages including

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Autodesk's AutoCAD™, ComputerVision's CADDS4X™, IBM's Architecture and Engineering Series™, and Alias' Sonata™. For visualization of design models, rendering and animation software is also available, such as Alias Studio™, Wavefront Advanced Visualizer™, Autodesk's 3D Studio™, and Renderize™ from Visual Software. (figures 9, 10, 11, and 12) Manipulation of rendered or scanned bitmapped images is accomplished using Adobe Photoshop™, and Media Logic's Artisan™ software

Naturally the network provides tools which support efforts to achieve basic computer literacy, for example, word processing, spreadsheets, hyperlanguages, 2D CAD and desktop publishing, primarily on personal computers. A growing and fundamental area of interest is communications software which links faculty, student and staff members for internal and external exchange. Access to the network's centralized file server enables storage for course materials and assignments, special research projects, and widely-requested data collections. A current project in applying the network to develop broad access to visual collections win provide personal computer access to a database of eight hundred slides from the GSD Loeb Library. On-line access to visual resources will substantially increase our reliance on digital images as a primary medium of exchange and communication. As such investigations increase the level of interest and understanding in network-supported visual communica-

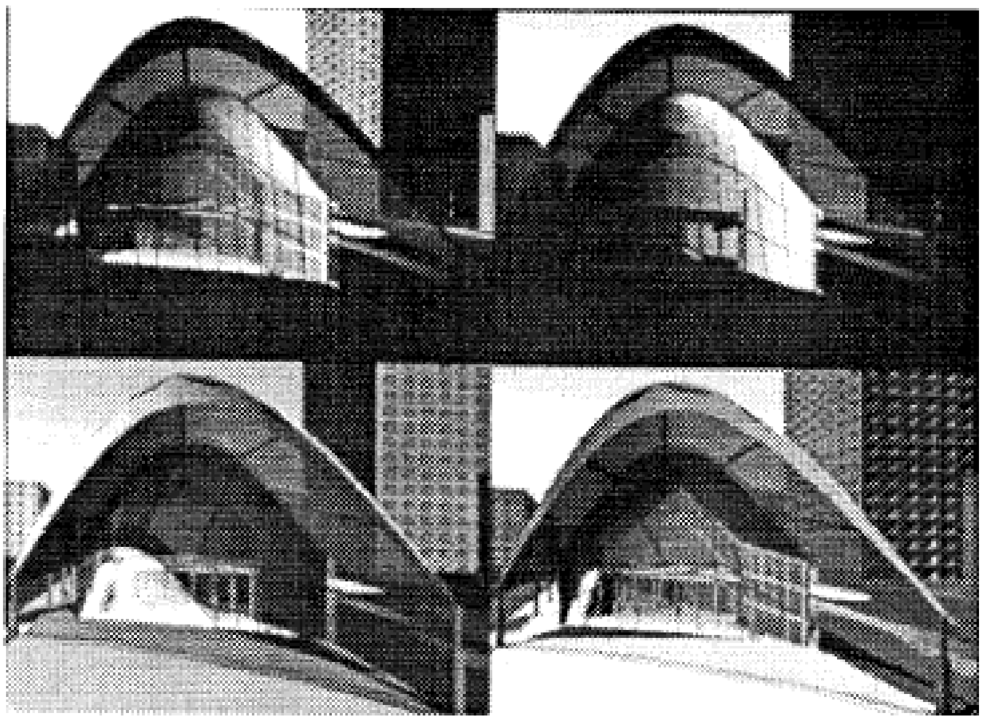

fig 9: Computer-based studio design for a bus terminal. Susan Yee, MDesS '92.

tions, expansion to other media and information sources such as video, sound, databases and 3D models, are planned for the future.

Borrowing from metaphors

In the development of a design environment such as the Daedalus network, it is useful to borrow from existing metaphors, both in the struggle to evolve methods and policies, and in their description to the user community. Metaphors which we have found useful are the library, the laboratory, the highway, the public utility, and the studio. In a way, the metaphor of the traditional design studio environment provides an excellent starting point for thinking about how designers should "enter" this "virtual realm", grapple with design issues, and ultimately produce and communicate solutions. Terminology or procedures from the traditional environment, for example, explaining the network diagrammatically in terms of analogous media, or introducing workstations in existing drafting furnishings, help to bridge traditional and electronic environments, and narrow the gap for designers for whom the

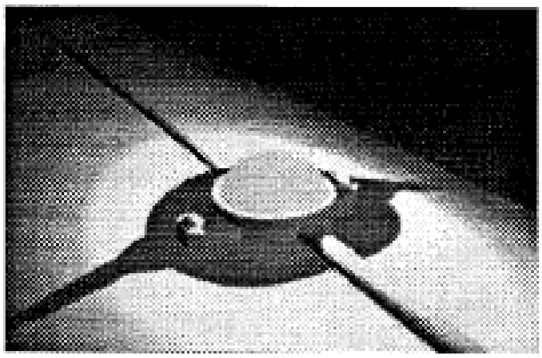
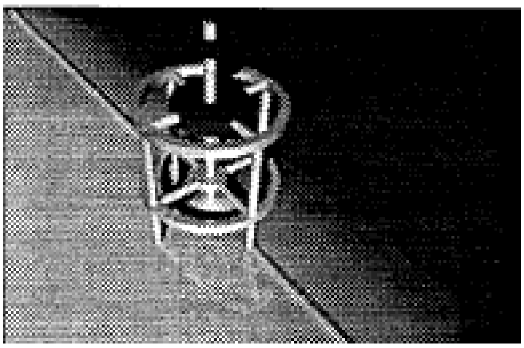

fig 10, 11 : Animations illustrate lighting and detailing for a pneumatic building. Kent Rollins, MDesS '92.

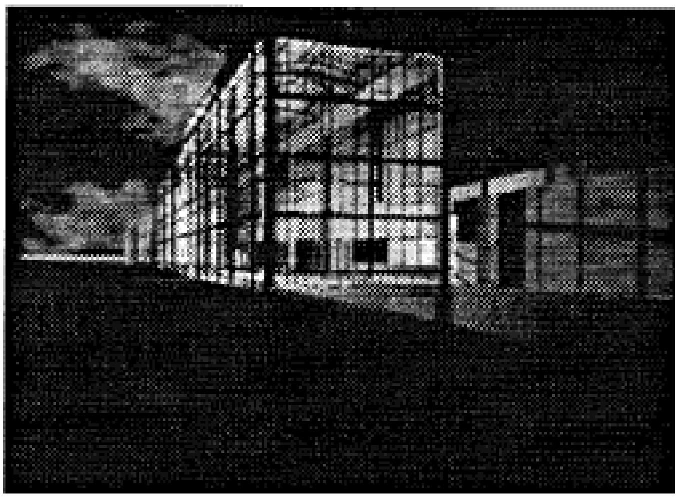

fig 12: To describe movement and lighting, animation and texture mapping were applied. Anne Scheou MDesS'92.

technological culture remains foreign. As in the traditional studio, the electronic design environment must be diverse enough to offer a robust set of tools, and must be flexible enough to support a universe of design methodologies. Unlike the traditional studio, however, the electronic realm offers limitless potential for the creation of virtual environments for creativity and experimentation, bulletin boards where groups can gather and debate, or central data repositories where participants can contribute ideas and designs.

The library metaphor assists us in developing an attitude about the tools to be selected. The software collection must be accessible and available, as are library resources. Similarly, the electronic design studio must be well-rounded in its offerings, and must succeed in providing broad access to lower end tools (useful to larger numbers of designers), and narrowly focused access to higher end tools (applied in smaller numbers but equally critical). The collection must serve both the novice and the highly skilled, in the same way that a library must serve the casual reader and the full-time researcher. Both groups have serious and differing requirements for applications access and support.

We are careful in our application of the laboratory metaphor as many designers retain a basic distrust of technology, preferring to ally their activities more closely with ail than with science. Nevertheless, the scientific culture of experimentation, of team-based problem-solving and quantitative logic, has much to offer designers. In pragmatic terms, workspaces configured for specialized peripherals successfully follow a laboratory model, where tools are made freely available, and experimentation is encouraged. The laboratory metaphor is also applied in small group applications training sessions where rapid assimilation of skills is necessary.

The metaphor of transportation, or the highway, informs our thinking about the network and its, communicative capabilities. As members of the instructional community make deeper use of electronic mail, internal bulletin boards, file transfer, and external sharing of data, concepts of traffic and network loading assist in the evolution of our network design.

Finally, the utility services metaphor has been useful in our development of a network access plan for student users attaching their own personal computers to the Daedalus network. In discussions about resources which would be needed for such a plan, and in deliberation about which group would be the most appropriate provider of various items such as security devices, network interface cards, software, printers or servers, a study of the concepts underlying public and private utilities was exceedingly helpful. Ultimately, this metaphor was useful in explaining the underlying logic behind our decisions, in a way that users and administrators could understand and support.

Success factors

The orchestration of this growing list of resources among a diverse user group remains a day-to-day challenge. A number of administrative components are key to the success of this enterprise. As mentioned earlier, assembling a staff group representing a broad spectrum of technical, managerial and instructional skills is critical. Staff members in our computer resources group offer technical skills such as systems administration, programming, hardware configuration, and also design practice and education, budgetary responsibility, and photography. In addition, staff members must assist in the process of skills development which students undergo as they experiment with innovative approaches. Optimally, some staff assistance would be made available to faculty who, being new at computer-based design processes, are nevertheless interested in experimentation, and require the assistance and advice of a computer-skilled staff member.

A faculty committee, or ad hoc faculty group, is necessary to represent the influence of curricular issues on the computer resource, and to provide a critical liaison between the computer resources department and the general faculty body. ideally, our department has direct links with the senior administration of the school, in order that technology issues remain under discussion as long-range plans are developed. The computer resources group plays a pivotal role in the investigation and anticipation of future technologies, in order that the GSD can position itself to move ahead of the professions.

A frequently-debated issue which impacts the structure of our educational resource throughout the school is the role of standardization. Absolute standardization on a single hardware and limited software platform, quite the opposite of the prevailing GSD philosophy, would substantially reduce staff overhead in implementing and interrelating disparate computer products. A commitment to providing a diverse and highly stimulating environment for design experimentation prevents us from this extreme position. A reasonable compromise, which we have adopted, calls for flexible standards which offer a limited number of choices, and thereby generate a manageable load on the technical staff.

Future directions

It is challenging to predict the future of the Daedalus network, in light of the rapid progress in available technology. At one level, it appears clear that network usage will continue to grow, as members of the GSD community develop computer sophistication, a process largely driven by the annual influx of more and more experienced students. The number of private student users will undoubtedly increase, as have the numbers of entering students who already own computer equipment. Emphasis may shift from today's predominant focus on the public utility to expanded support for private users.

In parallel with the growth in user base, network services will be developed. Projects to collect and provide access to a broad range of resources are actively being defined and developed. These include visual resources, aspects of the library collection, course-based documents and databases provided by faculty. The list of standard applications will continue to grow as well, as software vendors augment their products with network-aware licensing schemes.

To extend the growth of the network to its ultimate conclusion prefigures higher levels of integration. As a globally applied resource within the school, the network will provide a foundation for all sorts of communications. Faculty will employ the network to access resources for research and design. They will assemble lectures on-line over the network, and withn the classroom students will participate in viewing lectures presented through the electronic environment and will be able to interact with their instructors and fellow students in entirely new ways.

Evaluation and understanding

For the future, we must address the question of how the network functions as a context for learning and evaluation. Many who prefer traditional design methods ask, "What is a design network- good for ?" As a transition between traditional and electronic methodologies, the network adopts an additive posture. It provides alternative tools, but does not render the old ways of doing things obsolete. In its best application, it augments traditional methods.

It would be illuminating to conduct a divided studio based both in electronic and traditional design environments, to compare how application of the network affects individual design processes. The closest we have come is to monitor the progress of our computer-based studio course throughout several years, and to observe the rapid rate at which emerging design tools are consumed and digested with great skill. Recent results from this studio course where several final projects were presented on videotape suggest completely new evaluation methods will be required, as comparisons between static presentations on traditional media and animated presentations on videotape are difficult.

Gropius, in his speech "The Search for a Better Architectural Education" at the seventh CIAM conference in Bergamo in July of 1949, enumerated twelve key points for discussion. Among them was the importance of training students to work in teams and to emphasize collaboration with related disciplines. "This will prepare them for their vital task of becoming coordinators of the many individuals involved in the conception and execution of planning and building tasks in later practice." [1] It is clear that the network can provide a stimulating context for the development of team-based design approaches.

Further, Gropius emphasized the importance of theory over information. Taken in an electronic design context, thus we stress fundamental systems concepts above syntax and systems training. "The HOW is far more important than the WHAT In an age of specialization, method is more important than information. The training of an architect should be whole rather than sectional. In essence it should be all-inclusive throughout its duration, gaining in certainty of approach - that is, in clearness of thought and in the know-how of its realization. It should aim at teaching the student that it is through a creative attitude and independence of conception that he will arrive at basic convictions, not by accepting ready-made formulas. [1]

Ultimately we seek to understand the relationship between the work of design students and the environment in which they pursue their efforts. Seemingly, computers serve to amplify the strengths and weaknesses of their operators. Thus greater reliance on information technology, an imminent and apparent trend with enormous potential for transforming our profession, will make it even more critical for design educators to guide their students in intelligent and appropriate uses, and to provide a foundation of critical understanding of both the theory and practice of emerging design tools. If today we are poised at that land's edge where traditional methodologies can be recreated in the electronic design environment, as educators we must be prepared to leap into that unseen realm where, with the assistance of technology, designers will craft new metaphors and transform our ways of thinking about design.

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[1] Gideon, S. (1954), Walter Gropius, Work and Teamwork, Reinhold Publishing Corporation, NY, NY