USC/INFORMATION SCIENCES INSTITUTE

Society's need for computer technology is growing at an unprecedented rate. Basic and applied research at ISI is advancing to meet this need, with new projects and changes to the overall research profile reflecting areas of increasing importance. ISI's outstanding staff and facilities, combined with its history of flexibility and continued growth, make it an excellent environment for achieving new successes. We welcome this opportunity to provide a brief view of ISI.

Keith Uncapher

INFORMATION SCIENCES INSTITUTE
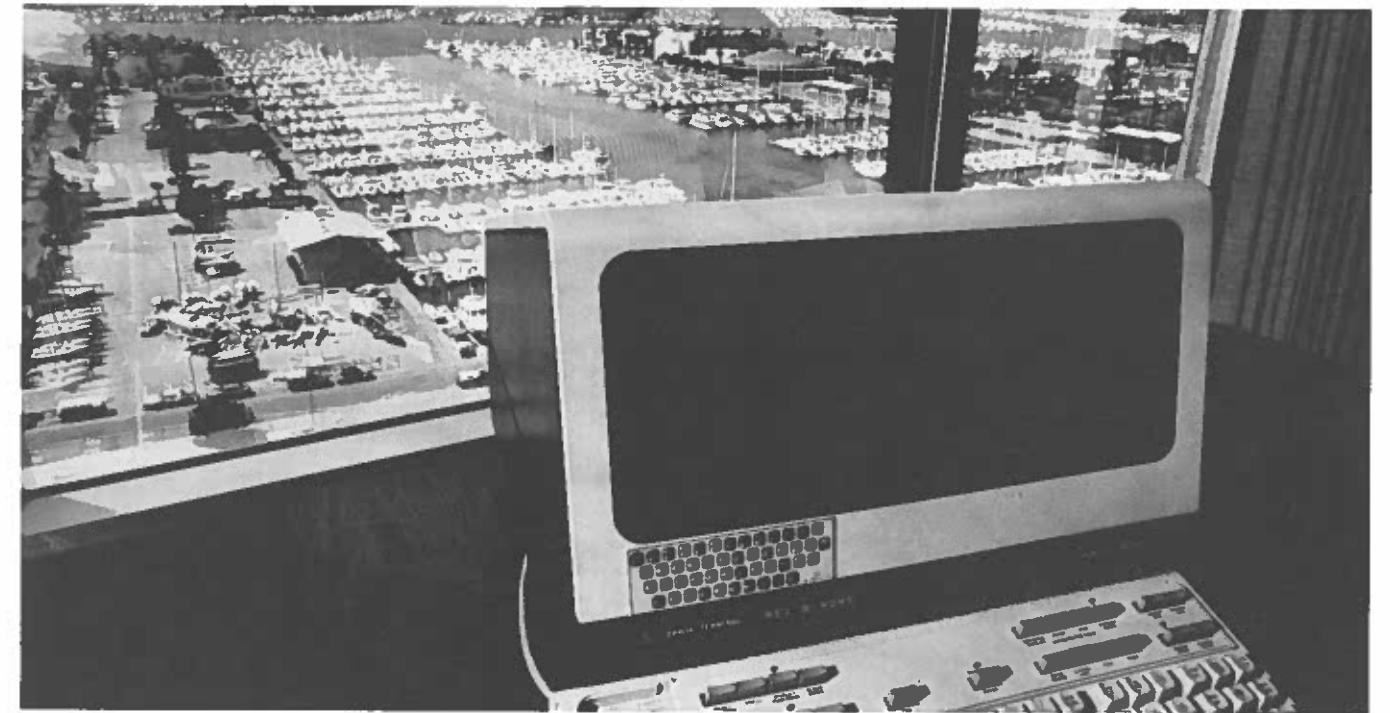
Information Sciences Institute is in its tenth year of operation as a center for computer science research. ISI's major goal is to generate and develop new ideas in computer science and to distribute those ideas to the community at large. The Institute combines the activities of its individual projects within a single research environment for its staff members; research is currently concentrated in the areas of artificial intelligence, software system specification, communications and networks, computing environments, and VLSI. Projects share computing facilities including new generation personal computers, large time-shared machines, and ARPANET service through one of the country's largest network nodes.

As one of three major research institutes administered by the University of Southern California, ISI has programmatic autonomy within the university structure. This gives ISI the freedom to identify and engage in significant research programs of its own choice. The Institute maintains a working relationship with USC's School of Engineering, particularly the Departments of Computer Science and Electrical Engineering. ISI benefits from interaction with faculty of USC and other local universities and provides opportunities for research and Ph.D. thesis supervision to graduate students from these universities.

The ISI Environment

ISI's 130 staff members (70 professionals) are organized into the dozen or so individual projects that make up the Institute's interdisciplinary research environment. Project members have significant responsibility for the conduct of their projects and the direction of their research. ISI encourages researcher visibility in the information processing community at large, including publication of research and participation in professional conferences. Performance of professional staff members is gauged in part by their creative influence on the research community outside ISI and their success in identifying new interesting areas of research.

The Institute provides a facilities-rich environment. Each staff member has a terminal for access to shared computing resources; in addition, individual projects provide dedicated personal machines and special hardware dictated by their research needs. Resources also include the Institute's library, hardware development laboratory, and an unusually high level of project and administrative support. University of Southern California facilities are available to all staff members.

ISI overlooks the Pacific Ocean from Marina del Rey, a suburban recreational community containing the world's largest man-made small boat harbor. Twenty minutes from downtown Los Angeles and USC, the Marina is far from the smog in the midst of some of the most desirable living areas in the Los Angeles basin. The full diversity of Los Angeles' ethnic, cultural, and recreational activities are within easy reach.

Tenth Anniversary

In May 1982, ISI celebrates its tenth anniversary. We are commemorating the event with a two-day seminar to look to the next ten years in the information sciences. Each of the following speakers will present his personal perspective of opportunities, goals, and responsibilities.

Michael Dertouzos, Director, Laboratories for Computer Science, MIT;
Edward Feigenbaum, Professor, Stanford University;
Robert Kahn, Director, Information Processing Techniques Office, DARPA;
Robert Lucky, Director, Electronic and Computer Systems Research, Bell
  Laboratories;
Steven Lukasik, Chief Scientist, Federal Communications Commission;
Allen Newell, University Professor, Carnegie-Mellon University;
Lawrence Roberts, President, Subscriber Network Products, GTE TELENET
  Communications;
Ivan Sutherland, President, Sutherland, Sproull & Associates, Inc.

Artificial Intelligence

The field of artificial intelligence is beginning to have major impact on how computers are used to solve problems. ISI projects are investigating fundamental problems in the representation and use of knowledge by computers as well as the experimental application of AI technology to real-world problems. Current activity is focused in the following areas:

Inference
- Control of reasoning processes that must deal with large amounts of knowledge
- Tradeoffs between detailed knowledge representation and sophisticated control structure
- Plausible inference and the representation of uncertain knowledge

Knowledge base design
- Consistent representation of various kinds of knowledge
- Maintenance of large knowledge bases
- Acquisition of domain-specific knowledge

Expert systems
- Architectures for expert systems
- Modeling of expert knowledge for delivery to nonexperts

Natural language
- Generation of English text
- Adaptation of parsers to new domains of discourse
- Informal specifications

Several projects contribute their individual viewpoints to this ongoing research. The *Consul* project is examining the use of knowledge-based inference to provide a domain-independent cooperative interface to a set of interactive services. The *Control of Expert Systems* project is using the Hearsay-III domain-independent architecture to develop better ways of providing the flexible control needed in expert systems. *SAFE* investigates the use of built-in process-description knowledge and dynamically acquired domain knowledge to produce formal program specifications from informal descriptions. The *Knowledge Delivery* project is applying the results of basic linguistic research to the problem of constructing multiparagraph English text.

Communication and Networks

Communication among computers has become an important part of computer science research, not only as a topic itself, but also in support of other areas. ISI is working to improve computer communications through the development of networks and network protocols ranging from office environments to international networks.

Applications

Advanced applications systems use integrated multimedia data for interactive conferencing, briefing aids, and computer mail. The user should be given choices among media including text, voice, graphics, facsimile, and video.

Environments

The communication environment is an interconnected system of networks of many different types, including long-haul (ARPANET), satellite (SATNET, WBNET), radio (PRNETs), and local (LCSNET, ETHERNET). A user and his computation processes should be able to access facilities across this entire environment.

The *Internet Concepts* project is working in the areas of protocol design, application, and verification. The *Wideband Communication* project is working in the areas of speech and video digital communication using a broadcast packet satellite network. The *Command and Control Graphics* project is working on device-independent color graphics to support command and control systems. The *Information Processing Center* supports a variety of computer communication facilities and programs; the *New Computing Facility* project will provide the framework for the next generation of these.

Computing Environments

ISI's interest in computing environments spans the full range of interactive facilities, from the maintenance of a large service-oriented ARPANET node to experiments with a coherent environment for providing natural language interaction with the user. The collective goal of ISI projects pursuing research in this area is a deeper understanding of three aspects of cooperative interaction in computing environments:

Cooperation among services

Unification of diverse hardware (including a variety of personal machines) and system software facilities into a single computing environment that is coherent from a user software viewpoint.

Cooperation among users and services

Creation of a single interface to all services in the environment that interacts naturally with the users (understanding requests and providing help).
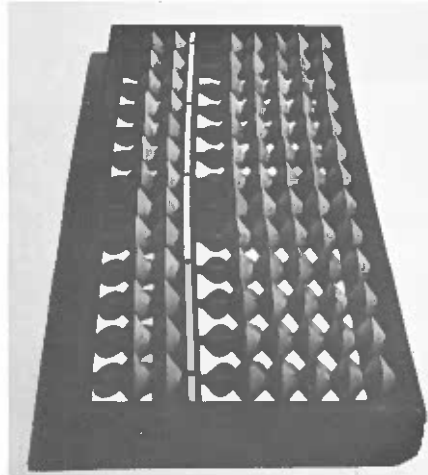
Cooperation among users

Support for group efforts in program development, document preparation, and other office and administrative interactions, i.e., a systemwide information management facility.

The *Information Processing Center* provides stable, continuous support facilities. The *New Computing Facility* project is planning for near- and far-term advances to support the needs of ISI's research community. *Consul* is attempting to provide a uniform, friendly user interface, using knowledge-based inference; the emerging *Information Management* and *CUE* projects are investigating other aspects of the uniform interface problem. *Command and Control Graphics* concentrates particularly on graphical interfaces. The *Wideband Communication* and *Internetwork Concepts* efforts deal with how to link computers effectively. The *Interlisp* project is developing an easily portable version of the language and its support system.

William Mark, David Wilczynski, Thomas Lipkis, and Bill Swartout

Cooperative Interactive Systems (Consul)

Current interactive systems must be made more habitable for a wide variety of users, especially those having little experience with computing. We are currently building the **Consul** system to explore methods for allowing natural interaction--natural-language requests, explanation of system facilities, user-understandable error handling--between a user and a set of online services (for text manipulation, message handling, etc.). Consul works by mapping user requests into appropriate system actions as dictated by a detailed model of system capabilities and requirements. This model is based on built-in service-independent knowledge, but is tailored to individual services via a dialogue-driven knowledge acquisition process. As each piece of a new service is built and added to Consul, the system engages in a dialogue with the service builder to determine how the piece fits into its model of the service so far and of interactive systems in general. Our research therefore includes not only modeling and mapping methods that generalize across services, but also a programming environment for service builders that integrates their services into Consul's knowledge base.

Bob Balzer, Don Cohen, Lee Erman, Martin Feather, Neil Goldman, Jack Mostow, Bill Swartout, Dave Wile, and Steve Fickas

Specification Formulation (SAFE), Testing (Gist Validation), and Implementation (TI)

This project comprises three interrelated efforts working to facilitate the creation, testing, and optimized implementation of program specifications. The first effort, called *Specification Acquisition From Experts (SAFE)*, is directed at helping people create unambiguous, consistent, and complete formal program specifications through informal description. While end users are quite capable of providing informal process-oriented descriptions of the task being automated, formalisms of any kind provide major impediments. The informal descriptions are characterized by partial, rather than complete, constructs. The system uses a knowledge base of program well-formedness rules to disambiguate and complete the informal natural language descriptions. An early version of the system has successfully converted several small informal specifications into formal specifications. Attention is now focused on handling large specifications through incremental formalization; this new implementation uses *Hearsay-III* as its base.

The second effort seeks to ensure that a formal specification matches the user's intent, by systematically investigating its behavior through symbolic execution. The tasks here include the design of a formal abstract specifica-

tion language (called *Gist*) and mechanisms for incremental specification based on elaboration, and the development of techniques for symbolic execution (some of which have already been developed within the SAFE context) and for explanation of the simulated behavior.

The third effort, called *Transformational Implementation*, seeks to provide a methodology guaranteed to produce only valid implementations of the formal specification by involving the computer in the implementation process to ensure that the evolving implementation remains consistent with the original formal specification. This is accomplished by limiting the activity of programmers to a choice of optimizations. These optimizations are embodied in a catalog of transformations, applied by the system in response to the programmer's choices, after verifying that they are applicable. A prototype grammar-based system has been implemented; current efforts are focused on structuring the steps of the development process and on facilitating the highest level optimization decisions--those that implement the freedoms provided by the specification language. Such a system supports multilevel design by mechanizing the movement (under user guidance) between levels. We are exploring the generality of this approach by attempting to apply it to VLSI design, which employs different design considerations and implementation techniques.

Control of Expert Systems

Lee Erman and Jeff Barnett

Expert, knowledge-based systems for particular problem domains (e.g., medical diagnosis, chemical analysis, and traffic control) are becoming increasingly important, both as practical tools and as a major area of AI research. This project is concerned with the architecture of such systems and, in particular, with their *control*--the division and allocation of resources during the execution of the expert system. An expert system often requires *soft control*--a flexibility of interaction among the various pieces of domain knowledge that allows for opportunistically allocating resources to activities most likely to make efficient progress. The solution to this problem itself requires the application of knowledge, both general-purpose (e.g., "A faster technique is preferred to a slower one") and domain-specific (e.g., for a medical consultation system: "An external test is preferred to an invasive one"). The conceptual and operational framework for this project is *Hearsay-III*, a system we have developed for building and experimenting with expert systems.

Knowledge Delivery in Multiparagraph Text

*William Mann, Yasutomo Fukumochi, Steve Klein, and Christian Matthiessen*

This project is developing new methods for autonomous text composition by machine, with the focus on generation of fluent English. The text generator, called *Penman*, is being developed to explore generation in multiple knowledge domains, including description of programs and program operations. Penman will seek to deliver knowledge (in English) from inside a system that was not originally designed to have a knowledge delivery component.

Penman contains a large systemic generative grammar of English. This grammar system extends the framework of M. A. K. Halliday with new semantic components and methods for interacting with a knowledge representation external to the grammar.

Formal Semantics

Vittal Kini, Dave Martin, and Allen Stoughton

The Formal Semantics project is carrying out research into methods for the validation and use of formal semantic definitions of programming languages. The Ada Formal Semantic Definition (FSD), written by the French group at INRIA, is being used as a vehicle for this research. A program which interprets the Ada FSD will be used as a tool to validate the FSD. The interpreter with the FSD installed within it will comprise a semantic-checker which takes Ada programs as input and either indicates where and why a program does not conform to the language semantics or else provides as output the denotations of the program. In the course of constructing the semantic-checker, the FSD will need to be parsed and type-checked, thus ensuring that syntactic and other minor errors in the FSD are revealed. It is expected that the semantic-checker will be employed in two phases. In the first phase, Ada programs, with known and well-understood intent, will be used as test case inputs. This phase will exercise the FSD, help to uncover deeper and less obvious errors in it, and instill confidence in its correctness. In the second phase, the checker may be used in answering detailed questions of interpretation of the language semantics. In addition to benefitting the definition of Ada directly, the project will provide insights into improving the state of the art in defining the formal semantics of practical programming languages.
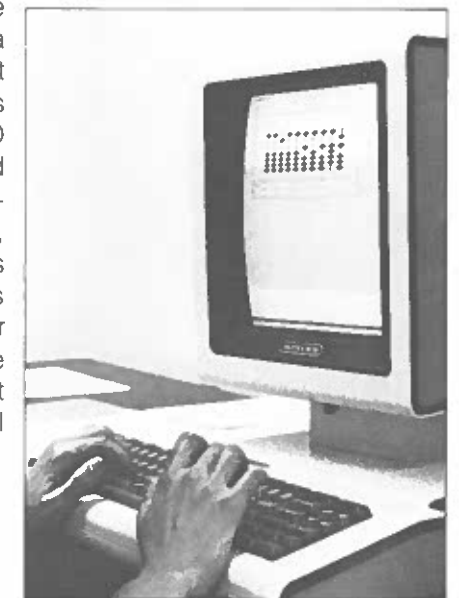
New Computing Facility

Dan Lynch, Danny Cohen, Joel Goldberger, Jim Koda, Jon Postel, and Craig Rogers

This effort will provide significantly improved computing facilities for researchers at ISI, as well as for remote and mobile users. Previous facilities have been almost exclusively large time-shared mainframes with individual file systems. The major goal of this project is to give each researcher a powerful, dedicated personal machine upon which he or she can perform most research and administrative computing. Only when the size of the task significantly exceeds the capabilities of the personal machine will the researcher resort to a large central server. There will be a single common file system, high-speed communication among all the computers, and common servers for other specialized tasks such as printing and external communication. Another goal is to allow new machines to be integrated into the facility with minimal effort. A key issue currently under consideration is the selection of a user interface suitable for the needs of ISI's research community.

Internetwork Concepts

Jon Postel, Danny Cohen, Greg Finn, Alan Katz, Paul Mockapetris, David Smallberg, and Carl Sunshine

Many packet-switched computer communication networks now exist; this project is investigating ways to interconnect them usefully. The project has three task areas: the formal analysis of protocols, the design and prototype implementation of internetwork applications, and the design of protocols and development of new communication concepts.

The protocol analysis area is focusing on the correctness (in the program verification sense) of the Transmission Control Protocol (TCP). TCP is the host-to-host reliable data stream protocol developed for the internet environment. Several program and protocol analysis tools are being explored.

The protocol applications area is focusing on computer mail. Two distinct systems are being developed: a text multinetwork mail system for use in the short term, and a multimedia mail system for use in the long term. Other applications will be explored in later stages of the project.

The protocol design and concepts area is focusing on the host-to-host and gateway level protocols, particularly the Internet Protocol (IP), a datagram protocol which is universal in the internet environment. There are many design issues to be resolved--for example, very mobile hosts, controlled routing, access control, fault isolation, and resource allocation.

Wideband Communication

Steve Casner, Bill Brackenridge, Danny Cohen, Randy Cole, and Ian Merritt

After several years of research with relatively low bandwidth packet networks, ISI is participating in a *Wideband Communication Program* (initiated by ARPA and the Defense Communications Agency) to investigate packet switching on a high-bandwidth satellite network. One goal of this project is to develop the technology required to support future packet speech systems with thousands of voice channels, beginning with an experimental facility that can be accessed by a much broader user community than that of the first demonstration systems; this will help to determine the feasibility of realizing the economies of integrated voice/data packet transmission. A second goal is to explore new modes of packet communication made possible by the increase in bandwidth of the satellite network over that of previous packet networks and to investigate how the added bandwidth can benefit old modes of communication. We are building systems for transmission of narrowband packet video, multiple channels of packet speech, graphics, text, and bulk data.

Command and Control Graphics

Richard Bisbey, Ben Britt, Dennis Hollingworth, and Pamela Finkel

The Command and Control Graphics project is developing a distributable, display-device-independent vector graphics system for use in a command and control environment. The user communicates with the system via a device-independent graphics language whose primitives are mapped to internal graphics protocols from which device-specific graphics orders are generated. The project is also developing graphics command and control application programs, including a Situation Display (naval force information displayed on a geographic background) and a Briefing Aid system that demonstrate the use of the graphics system. The software is currently in use at the Naval Ocean Systems Center as part of the Navy's Advanced Command and Control Architectural Testbed, as well as at sites connected by the ARPANET and the secure subnet.

VLSI Implementation System

Danny Cohen, Yehuda Afek, Ron Ayres, David Booth, Victor Brown, Joel Goldberg, Lee Richardson, Barden Smith, and Vance Tyree

The VLSI project is focused on research in the design methodology of VLSI circuits at various levels and on the development of the tools needed for providing fast turnaround fabrication service to the ARPA VLSI research community.

Research is progressing in the automatic generation of chips from purely functional (nongeometric/algorithmic) specification. Two distinct approaches and their integration are being pursued. First, we are working on a silicon compiler, called *Bristle Blocks*, which produces a limited class of chips, namely microprocessors, with remarkably efficient designs, competitive with manual designs. Second, we are pursuing a silicon compiler, *RELAY*, which accepts the specification of arbitrary synchronous systems in terms of hierarchically described synchronous logic equations. We note that the choice of appropriate specification language is of fundamental importance and that the target medium (silicon) has a character quite different from that of software.

We are also developing the concepts involved in managing useful libraries for popular subdesigns ("procedures"). Unlike software libraries, useful silicon libraries require many implementations of the same function. The geometric alternatives presented in multiple implementations provide for the possibility that people will find a design that fits nicely within the geometric constraints imposed by other parts of their design.

ISI is also developing and maintaining *MOSIS*, which supports the fast turnaround fabrication requirements of the ARPA VLSI research community. MOSIS handles many of the issues of information processing, geometric manipulations, quality control (by wafer probing and device testing), and general management. In addition to the management-oriented tasks, the MOSIS team is working on the development of standard acceptance tests and other facilities required for developing the interfaces needed to support the separation of the design from the fabrication process.

Interlisp-VAX Implementation

Dan Lynch, Ray Bates, Dave Dyer, Andrea Ignatowski, Steve Saunders, and Don Voreck

This project is implementing and will maintain a fully compatible, portable, large address-space Interlisp. The first version is implemented in C under UNIX and VMS for the VAX computer and was released in March 1982.

In addition to its ongoing research efforts, ISI is in the process of exploring new research directions that will likely develop into full-fledged projects. Exploratory work is currently under way in the areas of integrated interactive system design and information management.

Tom Kaczmarek et al.

Consistent Underlying Environment (CUE)

The Consistent Underlying Environment (CUE) project will examine the problem of constructing interactive systems whose various services (e.g., electronic mail, online appointment calendar, word processors) can be used in an integrated way to perform user tasks. For example, the task of sending a message to all the attendees of a particular meeting is quite difficult in current interactive systems, in which the mail and calendar services are totally separate subsystems. The goal of the CUE project is to create a methodology in which all of the services in the machine can be built into and accessed within a single interactive environment.

Bob Balzer, Dave Dyer, Michael Fehling, and Steve Saunders

Information Management

The aim of this new project is to build a support environment that facilitates the creation, integration, and evolution of computational services required by a community of interacting users. This environment will be based on uniform mechanisms for defining and instantiating information structures, building and modifying relationships among them, searching for those that satisfy predicates, establishing and maintaining consistency among objects, building services through event-based agents, and examining the behavior of such services. A key objective of this project is to develop techniques which allow such an environment to operate at sufficient speed to be practical.

The uniformity of the mechanisms on which the environment is based, and the simplicity of the underlying computation model (constrained objects), should enable users to comprehend and modify services created by others. This hypothesis will be tested by building the environment and a kernel set of services, and then extending them.

FACILITIES

Available and reliable computing power is a basic necessity for performing research in this field. ISI's **research computing facilities** currently comprise advanced personal computers (Xerox Dolphins, Symbolics LISP Machines, Three Rivers Perqs), Digital KL-10s, VAX 11/780s, PDP-11 minicomputers, and specialized devices for research in areas such as graphics, speech, and emulation. ISI's computing environment is currently undergoing major revision in response to changing research needs. The goal is to provide each user with a substantial increase in address space and computer cycles (both personal and time-shared) and advanced terminals for office and home use.

The **hardware development lab** is responsible for constructing any special equipment required for ISI research. The lab contains machine shop and electronics tools, including an online prom-burning facility and a prototype printed circuit board fabrication capability (currently under development). Past projects have included video recording systems, ARPANET and Ethernet interfaces, and equipment for digital transmission of speech and video. State-of-the-art prototype products have also been delivered to several universities and government facilities; lab developments have directly influenced new products at Hewlett-Packard and Digital.

Staffed by a full-time technical librarian, ISI's **library** features an extensive collection of books and current technical reports, subscriptions to more than one hundred technical journals, and online access to several bibliographic databases. The up-to-date collection covers the full range of computer science, with special depth in those areas of particular concern to ISI's researchers. The **publications department** has two full-time editors to assist in the preparation of proposals, articles, and conference presentations, and to publish and distribute technical reports and manuals. Additional services range from answering questions about document-preparation systems to completely rewriting the transcript of a conference talk into an appropriate form for publication. A full-time **graphics** designer provides expertise in designing and producing visual materials to supplement text and oral presentations. The graphics department also provides photographic, layout, and drafting support for project research.

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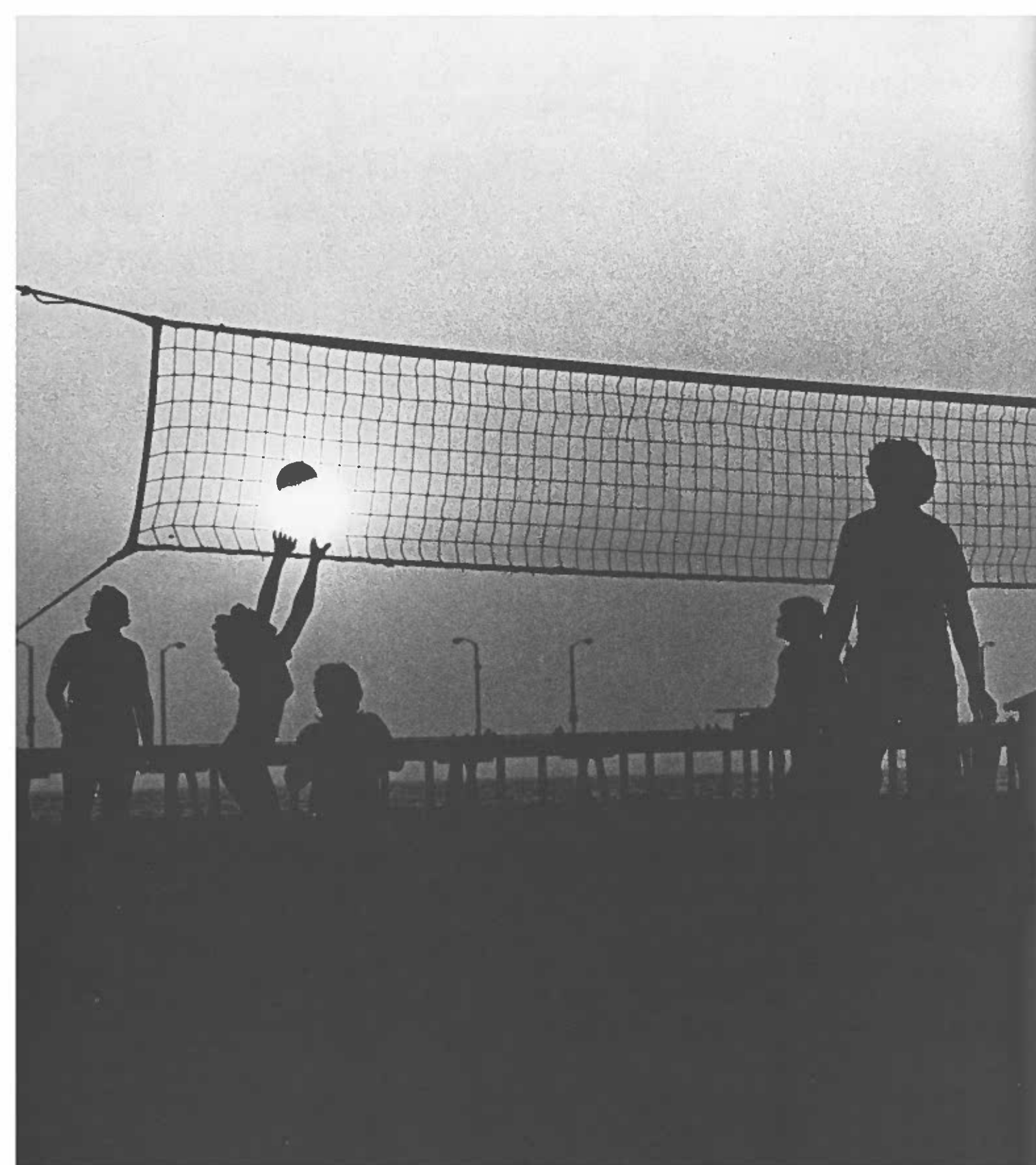
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