

## THE COMPUTER-AIDED DESIGN AND ENGINEERING FACILITY

The Computer-Aided Design and Engineering Facility was started in October 1978 and has now grown to 12 computer-aided design workstations and a computer-aided engineering network of 20 computers with enhanced hardware and software for use by all members of the APL staff.

### INTRODUCTION

APL's Computer-Aided Design and Engineering Facility makes available modern software tools for design, analysis, drafting, and numerical control for use in mechanical and electrical design projects. The facility has integrated computer hardware, software, and peripherals into an electronic database design environment whose goals are to provide shorter design cycles, better quality through efficient analysis and simulation capabilities, and repeatable manufacturing using numerically controlled manufacturing tools. The facility also provides training for designers and develops application and system utilities to enhance the computer-aided design/computer-aided engineering (CAD/CAE) environment.

A study of the capabilities of a CAD system was initiated in 1977. Two Computervision workstations were bought in 1978 and four more were added the following year. In 1983, a second system of six workstations was added. These systems have complete mechanical, manufacturing, electronic, microelectronic, and architectural design tools and limited engineering analysis software. Manufacturing software provides numerical control programming for support of numerical control ma-

chines. Twelve additional CAD workstations are planned in 1986, for a total of 24.

Figure 1 shows typical CAD workstation areas. In 1982, facility personnel initiated a study that determined the utility of CAE workstations at APL. The major manufacturers were evaluated, resulting in the selection of Mentor Graphics workstations. From a single workstation in 1984, the CAE capability has grown to 20 computers in a Laboratory-wide network. A diagram of the CAD and CAE facilities is shown in Fig. 2.

Training within the CAD/CAE facility ranges from introductory courses to advanced topics. In-house familiarization courses are provided in both the CAD and CAE environments to designers, engineers, and supervisory staff. After familiarization, designers take additional introductory courses and attend vendor-provided classes. On their return, the designers complete an apprenticeship on the system.

Design engineers learn to use engineering design and analysis tools by means of vendor classes and on-line tutorials, and by attending user group meetings and seminars. The vendor course and tutorials give the engineer



Figure 1—Typical workstations in the Computer-Aided Design Facility.

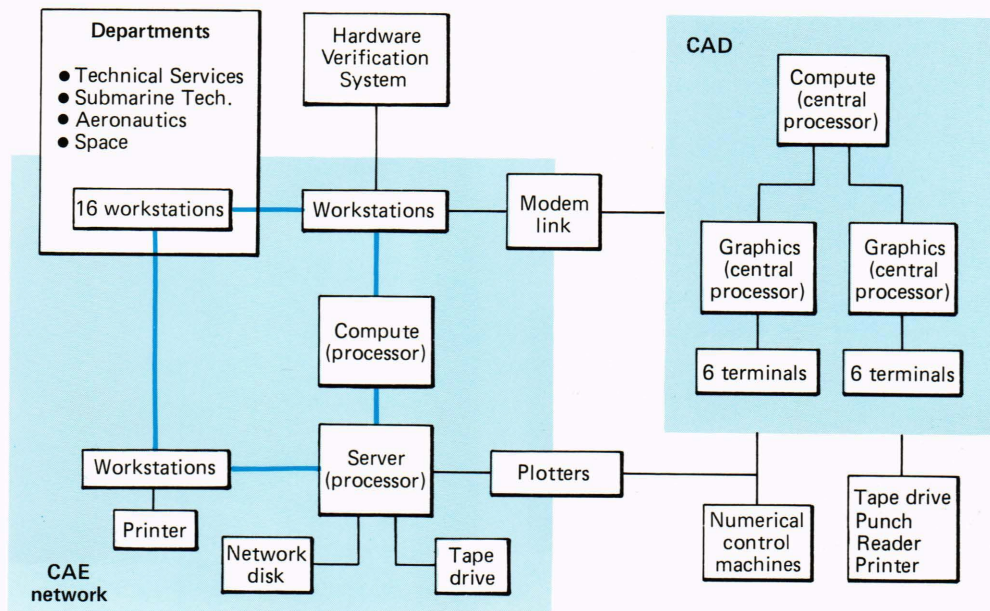


Figure 2—Diagram of the Computer-Aided Design and Engineering Facility.

the necessary knowledge to begin using the tools productively. On-site user meetings and seminars, which provide for exchanges of practical information among the participants on the network, discuss fixes, work-arounds, general design techniques, and specific design problems.

Systems operation and programming staffs are available for development of software utilities, hardware interfacing, and general consulting. When a user has a problem, the facility's staff works with him to solve it.

The work flow of a design project starts with a concept developed by an engineer that is turned into a complete design using an integrated collection of software tools. The design is then transformed into a manufacturing data package that is used to develop instructions for numerically controlled manufacturing machines. Both mechanical and electrical designs follow this basic path; however, the design flow and software tools required are quite different.

A mechanical design begins with a concept of the configuration and the functional requirements. Engineering designers develop the layout and analyze critical items like flexure, vibration response, and mass properties by means of finite-element and stress-analysis codes. Using this information, drafters make detailed drawings to describe the various parts for manufacturing. The detailed drawings are turned into machine-tool control commands by a numerical control programmer using information directly from the part's design database.

Electrical CAE software enables the engineer to develop an electrical schematic, using circuit simulation, timing, and fault analysis tools. CAD software then permits the layout designer to transform the design database into parts lists, circuit board artwork, and control commands for automatic fabrication tools. Part placement on the circuit boards is also specified. Outputs from these systems are also available for custom very large scale integrated (VLSI) circuitry and gate-array fabrica-

tion. (A detailed description of mechanical and electrical CAD design is given in the article by Schachtner and Ahlbrand.)

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APL's CAE network uses the Mentor Graphics software tools for electrical design. Mentor software is executed on Apollo computers that provide a wide range of hardware capabilities at each workstation. The Apollo computer workstation nodes are connected in a high-speed token ring network to allow the sharing of hardware, software, and data resources among the workstations. Apollo computer systems support three major operating systems: AEGIS, developed by Apollo Computer, and two versions of UNIX. General-purpose language support includes Pascal, Fortran, C, and LISP. Utilities are available for graphics, communications, peripheral interface, and software development.

The hardware and software for each CAE workstation have been selected to meet APL's engineering needs. Approximately 200 companies are offering CAE software tools for the Apollo system. Architectural, chemical, civil, electrical, mechanical, power systems, software design, and structural engineering disciplines are addressed. Additional APL interest and usage include data analysis, artificial intelligence, software development, and the study of distributed computing concepts.

Currently, the central CAE facility contains two workstations, a compute node and a server node. Sixteen other workstations are distributed throughout APL. Plans call for a network of approximately 40 CAE workstations by 1989. Sixteen of the current workstations support Mentor Graphics software tools (Fig. 3), and four workstations execute PATRAN for pre- and post-processing of CAD models for finite-element analysis.



**Figure 3**—CAE workstation located in the facility. The screen shows Mentor Graphics electrical design software.

The Mentor software tools support electronic design functions for all phases of digital design. These cover schematic capture, logic and fault simulation, timing verification, gate-array cell placement and route, and custom VLSI design. A standard user interface across the design tools enables the designer to transfer experience with one software tool to the others.

Three recent projects—a digital gate-array design, a wire-wrapped circuit design, and a finite-element analysis of solder joints—display APL's use of CAE design tools. The first used a Department of Defense very-high-speed integrated circuit gate-array description from Texas Instruments to develop an integrated circuit for interfacing with other very-high-speed integrated circuit components (see the article by Charles et al.). The second developed a digital circuit containing approximately 700 integrated-circuit components mounted on six circuit boards. Finally, the PATRAN software tool modeled solder joints of leadless ceramic chip carriers in the presence of thermomechanical stress (see the article by Clatterbaugh and Charles).

The three projects represent uses of CAE workstations that would have been difficult or impossible without the design tools. The gate-array design requires communication of the upper metal-interconnect layers of the gate array to Texas Instruments for its manufacturing process.

The second example displayed a more complex use of the Laboratory's CAD environment. After the digital design is input and simulated on a Mentor workstation, it is transferred to the CAD system for physical layout and documentation. Utilities extract a netlist from the CAE design and translate between the CAD and CAE formats. On the CAD system, a layout designer performs the automatic placement and routing functions that position the components and assign the digital gates to physical packages. Component location and pin numbers are back-annotated to the Mentor design for accurate circuit documentation. The CAD system provides



**Figure 4**—The Hardware Verification System being used to verify a gate array.

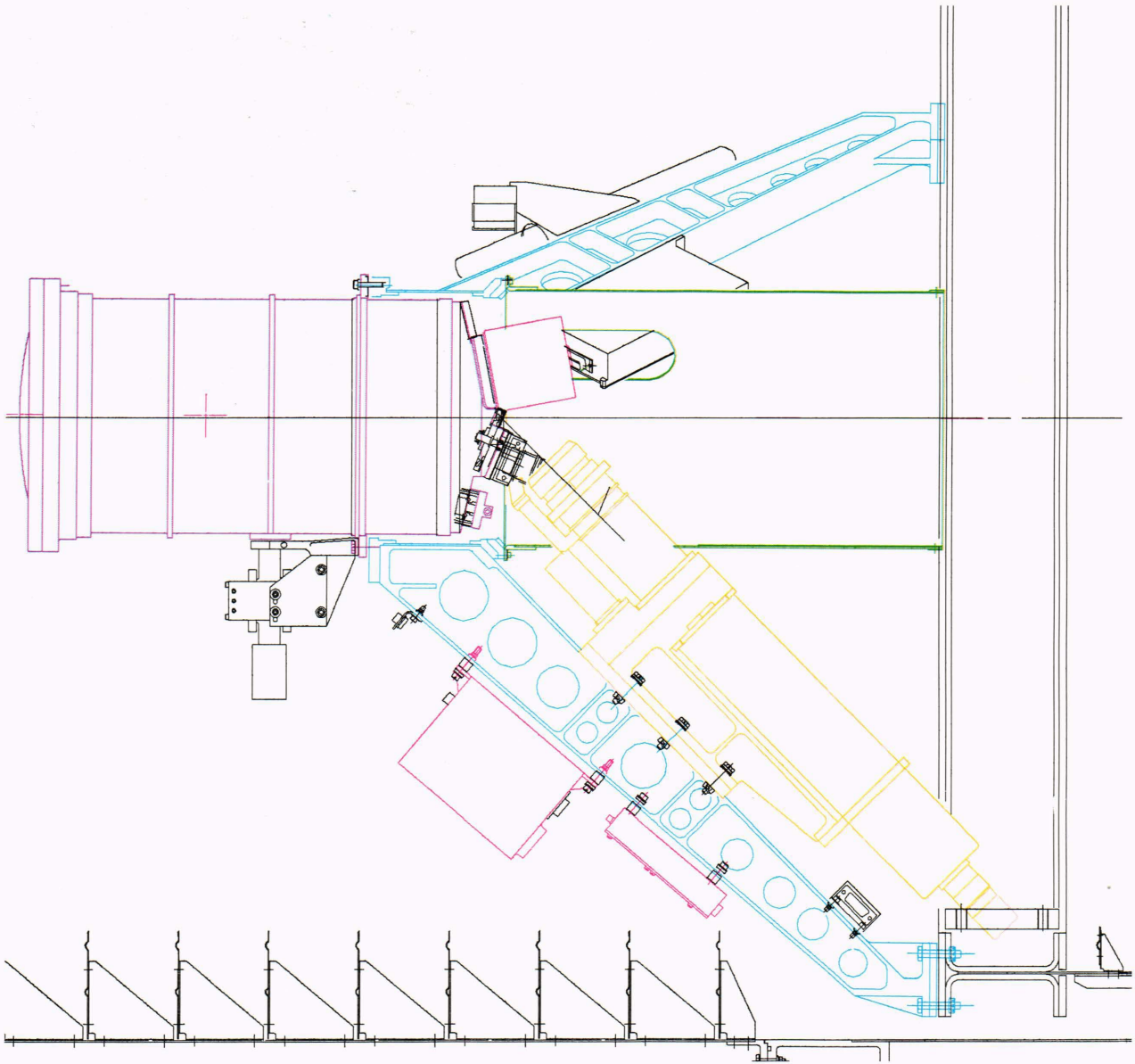
drawings of the populated circuit boards, a parts list, and control data for a semiautomatic wire-wrap machine. Finished wire-wrap boards can be electrically connected to the Mentor Hardware Verification System (see Fig. 4). This hardware converts simulation test vectors into digital input signals to the boards and records the output signals. Comparison of the simulation and circuit outputs provides verification of the manufacturing process.

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Outputs from the CAE workstation or hand drawings provide inputs to the CAD system. The CAE workstation input permits the engineer to transfer data directly to the designer's CAD tool instead of having it duplicated on the CAD system. This capability provides a faster and more accurate method of passing along the design information.

### Mechanical Design

The mechanical design software is used to produce two- and three-dimensional design layouts, assemblies, detail drawings, and numerical control outputs. The system's three-dimensional capabilities in the software's "model mode" are used primarily for conceptual design and interference checks on proposed hardware. Programs such as the Hopkins Ultraviolet Telescope, Dual Doppler Beacon, and Standard Rampart have made use of this capability. Figure 5 shows a drawing of the telescope; the article by Schachtner and Ahlbrand provides further examples. The models are wire frame drawings; a color workstation is used to discriminate parts. The drawings can be quickly rotated to any angle with con-



**Figure 5**—Plot of the sensor assembly from the Hopkins Ultraviolet Telescope, contained in the CAD model. Note how color is used to separate different components.

trolled perspective for better visualization, interference checking, or modification.

Individual two-dimensional detail drawings are derived from the model. Detailed fabrication drawings are made by semiautomatically adding dimensions and text to the existing part drawing. Drawing formats, standard notes, and other repetitive items are called up from the system's library and quickly added. The system has hard-copy output to electrostatic Versatec plotters on paper, vellum, or mylar film. Color plots, with up to eight colors, can be made with a pen plotter.

When computer-aided manufacturing is applicable for parts fabrication, the data used to control the related machines are produced on the CAD system. The numerical control programmer uses the geometry portion of the design database to define a "tool path." After verifi-

cation, the tool path is transferred to punched paper tape for use by the machine tool.

Engineering information for mechanical parts is also generated by the CAD system. Mass properties including center of gravity and moments of inertia are extracted directly from the model database. Although not as capable as the CAE software, a finite-element model for stress analysis of the part can be constructed. The finite-element model is transferred to the NAS 9160 computer analysis, after which the results are transferred back to the system for dynamic display of the distorted model.

### Electrical Design

The CAD system provides a variety of tools for use in printed circuit/electrical schematic design. The printed circuit/electrical schematic application package provides

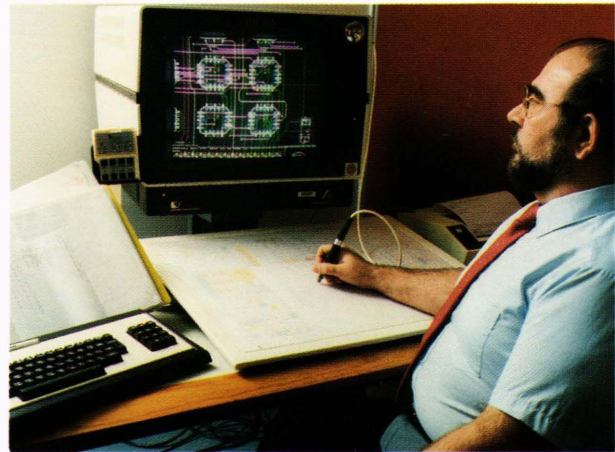
documentation for a printed circuit board equivalent to that obtained by manual drafting methods. Schematics, parts lists, layouts, artwork, assembly drawings, and detail drawings are prepared on the system using approved APL drawing formats.

Schematic diagrams are prepared by inserting library figures and then copying, moving, and connecting them as required. Text is then added to complete the drawing. The file structure allows access to multisheet schematics as if they were a single database. The operator can place parts in approximate positions, use nonorthogonal lines to interconnect them, and get a neat final drawing. Other commands check the database, create formatted listings of user-selected parameters, extract network data from schematics, and create a netlist. Parts lists, bills of material, and post-process data for use with other systems are also available.

Printed circuit board layout is performed using the printed circuit/electrical schematic package. Automatic part placement speeds the process of designing printed circuit boards. With this program, the designer directs component placement. He may also pre-place components, gates, or pins that will not be changed. The computer assigns gates to components and places the remaining components on the board.

Automatic routing of printed wiring is also performed by the printed circuit/electrical schematic application software. Starting with a placed printed circuit board, the program automatically routes the printed wiring. This establishes interconnections between pins having the same signal name while avoiding user-defined obstacles such as tooling or mounting holes, user-described keep-out areas, and pads. The router may be stopped for manual editing and then restarted to complete the process. A well-placed board results in an initial completion rate of at least 95 percent completed routing. After the operator interactively finishes the design, a comparison of the original schematic netlist with the circuit board database is performed. A user-defined rule file performs geometric checks on the routed circuit board. A completed board is shown Fig. 6.

During the design process, data needed to create drawings, numerical control tapes, and magnetic tapes for photoplotting are stored in the design database (see the article by Strider and Wagner). Necessary manufacturing drawings are created by selecting the database in-



**Figure 6**—A designer modifying routed interconnects on an NROSS circuit board. Only two of the interconnect layers are shown.

formation and adding required dimensional data and text. Data used for drilling and routing the printed circuit board are extracted from the database and automatically coded for the numerically controlled manufacturing tools.

#### THE FUTURE OF CAD AT APL

The engineering, design, and fabrication community at APL is rapidly expanding its use of computers to increase productivity, enhance quality, and consolidate information transfer. The CAD and CAE facilities capabilities are being expanded and refined to take advantage of new developments including the use of personal computers. Information flows from the conceptual design to fabrication without a manual or paper interface. Selection of hardware and software and the design of work flows will continually enhance this ideal.

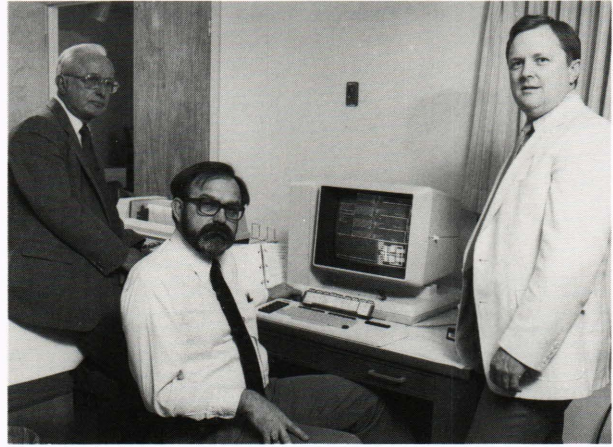
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