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COMPUTER–AIDED ENGINEERING, DESIGN, AND INFORMATION SYSTEMS AND SERVICES AT THE STEVEN MULLER CENTER FOR ADVANCED TECHNOLOGY

The Steven Muller Center for Advanced Technology contains both computer-aided engineering (CAE) and computer-aided design (CAD) facilities. The Engineering Design Automation Group, formed early in 1990, uses the facilities to support APL's CAE, CAD, and computer-aided manufacturing networks and the local area network resources of the Engineering and Fabrication Branch.

INTRODUCTION

The Engineering and Fabrication Branch, TEO, occupies the first three floors of the Steven Muller Center for Advanced Technology at APL. The first floor is dedicated to microelectronics, the second houses the conventional electronic fabrication facilities and the Materials Laboratory, and the third is home to the Engineering Design (TED) and Engineering Design Automation (TEA) Groups.

The TEA Group, formed in 1990, unites people with diverse backgrounds who will integrate the various computer-aided engineering (CAE) and computer-aided design (CAD) tools used throughout APL with the CAE, CAD, and computer-aided manufacturing (CAM) tools available within the TEO Branch. The group is responsible for support of both the APL-wide CAE network and the prime computer (Computervision) CAD/CAM systems within TEO, and for support and development of the local area network (TEOnet) that links all the TEO groups with each other and to the rest of APL. The support role encompasses user training and assistance with applications, network administration, workstation setup and connection to the network, network software installation, and software development. Each role will be examined in more detail in this article.

The TEA Group has three sections: Component Engineering, Applications Engineering, and Network Operations. Each has a specific function aimed at smoothing the flow of engineering design data from APL engineers through packaging design and on to fabrication.

COMPONENT ENGINEERING

Component engineering, or "parts libraries" management and development, is a new activity for APL. The Component Engineering Section is the first formal, central attempt to address an underlying issue vital to the successful implementation of CAE and CAD design tools: the creation, management, and development of a stable "corporate" library of approved and tested electronic and mechanical components available to APL packaging engineers. Successful library management will allow minimal rework of designs, with consequent cost and schedule savings, as the packaging effort proceeds and the resultant database is passed on to fabrication. Designs requiring high reliability, such as those for space or biomedical applications, can use parts already qualified and approved by reliability and quality assurance personnel.

In addition, a stable library of approved parts will insulate the engineering users and designers from some of the rapid changes inherent in the use of commercially available libraries. For example, new library releases often contain updated symbols or other retroactive "fixes" to older parts that may cause the parts to look or act differently in certain applications. From the user's perspective, the fix may thereby become a "bug," making the updated library undesirable.

Current activities focus on the creation of the library and a definition of an appropriate library management methodology, that is, a set of clearly defined procedures to allow a user to create and submit a part for validation and inclusion in the approved library. The submission procedures will be generic in that the overall process will generally be independent of the design environment, with only minor portions platform-specific. For example, an AutoCAD (mechanical design) or PCAD (electrical design) software user on a DOS-based workstation might use terminal emulation software to send his part across the network to the appropriate library directory on one of the Sun computers maintained by TEA. A TEA component engineer would then verify that the user's part had all the attributes required for inclusion in the APL library specific to that design environment and would add or correct as necessary. Another user, working on a Computervision (Sun) system, would create and transfer his parts files differently, but the result (a new standard part) would be the same for both users.

As a parallel effort, work is under way to standardize the graphics symbols used in electrical design and to ensure that the electrical components in the APL library include preferred parts lists of TEO customers, such as the Space Department's preferred parts list of high-reliability, flight-qualified items. Specifically, using a variety of commercial and in-house utilities, the nonproprietary symbols from commercial libraries such as Mentor Graphics and Logic Automation have been extracted as ASCII datasets and mapped into appropriate graphics command files in PCAD. Once the symbol has been generated, and suitable properties added and saved from within PCAD, it becomes available as a standard part. Figure 1 shows a typical part from one of the commercial libraries. Not all parts would require all attributes in every design environment. A simple part, such as a resistor, might have only the attributes part number, value, tolerance, power rating, type, and failure rate.

The diamond shapes (enlarged for clarity) shown in Figure 1 equate to pin locations where connectivity exists; the small "I" symbol on the lower left pin indicates the symbol origin. The other letters reference the type of device and the typical (TYP) graphic representation. The key features are the origin, connectivity, and reference designator, which must be specified properly for a schematic done on one system to translate correctly to another (e.g., to translate from PCAD to Mentor). One obvious result of standardization, besides proper symbol translation, is that circuit schematics look alike, regardless of the design system used for their creation.

On a more immediate level, the users of AutoCAD, PCAD, and Mentor Graphics in TEO are receiving some immediate support from the component engineering (and other TEA) staff for consolidating existing user libraries, generating pad stacks for printed circuit board fabrication, generating standard connectors and terminals, and using standard schematic borders. For example, new borders for Mentor Graphics users are now available with 0.2-in. pin spacing, which supersedes the earlier 0.1-in. spacing. When engineers use the 0.2-in. spacing, the TED packaging designers can meet military specification documentation requirements (required by some sponsors) without breaking up a dense schematic among multiple drawing sheets. Breaking up a design can introduce drafting errors, which, in turn, increase the possibility of nonfunctional final hardware. Standardizing the border libraries, in conjunction with working with designers to educate new CAE users about the trade-offs in using denser 0.1-in. designs, should result in cost and schedule savings for APL sponsors.

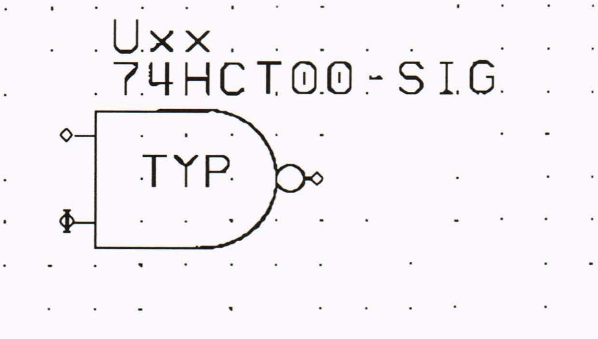


Figure 1. Typical part symbol from a commercial library.

APPLICATIONS ENGINEERING

Applications engineering activities in TEA are aimed at the system and application software integration issues that must be resolved to turn designs into finished hardware. In this context, "integration" has a fairly broad definition, because APL has acquired a wide variety of CAD tools in the past several years, many of which are based on personal computers; as the name "personal computer" suggests, relatively few file and data standards can be found in this environment. In TEO, a total conversion to CAE/CAD/CAM tools has occurred in the same time frame; the main focus is on the high-end workstations from Computervision and the Hewlett–Packard Apollo Division. Although the application software on such workstations is still usually proprietary, most resultant files and data are (or can easily be manipulated to be) in a standardized format. A growing number of personal computer users in TED are running various design and packaging applications. Integration of the diverse computer environments in TEO (and APL) has become vital to the efficient use of the resources.

Several examples illustrate the prevalence of CAE tools at APL. Projects in the Fleet Systems and Space Departments have used computer-aided software engineering (CASE) tools for more efficient development of the software used in complex, embedded processor systems.[1] The Aeronautics Department has used mechanical analysis CAE tools to visualize the motions of missiles as they rise from launch tubes.[2] Biomedical projects have used mechanical analysis CAE tools to analyze stresses on hip joint replacements.[3] Space Department personnel have used electrical analysis CAE tools to design gate arrays for high-speed circuits aboard satellites.[4,5] Staff members in the Space, Technical Services, and Fleet Systems Departments have used other electrical CAE tools to design integrated circuits from scratch.[6]

Occasionally, outputs from these design and simulation tools are final products (movies, pictures, integrated circuit masks) that require no further processing at APL. In most situations, however, the CAE database needs further processing with CAD/CAM tools before fabrication can begin. Specifically, CAD applications are used to create a detailed design database and/or artwork for printed circuit boards and mechanical structures; CAM applications then produce numerical-control tool paths. These processed outputs are then sent directly to the controllers of various machine tools and to the printed circuit board fabrication and test equipment.

Sometimes, however, the fabrication process is sufficiently unique or complex that suitable commercial CAM software may not exist, as in cable harness design and fabrication. Although CAE and CAD applications can produce the connectivity (wire running lists) for a harness, no single, integrated software package (encompassing both CAD and CAE environments) can also support the three-dimensional layout process necessary to determine wire lengths. This means that a technician still builds a complicated harness twice. The first iteration results in a mock-up harness on a wood and sheet-metal structure and includes many notes regarding the routing of the harness, the wiring order of each connector, the corresponding lengths of each wire, and so on. Design iterations or modifications needed because of systems testing often result in harness wiring changes, so when the real harness is finally fabricated, the technician's working notes are voluminous, and the probability of producing an identical harness for a later unit is remote.

Faced with the fabrication of a 7000-wire harness for the Space Department's MSX satellite project, TEO has tried to change this traditional design approach. Specifically, TEA has written software for the Mentor Graphics CAE design environment that will process the engineer's circuit schematic and then identify and extract the wires to be run within a specified cable.[7–9] The extract, processed with a database that provides connector information, produces a printout that lists the harness wires in the order in which they should be attached to a given cable connector. The listing can then be used directly during fabrication, and, if appropriate, the preferred wiring order for a given connector can be changed on the basis of the technician's feedback. Though still not providing length information, the fabrication technician's job will be simplified significantly, as will that of TED harness designers, with corresponding cost and schedule savings.

Concurrently, TEA and TED personnel are involved in testing a pre-release version of a software product that will provide a true three-dimensional harness design. During 1991, the combination of that (or perhaps another) product and the existing in-house software should dramatically streamline the overall harness design and fabrication process.

In general, the Applications Engineering Section tries to make the transition from CAE to CAD and from CAD to CAM as smooth as possible by identifying appropriate third-party translator software or by writing such software in-house, as for the harness fabrication effort. The need for such data-translation software is an industry-wide phenomenon, due largely to the relatively slow emergence of standards in the competitive, proprietary-software CAD/CAM and CAE environments. Most companies as well as APL have purchased various CAE or CAD systems from several vendors for many years (APL brought Computervision on-site in 1976 and Apollos in 1983, and has had personal computers since their inception). Historically, each vendor has cited proprietary advantages for its hardware and software, claiming its products to be ideal for a particular application. Until recently, much of the software was available only for the specific brand of hardware. The infamous "islands of automation" phenomenon resulted as customers purchased these special-purpose systems. As a rule, if N types of CAE/CAD systems are on-site, $N(N-1)$ data or file format translators will be needed to ensure complete interoperability.[10] Not only are general-purpose translators largely unavailable, but the translators that do exist are usually expensive, tend to focus only on the products of major vendors, and usually have very specific and comparatively limited scope. These problems would be eliminated if a single, "neutral" (i.e., hardware- and software-independent) data format were suitable for information exchange between any two platforms that supported the standard. If so, a vendor would only have to write a translator to and from the neutral file format to be able to advertise compatibility with a competitor's hardware (e.g., when trying to acquire the other vendor's installed customer base).

Figure 2 shows how engineering data would flow in a totally integrated database or single-vendor system. In practice, however, the situation is more often represented by Figure 3, where considerable effort may be required to move data, with potential errors at each step.

The TEA Group supports two major neutral format standards for data exchange: IGES (initial graphics exchange specification), and EDIF (electronic data interchange format). The former is most useful for the exchange of mechanical data (electrical support arrived sometime after the first release and has been catching up ever since). The latter is devoted to electronic data and has seen expanded use in CAE. Another emerging standard is an electrical modeling/circuit simulation language called VHDL (for very high density logic), which has its roots in Ada (the new standard DoD language) and in the DoD-sponsored VHSIC (very high speed integrated circuit) program.[11] Although VHDL is not yet supported by TEA, in the future it will be as a function of need and/or available staff expertise. The first VHDL tools should be available in TEO by mid-1991, arriving as part of a major upgrade to Mentor Graphics CAE applications.

The phrase "as a function of need," used in the preceding paragraph, has several broader implications for APL. The TEO Branch has numerous subcontractors

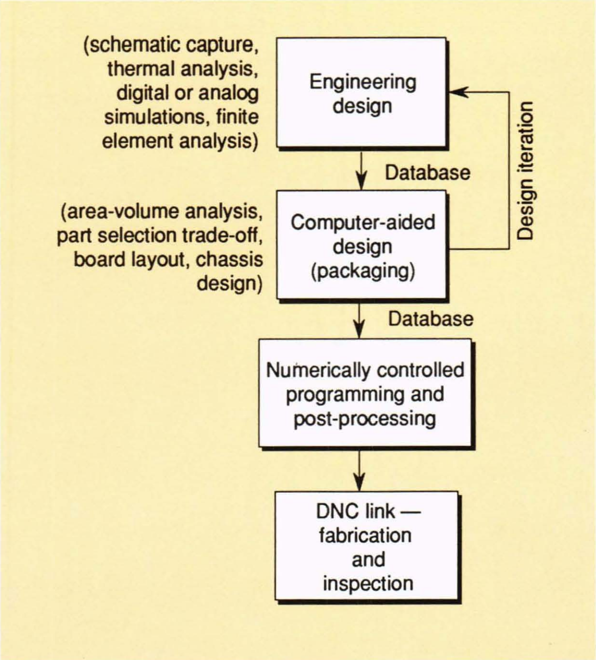


Figure 2. Idealized computer-aided engineering/computer-aided design (CAE/CAD) data flow. DNC = direct numerical control.

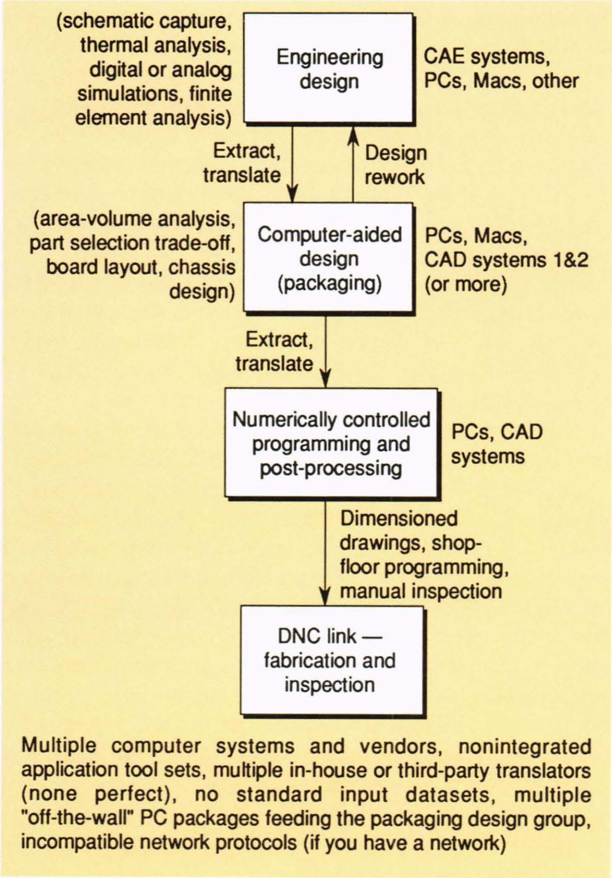


Figure 3. Realistic computer-aided engineering/computer-aided design (CAE/CAD) data flow. DNC = direct numerical control.

who do design/drafting work and return the results to APL. An initial effort is under way to standardize (where feasible) the data formats and physical media provided. Conversely, APL is sometimes required to deliver engineering design data to a sponsor in an electronic format, generally IGES, or a native CAE/CAD format.

Electronic deliverables will undoubtedly become more common for DoD contractors, because DoD has decreed that, for weapon systems entering production in 1990 and beyond, data from subcontractors (including business information and engineering documentation) will be in compliance with the CALS (computer-aided acquisition and logistic support) format.[12] Several military specifications are already in effect, notably MIL-STD-1840A (the parent specification), the MIL-STD 28000 series covering various specific topics, and MIL-HDBK-59 (the implementation guide). The CALS initiative has two planned phases. Phase I covers deliverables to the government; in Phase II, the government will require electronic access to the corporate/contractor databases developed to produce the delivered hardware.

The TEA Group is supporting the CALS initiative by participating in standards committee work and in the CALS test network, which is a confederation of Navy and subcontract organizations working on implementing the requirements of the pertinent specifications. To date, TEO can read and write a nine-track tape in the required MIL-1840A format, although the quality of the data extracted needs improvement. This poor data extraction goes back to the way the IGES standard, for example, has been supported by CAD system vendors. Each vendor has seemingly implemented a given logical construct (or entity) differently, so that a ruled surface may emerge as a plane, an annotation may disappear, or other vital information may be dropped in the translation into and out of the neutral format. Work will become intensive throughout the industry as the government deadlines approach for CALS compliance.

Meanwhile, the challenge for APL and TEA is to acquire or develop an appropriate (but finite) range of translation capabilities to ensure that a department engineer will be able to transfer his design database to fabrication without needing to rekey the information before packaging design. An initial matrix of the possible input and output system formats has been prepared, and the same matrix will be used to smooth the interactions with our program and project sponsors, as well as with APL design and drafting subcontractors. Given the diversity of engineering workstation hardware and software at APL, this is a major, continuing challenge. In fact, at times it is unclear to those documenting the possible combinations or writing translation software whether this diversity is a major strength (feature) of the APL environment or a bug flying in the face of rational systems integration.

NETWORK OPERATIONS

Network operations is the third leg of the TEA user-support triad. Personnel in this section try to make the various networked CAD/CAM and CAE tools as reliable and as available as possible. The section provides routine daily support for all CAD/CAE systems, typically including equipment maintenance, user help, new user installations, data archiving and backup, and disk space management. In addition, a significant amount of systems-level programming is done in the two Unix environments and in the HP-Apollo native operating system environment. In 1990, the operating system software on most of the CAE network workstations was reinstalled and reorganized into a standardized structure, true subnets with internet routing were established, and an uninterruptible power supply was added to critical user nodes in TEO. A major upgrade to CAD and CAE plotting was implemented with the addition of a 400-dot-per-inch color electrostatic plotter (Versatec model 3436) and its network-attached controller. Network attachment means that the plotter is no longer hard-wired to a specific CAD or CAE system, improving plotter availability dramatically. By May 1991, two network-attached plotters will be on-line. An interesting corollary to network attachment is availability of the plotter to APL at large via the Ethernet network. With HPGL or Calcomp 906/907 output from a PC-based CAD or project management package, in addition to site-licensed communications software, it is possible to obtain *E*-sized (34 in. high by 44 in. long) color output from any networked PC at APL.

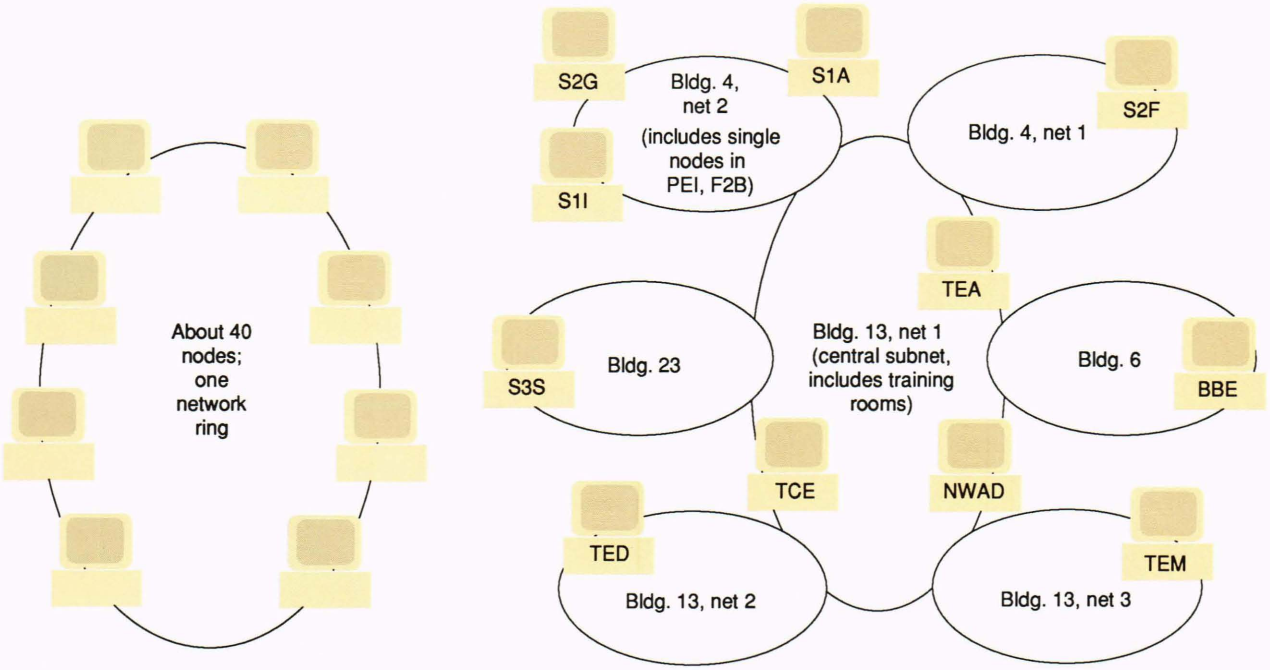
The operations section also provides support and development for a Novell-based local area network (called

TEOnet), which is used for electronic mail, TEO labor charge-back system support, data transfers throughout the branch, and tying the branch personal computers into the APL-wide network. Operations personnel provide necessary server administration and the occasional piece of new applications software. For example, working with the TEA applications programmers, the cc:Mail electronic mail package used in TEO has been tied to the APL-wide mail system and the world via a Unix gateway process and one of the HP-Apollo CAE workstations. The APL stockroom runs its carousel control software under the Novell operating system on a server configured by TEA and uses TEOnet to back up the server to the TEA MicroVAX (which runs Novell's Netware for VMS). Unix-based mail is being implemented on the Computervision workstations and standardized on the CAE network. The operations personnel are busy, because the combined systems user population now totals more than 300 and continues to grow as APL adopts more sophisticated design and fabrication technologies.

Figures 4 and 5 are simplified overviews of the CAE, CAD, and local area network physical plant that TEA supports. At the end of 1990, the CAE network had forty-four attached workstations and was expected to obtain three more in 1991. The TEO Branch uses thirty-five Computervision seats running CADDS4x mechanical and electrical design software (twenty CDS4000 Computervision seats with mechanical and electrical design software, and fifteen CADDStation seats with mechanical design applications, including solids modeling). Of these, ten of the CDS4000 seats will be replaced by May 1991 by five Sun SPARC (reduced-instruction set) workstations and five personal computers. By the end of 1991, essentially all the TEO personal computers should be on-line; all except about a dozen are, or will be, located in the Steven Muller Center for Advanced Technology.

Figure 4 shows the nominal CAE network topology, rearranged during 1990 (and continuing as required for new users in the future) into a subnet configuration to provide better support for local user work groups and improved network administration. Figure 5 shows the local area network arrangements on the first three floors of the Steven Muller Center; the network is standard thick Ethernet, supplemented by twisted-pair Localtalk trunks for Macintosh support. In addition, a Thin Net segment and a Localtalk passive star network were installed in the first-floor clean rooms. Their connection topologies will allow clean-room workers to add more computers easily without construction activities or the services of network personnel unfamiliar with clean-room requirements.

Each building floor has two independent Ethernet trunks, the second nominally reserved for future growth. On the third floor, however, both trunks are already being used, one as a dedicated CAD/CAE segment and the other for the administrative network traffic. The functional Ethernet segment on each floor is tied to a vertical riser trunk at the south end of the building through a routing gateway supplied by the Communications and



Nominal topology, January 1990
(rapid expansion in previous two years)

Nominal topology, January 1991
(continued growth, easier administration
and operational support)

Figure 4. Computer-aided engineering network topology. BBE = Engineering Group; F2B = Combat Systems Development Group; NWAD = Naval Warfare Analysis Department; PEI = Instrumentation Development and Operational Support Group; S1A = Computer Science and Technology Group; S1I = Space Sciences Instrumentation Group; S2F = Digital Flight Systems Group; S2G = Digital Ground Systems Group; S3S = Systems Integration and Test Group; TCE = Computer Engineering Group; TEA = Engineering Design Automation Group; TED = Engineering Design Group; TEM = Microelectronics Group.

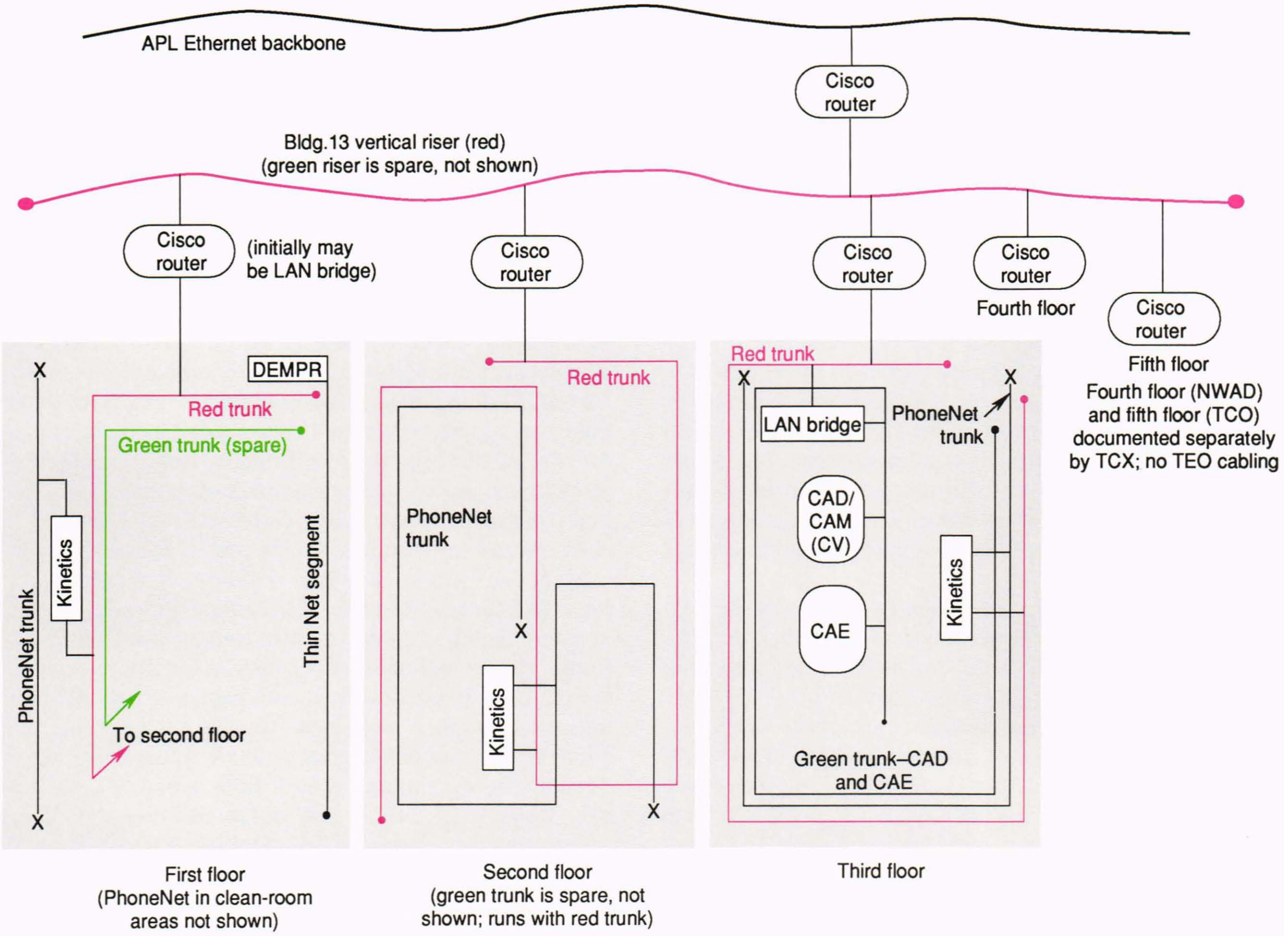


Figure 5. Network layout of the first three floors of the Steven Muller Center for Advanced Technology. Cisco = Cisco Systems, Inc. (a "Cisco box" is network jargon for an Ethernet multiprotocol routing/gateway device); CV = Computervision, a division of Prime Computer, Inc.; DEMPR = Digital Ethernet Multiport Repeater, an Ethernet multiplexer device from Digital Equipment Corp, Inc.; LAN = local area network; NWAD = Naval Warfare Analysis Department; TCO = Computing Branch Office; TCX = Communications and Networking Group; TEO = Engineering and Fabrication Branch.

Networking Group. The riser then ties to the APL-wide Ethernet backbone through a similar gateway. Network communications protocols currently supported in TEA include Transmission Control Internet Protocol, Digital Equipment Corporation network, Apollo token ring, Appletalk, Xerox Network Specification, and Internetwork Packet Exchange/Sequenced Packet Exchange. These are generated by eight different computer operating systems. Future enhancements will focus on updating network operating systems (to include minimizing the diversity of both protocols and operating systems), improving network applications and the user interfaces for them, and rearranging the Localtalk trunks configuration into a star-like configuration (with many branches radiating from a central area) that would support more devices and improve network management.

SUMMARY

The TEO Branch is a major contributor to, or the facilitator for, many hardware design projects and thus has a vested interest in the correct and proper use of upstream CAD and CAE tools. For example, when an electrical engineer fails to simulate (or simulates incorrectly) a circuit, the probability of the design being iterated twice or more during subsequent TEO packaging design and hardware fabrication increases significantly. Because the TEO effort typically occurs at the end of a program/project, each iteration can greatly influence the cost or schedule. Even minor delays can result in high, unplanned program/project personnel costs while other APL engineers wait for equipment for test or integration. One principal TEA goal, and a long-term challenge, is to minimize such situations by providing up-front familiarization training and support for design and engineering staff in the powerful CAD and CAE applications used in TEO (and on the CAE network), and in the various ways designs can be moved most effectively into and through the TEO CAE/CAD/CAM environments.

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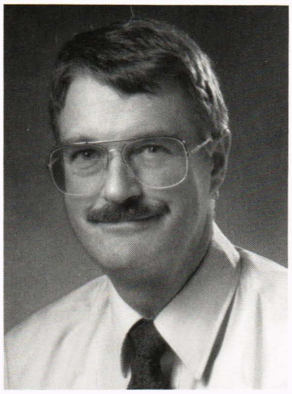
THE AUTHORS



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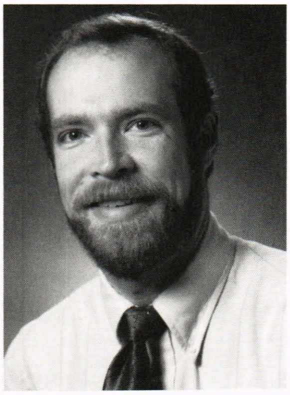

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