Appendix

Appendix A

Selected Case Studies: Summaries

The following section includes summaries of five case studies of instructional programs designed to develop skills that are presently associated with the use of programmable automation (PA). These five are part of a group of 14 such studies developed for OTA. Instructional activities described in the case studies summarized here include: 1) a robotics and computer-aided drafting program for high school students, operated by the Oakland County School System in southeastern Michigan; 2) the undergraduate and graduate degree programs in Engineering Technology offered by Brigham Young University, Provo, Utah; 3) CADAM Inc. 's* customer training in computer-aided design; 4) the International Brotherhood of Electrical Workers' programmable controller training system; and 5) the "CAD/CAM" operator training program based in Glendale, Calif. (representative of efforts characterized by strong industry, education, and government cooperation). The five studies were selected for inclusion to illustrate PA-related instruction of various types and levels of sophistication, as well as to highlight programs operating in different geographic areas,

case Study Research Methodology

Case study research began in July 1982 and ended in June 1983. The initial objective of the research project was to identify and contact a selected sample of institutions, organizations, and agencies known to offer or have the potential to offer programs designed to prepare individuals for jobs in computer-automated factory environments. Approximately 300 individuals representing industry, educational institutions, government agencies, professional associations, training and/or education associations, technical societies, and community organizations were contacted in the first stage of the research. This was augmented by a literature search. A sample of 100 training or education programs was identified, from which 20 were chosen to be the subjects of 14 case studies.

The following selection criteria were developed:

- *Gegraphical spread. — Programs* were chosen from all four quadrants of the country, with a concentration of four programs from the heavily industrialized areas of southeastern Michigan.
- *Instruction~ deliverers.* —The case studies include programs operated by primary schools, high schools, community colleges, universities, and 4-year colleges, a union/management-operated training center, and industries that produce and use PA equipment.
- *Type of programmable automation training.*—Programs chosen provide instruction in computer-aided drafting and design systems, robots, programmable controllers, computerized numerically controlled machines, automated vision systems for factory inspection, automated materials-handling systems, specialized semiconductor fabrication equipment, and CAD and CAM networking systems. In addition, university programs addressing the systems approach to computer-integrated manufacturing education, plus in-plant programs stressing the systems approach for managers, are included.
- *occupational categories of trainess–Programs* covered in the case study series address the needs of current or potential personnel in the following occupational categories: machine operators; electrical, mechanical, and other maintenance personnel; welders; electrical and electronics technicians; robotics technicians; mechanical designers and detailers; printed circuit designers; electrical drafters and designers; numerical control programmers; general-purpose programmers; integrated circuit designers; piping designers and drafters; manufacturing engineers; design engineers; systems engineers; research and development personnel; shop-floor supervisors; managers; and executives.
- *Size of institution or organization.—Companies* included range in size from firms employing under 170 individuals to multinational corporations employing hundreds of thousands of people. In terms of the size of the organization served by a single training division, the largest is 42,000. The educational institutions range in size from 2,500 to 34,000 students.
- *Funding source.* –Both public and private institutions and organizations are covered. Major public funding sources include Federal, State, and local government organizations.

*C AI)A M Inc. is a subsidiary of the Lockheed Corp.

The union/management-sponsored training program is supported by regular contributions from union members and by management subsidy.

Industrial sector. — Programs covered addressed the following industrial sectors: transportation equipment (including auto and commercial aircraft); electrical and electronic devices and machinery; nonelectrical machinery; and programmable equipment producers. Attempts were also made to identify successful programs in the metalworking industry.

Additionally, some programs were chosen because they demonstrated cooperation among educational institutions, industries, and (in one instance) State and local government participation. Two questionnaires-one for companies and one for educational institutions-were designed for use during onsite interviews (lasting 2 to 5 days each) conducted for each case study.

Case Study 1
Oakland County Vocational Education Centers: Robotics and Computer-Aided Drafting For High School Students

Background/Summary

The Oakland County Intermediate School District covers approximately 900 square miles to the north and west of Detroit. The intermediate district is comprised of 28 constituent school districts and includes most of Oakland County and small proportions of the adjacent counties of Macomb, Wayne, Livingston, Tenessee, Lapeer, and Washtenaw.* The approximately 211,000 children in the district live in communities of widely disparate economic status: some are among the wealthiest in the country, while others have disproportionate numbers of families on State and Federal aid.** In 1982, Pontiac, the largest constituent school district, had an unemployment rate of over 20 percent.

In 1967, voters in the intermediate district passed a half-mill levy to pay the construction costs for four area vocational education centers, one in each quarter of the county. The four centers—operated under contract to Oakland Schools by the constituent districts of Pontiac, Royal Oak, Walled Lake, and Clarkston-offer programs in 32 occupational areas. Three 2½ hour sessions—morning, early afternoon, and late afternoon—are offered for high school students, who spend the remainder of their school day at the "home' high schools; and the centers all operate evening classes for adults. The flexible vocational instruction offered at the centers complements the vocational education provided at high schools that operate individual vocational programs. The centers also provide basic-through-advanced instruction for students from schools that have no vocational programs of their own. Students who participate in a full 2-year course of study at a center get 900 hours of combined classroom and laboratory instruction in a specific vocational area.***

*This is Oakland Schools, a brochure published by the Oakland Intermediate District, explains that "in Michigan, every local school district is a part of an intermediate district; there is no exempt territory. The intermediate school district is a regional educational service agency created by State law to carry out certain legal functions at the direction of the State Department of Education,

** This is Oaklans and Schools.

***The number of hours in vocational education curricula is mandated by the State and is comparable to that offered in comprehensive high schools.

Oakland Schools also provides an additional aid to vocational progaming in both the local districts and the regional centers: curriculum specialists on the vocational education staff at the Oakland County Service Center assist instructors in applying current instructional technology, in keeping program content up to date, in obtaining funds and equipment, and in maintaining contact with local industries.

In the summer of 1982, the Pontiac Center offered a special 4-week introductory robotics program for incoming juniors and seniors. The intensive 64-hour course was a demonstration program designed to test the feasibility of teaching robotics and other "high tech" courses in the centers' regular school-year and summer offerings. As a result of the successful summer program, robotics and computer-aided drafting are now taught in a number of regular courses in three of the area centers.

The centers have approached the teaching of integrated manufacturing skill in a variety of ways: 1) teachers at the Pontiac Center have designed a semester-long course in robotics offered for the first time in January 1983; 2) the Royal Oak Center has obtained two computer-aided drafting stations for use in mechanical and architectural drafting courses, and instructors there are using homemade robots to teach basic robotics principles in fluid power and electronics courses; and 3) the Walled Lake Center also has a CAD system for use in its drafting program, and instructors are now using the Mini-Mover "teach robot"* from the Pontiac summer course to teach electronics, welding, industrial design and machine-shop students the fundamentals of robotics as these relate to the students' core disciplines.

Summer Robotics Program North East Oakland Vocational Education Center (Pontiac, Mich.)

Planning and Development.–The summer robotics demonstration program was conceived during an informal conversation between a vocational

*Teach-robots are miniature, table-top electric robots useful for teaching programing and robot motions.

education curriculum specialist from Oakland Schools Service Center and the principal of the Pontiac Vocational Education Center. Although the amount of time from initial conception (March 1982) to approval by the Oakland Schools' superintendent's committee (June 2, 1982) to program implementation (June 28) was short, the preplanning which enabled Oakland instructors, curriculum specialists, and administrators to create the program on such short notice had been going on for the past 10 years.

The preplanning began not with robotics itself but with an ad-hoc group of instructors and curriculum specialists meeting informally to explore the utilization of computer technology in the classroom. Five years ago, the computer group began preparing for robotics and other industrial applications of computer technology by making-and maintaining g—industrial contacts, expanding their working knowledge of microcomputers and programmable controllers, and familiarizing themselves with robotics. All this, according to the curriculum specialist who spearheaded the group, was done in anticipation of the time when robotics would be recognized as a suitable subject for high school vocational education.

Because of the necessity of waiting for the proper moment when public interest in robotics would be high enough to encourage the Oakland Schools' superintendents' committee to pass on such a program proposal, the preplanningg was necessarily informal. The years of informal planning, however, proved to be productive; when the board's approval was received in the beginning of June, the computer-group members were able to bring together a team of teachers with expertise in electronics, physics, machining, and computer programing who both devised the curriculum and delivered the instruction. The Service Center curriculum specialist and the Pontiac Center principal bought some equipment and contacted industrial representatives who donated or loaned the remainder and–with the help of the instructors-arranged for field trips to local user and producer firms and for guest lectures by application engineers, sociologists and others.

Goals.–The program was designed to meet two sets of objectives. The immediate instructional objectives were to familiarize the students with the fundamentals of robotics to help them make future career and educational decisions, and to increase their awareness of and interest in high technology in general. The long-range goals were: 1) to develop, implement, and make necessary modifications to the curricular materials with the object of providing them to secondary and postsecondary educational institutions offering robotics instruction; 2) to develop a core of people within the public educational system with knowledge of robotics; and 3) to demonstrate that a public educational organization is capable of initiating robotics programs in a timely fashion.

Administrative and Instructional Staff.–The summer program staff consisted of two administrators, five teachers, and three student programing aides. The chief administrator for the program, the principal of the Pontiac Center, was responsible for student enrollment, obtaining the equipment, arranging for the students to receive academic credit, and other administrative requirements; the Oakland Schools Service Center curriculum specialist coordinated all curricular activities. The team of five instructors developed the instructional materials and designed and delivered the coursework; and the student aides (two college students and one high school senior) were on hand to help with programing and writing software for the Apple computers used to interface with the small teach robots used in the course. All of the instructors had a minimum of 2,000 hours of industrial experience,' two were members of the Education Committee of Robotics International of the Society of Manufacturing Engineers, and some had experience teaching and writing curricula for colleges and other post-secondary institutions.

Facilities and Equipment. -Classes were held in a large classroom-laboratory in the Pontiac Center. Equipment used in the program included four desk-top teach robots (two of which were purchased, two of which were borrowed from distributors), six Apple computers, three cathode ray terminals (CRTs), two DEC writers (strike-on terminals) and electrical and electronic test equipment.

Student Selection.–Because approval for the program was received at the end of the regular school year (June 2), student selection procedures were highly informal. The program administrators discussed the program with the guidance counselors in all of the high schools served by the Pontiac Center. By the time the board's approval was announced, however, most of the high schools had started their final examination periods or had released their students for the summer. Schools in two large districts, Pontiac and Rochester, responded by announcing the program over their public address systems, requesting that all interested sophomores and juniors apply. Fifteen of the sixteen applicants were selected, and all but one completed the 4-week course. Interviewers looked for college-bound students with strong math and physics backgrounds and with some experience in electronics and/or computers. Approximately 75 percent of the applicants had the recommended background knowledge; the remainder of those admitted were chosen because of their high level of interest in the program. Of the 14 students who completed the program, one was female and one was from a minority group.

Curriculum. -Classroom and laboratory instruction was complemented by field trips to Pontiac Motors, ASEA's midwest robot facility, and a local robotics show. Students also heard guest lectures by industrial representatives from Pontiac Motor Division, ASEA, ETON Corp., and the Kasper Machine Co., and by two sociologists who talked about the social implications of robotics. The following topic areas were covered in lectures and reinforced by field trips, demonstrations, and laboratory experiments:

- *History and classification—Factors* influencing the growth of robotics in industry; manufacturing processes in which robots are utilized; definition and description of robots and their component parts; robot classifications (nonservo, point-to-point servo- controlled, and continuous-path servo-controlled); description of commercially available robots; and the potential areas of growth in robotics.
- *Simple machine process and robot terminolo*gy-Description of simple machine functions and the relationship between robot design-and-function terminology and the basic terminology of machine design.
- *Basics of electricity and motor operation control—An* introduction to selected fundamentals of electricity and electronics, specifically DC power distribution and simple DC circuits. Students learned to use basic instruments to monitor electrical power and to locate malfunctioning segments.
- *Microcomputer operation and programing–* Lectures and demonstrations of computer operation and practical experience in computer programing.
- *Robotic drive* systems-A segment in which students learned how to address the teach robots with standard computer programs and prepared specific programs for robot operation.
- *Robot applications-Review* of manufacturing operations related to robot applications and field trips to design and manufacturing facilities.
- *Opportunities in* robotics—Examination of the employment opportunities in the field of robotics; requirements of various job classifications as they relate to the individual's development of skills and academic knowledge.

Had the superintendent's committee approval been received earlier, the instructors would have attempted to add another 2-week segment covering pneumatics and hydraulics. Lack of time and difficulty in obtaining equipment, however, made this impossible.

Instructional Methods and Materials.–The choice of a team-teaching approach was dictated by the interdisciplinary nature of robotics itself and also by necessity—no one teacher in the Oakland system had all of the background knowledge and skills required to teach the full 4-week program. However, the team of instructors worked well together, and each individual member of the team enhanced his own knowledge of related fields while imparting his particular expertise to the students. The lead instructor–who was on hand at all times to teach specific class segments, guide the students through experiments, and to provide continuity as the course moved from segment to segment—was an electricity instructor employed full-time at the Pontiac Center. Industrial representatives taught the basics of robotics; a physics instructor taught the unit on simple machine processes and aided the students as they conducted physics experiments; an electronics instructor from the Walled Lake Center taught the segments on electricity and electronics; and a programing instructor from another intermediary district taught the basics of programing.

The first 2 days of the program consisted of introductory lectures, films, demonstrations, and a field trip to Pontiac Motors, where the students saw industrial robots in operation and visited the robotics training laboratory. From the third day through the end of the course, the majority of classtime was spent in practical laboratory work, progressing from experiments in basic physics and electricity through robot programing. Because of the limited time available for each segment and the students' impatience with lengthy explanations of a theoretical nature, the instructors had to condense all of the material and be highly selective in the presentation of some of the topics. The necessity to condense and select was most challenging in the 3-day electricity/electronics segment which, after an introductory lecture in basic electricity and the importance of electronics to the study of robotics, concentrated on DC power distribution and simple DC circuits.

As in the other segments of the course, the object in the electricity segment was to familiarize the students with some of the basic concepts and–most importantly-to whet their interest and encourage them to pursue studies providing them with more complete knowledge of the disciplines making up robotics.

The instructors also worked as a team to develop the curriculum and written materials for the course. Since no texts, manuals, or experiments appropriate to secondary-level teaching were available, the instructors-aided by the curriculum specialist and by experts from industry—developed laboratory manuals, experiments, a robotics glossary, and handouts defining and describing robot functions, components, and classifications. In addition, the instructors developed computer software for use by the students in programing experiments.

Student Evaluations of the Program.– In written evaluations, most students noted that they had enjoyed the class. The majority were impressed by the team-teaching approach and the opportunities for individualized instruction. A number stated that they intended to pursue robotics studies and some claimed that the course helped them to decide on a future career in robotics. Some students noted the lack of training in hydraulics and suggested that it should be included were the course to be repeated. The other criticism received was from two students who felt that the electricity segment was too theoretical.

The instructors are now considering methods of dealing with the electronics segment in future familiarization courses. Suggestions include: 1) placing the segment later in the course when students would be better able to understand its relevance; 2) making provisions for a supplemental class for those with no background in basic electricity; and 3) teaching electronics as it applies to robotics, rather than beginning with pure electricity / electronics.

All of those who completed the course received a half unit of credit, which was entered on their high school transcripts (one credit equals a full semester-long course).

Relationships With Industry.–1n the spring of 1982, program administrators and members of the instructional team met with General Motors (GM) representatives from the Orion Plant (a new facility with over 160 robots, which, at the time, was under construction) and from Pontiac Motor Division to determine the feasibility and appropriateness of offering robotics on the secondary level. The GM representatives and other industrial contacts agreed that introductory courses in robotics on the secondary level would not only benefit the students by providing them with an orientation to the field, but benefit industry by raising public awareness and student interest.

These industrial contacts, made in the preproposal stage of the program, also proved to be fruitful in the curriculum planning and program operation stages. The Pontiac Motors representative not only worked with the instructors to develop the curriculum, but delivered the introductory lecture to the first class and arranged for a field trip to the Pontiac plant. Other industrial representatives from firms that produce, distribute, and use automated machinery donated time and equipment to the program. While no formal industrial advisory committee was established before the summer program was offered, the curriculum specialist who helped administer the program (who is also the vocational/technical coordinator for the Oakland district) has set up an informal committee to provide advice on present and future programs and coursework.

Relationships With Labor Unions.–Local labor unions were not involved in the summer program, primarily because school officials looked on the summer course as a test case which would help them to develop prototype curricular materials which, they felt, were needed before asking for union advice or participation. Before the downturn in the area economy, local labor and company officials actively recruited students from the vocational education centers in the district, so that school representatives believe that union participation in an advisory capacity would be appropriate for computer-aided manufacturing coursework. Vocational education representatives are now making informal contacts with union shopworkers and hope to increase the level of contact with local unions in the near future.

Results.–Apart from achieving its objective of providing the participating students with an orientation to robotics, the summer program had a number of other salutary results. As one of the country's first robotics programs on the secondary level, it generated a great deal of public interest and received coverage in local newspapers, on local television stations, and in publications like the *Manpower and Vocational Education Weekly* and publications of the American Vocational Association. This positive publicity not only helped to convince school board officials of the viability of high school programs in robotics and other high-technology areas, but generated the beginnings of a communications network between Oakland Schools and other high schools both in- and out-of-State. The vocational education curriculum specialist who coordinated the program has received over 60 letters and calls from high schools, colleges, universities, and industries from across the country, all of which are either interested in establishing programs or have already done so. The local publicity also increased student interest in other programs offered by the centers, The Pontiac Center, for example, attributes an increase in enrollment for its electricity course to interest engendered by the robotics program. Enrollment increased from 35 in fall 1981 to 50 (capacity enrollment for two sections) in fall 1982.

Another result of the program can be seen in the current offerings of three of the Oakland vocational education centers (discussed in sec. II) and in a number of local high schools in the constituent districts served by the centers. The equipment purchased for the summer program is now in use in two of the centers. Most of the instructors who participated in the program brought robotics into their regular school-year classes (either as a segment in existing courses or as a free-standing, semester-long course) in the centers or in local high schools; and other instructors in the centers are now offering or planning to offer coursework in robotics or computer-aided design. The summer program also helped Oakland School officials to set up an articulation process with local private schools, community colleges, universities, and three industrial robotics programs.

The district is setting up a formal articulation agreement with nearby Oakland Community College whereby students who take robotics coursework in the Oakland Schools will receive advanced standing in the college's robotics program. The articulation process with the other schools and programs is, to date, informal. Other tangible results include the curricular and instructional material developed by the summer instructors-manuals, instructional units (both lectures and experiments), computer software designed for student use, the robotics glossary, and a study analyzing the reading level required for currently available robotics texts. These materials, and the experience gained in developing them, are now being put to use in classroom and laboratories throughout the district and will be refined and expanded in the immediate future.

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Case Study 2
Brigham Young University: The Education of Technologists

Summary/Background

The College of Engineering and Technology.– Brigham Young University (BYU)–with a main campus in Provo, Utah, and a campus in Hawaii—is the largest private university in the United States. Founded in 1875 as the Brigham Young Academy, an elementary school with 29 students, BYU currently has an enrollment of approximately 28,000 at its Provo campus and over 1,800 in Hawaii. While its primary intent is to provide undergraduate education, BYU does maintain a number of graduate programs on the master's and doctoral levels which have a combined graduate enrollment of 2,890.

Brigham Young University's College of Engineering and Technology has a total enrollment of approximately 3,400 students working on undergraduate and graduate degrees in six departments: chemical engineering, civil engineering, electrical engineering, mechanical engineering, industrial education, and technology. The four engineering departments offer traditionally structured undergraduate engineering programs and masters- and Ph. D.-level graduate degrees. The technology department offers three programs leading to the baccalaureate degree (manufacturing engineering technology, design engineering technology, and electronics engineering technology), and a master's program in computer-integrated manufacturing with program options in computer-aided manufacturing (CAM) and computer-aided design (CAD), and elective courses in computer-aided testing (CAT). In the fall semester of 1983, the technology department began to offer a graduate program leading to the degree of master of technology management.

Engineering Technology.–In 1967, BYU became the first educational institution in the country to receive accreditation from the Engineers Council for Professional Development (now known as the Accreditation Board for Engineering and Technology, or ABET) for its baccalaureate programs in manufacturing engineering technology and design engineering technology. In 1971, BYU'S B.S. program in electronics engineering technology was also accredited by ABET.

While engineering technology is closely related to engineering-and while the education of engineers and technologists overlaps in many areas—there are significant differences between the two disciplines. BYU'S College of Engineering and Technology offers the following definitions which clarify the distinctions:

- *Engineering* is the profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize economically the materials and forces of nature for the benefit of mankind.
- Technology is that part of the technological field which requires-the application of scientific and engineering knowledge and methods combined with technical skills in support of engineering activities; it occupies a position on the occupational spectrum between the craftsman and the engineer at the end of the spectrum closest to the engineer.[1]

Technologists, in essence, are applied engineers. This may at first seem to be a misnomer, since engineering is traditionally considered to be an applied discipline. However, a brief overview of developments in engineering education in the United States over the past 25 years clarifies the issue. When the U.S. space program began in the late 1950's and early 1960's, engineering schools began responding to the increased need for science-oriented courses by adding advanced courses in mathematics, physics, and chemistry to their curricula. In the process, traditional engineering laboratory courses in drafting, machining, and processing were dropped out of the curricula to make room for the more theoretical courses required to meet the needs of sophisticated space-age technology. As technical knowledge and applications multiplied, the gap spread between engineers, whose education was becoming increasingly theoretical, and technicians engaged in manufacturing and design occupations, Baccalaureate technology programs (some began as 2-year technician programs, while others were originally designed as 4-year pro-

[1]Brochure, College of Engineering Sciences and Technology, p. 9

grams) were created to bridge the occupational gap between the engineer and the technician.

According to BYU representatives, it is no longer possible for one person to master the skills and knowledge required to cover the spectrum from conceptualization to the manufacture of a final product. Now, the idea for a product often originates with marketing, engineering, or management; the engineers and technologists work as a team to develop the layout and detailed design and to test the prototype product. The technologist and engineer work together to plan, design, and test the machines or procedures for building a system or its components, and then the craftsmen and machine operators bring about the actual production. * In terms of theoretical orientation, the progression goes from abstract at the design research engineer's end, to highly practical at the technician's and craftsman's end. While the engineer, then, may be interested in why a system, product, or procedure performs so that he/she can create plans or designs, the technologist is concerned with how that system, product, or procedure performs so that the engineering plans can be applied in practice and are implemented in the most productive manner.

Engineering Technology Programs at BYU.– BYU'S Technology Department has gained national prominence, especially among industrial employers, many of whom say that the technology graduates have precisely those skills most in demand by firms implementing computer-aided manufacturing, design, and applied electronics procedures. Created with industrial needs in mind, the technology programs at BYU were quick to incorporate computer-aided techniques and machinery. In the early 1970's, individual faculty members in the manufacturing and design programs began exploring ways of acquiring computer-aided equipment to enable them to integrate CAD and CAM into the undergraduate curricula, and they initiated a number of research projects. In addition, data communications and real-time computer control were developed.

One research project used group technology classifications to create what has now evolved into DCLASS-a computer program that classifies, organizes, and retrieves information to assist in process planning, material selection, circuit design, generation of time staildards, and other industrial applications. DC0LASS is now licensed by 20 companies for use in 50 plants, and revenues received from the sale of DCLASS licenses help to support continuing research into computer-aided manufacturing by BYU faculty and students. In 1977, the technology department instituted a master of science degree program in computer-aided manufacturing; the program has expanded over the years to encompass computer-aided design and computer-aided electronics testing and is now known as the Computer Integrated Manufacturing Program. The masters program and the undergraduate programs in manufacturing engineering technology and design engineering technology are the primary subjects of this study. *

In recent years, BYU'S traditional engineering departments have been building their capacity in what they refer to as computer-assisted engineering* and have *joined* with the technology department to form the Computer Assisted Design, Engineering, and Manufacturing (CADEM) Committee to coordinate the use of computers within the College of Engineering and Technology and to increase communication and cooperation between departments.

Engineering Technology: Education and Research Activities

A common misperception by outside observers—including a number of BYU faculty and students outside the technology department-is that the department offers undergraduate programs in computer-aided design and manufacturing. Actually, however, while computer-aided methodologies and techniques are incorporated into the curricula of the three technology programs whenever appropriate, the programs themselves focus on providing students with a strong foundation in the basics of the three disciplines– design, manufacturing, and electronics–augmented by computer techniques currently in use in industry. It is at the master's level that the technology programs focus solidly on computer-aided manufacturing and design.

The incorporation of computer-aided techniques and coursework into the undergraduate curricula

*The Accreditation Board for Engineering and Technology (ABET) also recognizes the necessity of engineers and technologists working together as a team in industrial projects. According to ABET representatives, it is for this reason that over 700 associate and bachelor level technology programs have been accredited since the 1960's.

*The electronics technology program currently lags behind the other two technology programs in incorporating computer-aided techniques. This parallels the relative lag of industry in computer-aided electronic testing. This program will therefore receive less attention in the present study,

** Computer-assisted engineering (CAE) is defined by BYL engineering faculty as "the application of computers to the whole range of calculation and simulation tasks needed for modern professional engineering, including finite element analysis and routines for optimization, linkage synthesis graphics, and numerical utility.

varies from program to program-reflecting 1) current industrial practices in the three disciplines; 2) the varying amount of conventional manufacturing and design skills required by the different disciplines; and 3) the availability of industrial equipment. Thus, the design curriculum is most suffused with computer-aided techniques and applications both because of the large amount of CAD equipment in the department and because of the rapid spread of computer-aided design in industrial settings.

The manufacturing program, while it is provided with well-equipped labs, stresses conventional manufacturing techniques for the first 3 years of study to provide the foundation for the advanced computer-aided manufacturing techniques and applications taught in senior and graduate-level classes. The electronics program is the least involved in computer-aided applications-a reflection of the relatively late development of computer-aided testing (CAT) technology and difficulty in obtaining CAT and process instrumentation equipment.

Undergraduate Programs: Common Features.–

Goals.- The particular goals and objectives of individual programs are discussed in the program descriptions. The technology department as a whole, however, has identified a number of goals which have a significant general impact on the curricula and instruction in all of the programs. Some general goals are to "educate the 'whole person' " by requiring students to take a broad variety of general education courses and to instill in the students a recognition of the necessity of "life-long learning. " While life-long learning is, in the most basic sense, the responsibility of the individual, the graduate who stops learning rapidly becomes obsolete when he or she leaves school and enters a technical field. For this reason, the technology faculty places major emphasis on bolstering the students' commitments to learn how to learn on their own; to keep themselves apprised of new developments in their professional fields; and to continually update their skills and knowledge.

Faculty. -Two distinguishing features mark the members of the technology faculty. First, all have had significant industrial experience in their instructional fields. That experience ranges from a minimum of 3 to 5 years in industry to a maximum of 10 or more years. Second, while industrial experience is required of the faculty, doctoral degrees are not required. Of the 16 full-time faculty members, 6 have doctoral degrees and the remainder have masters' degrees in technology or engineering. Although the department actively encourages its faculty to engage in research and to publish the results, that research is often of a practical and applications-oriented nature.

Teaching Methods and Materials. -All of the technology programs emphasize practical experimentation and application of the theoretical material taught in the classroom. The programs require that approximately 50 percent of the students' time be spent in laboratory work. Comments by both students and faculty, however, indicate that many students spend more than the required amount of time in the laboratories, so that the ratio of lab work to class work may actually be higher than one-to-one. Another instructional method in the department is the assignment of actual industrial projects to undergraduate students. Instructors on the design faculty, for example, are frequently requested to use the school's CAD equipment to perform benchmark studies of company drawings to help them determine the efficiency of a CAD system for the company's particular purposes. The studies themselves are assigned as projects to upper-division design students, who thereby gain actual industrial experience.

Other advanced students participate in similarly practical research projects conducted or coordinated by department faculty. Several technology faculty members are now working on computer-aided learning techniques and instructional systems, one of which-the Computer Aided Simulation Training System (CAST)–is being developed for use in both industrial and educational manufacturing programs. When the CAST project is completed, the learning package will contain a total of 300 learning modules—each providing instruction on a specific manufacturing process. As these modules are developed, they are incorporated into the manufacturing curricula at BYU.

One problem facing the department is the unavailability of appropriate textbooks in the CAD, CAM, and applied electronics areas. Since textbooks on technology quickly become outdated, the department is continually looking for other ways of supplying students with written material. A "Group Technology Collection" has been established in the university library to give students access to the growing number of reports and articles on productivity, manufacturing processes, and new developments in hardware, software, computerized data bases, and other topics. In addition, copies of monographs discussing current topics in manufacturing and design are reproduced and distributed to students for their personal collections. Another "library" resource, although not textual, is a growing "parts library" containing a collection of manufactured parts, which are used in the classroom to illustrate the end-products of the manufacturing processes being studied.

Enrollment Trends. –Enrollment in technology department programs has tripled in the last 3 years. Currently, there are just under 1,000 students enrolled in the three undergraduate programs: approximately 210 in manufacturing, 220 in electronics, and over 550 in design. This poses a problem for the department and the university in that even the new facility will only be capable of accommodating 900 students. Consequently, a policy of "enrollment control" has been introduced on a university-wide basis. Since enrollments in all of the technology programs are increasing, and the manufacturing and electronics programs are expected to reach enrollments of up to 300 each within the next 5 years, the design program enrollment will be gradually reduced over the coming years. Of the approximately 1,000 students, fewer than 50 are women, and most of them are enrolled in the design program. * More detailed discussion of enrollment trends can be found in the program descriptions,

Cooperative Education.– The College of Engineering and Technology operates an active cooperative education program which gives students the opportunity to integrate their academic studies with periods of work experience. Some of the traditional engineering departments tend to discourage students from entering the cooperative education (co-op) program by structuring the curriculum into a lock-step sequence which creates difficulties for students who spend time off-campus.

The technology department, on the other hand, actively encourages its students to take advantage of the co-op program. Approximately 45 percent of the 128 students enrolled in the college's co-op program in 1981-82 were technology students who worked at such firms as Boeing, GE, General Dynamics, Ford Aerospace, Honeywell, Eaton-Kenway, and Westinghouse. Aside from the obvious advantage of obtaining practical experience to supplement academic knowledge and laboratory skills, a large number of technology students have the additional advantage of discovering through experience whether or not they want to accept the permanent job offers they usually receive from the co-op employers.

Ironically, the success of the co-op program has created a problem for the department in that a number of employers have tried to convince their co-op students to stay on with the firm rather than return to school to complete their degrees. Another problem, which is somewhat limiting to some technology students, is the geographical isolation of the Provo campus and the consequent necessity for over half of the co-op students to relocate temporarily to accept out-of-state employment.

Furthermore, a large number of BYU undergraduates are married-many with young families. These students, especially, find it difficult to accept an out-of-state co-op assignment. For these and other reasons—including competition from o" the downward trend in the economy (w used a number of firms to discontinue the programs), and increasing pressure on the university to turn out graduates-the co-op program has tapered off in recent years from a peak of 285 students in 1979-80 to 128 in 1980-82. Nevertheless, it still receives the support of the college and the active participation of technology students.

Counseling and Career Guidance.–The university counseling center offers both group and individual counseling for students with personal or academic problems, and the engineering college advisement center provides specific advice on engineering and technology programs. The university also has a career education program that provides the following services: 1) courses on life planning and decisionmaking, career exploration, and employment strategies; 2) interest testing; and 3) academic and occupational counseling.

In spite of all of these formal counseling and guidance channels, some technology faculty members feel that a great deal of the students' time and money is wasted because they do not receive comprehensive interest- and ability-testing when they are admitted to the university. This lack is felt most keenly in the technology department, where a major portion of the undergraduates are transfer students from other colleges and departments. Although some of these students discover the technology department through regular counseling channels, the vast majority learn of the department and the content of its curricula almost by accident—through friends, chance conversations, or parties outside the University.

•In recent years, BYU has been actively encouraging "equal opportunity and rights for women students. " According to the technology department chairman, women who graduate from any of the department programs will have an excellent chance of being hired because of equal employment opportunity programs. While the number of women in the design program is growing, many women drop out of the manufacturing program Technology department faculty say that this is primarily because a number of women are uncomfortable with manufacturing laboratory work.

Manufacturing Engineering Technology .–Like its sister program in design technology, the manufacturing technology program was organized in 1960 and accredited by what is now known as ABET in 1967. The program was constructed in such a way that, over the years, it has been able to accommodate the industrial trend toward computer-assisted processes and equipment without significantly altering its original focus. At the same time, the program has been refined over the years to minimize duplication, improve the course sequence, establish meaningful prerequisites, and give students flexibility in choosing areas of concentration.

Both the instructional program and the major research projects of the faculty and students are characterized by a highly systematic approach. That approach relies on the following:

- Definition of the subject matter (in this case manufacturing), its essential elements, and the activities involved;
- *Identification* of the need for a program in manufacturing technology and the processes and approaches to be employed to meet that need; and
- *Classification* of the processes and components of manufacturing to form the basis_ of a systematic approach to teaching and research. The notion of classification as employed by the manufacturing faculty rests on the following description: "Classification not only assists the memory by arranging individual items into groups, but also expresses a relationship of things and leads to the discovery of their laws."[2] BYU'S approach is based on an attempt to discover the laws governing manufacturing-including economic laws, laws of physics, metallurgy, control systems, etc.—define them, and teach them to the students.

BYU bases its manufacturing curriculum on a broad definition which encompasses the total manufacturing enterprise: "the series of interrelated activities and operations that involve product design, planning, producing, materials acquisition and control, quality assurance, management and marketing of discrete consumer and producer goods. " Manufacturing activities are classified into nine categories: product design activity, marketing, management, material control, manufacturing engineering, finances and personnel, production, and quality assurance. While the curriculum at BYU focuses primarily on one of those activities—manufacturing engineering-it also attempts to provide a background in the others.

To create the manufacturing curriculum, faculty members drew on their own industrial experience, informal industrial contacts, and a number of formal surveys and studies to assess industrial need, opinions of manufacturing educators, and requirements of accreditation agencies. After an exhaustive evaluation of the manufacturing discipline, the faculty found that the major factor distinguishing manufacturing engineers from those in other disciplines is the ability to do manufacturing planning and estimating. That ability, in turn, is built on knowledge of materials and metallurgy, production tooling, quality assurance, production information and control systems, plant layout and material handling, manufacturing systems and management.

The core courses developed to form the basis of the manufacturing technology curriculum are, therefore, those which develop the skills and knowledge required for manufacturing planning and estimating. * These are supplemented by special education courses in economics, mathematics, statistics and computer science, physical science, and electronics and design technology which provide the students with basic knowledge of other manufacturing activities related to their discipline. Also required are general and liberal education courses.

Program Goals and Objectives. -–The two major goals of the manufacturing engineering technology program are: 1) to give the students opportunities for individual development; and 2) to prepare them with the latest knowledge and skills needed to lead or supervise personnel engaged in manufacturing operations, and to help in the development of new products and processes.** To achieve those goals, students are provided with theoretical instruction linked to extensive application experience. The core coursework is planned around eight specific areas of study which correspond to the requirements for manufacturing planning and estimating

[2]Dr. Dell Allen, Professor, Brigham Young University.

*To further refine the curriculum, the faculty conducted a survey of graduates of 13 manufacturing technology programs, their managers, and educators from the institutions offering the programs. Tabulated results of the survey were then evaluated by seven experts, who also voted on various performance objectives to be maintained in manufacturing curricula. These performance objectives were also incorporated into BYU manufacturing technology curricula.

The following comment by a Bechtel Corp. representative should be noted: "The hard, cold, practical fact is that anyone with any type of engineering education will aspire to be called an engineer, and there is not the nice, clean interface that the educators think there is between the duties of the many people engaged in an engineering-oriented program, be it design, construction, manufacturing, or operations. " (Quoted from ***Engineering Technology Education Study Final Report,* p. 51.)

discussed above. These eight areas are: 1) manufacturing planning, 2) manufacturing processes and materials, 3) manufacturing development, 4) production tool and machine design, 5) production planning and control, 6) plant layout and materials handling, 7) inspection and quality assurance, and 8) manufacturing management. Specific objectives have been developed for each area of study.

Space limitations preclude a full listing of the objectives listed under each area. The objectives for instruction in manufacturing planning, therefore, will serve as an example. Those objectives are as follows:

- To familiarize the student with the function of discrete component manufacturing systems and the characteristics, analysis, and synthesis of such systems with emphasis on computer-aided manufacturing planning.
- To aid the student in developing the ability to analyze parts and products for manufacturing feasibility, to plan process operations and sequence, to estimate manufacturing costs, and to select manufacturing tools, machines, and equipment.
- To explore the various technical aspects of automation and numerical control systems (including labor-management responsibilities); to give students experience in manual and computer-aided numerical control programing; and to give them experience working in local industries to solve manufacturing problems through the use of mechanization and automation.

Computer-aided processes and techniques are incorporated into the coursework when appropriate; it should again be stressed, however, that the undergraduate curriculum emphasizes and builds on conventional manufacturing techniques and processes which serve as a foundation for the study of computer-aided manufacturing.

Facilities and Equipment.–The manufacturing technology laboratories are distributed through four buildings on the campus. The laboratories—some of which are shared with the Mechanical Engineering and Industrial Education Departments—occupy over 15,000 square feet (total) and include facilities for machine-tool operations, fluid power experiments, casting processes, metal forming, metallurgy, quality assurance, materials science, welding, metal forming, and advanced welding. Also available are a CAD computer area and a large machine-tool-performance and CAM lab.

A comprehensive listing of the conventional and computer-aided equipment available to manufacturing technology students is not consistent with the space limitations of the present study. Following is a description of the major equipment items in the CAM Laboratory:

- a high-performance Evans and Sutherland graphics system for use in process simulation and material flow studies;
- fabrication equipment, including a 3-axis computer-controlled milling machine used for undergraduate instruction and for some prototype production, and a Sheldon CNC lathe equipped with an Allen Bradley controller;
- two material storage systems-an Eaton Kenway mini-load stacker and a White Company carousel unit—used in conjunction with the manufacturing program's plant layout and material-handling course. The two systems are also used for storage of tooling and in-process inventory;
- an ASEA industrial robot capable of welding, grinding, inspection, assembly and motor rewinding which is used in graduate and undergraduate projects; and
- a 3-axis Cordax Model 1000 coordinate inspection machine, which will soon be supplemented by in-process sensors—including laser scanning devices and equipment for measuring force, temperature, position, and velocity.

The CAM laboratory has three major uses: 1) teaching at both the undergraduate and graduate levels; 2) R&D conducted by faculty and students; and 3) demonstrations and seminars for faculty, students, and industrial visitors. All of the production machines in the laboratory are computer-controlled to facilitate the development of a demonstration system in which all of the equipment will be networked into a distributed manufacturing system via common databases, To develop the proposed integrated system, the students and staff are in the process of setting up a "CAM Mini-Lab" where they can test the integrated manufacturing process on a small scale before attempting to use the full-size industrial equipment. Current equipment in the Mini-Lab consists of the following:

- An IBM-PC System used to retrieve a given part shape from a data file and to modify the basic dimensions to the required configuration. The output is then scaled and plotted on a hard copy device.
- The part information is then transmitted directly to an *Apple CNC Lathe controller* that

retrieves the cutter path routines to make the part.

- *A Microbot robot* retrieves the part stock from an automatic storage and retrieval system and inserts this part in the lathe chuck.
- The part itself is then automatically produced on a *minature CNC lathe.*

In the near future, a miniature computer-controlled milling machine, a turret punch for sheet metals, and a newly designed robot will be added to simulate a fully integrated production facility.

Curriculum. -Freshmen begin with a course on basic machine-tool operation and an overview of the primary processes and materials used in manufacturing. They are also required to take basic graphics or drafting courses from the design technology division and an "Introduction to Engineering and Technology" course required of all technology students. Sophomore- and junior-year studies focus primarily on the manufacturing processes courses that form the backbone of the curriculum. These processes include machining, welding, casting, forming, molding, and heat-treating, and are supplemented by "related" technical courses in material science, fluid power, and electronic control, and "supporting" courses in computer sciences, mathematics, physics, economics, and technical writing. Sophomores and juniors also take courses in quality assurance, production planning, and machine-tool performance.

While a number of the freshman- through junior-level courses include sections on computer-aided manufacturing techniques, machines, and processes—most notably, the numerical control course, which contains a lengthy section on computer-assisted programing-it is not until their senior year that students may begin to focus on the curriculum's "minor option" in computer-aided design or manufacturing. At that stage, manufacturing students interested in design or programing may take advanced CAD courses from the design section or computer programing courses from the computer science department. Those interested in computer-aided manufacturing may take courses in robotics, computer-aided materials handling, computer-aided manufacturing systems, advanced N/C programing, N/C software development, and group technology.

All of the manufacturing courses have an associated laboratory requirement, and students spend approximately 50 percent of their time in the laboratories applying the theoretical material learned in the classroom. All students are assigned a number of individual and group projects during the course of their studies. The projects are designed to foster analytical and creative problem-solving capabilities, to help the students understand the importance of proper design and good manufacturing planning, and to teach them how to work as part of a development or production team.

A number of these projects are conducted as part of a senior-level course titled "Manufacturing Development Lab, " which is designed to be the culmination of the students' training. Students in this course are expected to use the concepts and skills learned in previous processes and planning courses to tool-up and produce usable products, to perform in-depth manufacturing analyses, or engage in other production and planning activities identical to those performed in industrial environments. Products produced by students in the development lab include an electrically driven wheat mill and parts for a miniaturized turret punch press to be used in the CAM Mini-Lab, together with feasibility studies on the manufacture of the press. Students have also participated in joint projects with industry on plant layout and materials handling, machinability studies, and group technology and material classification and coding studies.

Enrollment Trends.–Beginning with two students in 1960, the manufacturing technology program has shown a relatively steady enrollment growth over the past two decades. With a current enrollment of 180 students, the program is expected to reach its enrollment ceiling of 250 students by 1985. The manufacturing program has the lowest number of female students of all the technology programs (three women are currently enrolled) and the highest number of transfers from other departments. In fact, very few of the Manufacturing Technology students enter the program as freshmen; from 30 to 40 percent of the students transfer from one of the engineering departments while the remainder come from a variety of other colleges and departments throughout the university.

An ongoing project within the manufacturing section is the development and analysis of manufacturing student profiles. This study shows that most manufacturing students have had from three to five other majors before taking up manufacturing technology, have an average of 2 years of industrial experience, and are 26 years old when they graduate. A recent study of approximately 30 manufacturing seniors indicates a number of similarities among those studied: their major interests were in mechanical things, seeing things work, seeing how things work, technical production management and supervision, and computer programing. Asked to assess their own abilities, the students rabed themselves high in inventive ability, visualization of interaction among various components of a process, ability to do practical, "hands-on" engineering, ability to organize and schedule projects, ability to make decisions when not all the facts are available, ability to work under pressure, and ability to work well with people.

Placement.–From 95 to 99 percent of each graduating class of manufacturing technologists find jobs in industry. Most graduates receive multiple job offers at starting salaries that show a steady increase year by year. Although current salary information is not available, surveys of 1980-81 graduates show an average starting salary of $23,500, with salaries ranging from $21,000 to $27,600.

The majority of graduates are employed in the automotive and aerospace industries, heavy equipment manufacturing, computer-related production, and firms producing high-technology ordnance materials, Among the companies most active in hiring BYU manufacturing technology graduates are IBM, Texas instruments, Ford, John Deere, Caterpillar, General Dynamics, General Electric, Hughes, U.S. Steel, Hewlett Packard, Boeing, Lockheed, and Cummins Engine.

A large proportion of the graduates are hired as manufacturing engineers; others are classified as industrial engineers, process engineers, design engineers, quality-assurance engineers, research engineers, and production engineers. A significant number go directly into management-most as managers, some as management trainees. The remainder assume a variety of positions and are hired as trainers, estimators, N/C programers, systems analysts, technical service representatives, production schedulers, and lab technicians.

Design Engineering Technology .–The design technology program was not only the first technology program in the United States to award a baccalaureate degree in design and drafting* but also the first 4-year program to be certified at the engineering designer level by the American Institute for Design and Drafting (AIDD)** and, along with BYL'’s manufacturing technology program, the first 4-year technology program to be accredited by ABET.

As the field of industrial drafting and design adapted to computer-assisted techniques, the design technology faculty attempted, as best it could, to keep pace with the rapid industrial advances. By the early 1970's, students in the design technology program were using APT part-programing language to complete manual programing and batch processing exercises, keying the manually produced programs onto a Flexiwriter which produced machine control tapes that were then verified on a Gerber plotter. At the same time, faculty members were actively exploring ways of automating the design graphics processes in the program by making contacts with industrial representatives, keeping themselves informed of the latest processes and their potential, and attending and speaking at professional gatherings.

It was at one such professional meeting–an AIDD convention–that a design technology faculty member was approached by a representative of Applicon, a major turnkey computer graphics firm, who had been impressed by his presentation describing the design program's attempts to incorporate industrial techniques into its curriculum. As a result of that meeting, Applicon eventually donated a computer graphics system to the design program. The one-terminal Applicon system was installed in 1975 and the faculty began developing coursework to incorporate computer-aided design instruction into the curriculum.

During the past 8 years, the relationship between Applicon and BYU'S design technology section has remained strong and has resulted in the donation of two new Applicon systems (one of which replaced the original, already-outdated, system). In addition, because of the curricular advances made possible by the use of the Applicon systems for instructional purposes, Computervision, GE-Calma, and other CAD systems have either been donated by the producers or provided at a minimal cost to the college (see section on Facilities and Equipment). The design curriculum currently taught at BYU would not have been possible had the faculty been less successful in maintaining industrial contacts and encouraging industry to donate equipment.

Program Goals and Objectives.—The primary goal of the design engineering technology program is to "expose the student to challenging opportunities in mechanical design, including new materials, techniques, processes, etc., and thoroughly acquaint him with the current trends, ideology, and tools of technical and computer-generated graph-

* According to the design technology faculty, many companies had been forced to employ graduate engineers to fill design positions because of industry's growing need for qualified technical personnel. The design faculty viewed this process as "counterproductive in view of the engineers' sophisticated training and interests" and developed the design technology program to produce graduate designers specifically trained to meet the industrial need.

** AIDD is a professional group organized to advance the state of the art in the industrial drafting and design community. The institute has *an* educational arm which certifies high school, techncian-leiel (2-year), and baccalaureate (4-vear) design programs.

ics. " The educational philosophy that supports that goal is that "students must have a foundation in theory, coupled with viable applications experience, before education becomes truly meaningful. " That philosophy, shared by the other sections of the technology department, sets the technology curricula apart from traditional engineering curricula and results in an instructional program in which fully half of the student's work is practical, "hands-on" experimentation and application.

Among the technical objectives of the design program are the following: 1) to familiarize the student with basic problems in design development, including documentation and production techniques, precision dimensioning and tolerancing (among these techniques are computer-assisted design, parametric design, and automation within the design cycle); 2) to teach basic computer-aided design, manufacturing, and engineering (CAD, CAM, CAE) principles; 3) to assist the student in becoming knowledgeable about the proper use of modern production tools, machines, and equipment; 4) to aid the student in learning the basic manufacturing processes and how to achieve economical production by selecting the proper process; 5) to acquaint students with numerical control systems and their applications; and 6) to provide students with opportunities to participate in actual industry-related design problems.

Facilities and Equipment.–At present, the engineering sciences and technology building houses four instructional laboratories containing interactive graphics and computer-aided desigm equipment. One of these laboratories, called "The Apple Lab, " contains a total of 25 microcomputers (including 8 Apples) that are programed to simulate many of the basic computer graphics functions of Computervision or Applicon systems. The Apple Lab is used to train freshmen in the technology and engineering departments in the basics of computer graphics. Students in more advanced classes use sophisticated industrial equipment located in the other instructional laboratories. That equipment includes two Applicon 885 multiworkstation IMAGE configured systems (eight workstations); a Computervision CADDS three multiterminal system; a ComputerVision CADDS four multiworkstation system; a Calma DDM system, also multiterminal; and a Tektronix 4054 system used principally by electronics students.

Curriculum. -In contrast to the manufacturing technology curriculum—which stresses conventional manufacturing skills and knowledge in the beginning of the programs and moves gradually into computer-oriented processes on the senior and graduate levels—the design curriculum focuses on computer-aided techniques and applications from the outset.* All design students study seven principal areas-graphic science standards, problem analysis, planning, design synthesis, evaluation, documentation, and application-all supplemented by the computer systems in the school laboratories,

The design program builds on the basic design and drafting skills and knowledge developed in the required freshman and sophomore courses covering the fundamentals of engineering graphics, mechanical drafting (which includes automated drafting techniques), and principles of descriptive geometry. While computer-aided techniques are taught as part of individual lower-division courses, half of the required courses for juniors and seniors focus entirely on computer graphics and computer-aided design. Two of the six design courses required during the junior year, for example, are: 1) "Professional Graphics Applications-Interactive Computer Graphics," and 2) "Computer-Aided Design-Interactive Graphics 1."

- '*Professional graphics applications* reviews the development of computer graphics; covers the fundamental terminology, concepts, and principles of computer graphics; introduces the students to the uses and applications of 2- and 3-dimensional systems; and teaches operational techniques. Students in this course study the capabilities and functions of Apple, Applicon, and Computervision systems and complete laboratory work focusing on operational techniques required by each system.
- *Computer-aided design-interactive graphics 1* provides students with exposure to a broad range of engineering applications that can be executed on CAD systems; trains them to execute vendor-prepared applications packages dealing with engineering problems, and exposes them to CAD software development. Among the applications and techniques studied in this course are finite element modeling, digitizing, parametric programing, numerical control part programing, and detailing 3-D drawings.

In their senior year, students are required to take two other computer-oriented courses:

- *Basic computer-assisted part programing* provides students with a practical working

*This, according to design program faculty, reflects current practice in industry, where CAD techniques are more widespread than CAM techniques.

knowledge of APT programing techniques; gives them a frame of reference to help them to understand and implement computer-aided design and manufacturing processes; and explores the impact of APT and automation in general on the traditional techniques and philosophy of engineering graphics.

- *Design technology-CAD software development (interactive graphics* 2) explores CAD software development research techniques, programing, and operation of automated and computer graphic equipment with the object of acquainting students with CAD databases and database manipulation tools. *

In addition to the required courses, two graduate courses in advanced computer-aided design and advanced CAD applications are open to seniors as elective courses (see section on Graduate Programs).

Enrollment Trends.–The design technology program has the highest enrollment of the technology programs. In fact, with a 1982-83 academic year enrollment of 574 undergraduates, the design faculty is now in the position of having to introduce enrollment controls to eventually reduce the number of design students to 300. The primary reason for adopting this measure is to enable design students to spend a minimum of 5 hours a week working on the CAD stations. Approximately 30 of the design undergraduates are women, giving this program the highest percentage of female enrollment of all the technology programs.

A recent analysis of the enrollment figures (done when the enrollment totalled **555)** revealed that 77 of the design students were freshmen; 119 were sophomores; 155 were juniors; and 204 were seniors. The relatively small number of freshmen and sophomores does not reflect an enrollment decline at the lower division level; rather, it reflects a general enrollment trend seen in all of the sections of the technology department of upper-division transfers from other disciplines.

Placement.–Like the other BYU technology programs, the design program has a placement rate approaching 99 percent. With only occasional exceptions, those who do not accept immediate employment in the design field go on to graduate school or into the military. One reason for the high placement rate is that the faculty actively encourages students to work in industry to get application experience before going on to graduate work. Most students receive two or more job offers, and program graduates have been employed in the following firms (to list but a few): Sandia Laboratories, General Electric, Texas Instruments, Boeing, Applicon, Garrett Corp., John Deere Product Engineering Center, Hughes Aircraft, General Dynamics, Signetics, U.S. Steel, Martin Marietta, Xerox Corp., Calma Co., Bechtel Power Corp., Westinghouse, Rocketdyne, and Motorola.

The majority of graduates are employed in engineering positions directly after graduation. Specific occupational titles assigned by the hiring companies include the following: design engineer, CAD applications engineer, process engineer, manufacturing engineer, CAD/CAM engineer, computer engineer, rocket design engineer, software engineer, product design engineer, associate engineer, and engineer. Others are employed as CAD/CAM programmers, software analysts, tool designers, CAD support technologists, computer graphics specialists, and CAD/CAM consultants.

A number of graduates are hired as CAD or CAD/CAM managers or as management trainees, and a growing number are hired as CAD/CAM trainers. Another growing occupational opportunity for which design graduates are well prepared is technical marketing support—a number of recent design graduates have been hired as technical personnel who accompany equipment salespeople to answer the customer's technical questions and to help them make realistic appraisals of whether or not CAD and CAM equipment will perform desired functions in specific environments.

Graduate Programs.–In 1977, the technology department established an M.S. program in computer-aided manufacturing. Now retitled computer-integrated manufacturing (CIM), this program currently offers separate options in CAM and CAD and may in the future offer an option in computer-aided testing (CAT) for those students specializing in advanced electronics applications. The renaming of the CIM program not only made specific options in design and manufacturing available but also emphasized the thrust of the program, which is to provide students with training in the use of specific computer applications (e.g., robotics and group technology) as the basis for the study of integrated manufacturing where a variety of computer-aided equipment is linked in a distributed system.

One unusual feature of the CIM program is that over half of its students are professional engineers

*Students are also required to take a noncredit "Design Technology Seminar" each semester. Seminars are held twice a month. Once each month the design technology students join with all students in the college to attend the Engineering College lecture covering a recent topic in engineering; the other monthly meeting addresses recent developments in computer-aided engineering and is specifically geared for design students.

and managers employed by the Western Electric Co., who attend condensed, intensive versions of the regular school-year courses for 5 weeks each summer over a period of 5 years. The remainder of the students enrolled in CIM are full-time graduate students. At present, 30 full-time students and 60 Western Electric engineers are enrolled in the program. The first eight Western Electric students completed their coursework during the spring 1983 term.

In the fall of 1983, the technology department began to offer another graduate degree program in technical management. This new program offering is the result of a cooperative effort between the College of Engineering Sciences and the School of Management, and will combine MBA courses with technical electives from either the technology department or the traditional engineering departments. Students choosing to supplement management courses with technology coursework will pursue the technology management option, while students electing to take coursework from the engineering departments will follow the engineering management option.

Since the technology/engineering management program has not yet been offered, the remainder of this section will be devoted to the program in computer-integrated manufacturing.

Program Goals and Objectives: Computer Integrated Manufacturing.–The major goal of the CIM curriculum is to prepare graduates to integrate computerized systems in manufacturing environments, and to do so with a high degree of effectiveness. Specific objectives defined to support that goal are the following:

- to instruct students ‘in the principles, elements, philosophy, and techniques of effective manufacturing system design;
- to aid students in developing the ability to integrate computerized systems to solve practical, recurring problems; and
- to provide guidance to students completing the M.S. thesis requirement, which involves an in-depth study of a social, economic, or technical aspect of computer-aided manufacturing systems.

Entrance Requirements.—The program is specifically designed for students with recent industrial experience who wish to develop specialized skills and knowledge in technical and managerial aspects of computer-aided manufacturing and design. Applicants must, therefore, have at least 1 year of relevant industrial experience.* Other entrance requirements include: 1) a bachelor's degree in engineering technology, or, with the consent of the department, a B.S. in an allied discipline such as engineering; 2) evidence of completed coursework in manufacturing processes, materials science, design and graphics, electronics, computer programing, physics, and calculus.

Faculty, Facilities, and Equipment.–Graduate courses are taught by approximately two-thirds of the technology faculty. Facilities and equipment are the same as those available to undergraduate technology majors.

Curricula. -Both CIM options are structured to accommodate industrial requirements and to prepare students for advanced work in computer-aided design and manufacturing. While students may create individually focused options within the two formal options (CAD and CAM), specified courses are required to form a foundation on which to base the individualized program.

CAM Option–Students choosing to specialize in computer-aided manufacturing take the following courses:

- *Computer-aided facility design and materials* handling-theory and application of plant layout techniques, emphasizing materials handling systems.
- CNC *part* programing-programing techniques and requirements for the manufacturing of components on computer numerical control machining centers, emphasizing programing, applications, and software development.
- *Group* technology-classification theory and practice applied to workpiece-classification-and-coding and statistics, production in manufacturing cells, design retrieval, and generative process planning (all with an emphasis on computer applications).
- *Computer-aided manufacturing* systems–basic activities, elements, and principles of computer-aided manufacturing, including terminology, systems integration, architecture, database development, interfaces, and computer hardware/software requirements.

*The only exception to this requirement is that students who have completed a year of cooperative education experience (which, in actuality, is only 8 months of work experience) are eligible to apply. The technology faculty, however, actively encourages technology undergraduates contemplating this advanced degree to work full-time in industry before applying in order to gain a practical understanding of industrial practices before beginning graduate work.

Industrial robotics---history and philosophy of robotics, industrial applications, programing, economic justification, and integration with production systems.

Students are also required to take a course in computer-aided design (see below) and a graduate seminar, and may choose from a number of senior- and graduate-level manufacturing, design, and electronics technology courses or courses in computer science, mechanical engineering, or business management to complete their option.

CAD Option .–Students taking the computer-aided design option are also required to take the manufacturing technology courses in group technology and computer-aided manufacturing systems. Two advanced CAD courses are also required:

- *Computer-aided design: interactive graphics 3—CAD* systems management philosophies, including systems evaluation, cost justification, procurement procedures, implementation, and management/operator training programs.
- *Advanced CAD* applications-philosophy, methods, and applications of engineering techniques pertaining to present and future trends of finite element and solids modeling; complex numerical control methods.

Elective coursework may be chosen from all three curricula of the technology department, the computer sciences department, and the mechanical engineering department.

Electronics Technology Coursework.-Although there is, at present, no formal electronics option in the CIM program, a number of upper-level and graduate courses that focus on computer-aided applications and techniques are available to students in the Cl M program. Among these are computer-aided testing and instrumentation, electronics fabrication and assembly, and real-time sensing and control. *

Research.-All CIM students are required to do research and write a thesis, preferably on a practical aspect or application of computer-integrated manufacturing systems. In practice, areas of research have been very broad. A number of students participate in ongoing faculty research, while others initiate independent research projects in subjects such as selection of CAD equipment, CAD training, CAD system performance, computer-aided materials selection, carbide selection, finite element modeling, automated steel mills, solids modeling, software quality assessment, and the cost of product quality and its relation to market share.

The Western Electric Program.– In 1978, Brigham Young became one of a handful of universities participating in Western Electric's "On-Campus Summer Program, " which provides selected Western Electric employees with the opportunity to attend graduate school on-campus for 4 to 5 weeks during the summer for a 5-year period. While the other participating universities—including Clemson University, Kansas State University, New Mexico State, Purdue, Texas Tech University, and the University of Illinois–offer a variety of advanced courses, some of which focus on CAD and CAM, Brigham Young is the only one to offer a degree program in computer-integrated manufacturing. Although Western Electric does not require the 60 employees currently attending BYU to enroll formally in the CIM degree program, almost all have chosen to do so. Those who formally enroll in the program must complete the same thesis requirement as all regular CIM graduate students, and all of the Western Electric employees receive the same classroom instruction and laboratory practice. Each summer, two courses from the CAM option are restructured to fit into an intensive 5-week period so that students complete the equivalent of two 14-week courses. The first eight graduates completed their studies in the summer of 1983, and two or three additional students were to complete their degrees by the end of the year.

Western Electric covers all of the students' formal costs— including fees, tuition, housing, and books–and also reimburses BYU for the salaries of the Technology faculty and staff, and for equipment use and maintenance.

Enrollment Trends, Attrition, and Placement.— While the number of Western Electric engineers officially enrolled in the CIM program has gone as high as 60, academic year enrollment is limited to 30. Of the 30 students currently enrolled in the academic year program, approximately two-thirds are graduates of BYU and over half are graduates of BYU technology programs. Many C IM students take leaves-of-absence from their companies to take the coursework, and attempt to complete the thesis requirement after returning to their jobs. This practice is the primary cause of attrition (approximately 33 percent), which often occurs after the coursework has been completed and when students return to work rather than remain

*The " Real-Time.Sesing and Control" course focuses on writing computer language for computer operations that run in real time (ie, , are not stored by the computer and computed in a Batch model.

on campus to write their theses. The placement rate for CIM graduates, on the other hand, is 100 percent. Average entry-level salaries received by CIM gradutes range from $27,000 to $33,000, although some program graduates have received offers as high as $50,000.

Industrial Affiliations

The technology faculty operates on the philosophy that, in meeting the needs of industry it is meeting the needs of its students. The discussion in the preceding section has brought out a number of ways in which the faculty has sought industrial advice, secured industrial donations, and engaged in research that is either industry-oriented or conducted in cooperation with industry. The following paragraphs describe specific formal channels through which the technology department communicates with industry and discusses the department's position on the formation of an industrial advisory council.

Channels of Communication.–The technology department participated with the other departments in the college to form the Alliance With Industry Program in 1981. The 20 companies who participate in the program* each provide an annual contribution of $10,000 or more to support the college's research and educational programs. Benefits to the industrial partners include the following: 1) licenses for software developed by college faculty (including high-resolution graphics software developed by a member of the engineering faculty), 2) research results in methodology and applications, 3) help in solving special industrial problems, 4) seminars for technical personnel, and 5) access to BYU graduates skilled in computer-aided techniques. Benefits to the college, aside from donations of funds and equipment, include industrial advice and interaction and the opportunity to do research on current industrial problems.

Apart from its participation in the college-wide alliance with industry, the technology department has also formed independent alliances. Each year, the department holds two DCLASS conferences, one for users who have licensed the software and one for nonusers who are considering purchasing a license. The users conference provides a forum for the exchange of ideas and the presentation of new DCLASS applications; the non-users conference includes an initial orientation followed by demonstrations, workshops, and presentations by industrial representatives who use DCLASS and by technology department faculty.

The Manufacturing Consortium that supports the development of CAST holds twice-yearly meetings to review and approve the instructional modules as they are completed. The industrial members of the consortium also provide financial resources and technical information on the manufacturing processes which are the subject matter of the instructional packages, and the educational members write the software, participate in the review process, and help to evaluate the teaching/learning process employed.

The Western Electric program described earlier in this study gives the technology faculty an opportunity to work intensively with engineers and technical personnel, and faculty leave programs allow faculty members to renew their working knowledge of industrial practices by accepting short-term employment in industry. In addition, all faculty members take at least one trip a year to attend meetings of professional and technical societies. Another fruitful channel of communication is provided by industrial visitors. Literally thousands of industrial representatives visit the department each year– some to view the facilities and equipment, some to deliver or attend seminars, and many to ask advice on computer-aided equipment and methods.

Evaluation of Present and Future Capacity

When asked to evaluate BYU'S technology programs on the basis of the skills and ability of their graduates, one employer replied: "On a scale of 1 to 10, I'd rate them 10. " Other employers contacted agree, noting that BYU graduates not only have "just the right education, " but often require less on-the-job orientation training than traditionally educated engineers, and are also more mature and more willing to work extra hours and at odd hours than most engineers fresh out of college.

The Rocky Road to Success.–Evaluated with respect to its own stated goal of preparing students for positions requiring applied engineering, process planning, and systems management skdk, the BYU technology department clearly is highly successful. Its present capacity to provide its students with the CAD and CAM skills sought by increasing numbers of industrial firms is perhaps best described by the adage, "success breeds success. " Because the faculty has been able to obtain

*These include B. F. Goodrich, Boeing, Digital Equipment Corp., Evans & Sutherland, Garrett Corp., Hewlett Packard, Exxon, GE-Calma, Genrad, GTE, and Computervision.

industrial donations, state-of-the-art equipment, industrial advice, and real-world research problems for its students to work on, BYU technology graduates are sought after by industry. And because of the graduates' success in industry and the faculty's achievements in research, the technology department now has more offers of equipment and industrial research projects than it can handle and is in the position of giving advice to companies less technologically advanced than it is.

A look at the history of the technology department since its inception in 1960, however, reveals that its present-day success story grew out of a Cinderella tale. When the baccalaureate programs were first established, and for many years afterwards, the members of the technology faculty saw themselves as "underdogs. They were looked down upon by many of the engineering faculty, and unrecognized by most of the rest of the university, and their 4-year programs were often confused with the 2-year technician programs also offered by the technology department at that time. Industry-oriented and intent on filling the gap created by the increasingly theoretical focus of traditional engineering education, the technology department resisted promptings by engineering societies, accreditation agencies, and some of the college faculty to "add more courses the students wouldn't need in industry in order to become accredited-it wasn't worth the tradeoff. "

Eventually, the manufacturing and design programs-which substituted application-oriented, laboratory-based courses for the most highly theoretical coursework in engineering disciplines-became the first accredited technology programs in the country. Although accreditation was beneficial to both the students and the faculty, it did not solve their problem of being looked upon as either second-rate engineers or as supertechnicians. However, the department's industrial focus and the faculty members' desire to prove that neither they nor the discipline of technology were "poor relations" were significant factors in the department early concentration on computer-aided design and manufacturing.

Because the programs were designed to teach state-of-the-art industrial skills and applications, the faculty began exploring ways of obtaining equipment and incorporating programmable automation into the curricula approximately 10 years ago, when it became clear to them that CAD and CAM would eventually become required fields of knowledge. Furthermore, because the programs' curricula were not bound by engineering accreditation requirements, which allow little space in a 4-year curriculum for the inclusion of new courses, coursework focusing on CAD and CAM could be incorporated into the technology curricula with relative ease.

The final hurdle for the technology department was industry itself. Faculty members went from company to company in the early 1970's, but did not succeed in obtaining donated or reduced-price equipment until they proved their genuine interest and capability by demonstrating to Applicon that their students were doing all that could be done to automate the drafting courses with the limited equipment at their disposal. It was at this stage, when the department received its first major donation (the Applicon CAD system) that Cinderella was allowed to try on the glass slipper. The other slipper-a $130,000 Kerney & Trecker CNC milling machine, which the company sold to the department for $50,000—was fitted shortly thereafter. These two significant equipment additions enabled the faculty to begin to incorporate sophisticated computer-aided techniques into the coursework; they also encouraged other firms to donate funds and equipment.

Technology and Engineering: Interdepartmental Relationships

Once it "proved itself," the situation of the technology department improved both inside and outside the university. Although perfect accord between engineering and technology faculty members is not always achieved even now, the vast majority of faculty members in the college view engineering and technology as partner-disciplines, both of which are necessary to provide the broad spectrum of education and training required to prepare graduates for engineering and engineering-related positions in industry. Civil, mechanical, and electrical engineering students are now required to take design technology courses, and many engineering students take courses from all three technology programs as technical electives,

Technology students were always required to take engineering courses relevant to their major program-and a third to a half as many physics, chemistry, and mathematics courses as engineering students. There has been limited discussion about increasing the number of statics, dynamics, and strength-of-materials courses taken by technology majors to equal those taken by engineers, and there is some discussion about increasing the numbers of physics and mathematics courses in the technology curricula.* As the commonality between technology and engineering curricula grows, more and more students and faculty perceive the difference between the two disciplines to be one of approach and mission, rather than one of level of education.

Computer-Aided Engineering, Design, and Manufacturing (CAEDM) Committee

Both technology and engineering faculty now feel that they have an excellent relationship with each other, in contrast to the situation in many other universities which have both programs. The CAEDM Committee, created in 1980, provides a formal channel of communication between the technologists and engineers, and a number of professors in both departments coordinate research projects in which technology and engineering graduate students work together as part of a research team. College faculty believe that this team approach has a great deal of significance for academia and industry alike. **

The BYU technology department-whose primary focus is on the implementation of engineering designs--has been instrumental in increasing the engineering departments' awareness of the need to produce industrial designers who are more cognizant of manufacturing concepts and requirements. One tangible example of interdepartmental cooperation in this area is a CAEDM-sponsored short-course for faculty and students delivered by a representative from GE, which has instituted a version of a Japanese procedure that rates engineering designs on the basis of ease and efficiency of assembly. Another example is the work now being done in the CAM Mini-Lab, where electrical and mechanical engineering students, computer science students, and technology students all participate in projects addressing the manufacturing process from design to production and the problems of networking diverse CAD and CAM equipment.

The technology department also stimulated the engineering departments' interest in CAD and CAM, which, in turn, was a stimulus for the current focus on computer-aided engineering (CAE). The college as a whole has also benefited from the industry interest generated by the technology programs and graduates. Much of the computer-aided equipment obtained by the technology department serves the entire college, and the engineering departments have now obtained computer graphics and computer-aided data acquisition and analysis equipment through industrial donations and cooperative agreements with equipment manufacturers. In addition, the growing reputation of the technology department in industrial circles has brought in interviewers from across the country who hire engineering as well as technology graduates.

The Alliance With Industry Program, formed under the auspices of CAEDM, brought the university $1,858,000 in industrial equipment and in funds used to augment the computer-aided capabilities of the college. In April 1983, CAEDM hosted a conference for 380 representatives from 120 universities across the country who are either planning or developing programs in computer-aided manufacturing, design, and engineering. Thirty speakers from 25 universities that have initiated such programs gave presentations on the approach taken at their respective institutions; and all of the participants had the opportunity to discuss common problems, individual experiences, and appropiate strategies. The object of the conference, called University Programs for Computer-Aided Engineering, Design and Manufacturing (UP CAEDM) was to increase communication among universities and to provide impetus for the implementation of teaching and research programs in CAD, CAM, and CAE.

Problems.—While cooperative endeavors like those mentioned above have brought the faculty of the technology and engineering departments together, the college is not entirely free of the traditional misunderstanding among engineers and technologists. Some of the technology faculty still bear the scars of old battle wounds and refer to the "arrogance" of the engineering discipline as a whole, and to the "old boys' club" atmosphere that links engineers nationwide and excludes technologists. They consider their own college education in traditional engineering schools to have "mistrained" them for industrial occupations. Some engineering faculty, on the other hand, resent the fact that most technology department graduates are classified as "engineers" when they

*There is some disagreement among the technology faculty on the issue of increasing the math and physics courses, which would entail either extending the technology curricula beyond the limits of 4-year programs, requiring students to take, more courses each semester, or dropping courses that the majority of the faculty consider to be essential for technologists.

** A petennial problem in industry has been lack of communication between engineers who design the products and the manufacturing departments responsible for production. Because of this lack of communication, and because engineers normally receive little formal education in the requirements of the manufacturing process, industrial designers often fail to take manufacturing requirements into account when designing a product — a procedure that can lead to loss of money, loss of production time, or (in the worst instace) a product which a product which not be manufactured move into industry; they fear that such graduates may be "misrepresented" as degreed engineers. Another problem for the engineering faculty is that a number of visitors from industry and academia overlook the computer-aided engineering facilities and devote their entire attention to the CAD and CAM facilities of the technology department. The resentments on both sides are, however, gradually being overcome by the spirit of cooperation that now exists within the college. They are but pale reflections of national tensions between technologists and engineers.

Working With Industry.–Having designed its programs to respond to industrial needs and having concentrated on industrially oriented research, the technology department is now able to work with industry on many levels. The continuing success of the Western Electric program and the satisfaction of the Western Electric employees who) attend the summer sessions indicate the suitability of the technology curricula to current industrial needs, as do the multiple job offers received by technology graduates. The growing number of companies purchasing DCLASS licenses and exhibiting interest in the CAST system indicate that the research performed by technology department faculty and students also fills an industrial need. Some faculty members, in fact, are in the position of being able to pick and choose from a large number of potential industrial research projects.

Because of the similarity of interest between technology department faculty and professionals in industry, and because of past success in research aimed at solving current industrial problems, individual faculty members have been able to engage in long-term research projects resulting in a number of shorter-term benefits to industry. DCLASS, for example, is now put to use by a number of firms for classifying and retrieving information and for generating process plans, time standards, and a number of other applications. At the same time, the creator of DCLASS is conducting long-term research into the potential use of DCLASS as a systems integration tool.

Revenues from the sale of DCLASS licenses have helped to buy equipment and renovate facilities and may soon be augmented by the sale of CAST training modules and the CAD training aides that allow Apple computers to simulate interactive graphics systems. In many instances, the department has been able to save the expense of maintaining computer aided equipment by writing software programs for equipment vendors in exchange for maintenance services.

The major problem-area still remaining for the technology department in respect to working with industry is the attitude taken by some firms toward the occupational categories appropriate for technology graduates. This is discussed in the following section.

Future Capacity .—Judged by its present success, the direction of the faculty's research, and its determination to maintain its awareness of industrial needs and techniques, the future potential of the technology department to continue producing well-trained graduates versed in computer-aided techniques and familiar with a wide range of computer-aided equipment seems high indeed. The major limitation is the small size of the department—which, because of enrollment control, will become smaller still-and difficulties encountered in managing the growing numbers of computer-aided systems, which entail coordinating frequent upgrades and updates with the student need for equipment time.

Although college and university administrations have been generous in assigning funds to upgrade old facilities and build new ones for the technology and engineering departments, the technology department's resources cannot expand to accommodate all of the activities it would like to engage in. For example, a number of companies have requested that the department operate programs for their employees on the model of the Western Electric program. The department has had to turn down these requests for lack of resources. It will, however, attempt to offer a series of 2-day to 1-week seminars for industrial employees focusing on computer-aided design and manufacturing,

A general policy of the department and of the university is to sacrifice size for quality. The new enrollment control procedures, for example, will effectively close off enrollment for the Design Program for the next year or two, but wiII also result in more CAD-terminal-time for those students already enrolled. of the three technology programs, manufacturing exhibits the greatest capacity for future enrollment growth (student interest has been fueled by the national interest in productivity and the potential of computer-aided manufacturing), while the electronics program has the greatest potential for expanding its curriculum to include new courses focusing on computer-aided equipment and techniques. The Electronics faculty has already acquired six HP87XM computer-aided test stations to be used as personal instrument, systems, and a Tektronic 4054 computer graphics system for printed circuit board design.

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Future departmental plans call for an ECAM (Electronics-CAM) minilab to be established in the new technology building when it is completed.

The technology department, in cooperation with the mechanical engineering department and the electrical engineering department, developed a proposal for a three-element graduate program in manufacturing systems in response to IBM's announcement that it would provide college and university grants for the development of new curricula in manufacturing techniques. BYU has received notice that it has been awarded an IBM 4341 computer system with 10 CADAM graphics terminals. This system will have a significant impact on the capacity of the three departments and of the college as a whole to train more students than they can presently accommodate.

The technology department's potential capacity to provide education in programmable automation is not entirely limited by the size of the department, if one considers the indirect impact of the programs as models for other schools, the willingness and ability of the faculty to provide information to academia and industry alike, and the potential of the computer-aided simulation training packages and the CAM-Mini Lab concept.

BYU Technology Programs as Models for Other Educational Institutions.— The manufacturing technology program has been used for many years by the Society of Manufacturing Engineers **as a** recommended model for 4-year manufacturing pro grams. In addition, representatives of 15 to 20 colleges and universities visit the BYU technology department each year with the expressed intention of creating their own programs on the BYU model.

Technology department faculty representatives offer the following comments on the feasibility of such attempts. While they have personal knowledge of a number of successful programs modeled on their own, they point out that the crucial requirements for a program like theirs are often met only with difficulty. The first requirement, from their point of view, is the necessity of "giving up the title of manufacturing engineering in order to give industry what it really wants. " This is a step that a number of engineering schools do not wish to take.*

Once this step is decided upon, other pitfalls exist. One is the tendency of some schools to place manufacturing technology programs in the department of mechanical engineering and to offer them as options. The danger here, according to BYU faculty, is that the technology program is then likely to become a watered-down engineering program rather than a parallel-track program. Another necessity is that each course in the curriculum be accompanied by an associated laboratory requirement. This means, of course, that appropriate equipment and facilities be available. Another major requirement is that the faculty have industrial experience and be comfortable teaching a less theoretical, practically oriented curriculum. The final requirement is interest on the students' part. While faculty can help to generate that interest, it could be difficult to do so in a strong traditional engineering college where students are bent on becoming degreed engineers and have little interest in less theoretical studies.

Technology Transfer. –The technology department—and, especially since the formation of CAEDM, the college as a whole–has been, and will most likely continue to be, an excellent conduit for technology transfer. The faculty demonstrates a strong determination to continue to learn from industry and an equally strong desire to share what they have learned and their methodology of teaching with other educational institutions. The UP CAEDM conference, in particular, has the potential of becoming a regularly occurring event: the second such conference is being hosted on the East Coast by Lehigh University in 1984. If that potential is realized, BYU will have provided the impetus for a sorely needed forum for continual exchange of information. *

Technology department faculty also express the intention of continuing the present practice of working as consultants to industrial firms and government agencies and of providing informal advice and services to industry representatives who visit the department to obtain information on CADICAM systems and applications. Thus, the technology transfer provided by the technology department and other departments in the college is likely to continue to operate on multiple levels to the benefit of BYU, other academic institutions, and industry.

Computer-Based and Computer-Aided Instructional Packages. –As modules of the Computer-

● According to one technology instructor, "You can't take a true-blue theoretical engineer and expect him to teach technology; if you do, there's a danger that the faculty will make the technology courses too theoretical and the students will wind up with a pseudo-technology degree. "

*An informal survey conducted by this researcher of selected colleges and universities revealed an astonishing lack of knowledge about the activities of other institutions on the part of faculty members actively engaged in planning or developing CAD and CAM programs. While some faculty members contacted did have some information about existing programs in colleges and universities, they often did not know the direction and focus of those other programs or had inadequate information about specific research and curriculum development activities.

Aided Simulation Training System (CAST) are completed and approved by the Manufacturing Consortium, they will be made available to industries and educatioal institutions for a minimal fee (covering the cost of reproduction and mailing). The manufacturing technology professor responsible for developing and coordinating the project is hopeful that within the next year, videodisk technology in the United States will be well enough advanced to allow the CAST development team to produce the training modules on interactive videodisks. At present, a demonstration videodisk has been produced for use in further research studies on interactive instruction, and sound-slide presentations of some of the modules are being tested in manufacturing technology classes at BYU. The CAI) trainin g package for use on Apple computers is also in the development stage, and one of the design technology faculty has formulated a concept for computer-aided CAD instruction which he hopes to develop in the near future.

CAM Mire" Lab. -Technology department faculty are also seeking funds to enable them to build duplicates of the miniature factory that will be contained in the CAM Mini Lab and to provide them to 20 universities across the country. The recipient universities would be encouraged to attend ‘‘software exchanges, whereby advances made by one party would benefit the group as a whole. The estimated cost of producing the hardware for one minilab is $50,000, which is equal to or less than the cost of many single items of computer-aided equipment.

Projects such as those mentioned above expand considerably the department potential capacity to have a direct effect on education and training in the field of programmable automation, The DCLASS users and nonusers conferences, the Western Electric program, and short courses for professional engineers offered by the engineering departments further expand the college’s ability to reach beyond the university campus to provide educational opportunities to working professionals.

Case Study 3
CADAM Inc.: Customer Training in Computer-Aided Design

Summary

CADAM Inc., a subsidiary of Lockheed Corp., produces computer-aided design and manufacturing (CAD/CAM) software, most of which is licensed to customers through IBM and other computer hardware firms. Customers may also buy CAD/CAM software directly from CADAM for use on systems that are "plug-compatible" with IBM systems.

CADAM provides basic computer graphics training free of charge to all customers who purchase software directly from the firm (two employees per customer) and charges $1,250 per student for basic training classes to all customers who license the software through IBM or other hardware distributors. Customers may also purchase the basic training in self-study packages for $650 per kit. The software firm offers more than 11 computer graphics programs, ranging from basic training in the CADAM system of computer-aided design, to courses on 3-D piping and 3-n surfaces, to numerical control (NC) programing, to finite element modeling.

In addition, CADAM offers a training consulting service designed to assist customers who have unique problems or special requirements, All training beyond CADAM basic is delivered for a fee, which ranges from $550 to $3,100 per student, depending on the length and complexity of the course. The majority of students are machinists, designers, drafters, and engineers.

While CADAM provides both in-plant training for all of its employees and what is referred to as "scope" training (training on the computer terminal in the operations required to use various CADAM® system ware packages),* this study will focus primarily on the customer training offered by the firm. When it was established in January 1982, its Lockheed Corp. founders committed themselves to providing "high quality training" which they saw as crucial to support the company goal of becoming a major developer and distributor of software in the CAD/CAM field. Today, the training department—which includes curriculum designers, internal trainers, and customer trainers —accounts for 8 percent of all CADAM employees (an unusually high percentage), and the director of training reports directly to the president of the firm. This, again, is unusual, since most training departments report through marketing, customer relations, or personnel.

*CADAM is a registered trademark and service mark of CADAM Inc

Company Characteristics. -As of July 1983, CADAM employed approximately 280 people in its four major divisions: software development, marketing, training, and administration. Seventy-five percent of CADAM employees are in the software division; marketing and trairing have 10 percent each; and the remaining 5 percent are in administration, At present, the firm operates out of one facility, located near the Lockheed-California plant in Burbank, Calif. CADAM management plans to increase the software division by 40 employees during the latter part of 1983 and to maintain the training department at its current level.

The decision to incorporate what was once Lockheed's CADAM division* was fueled by the perceived necessity of providing CADAM management with the flexibility it needed to operate in a fast-moving CAD/CAM marketplace with a wide variety of potential customers in-aerospace, shipbuilding, automating, architectural planning, and a number of other industries. Distinguishing CADAM from the majority of CAD software and software-hardware houses is the firm's concentration on developing software for mainframe CAD/CAM systems, specifically the IBM 370, 303X, and 4300 series, rather than for turnkey, or standalone, systems utilizing minicomputers.

According to company representatives, the advantages of mainframe as opposed to turnkey sys-

*In 1967, the origial CA DAM software was developed by Lockheed-California engineers to aid in the numerical control (NC) programing and airframe design for Lockheed Aerospace Products. CADAM system software was originally created for use on IBM mainframes, but by the mid-1970's, Lockheed had also designed a CADAM package for use on Perkin Elmer minicomputers, By 197.5, Lockheed was selling CA DAM system software to users outside of Lockheed Corp. By 1979, in addition to marketing the system, IBM also adopted CADAM is its internal CAD/CAM software. IBM and Lockheed entered into a contractual arrangement in 1977 whereby IBM would market and distribute CADAM system software under the IBM installed user program (IUP), which makes software developed by IBM users available to the general public.

terns are increased database capability and the ability to network CAD/CAM databases (including the ability to transfer data between CAD and CAM systems), the ability to interface to other information systems, the greater growth capability of mainframes (to which over 100 terminals can be connected), greater telecommunications capabilities between far-flung terminals, and the increased speed, accuracy, and computing ability offered by 32-bit (mainframe) as opposed to 16-bit (minicomputer) systems. * By offering these features, CADAM believes it has a solution for an entire enterprise—not merely a department or group.

According to CADAM's president, CAD/CAM technology is most profitably and productively used by firms that are not merely seeking to automate single processes, such as design drawings or NC part programing, but are instead developing the capability to make their design and manufacturing processes into a single integrated system. CADAM management thus *views* the firm's major role as that of a systems catalyst, since they maintain that CAD/CAM systems can, when used by knowledgeable users, become the backbone of a computer-integrated manufacturing (CIM) system. In this sense, CADAM has two major markets: firms that use CAD or CAD/CAM systems for some processes, and, most important, firms that are in the process of developing integrated system capabilities. At present, CADAM has over 250 corporate users, including IBM (with almost 100 installations and several hundred terminals that make use of CADAM software), GM and other American firms, the majority of the largest Japanese automakers and shipbuilders, and firms throughout Western Europe, Canada, South Africa, and South America.

Training Organization and Philosophy .–Lockheed-California began CADAM system training for employees in the late 1960's, shortly after the CADAM product was developed; Lockheed instructors have been delivering CADAM system training since 1975, when software packages were first sold to outside users. As a company, then, CADAM had the advantage of starting out with a track record of training both customers and employees on a system that had been used in production environments for over 15 years; it also inherited 10 Lockheed-developed CADAM training programs and a number of experienced trainers.

Top Priority Accorded to Training.–According to CADAM's president, training was an integral part of the strategic business plan created prior to CADAM's incorporation. Convinced that customer support–including training, curricular aids, and consulting services—was a major requirement for success in the CAD/CAM field, CADAM management set out to establish a training department that would provide curricular materials and training of a consistently high quality. The new director of training and education, hired in November 1981, was given a mandate to produce quality training and to turn the training department into a profit center for the firm. As head of one of CADAM's four major divisions, the director of training reports directly to the president of the firm and has both flexibility (in structuring the training department, hiring trainers and program designers, and organizing and developing the training material) and accountability (for producing "quality product support" and for turning a profit).

CADAM management believes that a system of checks and balances--involving cooperation between trainers and designers and between the software division and the training division, as well as accountability on the part of each division to the others and to top management-produces a form of "quality assurance" whereby the product itself is designed with users and training requirements in mind, and the training effort supports the sale and use of the software.

Relationships With Educational Institutions.—Aside from the training division's informal relationship with the [University of Southern California's (USC'S) Instructional Technology Department, CADAM has numerous cooperative relationships with colleges and universities in California and throughout the country. In September 1982, IBM announced its intention to award $40 million worth of grants of hardware and of funds to university and college engineering schools to develop new curricula in manufacturing techniques. CADAM intends to supplement the IBM hardware donations with donations of software licenses.

Independently of the IBM grant, CADAM donates software to a number of universities and colleges, to be used in teaching CAD/CAM fundamentals, and occasionally provides CADAM training to selected colleges and universities for free or for

*Many of the major turnkey vendors, however, are coming out with 32-bit minicomputers, which, according to Merrill Lynch's 1982 ***CAD CAM Review*** *and outlook,* " *appear* capable of stemming the inroads of mainframe computer competition (p. 1). While mainframes have more CPU power and speed, the new 32-bit mini systems offer more extensive applications software and, except for "high-end large sophisticated needs, are superior to mainframes in price/performtince comparisons (p, 9), a reduced rate. A more active relationship exists with a smaller number of schools to which CADAM also provides test releases of software. This arrangement gives students experience in solving software problems while, at the same time, aiding CADAM software analysts in debugging the software. With yet other institutions–UCLA and Rensselaer Polytechnic Institute for example—CADAM has engaged in joint development work. UCLA's Department of Manufacturing Engineering has received grants of IBM hardware and CADAM software, which it has integrated into the curriculum of three separate courses. CADAM and UCLA manufacturing engineering faculty and graduate students are also engaged in joint research to determine how to classify CADAM-made drawings into part families by using group technology codes, with the ultimate object of developing an integrated manufacturing planning system.

Another cooperative project conducted by UCLA aims to narrow the traditional communications gap between the design and manufacturing departments in industries by designing a "smart" CAD system that will monitor the design process and prompt the designer if he bypasses manufacturing considerations while designing a part, tool, or product. Another UCLA-CADAM project involves research into incorporating three-dimensional graphics capabilities into CADAM system software.

Other educational institutions with which CADAM maintains a close working relationship include Rensselaer Polytechnic Institute, Michigan Technological Institute, MIT, and California Polytechnic State University. Section III of this study discusses possible future projects with colleges and universities which may have a direct impact on CADAM system training itself and on the educational offerings of participating schools.

Training Division Staff.—The training division consists of the director of training, the internal training group, the customer training group, the program (i.e., curriculum) designers, and three support personnel.

The training director, who was in computer sales for IBM from 1956 to 1969 and then moved into the industrial training field as an early employee of Tratech (a for-profit training firm) and a training consultant, combines experience in the computer and training fields with formal training as an accountant. The remainder of the professional staff in the training division is approximately equally split between employees with advanced degrees in instructional design, education, or the sciences, and employees with practical experience working on and teaching the CADAM system.

The manager of customer training is a long-time Lockheed employee (previously a drafter/designer) who was trained as a drafting designer on CADAM when it was first put into use in the late 1960's. A trainer in the CADAM system since the early 1970's, he became manager of customer training shortly after moving to CADAM from the Lockheed training department. Five of the six trainers combine production experience as CADAM system designers with experience as CADAM system trainers for Lockheed. The senior instructor has 20 years of training experience, 15 of which were spent training Lockheed employees and customers on the CADAM system.

The manager of the program design staff has completed advanced graduate work: in the USC instructional technology department and worked previously as a manager for another firm. The four program designers also have graduate and/or teaching experience in instructional technology at USC (one was an instructor, one an assistant professor), and one also has 10 years of industrial experience. All have had extensive experience in writing instructional curricula.

The difference in backgrounds between the trainers and the program designers reflects CADAM management's position that CADAM employees should specialize in what they do best—that trainers should be practitioners with engineering or shopfloor experience and that curriculum developers should be trained communication specialists. The horizontal nature of CADAM's internal organization-whereby trainers, program designers, and software developers are on parallel organizational levels—is intended to encourage cooperation and to make all technical-level employees accountable for portions of product development and support.

Training Facilities.–Approximately half of all the customer training is delivered at CADAM's training facility, located at the CADAM plant and also used for employee* Group II mainframe computer, which is shared with the marketing group,

Customer Training

Goals. -Major goals of CADAM customer training are to provide a high level of training support to the customers and to do so on a profitable basis.

*The remainder of the training is delivered onsite at the customer location.

Recognizing that the CADAM system cannot be effectively utilized by customers who have not been properly trained and that well-trained users are those most likely to be satisfied with the system and to expand their use of it, the training director established the program design department to support these goals with its own particular set of objectives.

These objectives are to develop a complete set of training tools for each customer training program, to make those tools (written curricula, study guides, training guides, training aids, etc.) as consistent as possible both in content and delivery, to package appropriate courses as self-study programs to reduce trainin g costs, and to develop new instructional programs to keep pace with software development and new software applications. The trainers' goals are to make sure that the students have a basic understanding of how the CADAM system operates and a specific understanding of the particular application package they are being trained to operate.

Contractual Arrangements With Customers.—When CADAM sells or leases software licenses directly to end-user customers, free basic terminal operation training is provided for two customer employees. Intermediate terminal operation training and other CADAM training courses are then available to these customers for a fee.

Direct licensing makes up the smallest portion of CADAM sales. By far the largest distribution is through IBM, with which CADAM has three separate contracts: one for software licensing, one for software development and enhancement, and one for training. Under current contracts, IBM markets both CADAM system software and CADAM system training, and primary responsibility for provision of training and other support rest with IBM, which contracts with CADAM for actual training delivery. Responsibility for scheduling customers into training classes is also IBM's: CADAM provides IBM with a projected 6-month schedule of training courses, and IBM schedules customers into available classes. The contractual relationship with Perkin Elmer and Fujitsu are somewhat different than with IBM.

Program Design.—The principles of "instructional design"* will eventually be used in all of CADAM's training programs. At present, two courses have been fully revised by the program designers: 1) CADAM basic, and 2) 3-D piping, a new course designed for a software application program for the construction of pipe runs and spool diagrams. Four additional courses –basic II, analysis, CADAM implementation, and CADAM installation-were to be ready by the third quarter of 1983. As applied by CADAM designers, instructional design provides a systematic approach to defining, developing, and evaluating training programs-an approach which attempts to combine flexibility with an organized structure, The instructional design system is usable both for creating new programs and for revising old training material.

The instructional design system used by CADAM designers is a nine-part process which, in the case of the revision of CA DAM basic training, took approximately 9 months to complete. The process is broken down into three major functions: 1) definition of the problem or situation, 2) development, and 3) evaluation.

Customer Training Programs. *-CAD AM offers a total of 11 customer training programs plus a training consulting service. This section describes the basic terminal operations course.

Basic Terminal Operations.–CADAM's basic training program is offered approximately twice a month. Previously a 4-day course serving four students per class, CADAM Basic is now a s-day course which can accommodate four to eight students and can be taught by CADAM instructors or trainers from customer firms, or can be used as a self-study package. When delivered by CADAM trainers, the basic course is priced at $1,250 per student; when sold as a self-study package, the cost is $650 per study kit with additional workbooks priced at $70 to $150 each.

Course Goals.–The major goals are to teach students to use the basic functions of the CADAM system to create engineering drawings and to understand the basic concepts and purposes of the system as applied to their own professional needs and work environments.

*" Instmctional Technology" or "Instructional Design" was originally developed in the late 1940's and early 1950's as a means of systematizing training and educational programs. It incorporates psychology, sociology, adult education, and other disciplines to create instructional programs that take into account such factors as audience makeup, level of learning, educational levels and occupational background of the students, and their responses to the type of training or education provided (e.g., responses to learning to work on computers). A consortium of universities (including USC, Michigan State, Syracuse University, the University of Indiana, and Florida State) have developed fully fledged graduate programs in Instructional Technology (IT).

*CA DAM Inc. training programs not described in the preceding pages are the following: advanced numerical control programing, 3-D surface, 3-D piping, finite element modeling, and analysis procedures, management overview basic II terminal operations, job planning/on-the-job training, basic numerical control programing, and instructor training.

Prerequisites/Occupations Served.–The single prerequisite for the course is the ability to read blueprints. Most students who have attended the course have been drafters, designers, engineers, NC part programmers, and managers of departments in which the system is installed. Originally used by industrial designers, the CADAM system is now also used by architectural designers, facilities planners engaged in floor and shelf layouts for markets, hospital supply houses and other firms, and by electricians and electrical designers who use the software for the design of printed circuit boards and wiring diagrams. Occupational categories of students enrolling in CADAM basic course are thus becoming more diverse as the applications of the system multiply, and there are plans to adjust the basic course to reflect the changing audience,

Curriculum.– The course consists of eight lessons, each of which builds the students' ability to operate the CADAM system by introducing them to the use of one or more of the system's function keys. By use of the function keys, the operator calls up programs that enable him to create basic geometric shapes, to "edit" the geometry of his drawing—the "relimit" function key, for example, is used to trim or extend geometric elements—to indicate dimensions and to add notations, and to perform a variety of other operations. By the end of the course, the students will have learned the use of all of the function keys required for basic engineering drawings and will, in the process, have completed a series of practical exercises that result in a completed design of an industrial robot arm.

Lesson one begins with a general introduction, including a brief history of the CADAM system, its benefits, and the needs that it can fill; an introduction to the workstation (including a hardware demonstration); and an overview of the general operation of the system. Following the introductory lecture/demonstration, the students complete an audio-tape-guided introductory lesson on the graphics teminal, in which they learn how to enter and exit the system ("logon" and "logoff") and to perform a few simple operations. They learn, for example, to perform the basic file manipulation required to start a new drawing, call an existing drawing to the screen, and file a drawing on the computer disk.

From lesson two onward, the students spend approximately 70 percent of their time working on the terminals and learning the system by means of practical exercises. In lesson two, they learn how to use the circle, line, and point function keys to create points, lines, and circles at specific locations; to use the offset key to create a line in a desired direction, for example, or to create a new concentric circle; and to perform procedures for moving, sizing, setting, and presetting the display on the screen by use of the "window" function key, which can focus in on a small section of a drawing or can widen its focus to present a full drawing on the screen (like a camera taking either closeups or distance shots).

In subsequent lessons, the students learn to edit the basic geometry they have created (to create corners, to trim or extend elements, and to change the representation of an element from one line-type to another); to capture one or more elements for manipulation as a single entity or group, to analyze existing elements (e.g., lengths of lines, radii of circles, and relative distance between a pair of elements); to create textual notes and symbols to accompany the drawing on the screen; to create auxiliary views; to plot hard copies of the drawing; and to perform other basic functions.

In the final lesson, the students also learn job planning techniques and how to create and use a standard library of drawings. *

*Instructional Methods.*** The basic course is approximately 10 percent lecture (if delivered by an instructor), 20 percent in-class reading, and 70 percent practical experience on the terminal.

When used as a self-study course, the student workbook provides course content information and guides the student to consult the procedures guide which comes with the training package to help him/her complete exercises on the computer terminal. CADAM also provides instructions to managers to help them monitor the instruction and strongly recommends that, even when the course is delivered in the self-study mode, an experienced CADAM system user be on hand to answer questions and provide other assistance.

When used in a group learning environment, the workbook provides structure and support for the learning process, but the trainer becomes the primary resource by lecturing on course material, giving guidance to the students, and pacing the course to the students' speed.

The three critical elements in the instructional method—stressed by the trainers and in the work-

*A standard library is a collection of drawings of standard parts or models used frequently by a specific firm. Once the original drawings are completed by the firm's designers, they are stored in the CADAM library file and can be called up and used (as is, or modified).

**This section is adapted from the CADAM Manager's Guide.

book itself–are reading, planning, and careful performance of the exercises. The instructors encourage the students to read for conceptual understanding and to underline especially important sections. Planning is also an integral part of the instructional methodology. Each exercise is accompanied by a planning sheet for the students to complete. Once they read about the skills required to perform specific operations, they reinforce their understanding by planning how they will utilize those skills to complete the practical exercise. They then develop the skills by performing the exercise specified in the workbook.

Since each lesson is constructed of interlocking steps—each of which presents new information and introduces new skills while reinforcing skills and information learned in previous steps—students are strongly encouraged not to skip over any of the reading or planning phases. *

Traing Materials. -Each student receives a workbook, a *Training Handbook and* Proedures *Guide,* a magnetic tape which is fed into the computer and contains student exercises, and audio tapes for the audio-guided segment in lesson one. In addition to the student material, the customer firm also receives a manager's guide.

Evaluation of Students.– Each lesson of CADAM basic contains a self-evaluation quiz to help students gage their own progress in the course. Successful completion of the training does not depend on passing a final examination, but employers sometimes request the trainers to provide them with informal evaluations of the students to help them determine which should be given chief responsibility for operating the system at the customer's site.

Student Evaluation of the Course.–Students are asked to complete written evaluations of the course, the instructor, and the training materials. On a seven-point scale, students rate the course objectives, handouts, visual aids, homework, course content, applicability to their own needs, and the instructor. They also provide comments on the usefulness of the material, and their own ease or difficulty in absorbing it, and suggestions for improvement. After the interim revision of the course, ratings improved by up to two points, jumping from five or below to over six on the seven-point scale.**

*See p. 23 for customer response to the 'reading-planning-performance' methodology.

**Since the final revision of the course was released shortly' before the writing of this study, information on student evaluations of the final version of the course was not available.

Follow-up.–At the present time, follow-up of program graduates is informal. * CADAM maintains a hot line which can be used by customers who experience software difficulties or run into operation problems they cannot solve, and a number of customers call the trainers directly for help with difficult problems.

Results

Number Trained. -From January through September 1982, CADAM instructors trained over 700 customer employees. That number, however, represents a small portion of trained CADAM system users, according to CADAM's training director. Because of the significant investment of time and money involved in sending employees to the ~ADAM training facility *or* bringing a CADAM trainer to the customer site, most users send an "advance guard' who receive the training and return to train other employees.

Productivity Results.–While it is difficult to obtain quantifiable data on the results of the training as discrete from the results of system use, the subjective evaluations of CADAM customers and the improvement in the student ratings of the basic course on CADAM's own seven-point rating scale indicate that, for the most part, CADAM system training effectively supports the product. Nevertheless, a few customers have experienced some problems with the training.

Problems/Solutions.—

Organizational Difficulties: Personnel and Instructional Materials. –The most significant problem faced by the CADAM training division was that of organizing the training staff and the training material to lower the cost and increase the consistency of the training itself. Creation of the program design department freed the trainers from the responsibility of developing their own training material. The self-instructional training package developed for the basic course also frees CADAM from some of the service costs (providing an instructor to teach the course, etc.) and offers customers the option of purchasing training for slightly more than half the cost of the instructor-delivered course. While not all CADAM courses are amenable to the self-study format, the training division plans to package the basic II terminal operations, analysis procedures, and 3-D piping courses as self-study programs.

Solution to the problem of organizing the staff and materials, while decreasing the cost, created

*The training director intends to formalize the follow-up procedures once all of the customer courses have been revised.

another problem. Some of the instructors had difficulty accepting the change in focus in the revised basic course—from the individual instructor's interpretation and explanation to the highly structured and print-centered instructional material. These instructors point out that the new course allows for less interaction between students and instructors. Other instructors, who have taught the basic course so frequently that they felt themselves growing stale, believe that the new basic course allows them to aid the students' progress with more ease than in the past, and these trainers appreciate the opportunity to apply their efforts to the more advanced courses.

The solution to this problem of mixed instructor response to the new training method is being achieved through a give-and-take process of gradual accommodation. The instructors are required to learn new techniques and methods which focus on facilitating the students' understanding of the print-centered material rather than on the instructors' own expertise and experience with the system. However, the division management points out that the instructors will be able to become experts in teaching specific aspects or applications of the system in advanced courses which will continue to require a large degree of teacher-student interaction. While the students lose some degree of personal interaction, they receive instructional materials which thoroughly cover each step of the process in a consistent manner and which can be used as readily accessible review material after the training is completed.

Trainee-Centered Problems.–As with other training programs in computer-aided manufacturing and design, approximately 5 percent of trainees in the CADAM basic course exhibit resistance to it. CADAM training division representatives say the root cause of this is "computer anxiety, " a syndrome with two major aspects: the trainees' fear that they will be replaced by a computer and the corresponding fear that they will not be able to master the "monster" that is replacing them.

In some instances, "computer anxiety" is accompanied by another negative response, labelled by CADAM trainers as the "It'll All Go By" syndrome (the belief that computer-aided design is a flash-in-the-pan trend which will never create significant changes in design work). Trainees who do show this type of resistance are in the minority and are, according to CADAM trainers, usually designers, engineers, or drafters nearing retirement age. While the growth of CAD/CAM has reduced the numbers of trainees who believe that "it'll all go by," "computer anxiety" remains a significant problem for some trainees. CADAM trainers address this problem by explaining that the system is a new tool that can only make their jobs easier. The student workbook for the basic course also helps the trainees to overcome their anxiety by, again, referring to the system as a tool rather than as a threat and introducing the students to the terminals within the first 8 hours of instruction by moving them into a hands-on exercise that is easy to execute and has minimal potential for failure.

CADAM trainers estimate that fewer than one-quarter of the initially resistant trainees (2 percent of the total student group) retain their resistance after the first two 2 days; they report that many such students have returned to take advanced courses. Approximately 1 percent of all trainees fail to learn the system, not because of resistance to the training, but because of a "mental block, " or inability to understand what is required to operate the system.

Another problem—one experienced by the majority of trainees-is that the basic course presents such a large volume of information that most students do not grasp all of it during the week-long course. Extension of the course into a second week was rejected as a solution because the customer firms can rarely spare their employees for that length of time. The new instructional materials are designed to address the problem of "overload" by presenting the information in the building block pattern with built-in redundancies to reinforce knowledge of the previous steps. In addition, the new course material works as a reference guide once the training has been completed.

Evaluation of Present and Future Capacity to Meet Training Needs

Merrill Lynch states: "As users become more sophisticated, we envision a move toward general purpose mainframe computers at the high end application level for maximum performance and ability to do data base management , . . . This trend implies a change in character of some vendors toward being CAD/CAM system integrators. "[3] CADAM's orientation to the systems integration approach, and CADAM management's belief that training is an integral element in that approach, may be the

[3]*CAD/CAM Review and Outlook,* 1981, p. 2. The Merrill Lynch 1982 *CAD/CAM Review and Outlook* user survey, however, found that among the overall disadvantages of mainframe systems are insufficient software and support, high initial expenses, and the fact that the entire system goes down when the CPU does.

key to the future potential of both the software product and the training that supports it. However, it should be noted that under its installed user program IBM also markets CAD software produced by other firms.

Two of those software packages–CAEDS, developed by Structural Dynamics Research Corp., and circuit board design system, developed by a Canadian firm-address specific CAD applications and not the broad design and manufacturing market aimed at by CADAM; but the third package–CATIA, developed by Dassault Systems in France-does, according to an IBM representative, have some potential "overlap" with CADAM Inc. 's software applications. In addition, IBM also markets a CADAM training package, called a "Graphics Training Aid, " developed by Westinghouse's Industry Motor Division in Roundtree, Tex. The Graphics Training Aid was purchased by approximately 50 companies in 1982, primarily those intending to set up their own internal CADAM training operations.

While neither Westinghouse nor IBM views the Westinghouse Training Aid, which most buyers purchase as a self-study package, as being in direct competition with CADAM system training, the Westinghouse package does give the customer the option of purchasing training other than that supplied by CADAM. Furthermore, CADAM training is also sold by independent engineering and consulting firms—one of which, according to one customer interviewed, delivered 2 weeks of "excellent" training to his employees. The "partnership" with IBM, then, does not give CADAM a monopoly on IBM's hardware customers--nor does the firm's own training department have a monopoly on CADAM training,

Customer Evaluations.–Six CADAM Inc. customers, most of whom had received training after either the interim or final revisions of CADAM basic had been completed, were interviewed. Most of them represented medium- to large-sized firms which had previous experience with either the CADAM system or other computer-aided design systems, and some are actively engaged in networking CAD and CAM capabilities. Responses to a request for an overall evaluation of the training—including content, delivery, and applicability to specific company needs—ranged from "reasonable" and "good" to "excellent." One customer, who had received CADAM training in January 1982, went to an outside consultant for further CADAM training a few months later and returned to CADAM at the end of 1982 for more training, said that training and other support supplied by CADAM was inadequate in January but had shown "great improvement" and "greatly increased attention to detail" by the end of the year.

Benefits.–One customer—who had made a 3-year study of the CAD market before purchasing a system—said that the real benefit of the training delivered by the CADAM training department, as opposed to CADAM training delivered by other vendors, is that the trainees learn how to make the most efficient use of the system in the shortest period of time. Most of the customers said that, after completing formal CADAM system training programs, they felt well prepared to embark on the most significant portion of the training—the period directly following the formal course when the systems are used for actual production work. During this 2- to 4-week period, most of those interviewed reported that their new CADAM system operators got "up to speed" (i.e., produced designs at rates which matched or exceeded manual drawing times) even faster than anticipated. Those who had purchased or were considering purchasing the self-study packages felt that this new option was a tremendous benefit, primarily because of the perceived need for ongoing internal CAD training.

Problems.–Aside from the problems mentioned in the preceding pages of this section, the most frequently articulated problem was that the terminals at the CADAM Inc. training center occasionally went "down" or had poor response-time. (None of the customers interviewed have had equipment problems at their own installations, however, and many reported "incredibly quick' response times averaging 0.15 second.) While the equipment problems at CADAM–which are currently being addressed–do not reflect on the trainers or on the training materials, they did create an atmosphere of frustration which colored the trainees' perception of the training course. One customer, whose firm is located in the Southeast, has had numerous problems with the CADAM hotline, which, he claims, is often inaccessible to Eastern customers because it only operates durring business hours on Pacific time. This customer has lodged a formal request to encourage CADAM to extend its hotline hours to accommodate customers located in other time zones.

All of those interviewed agreed that CADAM training is extremely expensive relative to customer training provided by the majority of other computer-aided-design firms. While most accepted the high cost of the training as either a necessary evil or as the price of learning to be effective users of the CADAM system, one customer labelled the price of the training as "outrageous–highway robbery." Although most of those interviewed thought that the cost of the self-study packages ($650 per kit, as opposed to $1,250 per student for the Basic course) makes CADAM training a more reasonable investment, one believed that even the self-study package was "twice what it should be."

Training for Profit: Pros and Cons.–CADAM's training director points out that, while many hardware (and hardware/software) firms provide training free of charge to their customers—or at rates far below those charged by CADAM–by, in essence, folding the cost of training into the hardware or software prices, CADAM's procedure of pricing training to cover the operating and development costs of the training division creates certain benefits for both the customer and the training deliverer,

For one, customers get what they pay for—i.e., customers who require little or no training are not subsidizing the training of other customers. Secondly, he says, because training costs are frequently buried in equipment or operating costs, most companies do not recognize that good training is expensive to develop and deliver. It is for this reason, he believes, that training is often "too little and too late" and is often among the first support functions to be cut back during economic downturns; so that, along with recognizing that training is a necessity if sophisticated equipment is to be used effectively, company management must also recognize the actual costs of creating and maintaining training functions.

The status of training within CADAM's organizational structure—the fact that the training function is the sole responsibility of one of the four major divisions—indicates CAX)AM management's recognition that training itself is of pivotal importance in the CAD/CAM field. The scope and degree of CADAM's commitment to training is possibly unique in some respects. Cert airily the relative size of the training division (8 percent of the firm's employees) is unusual,* as is the fact that the training director reports directly to the president of the firm.

Also unusual is the degree of flexibility and responsibility accorded to the training division. The division is responsible for providing "quality" training to support the software product and for making a profit. Also, it is given the flexibility, the resources, and the communicative channel with the product development department necessary to fulfill that responsibility. A comment by a training division representative provides a cogent description of the firm's approach to training in general: "We're trying to turn the old situation of training departments around. Most training departments are not given enough responsibility and accountability and have a subservient position in the company, reporting through many levels of bureaucracy, In a high tech field, training can no longer be handled in a subsidiary, low-level, low-priority fashion-it too important. Things are too volatile and they change too fast."

By designating the training division as a profit-center and by providing it with the resources and organizational support to produce a well-designed training product, CADAM management has made an investment in the training itself. This means that the training product must be high-quality if the firm is to realize a return on its investment indirectly (in terms of product support) and in terms of direct profit from the training charges. Profit realized from the training is used to pay the training division's operating costs and to fund development of new training programs and refinement of already-existing courses,

As a profitmaking entity whose training product entails a great deal of expense—both to the customer and to CADAM—the training division runs the risk of, as one customer put it, pricing itself out of the training market. And when high prices are combined with a reluctance on the trainers' part to go beyond the contents of the basic course when students ask about advanced applications, the CADAM training division also runs the risk of giving some customers the impression that their specific needs will be attended to only insofar as they do not extend into areas covered by further training, i.e., which entail further purchases of training.

On the other hand, statements by trainers in some user firms support the assertion of CADAM'S training director that the common practice of burying training costs in operating or other expenses keeps management unaware of the real costs of providing training. It is possible that what is perceived as an "outrageous" training cost actually reflects a reality that most industries are not used to seeing. The training division's cognizance of the need to lower training costs while maintaining quality resulted in development of the self-study packages that both reduce cost and en-

* It should be noted, however, that the ratio of training division personnel to other CADAM employees would be more difficult to achieve in a larger firm.

able customers to train future generations of users with the same instructional material. It remains to be seen whether the self-study package will solve the problem of high cost.

The firm's capacity to meet the direct training needs of future CADAM customers will depend on its ability to maintain its gains in improving the quality of the courses and to develop new courses while keeping its prices within reasonable limits. CAD AM approach to training presents an interesting conundrum. On one hand, CADAM illustrates that significant time and money spent to make training a "first priority' can be seen as investments rather than as begrudged expenses. The firm also illustrates that the investment of those resources in well-designed and adequately tested training can increase productivity and profit. On the other hand, it maybe a matter of questionable prudence for CADAM to be among the few software providers pricing their training "realistically. " Can they "educate" the entire population of users as to the actual costs of training, or will other training vendors who offer "CAD AM" instruction at a lower price deprive the trainin g division of significant numbers of students?

Although CADAM training appears to be of a high standard, it also appears to some customers that CADAM's packaging of training as a high-priced commodity sometimes impinges on its overall effectiveness by limiting the information available to trainees in the basic classes. It would seem then, that there is an attitudinal problem on the part of both the recipients and the provider of training, each with his own expectations of the proper form of training and the behavior of trainers. More explicit communication between the trainers-who must use the limited time at their disposal to present a great deal of material in a systematic fashion—and the customers—who have varying needs which may not always mesh with the highly structured basic course–would ameliorate this difficulty.

Case Study 4
Programmable Controller Training Program

International Brotherhood of Electrical Workers, Local 11 Los Angeles County Chapter, National Electrical Contractors Association

Summary

The Los Angeles Electrical Training Trust is the training arm of the Joint Apprenticeship Training Committee of the International Brotherhood of Electrical Workers (IBEW) Inside Construction Local 11 and the Los Angeles Chapter of the National Electrical Contractors' Association (NECA). The Training Trust, supported by Local 11 members and the electrical contractors who employ them, provides a 4-year apprenticeship training program and voluntary courses for Local 11 journeymen.

In the late 1970's, the Trust began addressing the need to provide journeyman training in the skills required to install, troubleshoot and maintain the electronic devices that were beginning to replace a number of the hard-wired electrical devices involved in inside-construction in factories, plants, and offices. This study focuses on one set of course offerings provided by the Trust—a series of three courses on the installation, programming, and troubleshooting of programmable controllers,

Background: Los Angeles Electrical Training Trust

The Los Angeles Electrical Training Trust (ETT) was established in 1964 to support educational and training programs for apprentices and journeymen covered under the collective bargaining agreement between IBEW Local 11 (Inside Construction) and the Los Angeles Chapter of the National Electrical Contractors' Association (NECA). * As provided for in the Labor Management Relations Act of 1947, the Trust is jointly operated by local union and management representatives and is supported by regular contributions from Local 11 members and their employers. Under the terms of the current collective bargaining agreement, Local 11 members contribute 5@ for every hour worked into the Trust, while their employers contribute 150 for every employeehour. While the primary responsibility of the Trust is to provide apprenticeship training, the Los Angeles ETT–along with a number of the other local IBEW training organizations in the United States–also operates an active journeyman skills improvement program.

All apprentice and journeyman courses are held in training facilities that are either owned, leased, or rented by the Trust. To accommodate the approximately 7,000 journeymen and 650 apprentices in the Local's Los Angeles County jurisdiction (covering 4,069 square miles) the Trust maintains five training centers: one "Metro Facility" in downtown Los Angeles, and one in each of the district's four other dispatch areas. The Metro Facility, opened in March 1981, contains seven classrooms and 8,000 square feet of laboratory area (including a $300,000 process instrumentation lab, as well as laboratories for welding, house wiring, conduit bending, motor controls, transformers, fiber optics, high-voltage cable splicing, air conditioning, and fire alarms and life safety instruction). Two of the dispatch area training facilities have permanent laboratories, while the other two occupy rented space which is converted into temporary laboratories for training purposes. *

Training Trust Administration and Staff .-–In accordance with the provisions of the Labor Man-

*Local 11 is one of 365 I BE W reside construction locals, whose membership work primarily for independent electrical contractors. The IBEW also maintains manufacturing locals, serving electrical/electronic manufacturing firms; maintenance locals, whose members do in-plant maintenance; utility locals serving public power companies: and telephone locals. Because members of Inside Construction Locals often work for a series of small to medium-sized contracting firms which do not have the resources to provide in-plant skills training, the Inside Construction Locals are among the most active in delivering journeyman training under the auspices of Joint Apprenticeship Training Committees.

The National Electrical Contractors Association maintains 135 local chapters throughout the United States. The Los Angeles Chapter currently has 230 member contracting firms, 35 of which have 30 or more permanent employees and often provide design and engineering as well as installation services. The remainder of the members employ an average of 10 to 12 full-time workers. NECA members provide electrical contracting services to a wide variety of customers, including manufacturing firms, powerplants, newspapers, hospitals, schools, and offices. A number of NECA members are also members of the IBEW.

*By the end of 1983, the Trust hoped to have established permanent training facilities in all of the dispatch areas.

agement Relations Act, the Trust Fund is controlled and administered by a six-member Board of Trustees with equal union-management representation. In addition to the Board of Trustees, the Los Angeles ETT is also served by five Joint Apprenticeship Subcommittees (JASC–one in each of the district's five dispatch areas) and the Joint ,Journeyman Educational Advisory Committee (JJEAC). On the permanent staff of the Training Trust are the director, a staff representative in charge of apprenticeship training, a staff representative for journeyman training, and a senior instructor. The majority of the courses are taught by journeyman electricians who serve as part-time instructors for the Trust.

The Trust director is appointed by the trustees and is responsible for the ongoing operation of the training programs. The current director, appointed in 1978, has had previous experience as both an IBEW journeyman and an electrical contractor. Both staff representatives have worked as IBEW journeymen and foremen, and both have had previous experience working with training and educational programs. All of the approximately 25 part-time instructors who teach the apprenticeship programs are credentialed as part-time instructors by the State of California. The 58 instructors who teach journeyman courses are not required to obtain State teaching licenses; approximately half of them, however, are credentialed.

Philosophy of Training: General Goals.-The major goal of the Electrical Training Trust is to deliver comprehensive apprenticeship training and provide journeymen with the opportunity to improve or reinforce existing skills and develop new skills required by the changing electrical/electronics field. According to the ETT's director of journeyman training, the line between electricity and electronics is beginning to dissolve; electricians intent on keeping their skills current, therefore, must develop new skills in electronics and computer-aided equipment.

Because of the voluntary nature of journeyman training, the Trust's educational philosophy aIso stresses motivation and creating an awareness of new skill needs to encourage journeymen to take advantage of the training courses offered. Individual motivation and self-initiative are especially significant, since approximately 25 percent of the membership is hired for relatively short installation jobs out of the union hiring hall. Of the remainder, approximately 60 percent are permanently employed and 40 percent work for two to three contractors per year.

Another aspect of the Trust's training philosophy is that it is the right of each journeyman who works at least 6 months per year to take any course offered in the skill-improvement program if he or she has completed the prerequisite courses, To avoid discouraging voluntary participation in the program, no grades are assigned at the end of the courses, and (for the majority of courses) no selection criteria are applied. The introduction of coursework on computer-based equipment like programmable controllers and process-instrumentation devices has, however, created exceptions to the general free-enrollment procedure. Because not all of the students who enrolled in the intermediate programmable controller courses had a solid grasp of the fundamentals taught in the basic course, selection procedures have now been instituted for that course, The process instrumentation program–a lengthy series of courses totalling 795 hours–requires students to pass an evaluation as an admission requirement and to pass examinations before proceeding from one course to the next.

Training Overview.– The Los Angeles Training Trust delivers required courses for apprentices and "pending examination wiremen " and voluntary courses for journeymen. Apprentices take a total of 840 hours of work-related classroom instruction at the Trust, extending over a 4-year period (3 hours per night/2 nights per week). * Related instruction courses include electrical code, mathematics, blueprint reading, first aid, pipe bending, welding, instrumentation, basic transistors, and electronics. Applications for the apprenticeship program are accepted every 2 years in Los Angeles. During the most recent application period, 1,650 candidates applied for the 100 to 200 apprenticeship openings anticipated over the next 2 years. New apprentices are admitted to the program on the basis of their rank score from the oral interview.**

"Pending examination " (PE) wiremen are experienced electricians who have not gone through the

*The L. A. Trust apprenticeship program is based on the4- year program offered by the National Joint Apprenticeship and Training *Committee* in Washington, D.C. While the International sets guidelines for apprenticeship training, Locals have flexibility in setting their own programs. The Inside Construction Local in Detroit for example. requirers 672 hours of related instruction, delivered *once every 2* weeks 18 hours per day).

**Of the 1,650 recent applicants, 1,150 passed the qualifying examination. which focuses on mathematics skills. Those who qualifed on the basis of the examination were then interviewed and were ranked from 1 to 1,150 on the basis of the interview As apprenticeship opening. occur over the next 2 years, candidates will be called according to their placement on the list.

apprenticeship program but who instead become members when their employer signs an agreement with the Local. The PE program originated in Los Angeles in 1980 and has now spread throughout California and into some other States as well.* PE wiremen receive journeyman wages but are required to take an evaluation examination and to attend a concentrated 2-year, four-semester course series to reinforce their knowledge through formal study and to upgrade their skills, At the end of the program, they take the formal journeyman's examination to achieve full journeyman status.

Both the apprenticeship and the PE programs are administered through the Los Angeles County Schools' Regional Occupational Program, which serves as registrar for the two Trust programs discussed above.

Approximately 2,000 journeymen completed voluntary skill-improvement courses in 1981-82. Journeyman courses range from 3-week reviews of recent changes in the national electrical code to 13-week courses in advanced blueprint reading to a 3 l/2-year series of courses on process instrumentation. ** The journeyman skill-improvement program is focused on reinforcing core trade skills and introducing new skills in demand in the local marketplace. Among those new skills are those required to install, program, troubleshoot programmable controllers, process instrumentation skills, and test and splice fiber optics cable.

Programmable Controller (PC) Courses

Planning and Development.—The need for coursework in programmable controllers was first brought to the attention of the Training Trust in 1978 by members of the Joint Journeyman Educational Advisory Committee (JJEAC). One of the committee members—a general construction manager for a large contracting firm that designs, engineers, and installs computerized systems for materials handling and process control–played an instrumental role by convincing the committee of the need, by providing advice on prerequisite coursework and equipment, and by recommending potential instructors.

Following the advice of its "area expert, " the committee recommended that the Trust first develop a motor controls course to aid in preparing interested journeymen to take the more advanced PC courses. Westinghouse's Standard Control Division in El Monte, Calif., proved to be extremely helpful in the development stage, both by providing equipment at a greatly reduced rate and by recommending one of its applications specialists to be the course instructor. The curriculum for the first programmable controller course was developed by the Westinghouse specialist, reviewed and modified by JJEAC to increase its focus on the specific needs of Local 11 journeymen, and approved by the Board of Trustees late in 1980.

The first class was offered in October 1981, and the course has now become a staple offering of the Trust's journeyman skill improvement program. In the fall of 1982, the Westinghouse specialist who developed and taught the basic course began teaching an intermediate course, PC III, to graduates of the basic course. PC II, a hands-on course covering similarities and differences of four of the major programmable controllers on the market, will be offered in the summer of 1983.

Goals and Objectives.—Specific goals and objectives of the programmable controller courses support the major objective of the Training Trust's journeyman skill improvement program, which is to provide Local 11 members with the opportunity to develop knowledge and skills in all areas of electricity/electronics applicable to employment opportunities in the Los Angeles area covered by the Trust agreement. This entails not only meeting current needs, but attempting to forecast future needs so that the Local will be able to provide a trained work force when opportunities occur. Courses that develop skills in high-technology fields such as programmable controllers, process instrumentation, and fiber optics are considered by the Trustees and the JJEAC to be crucial areas of education and training for journeymen who want to keep pace with the skill requirements of the local marketplace. In the words of the Trust's director of journeyman training, "The only things we have to sell are our skills and knowledge-these must be pertinent. "

Since the Trust was established to serve both union members and the contractors who employ them, its goal in offering the programmable controller courses is twofold: to provide appropriate skill training to Local 11 members, and to meet

*In many areas of the country, experienced electricians who enter Inside Construction Locals when their shops are organized automatically become full-fledged journeymen. Approximately 400 P. E. wiremen are now taking courses at the L. A. Training Trust.

**Process instrumentation is the application of electric, electronic, and/or air controls to regulate pressures for measuring fluids or gases and for indicating and controlling levels, temperatures and flow of liquids or gases. Students in the process instrumentation program are taught how to inspect, calibrate, install, tune, and troubleshoot computer-aided instrumentation and process-control systems used in chemical and petrochemical plants, refineries, breweries, food processing, and other industries.

the needs of signatory contractors, more and more of whom are making installations involving programmable controllers. The specific objectives of the series of PC courses offered by the Trust are to train journeymen to install, provide power to, program, and troubleshoot programmable controllers. The goal of PC 1 is to provide a basic introduction to installation and programing requirements so that a graduate of the course could, under the direction of a skilled foreman, aid in PC installations on the job. The goal of the intermediate course is to provide additional information and practice in programing and to teach troubleshooting techniques to enable members to do installation work with less supervision.

With the addition of the PC 111 course, the PC series will fulfill its overall objective—to familiarize advanced students with installation, programing, and troubleshooting techniques specific to the major PC systems in use in the Los Angeles area in order to provide them with increased work opportunities.

Administrative and Instructional Staff.–The Trust "staff representative" who directs the journeyman skill-improvement training is an active supporter of ''high-technology training' for journeymen. The journeyman training department took major responsibility for locating the equipment and the instructor for the original PC course and for ongoing coordination of what is now a series of courses on programmable controllers.

Until the first few months of 1983, all of the programmable controller courses were taught by a single instructor, a Westinghouse applications specialist employed by the sales and customer support group of the Standard Control Division's Numa Logic Department. His prior technical experience includes work as an IBEW journeyman electrician-then as a draftsman, nuclear power engineer, and control panel designer. Previous to his employment by the Training Trust as a PC instructor, he had taught a series of courses on programmable controllers to employees of the Los Angeles Department of Water and Power. By the spring of 1983, four new instructors-Local 11 journeymen who have either taken previously offered PC courses at the Trust or have on-the-job experience—will begin teaching the basic course. 1n addition, they have completed customer courses, paid for by the Trust and delivered by Allen Bradley, Modicon, and Westinghouse–all major producers of programmable controllers in the United States.

Equipment.–The "Metro Facility" of the Training Trust contains four classrooms and three classroom\labs, one of which is available for PC courses. In addition, PC classes are also offered on a rotating basis at training sites in four of the district's dispatch areas. As of this writing, the Trust owns two Westinghouse 700 series Numa Logic Programmable Controllers, which are transported by the instructor from one training facility to another as the occasion demands. * The administrative staff of the Trust is currently in the process of purchasing programmable controllers manufactured by Allen Bradley, Modicon, and Texas Instruments in preparation for the PC 111 course to be offered in the summer of 1983.

Costs and Funding.–The journeyman skill-improvement courses are supported entirely by Training Trust funds. Most cost items for the programmable controller courses were not available (administration, instructor salaries, student materials, or classroom rental). The two major items of equipment currently in use—the Westinghouse programmable controllers, valued at $25,000 each—were purchased by the Trust for a total of $10,000. In addition, the Trust has set aside funds for the purchase of the other three PC systems to be used in the advanced course.

Costs to Students.–Tuition and instructional materials are free of charge to eligible journeymen and apprentices (see Selection, below). However, to encourage students to complete the courses, a $10 deposit is charged at the beginning of every course and is refunded to those students with satisfactory attendance records.

Selection Procedures and Enrollment Trends.—

Selection—Journeyman skill-improvement courses are open to all members of Local 11 who have worked 6 or more months out of the preceding year for signatory unions.** Apprentices are discouraged from doing so until they have learned the fundamentals of the trade. To date, no apprentices have completed the basic course.

Until recently, no enrollment control existed for either the basic or intermediate PC courses, aside from the necessity of completing the basic course

*Though the Metro Facility provides secure storage space for equipment, the other training sites do not. Furthermore, classes have, in the past, been offered concurrently at more than one facility. The compact, transportable equipment therefore gives the Trust the flexibility to offer classes at more than one site.

**Since the Traing Trust is supported by a small proportion of the fringe benefits attached to the wages of working members of the Local and by contractors who are signatories to the trust agreement,

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(PC I) before signing up for PC 11.* Since, however, regular attendance is the only formal graduation requirement, some graduates of the basic course have signed up for the intermediate course without the prerequisite skills and knowledge to benefit from the more advanced instruction. In February 1983, a new policy was established whereby members who enroll in PC I take an entrance examination covering motor control theory. Those who do not pass the exam are encouraged to take the motor controls course offered by the Trust before continuing with the basic PC course. Admission to PC II is now at the discretion of the instructor, who will base his decision on a review of completed homework exercises required in PC I.** When the advanced course, PC III, is delivered in the summer of 1983, only those whose homework in PC II exhibits a thorough understanding of the intermediate course will be accepted. Those who are not accepted into PC II and PC III will be encouraged to retake the preceding course to bring their skills up to the required level.

Enrollment Trends/Attrition.-Accod.ng to the Westinghouse instructor, the PC I and II courses have been very well attended, sometimes drawing as many as 32 enrollees for a single course. The complexity of the coursework, however, and the need of some of the PC I enrollees for background coursework in motor controls and solid-state electronics, has resulted in an overall attrition rate of approximately 33 percent.*** While the preferred class size is 12, classes have ranged in size from 8 to 18 students. (Especially large classes are split in two, which, until the recent addition of the two extra instructors, presented problems for the Westinghouse trainer, who had to teach classes twice a week to accommodate all interested students.) Both enrollment and attrition are less in PC II than in PC I.

The employment situation of the journeyman electricians who enroll in the PC courses varies considerably. Some are permanently employed by signatory contractors;* some work for single contractors for long stretches of time (6 to 12 months) on major installation jobs; others work "out of the hall," i.e., are not permanently or semipermanently employed but rather are hired for relatively short jobs out of the union hiring hall. Because of the current economic situation in Los Angeles, a growing number of the students in PC courses work out of the hall.

Two additional factors play a part in this enrollment trend: 1) large electrical contractors who provide design and engineering services as well as installation often provide in-house training for their Local 11 employees who install programmable controllers, and it is these contractors who do most of the PC installation in the county, and 2) a number of smaller contractors who are prepared to do installations involving programmable controllers—and who would be likely to encourage their employees to take the PC courses or to hire course graduates-have been affected by the construction slump.

Curricula: PC I—PC 111.–PC I and PC 11 were both designed to be 18-hour courses, delivered in 3-hour segments 1 evening a week for 6 weeks. However, because of the amount of material to be covered in the basic course, recent PC I courses have been extended to 7 weeks. PC 111, currently in the development stage, will be from 16 to 24 hours in length and will take place on the weekends to enable students to attend intensive 8-hour-a-day classes.

- PC *I.* —Students in this introductory course learn terminology, the basics of the theories behind programmable controllers, how to address the equipment, how it works, and basic installation, programming, and applications. Since the majority of students enter the class with limited experience in solid-state controls, the first two sessions are devoted to basic theory–an introduction to logic and to Boolean algebra (session I), an introduction to solid-state controls, and a comparison between solid-state and electromechanical devices (session II).

  Programmable controllers are not introduced until the third session, when students learn what programmable controllers are, how they compare to electromechanical controls, and some basic PC applications. installation and basic programing (including an overview of input and output devices and special functions involving timers, counters, and other devices) are covered in session IV. Sessions V-

employees covered under the IBEW Local 11 agreement who have worked at least half the workdays of the year previous to enrolling in classes have contributed to the trust fund and are therefore eligible. Occasionally, members who have worked less than the normally required 6 months are allowed to attend classes. These decisions are made on a caseby-case basis.

● Students with previous experience working with programable able controllers on the job may also test-in to the intermediate course without having completed PC I.

● *Successful completion of homework assignments is not a requirement for graduation, only for entrance to the next course.

● **In recognition of the potential for attrition, the instructor has instituted the following practice. An entrance test concentrating on motor controls theory is given on the first night, and those interested in participating were then interviewed and were ranked from 1 to 1,150 on the basis of the interview. As apprenticeship openings occur over the next 2 years, candidates will be called according to their placement on the list.

● Contractors who operate "union houses" and are signatory to the collective bargaining agreement between Los Angeles NECA and IBEW Local 11.

VII are primarily devoted to discussion and practice of programing for specific applications. In addition, session Vii also covers "multiplexing," i.e., carrying out multiple functions simultaneously in an independent but related manner, an operation that often involves combining several signals so that they can be handled by a single device.

- PC 11 provides graduates of the PC 1 course with the opportunity to practice the basic programing techniques they learned in PC I and to learn more advanced programing applications. For example, they learn to program the PCs to control a "bad parts detector" on a manufacturing plant conveyor system by writing and inputting programs for counting the total number of parts on the line, counting the number of faulty parts, and for rejecting the parts that are flawed. 1n addition, the students complete a number of troubleshooting exercises: the instructor puts "bugs" into the classroom equipment and requires the students to tell him why the equipment is not working, how they would fix it, and what the result will be once the adjustment is made.

  Both the programming and the troubleshooting experiences are of use to inside wiremen who, when they install programmable controllers, often run a basic program for testing purposes and troubleshoot equipment problems that may occur. Some wiremen may also work for contractors who may be called back to a facility to troubleshoot and repair equipment that they installed initially.
- PC 111. —This course, now under development, will teach graduates of PC I I how to install, program, and troubleshoot the major models of programmable controllers currently on the market. Accordingly, the course will focus on teaching the students the differences and similarities between the Westinghouse Numa Logic 700 Series used in PC I and PC 11 and the models produced by Allen Bradley, Modicon, and Texas instruments, The Trust is currently proceeding with plans to purchase the equipment, and the Westinghouse instructor is designing the course materials.

Instructional Materials and Teaching Methods.— Instructional materials for the PC I course were developed by the Westinghouse instructor specifically for use in Training Trust courses, Using some material from the Westinghouse Numa Logic programing and applications manuals and some original material, he devised an instructional package specifically geared for skilled tradespeople with knowledge of electricity but not necessarily of electronics. The same approach—based on relating the principles, theories, and operation of programmable controllers to the theory and operation of electrical and electromechanical devices—is used in lectures and hands-on exercises. When teaching Boolean algebra, for example, the instructor relates it to common electrical problems the trainees already understand, and specific Boolean algebra problems given in class and for homework are based on actual wiring problems the electricians would be likely to run into in the field.

Another example of this approach would be the instructor's method of teaching the theory and operation of timers and counters, which are among the basic components of PC systems, He explains the use and purpose of timers and counters by relating them to relays and electromechanical devices; explains how programing takes the place of wiring when dealing with programmable controllers; and assigns in-class, hands-on exercises to reinforce the basic concepts.

The initial exercise is always reinforced by a second exercise which is very similar to the first. Homework, including reading and problem exercises, is assigned weekly to further reinforce the material taught in class and to lay the basis for the next week's lecture and laboratory work. Although no final grade is given, tests are conducted at the beginning and end of the course and are supplemented by weekly quizzes-all of which help the instructor to know what to emphasize for each individual class,

Both PC I and PC II are approximately 70 percent lecture, 30 percent hands-on. In PC 11, the programing and troubleshooting exercises become more difficult as the course progresses, as the students are taught to reapply what they have already learned to increasingly difficult problems. No specially designed training manual is used for PC II. Instead, students use Westinghouse programing and applications manuals. Students in PC III will have access to the programing and application documentation for all of the systems taught and will learn to write basic programs and modify existing programs on these systems. In addition, they will learn to identify similar problems in all the models, along with methods for troubleshooting the various systems. Students in this advanced course will be expected to complete a great deal of reading on their own time to free up the majority of the class time for practical installation, programing, and troubleshooting exercises.

To increase the amount of hands-on time available to each student in the PC 1 I classes, a new system was inaugurated in the 1983 winter-spring schedule. Each student in these classes had the opportunity to take a programmable controller for a week of at-home practice. In addition, students in future classes will also have access to the new training equipment presently being purchased, which will be made available to them at the Metro Facility when it is not being used for training purposes.

Course and Student Evaluations.—

Evaluations of the Courses—Students complete written evaluations of the course, the instructor, the facilities, and the instructional material. While there is no formal course evaluation by the trustees, the JJEAC, or the Training Trust staff, both the IBE W Local and the local NECA chapter provide unofficial channels for evaluation of the course by both contractors and journeymen. Contractors who employ union members who have completed the class give NECA informal evaluations of the workers' skills, and this information is transmitted to the Trust through the contractor-members of the Trustee committee and the JJEAC. Similar informal evaluations reach the Trust via the union representatives who sit on the various committees.

Evaluations of the Students.–Since journeyman skill-improvement courses are taken on the students' own time and on a voluntary basis, no course grades are given, and it is not necessary to pass a final examination to graduate from any journeyman course. However, the new selection criteria for admission to PC I and PC 11 will require that students in the less-advanced courses illustrate the ability to proceed with more-advanced coursework as an admission requirement to PC II and III.

Results

As of February 1983, 89 Local 11 members had completed the basic course and 29 had completed the intermediate course. Since the Trust has no formal follow-up mechamism for tracking graduates of the journeyman courses, it is difficult to assess the overall results of the training in terms of job performance and/or expanded employment opportunities. Interviews with the Training Trust staff, the PC instructor, students, and contractors have produced some data, which, though limited, illustrate some training results in specific instances.

Of nine journeymen interviewed in the January 1983, PC II class, one was currently working on a PC installation, one had been hired from the hall to work on PC installations in the past, and another was preparing to become one of the new PC instructors. All three were taking the course to increase their applications and troubleshooting skills, and one noted that the course was especially helpful in teaching him to recognize troubleshooting problems. The other six had not had the opportunity to work with programmable controllers on the job, but were taking the course for two reasons: 1) to prepare themselves for future opportunities, and 2) because they believed it was incumbent on them to develop the skill to work with the electronic and computer-aided equipment they now see to be replacing electromechanical devices in many operations.

Those who worked out of the hall stated that the PC courses they had taken would give them a distinct advantage in obtaining work, since they would be able to respond to "specialty calls" (requests for workers with specific skills) for PC installation when these come into the hiring hall. *

Six of the eight contractors interviewed provided in-house PC training for their Local 11 employees. ** One, however, said that he "expects" his employees to take the Training Trust PC courses and that eight of his employees who had taken the course had improved their skills. While one large contractor who provided formal training classes did not see the need for his employees to take the Trust classes, he did support the training for other, smaller contractors. Three others who provided their own training did not have a present need for more employees skilled in PC installation. They could anticipate, however, a future need and thought that the course graduates would be attractive hiring prospects.

One employee of another of the contractors had taken the class but, because the contractor had an adequate number of employees who were experienced in PC installations, the course graduate had not yet had the opportunity to do any installations. He would, though, be "first in line" for such work should the need arise. Another contractor, who had hired two course graduates, noted that the PC and process instrumentation courses provided by the Trust save contractors time and money by enabling them to make installations with-

*Although no formal refresher courses are provided for those who do not have the opportunity to practice their new skills on the job, Local 11 members may maintain and increase their skills by taking the more advanced courses. PC 111 is so designed that students can benefit from repeating it one or more times to get additional hands-on practice.

**Training ranges from formal classes to on-the-job instruction.

out first having their employees trained by equipment manufacturers' representatives.

In terms of direct results of the training, employers' and students' comments indicate that a relatively small proportion of the graduates (possibly a third) have had an opportunity to make use of their training on the job. Since, however, graduates of the courses delivered as far back as 1981 were not available for interviews, the actual number of graduates currently using their skills may, in fact, be much larger.

For the remainder of the graduates, the primary result of the training has been to increase their employment potential and to offer them the opportunity to work with a higher level of technology which, according to all the journeymen interviewed, is "more interesting and less dirty" than the "wire pulling" and pipe bending they often do on installation jobs. According to the Westinghouse instructor, who is also engaged in sales and service of PCs and other control system components, today's $370 million PC market represents a tremendous growth over the last 3 years. He predicts that, by 1990, the market will have grown to at least $500 million and that one result of that growth will be an ever-increasing need for properly trained workers on the part of electrical contractors who install (and often design and engineer) control systems for manufacturing facilities, processing plants, newspapers, and numerous other enterprises,

According to the chapter manager of the Los Angeles chapter of NECA, the training provided by the Trust gives small- and medium-sized contractors who do not have the resources to train in-house the opportunity to bid on installations incorporating PCs and other sophisticated controls. Not only will the Trust classes train their permanent employees, but they also help to develop a pool of trained workers in the hiring hall who can respond to the PC specialty calls from contractors. This issue—i.e., the future potential of the graduates and the potential opportunities their new skills create for local contractors—will also be evaluated in section III. The remainder of this section will focus on problems directly affecting the training courses, and the solutions to those problems.

Problems/Solutions.–Because so many of the students do not have the opportunity to work with PCs on the job, it became increasingly clear to the instructor that the amount of class time available for hands-on experimentation and practice on the equipment was inadequate. Two new procedures, both instituted in the first few months of 1983, lessen the effects of this problem.

The extension of the PC I course to seven sessions has added 3 additional hours of hands-on time, upping the total class hours available for laboratory work from 6 to 9. While the extra class time is helpful, students in a class of 12 (the average size of Training Trust PC classes) still have less than a few hours each on the equipment. It is the second solution, therefore, which is the most promising: in the PC II classes that began in January 1983, all of the students took one of the PC consoles home for a week or more. This allowed them to apply what they learned in PC I, and to experiment with some of the programing applications they covered in the PC II. According to the instructor, an "immense" improvement was seen both in the weekly homework and in the final examination once all of the students had ample hands-on opportunities.

Another new practice, soon to be instituted, will allow for even more hands-on opportunities. The Metro Facility laboratories will be made available during the day and on those nights when PC classes are not in session. This will enable advanced students in PC II and students in PC III to practice on the Allen Bradley, Modicon, and Texas Instruments programmable controllers, while PC I and less advanced PC II students can continue to use the Westinghouse systems at their own homes. Since there is usually little or no overlap in the scheduling of PC I and PC II courses, this system should provide ample hands-on opportunities for any student willing to avail himself of them.

A second problem, closely related to the first, is the lack of time in an 18- to 21-hour course to cover a great deal of complex material. Here, again, the extra session recently added to PC I will be of help, as will the recent emphasis on encouraging those who do poorly on the entrance examination to first take the motor-controls course. The instructor also encourages beginning students to take the Trust's process instrumentation course, which covers the fundamentals of solid-state electronics and provides those students who take it with basic skills and information applicable to the PC courses. The more information about motor controls and solid-state electronics entering PC students have, the easier it becomes to move quickly through the introductory material in the first two sessions and spend more class time on PC programing, installation, and applications.

Another related problem is the widely varying knowledge and skills of the students. The instructor estimates that, in a class of 12, four or five usually exhibit a ready grasp of the material. An-

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other two or three demonstrate a less-than-complete understanding, while the remainder are unable to make the transition between the principles governing electricity and those governing electronics and do not grasp the different approach required by programing as opposed to hard wiring. On the other hand, he notes that many students who "don't get it" the first time around show great deterrnination and repeat the basic course one, two, and even more times.

Because the courses offered by the Trust are free of charge to the students, motivated students who nevertheless require additional time to absorb the material can learn at their own pace—and, according to the instructor, "once it clicks, the worst hurdle is over and the rest comes with practice and application. " On the other hand, the great variety of aptitude and learning speeds within a single class does present a problem for the instructor and holds back the faster learners, The newly instituted enrollment controls should relieve this problem to some extent, especially in PC II and III, but it is doubtful that it can be entirely solved. Similar problems have been noted in classes delivered by reprogrammable equipment vendors and by many teachers of introductory courses in a vast array of disciplines.

A final problem noted by the instructor is also one that is common to other industrial training courses involving reprogram able equipment. The problem—resistance on the part of many students in the basic course to the new concepts, theories, and techniques that must be learned-manifests itself in the Training Trust PC I classes as an initial attitude of skepticism held by as many as half of the first-night enrollees. The instructor, therefore, devotes a portion of the first night's lecture to a general discussion of the growth of solid-state controls and computer-aided equipment and the present and potential effects of the changing technology on an electrician's job.

He then presents his own perception of the trade—that, in the very near future, if not in the immediate present, there will be two kinds of electricians: technicians and those who, as the technology expands, will be stuck with lower level jobs. Technicians, he says, will get better, steadier work, while the others will spend more and more time in the hiring hall.

While most of the students respond positively to his appraisal, a few maintain their skepticism and either drop out of the class or continue attending without applying themselves to the course material. In many cases, it is older workers who are either nearing retirement-or who face the prospect of unlearning much of what they have spent years learning-who are the most resistant to the new technology. On the other hand, a number of older students have learned rapidly and well.

Evaluation of Present and Future Capacity

Present Capacity.–According to local and national IBEW representatives and local representatives of the National Electrical Contractors Association, the Los Angeles Electrical Training Trust has the financial resources and the solid backing of both management and labor required to maintain its current level of high-technology training and to extend that training into other high-technology fields as the needs arise. Local IBE W and NECA officials believe that their working relationship is among the best in the country, and this sentiment is echoed by individual contractors, union members, and the Training Trust staff. The relationship between the union and the contractors' association is, of course, a crucial factor affecting the administration, direction, and the specific training courses offered by the Trust, since the trustee committee, the educational committees, and all of the subcommittees have equal representation by labor and management.

High-technology training courses like those in programmable controllers and process instrumentation are clearly advantageous to both the union and the contractors' association. According to the Westinghouse instructor, PC manufacturers are already having difficulty keeping up with installation and service support requests. As the PC market expands, manufacturers like Westinghouse will-as Allen Bradley, Texas Instruments, and Modicon have already done—turn more and more to support system houses operated by electrical contractors and distributors to provide design, engineering, installation, and service to the end-user. * This will result in expanded opportunities for electrical contractors and a correspondingly expanded need for electricians trained in PC installation and service.

PC III training is especially beneficial to the small contractor who operates independently of the major manufacturers and who does not have the advantage of distributing the equipment or of

*Whereas Allen Bradley, Modicon, and Texas Instruments use system houses for sales as well as design, installation, and support services to the customer, Westinghouse plans to continue selling its own systems and to recommend certain system houses for engineering and service, customer referral by the manufacturers. Such small-to-medium contractors must be able to handle installation and service of a variety of models in order to bid on a larger number of contracts and to purchase the best and most cost-effective systems for his customers' specific needs. It is, therefore, to their obvious advantage to have permanent employees who are well-versed in a number of different systems and to be able to place PC "specialty calls" in the hiring hall when they need extra workers for a large installation.

Local contractors interviewed had installed programmable controllers in a wide variety of enterprises, including food processing plants, refineries, breweries, battery plants, and shipyards. A number of contractors specialize in conveyor systems and had installed PC-automated conveyors in manufacturing and processing plants and in airports. Two of the larger contractors had, in the past, installed PCs in auto assembly plants-including Ford, GM, Toyota America, and Honda. Now, however, they are feeling the effects of the economic downturn and are forced to look out of the area for large, heavy-manufacturing installation jobs.

Although the depressed state of some segments of the local construction market has resulted in fewer contracts and less work for electricians at the present time, both management and union officials are committed to increasing the training effort. The relatively favorable construction market in years past has produced a sizable trust fund, making it possible for the trustees to invest in the equipment and courses they believe are necessary to prepare the workers to compete for present and future jobs. Furthermore, some segments of the market show signs of an upswing. There has, for example, been a recent resurgence of the petroleum industry in the area, which has produced work for contractors and electricians skilled in process instrumentation.

Current Training-Retraining **Issues.**—

Higher Wages for Increased Skills?—One of the most significant training-related issues facing the union and the contractors' association is the feeling on the part of a number of contractors and some union members that those journeyman electricians with high-technology skills should draw higher wages than those who do not upgrade their skills.

Supporters of the double wage structure for journeymen fall into a number of camps. Some support the notion of a "super-journeyman," i.e., a journeyman who is, essentially, a technician with skills in such areas as solid-state controls, process instrumentation, nuclear instrumentation, and/or fiber optics and who would draw a higher hourly wage than journeymen with "low-technology" skills. The reasoning is that those electricians who are already journeymen and have, essentially, been "caught short" by the new technology should not be "punished" for not developing new skills, but that those who do upgrade their skills should be given monetary incentives for doing so.

Other supporters of the double-wage structure believe that a "sub-journeyman" classification should be created for those without high-technology skills. Subjoumeymen would make less money than fully fledged journeymen with technician-level skills and, again, would have a monetary incentive to develop expertise in electronics.

Other variations of support for a double, or a sliding, wage scale would not change traditional occupational classifications but would, in some manner, provide higher wages for increased skills. This could be achieved by classifying PC installation, process instrumentation, and other work involving high-technology skills as "specialist categories. " This means that journeymen working on jobs involving those skills would receive a premium wage for the duration of that job. Two such specialist categories already exist: cable splicers, who do hazardous work on high-voltage cables; and electricians who are also certified welders. Both receive extra pay when working on jobs requiring these extra skills. Those who would make PC installation and process instrumentation into specialist categories maintain that this would provide an additional incentive for electricians to upgrade their skills without creating sweeping changes in the occupational structure of the union.

Local and national union officials are opposed to the above-mentioned variations of a wage differential. The business manager of Local 11 points out that the creation of a "super-journeyman' category would place a burden on contractors, who are already paying journeymen a regular wage of more than $23 an hour in Los Angeles. On the other hand, he believes that the creation of a "sub-journeyman" classification would defeat the philosophy of the apprenticeship program and would serve as a disincentive for apprentices, who would have a double hurdle before becoming fully fledged journeymen. Creating a "specialist category" for PC installation, he believes, is a stop-gap measure that would, while creating a monetary incentive for electricians, also place monetary restraints on contractors. His approach—which is also the approach of training and education representatives at International headquarters-is to focus on upgrading the general skill level of Local 11 journeymen to include skills in programmable controllers and other solid-state electronic skills.

While both the local and international union representatives recognize that their approach is more costly in terms of time (i.e., that higher wages for high-technology skills would induce more journeymen to take advantage of training opportunities), they also believe that the industry cannot afford another wage increase. According to Local 11 representatives, those electricians who do not develop the skills required by the advancing technology will be less and less capable of performing the work and will, eventually, "be phased out" because of inability to obtain work. International IBEW representatives concur in that prediction and emphasize that the value of a broad-based apprenticeship program is that it creates a flexible tradesperson skilled in a wide variety of tasks. Highly paid specialists, they argue, are too limited for the type of work required by the vast majority of contractors.

Future Capacity.–The future capacity of the Los Angeles Electrical Training Trust to provide training and education in programmable automation and other increasingly technical electronic applications is dependent not only on the internal capacity of the Trust to provide courses but also on the continuing strength of the union itself. A 1980 electricians' strike resulted in higher wages, but also caused the loss of 50 to 100 small contractors from the Los Angeles NECA chapter. The strike, which occurred in June, was followed by a depression in the local construction market, which put further strains on the remaining union contractors. At present, the approximately 40 percent of electrical contractors in the Greater Los Angeles Area who still maintain union shops must contend with nonunion contractors who can often underbid them because of the lower wages received by nonunion electricians.

Both the Local and the International recognize the problem that the higher union wage scale poses for the contractors. What the union has to offer, they say, is responsible negotiation; an insistence on apprenticeship training and an emphasis on journeyman training; and a skilled pool of available labor in the hiring hall that obviates the necessity of "permanently" hiring in times of plenty and firing in lean times, Los Angeles NECA representatives and local contractors interviewed specifically emphasized their belief that the management of Local 11 is both responsible and responsive to the needs of the contractors.

The L.A. Training Trust–which stressed the value of increased training when times were good—is emphasizing it even more in times of difficulty. It is building its capacity to offer more—and more advanced-courses to those who have the individual motivation and who have responded to the constant encouragement to take advantage of the training opportunities that exist. The PC 111 course should take instruction in programmable controllers well beyond the "familiarization" level of the PC I course. The process instrumentation program will produce "technicians" qualified at four advancing levels: device level, loop level, system level, and instrumentation/process control level. The Trust is also currently preparing instructors to teach fiber optics courses, and is exploring the possibility of purchasing a Heathkit robot for a proposed robotics course.

In addition, the Los Angeles Trust has offered to assist IBEW locals in other nearby jurisdictions by opening the Trust laboratories to other Locals by reciprocal agreement and helping them to design high-technology courses. Information provided by the Los Angeles ETT and by other local IBEW training organizations funded by JATC trusts is also being used by the International training organization to develop PC courses that, within the next 6 months, should spread to at least 100 other training sites. The international organization is also developing materials to assist local organizations in teaching semiconductor and fiber optics programs.

It is, however, utlimately the responsibility of individual union members to support the Local's and the International's claims of quality training by voluntarily upgrading their skills in high-technology fields. The Training Trust itself is now facing the problem of attempting to provide "quality training" while, at the same time, providing the opportunity for all of the eligible Local 11 members to attend the courses. The evaluation and selection procedures instituted for the process instrumentation and programmable controller's courses go against the grain of the Trust's basic philosophy, but they nevertheless represent problems that are now being addressed.

To maintain credibility, the Inside Construction Locals must continue to provide workers whose skills are appropriate to the contractors' needs. If training organizations like the Los Angeles Training Trust cannot upgrade the skills of significant numbers of journeymen through the provision of voluntary courses, the union may be forced into giving serious consideration to the "sub journeyman" concept—which, of all the variations of the notion of wage differentials based on high-technology skills, seems to be gaining the most adherents.

Case Study 5
CAD/CAM Operator Training Program: Glendale, Calif.

Summary

The Glendale CAD/CAM* operator training program was sparked by the spirit of innovation and cooperation on both the State and local levels. Funded by a combination of Federal and State moneys and sponsored on the State level by two State agencies, the Glendale program is one of six pilot programs in California which bring together colleges, industries, and local government agencies to train California residents to work in emerging or expanding technological fields. The Glendale program, which trained participants with drafting backgrounds to utilize computer-aided design systems for mechanical design and printed circuit board detailing, was a cooperative venture between Glendale Community College, local industries, the City of Glendale, and other local organizations. At the end of the first cycle of the program, 7 of the initial 12 enrollees were employed as CAD/CAM operators and three others found related drafting jobs. At this writing, the second cycle is still in session.

Background

Coordinated Funding Project for New Vocational Education Programs.—The Coordinated Funding Project—administered under the joint sponsorship of the Chancellor's Office of California Community Colleges and the State's Employment Development Department (E DD)—is an innovative, State-level response to the need to develop vocational education programs in emerging and expanding technologies in a period of budget cuts and reduced resources for educational programs. The statewide project was created in response to recommendations of a legislative "Task Group" set up in 1979 to review vocational education in California and to suggest how vocational education funds could be utilized most effectively. In its final report, the Task Group made the following recommendations: 1) adoption of State-level administrative policies to allow for consolidation of resources,** 2) greater private-sector involvement in vocational training, and 3) expansion of programs linking worksite training and classroom instruction.

The Coordinated Funding Project is a combined effort on the part of the Chancellor's Office and the EDD to consolidate State and Federal funds from three sources–the Comprehensive Education and Training Act (CETA), the California Worksite Education and Training Act (CWETA), and the Vocational Education Act (VEA)—to support pilot education and training programs involving a high level of coordination between colleges, private industries, and (in some instances) local government bodies.

In November 1981, the project staff sent Requests for Proposals (RFPs) to all of the community colleges in California asking for concept papers outlining innovative programs in emerging or expanding technologies or labor-intensive occupations that combine classroom instruction with worksite training in order to: 1) upgrade basic work skills, 2) provide entry-level training, or 3) enhance or build on the skills of displaced workers. The colleges were specifically requested to design programs for occupations not included in their current curricula and to seek new solutions for long-existing problems. Specific objectives to be met by each local program included the following:

- to provide vocational training programs meeting specific local employers' needs;
- to involve local employers and other appropriate entities in project planning, curriculum design, and training implementation;
- to provide effective job skills training to the project participants;
- to obtain continuing employment with career advancement potential for project participants; and
- to incorporate the resulting curriculum into ongoing college vocational education programs,

Over 50 colleges responded to the RFP, and in January 1982, four individual colleges and two college consortia were awarded contracts totalling $800,000 (for all six programs). The top-ranked proposal was a program submitted by Glendale Community College (GCC) to train CAD/CAM technicians. In February 1982, GCC was awarded $84,271 to train 24 participants (12 in each of two

*Computer-aided design and computer-aided manufacturing.

** It was noted in the report that the existence of a "myriad of programs providing occupational training" had resulted in fragmentation of funding and administrative procedures and created a significant obstacle to effective coordination.

training cycles);* shortly thereafter, five other schools or consortia of schools were awarded contracts to train participants in fields such as computer-aided drafting, computer-assisted machining, digital electronics and microprocessors, business machine and computer repair, and solar and alcohol technology and wood products manufacturing.

The remainder of this study focuses on the CAD/CAM technician program operated by Glendale Community College. In the fall of 1982, a new State initiative, titled "Investment in People, " set aside $3,400,000 to fund other college programs of a nature similar to those supported by the Coordinated Funding Program. Glendale submitted an Investment in People proposal containing a modified and expanded version of its original CAD/CAM program and was awarded $55,885 to train additional participants in various computer-aided design applications.

Glendale CAD/CAM Operator Training Program.–The Glendale program is an attempt to demonstrate the feasibility of coordinating a variety of funding sources (CETA, CWETA, and VEA) as well as the efforts of a variety of participating organizations and agencies. The project is a joint effort on behalf of Glendale Community College, Jet Propulsion Laboratory, Singer Librascope, Computervision, the City of Glendale, and the Glendale Private Industry Council. The remainder of this introductory section is devoted to brief descriptions of these participating organizations and the part each plays in the CAD/CAM program. Section II describes the project activities of each major player in greater detail.

Glendale Community College.–Glendale Community College (GCC), designated as the training program operator, is fully accredited by the Western Association of Schools and Colleges as a 2-year institution providing both general and specialized education to youth and adults. Its four primary objectives are to: 1) educate students to meet the lower division requirements of a university or 4-year college, 2) provide post-secondary vocational education for students preparing for entry-level positions and for employed students upgrading their skills for job advancement or to meet new job requirements, 3) post-secondary education for "personal improvement" (i.e., coursework taken to satisfy individual interests and which does not lead to a degree or certificate), and 4) adult education "below the lower division level, " which includes coursework leading to the high school diploma, career and vocational classes, citizenship classes, and classes serving special interest needs of the community.

GCC was founded in 1927 and, until recently, was under the jurisdiction of the Glendale School Board, which was also responsible for the primary and secondary-level education system in the district. In the fall of 1982, a new school board, solely responsible for the Glendale Community College District, was created. This action is especially significant in relation to the school's regular vocational education programs and to special projects like the CAD/CAM operators program in that the president/superintendent of the new school board has expressed a specific coremitment to vocational education and is a member of the Glendale Private Industry Council (see below). Approximately half of the college's 10,200 students (5,200 full-time; 5,000 part-time) are either enrolled in technical or vocationally-oriented certificate or transfer programs* or take one or more vocational education courses.

The CAD/CAM Operators' Program was coordinated by the college's director of special programs and was taught by the senior drafting instructor.

Jet Propulsion Laboratory (JPL).—JPL was established by the California Institute of Technology (Cal Tech) as a private, nonprofit research and development laboratory.** Located on the outskirts of Glendale in La Canada, Calif., JPL employs approximately 4,600 people: approximately 2,400 are engineers and scientists; 2,000 are support personnel; and 200 are engaged in manufacturing prototype products (see following paragraph). When the laboratory was founded in 1945, its major activity was to complete rocket research and development for the U.S. Army. In 1959, it became a National Aeronautics and Space Administration (NASA) research center. Today, although its principal contract is still with NASA, JPL also has research and development contracts with the Department of Energy, the Department of Defense, the National Institutes of Health, some local agencies, and some private industries.

*Each training cycle consisted of 12 weeks of formal classroom/laboratory instruction, followed by 200 hours of worksite training at the participating companies.

*Certificate programs are primarily business or technical programs designed for students preparing to enter the job market upon completion of the program. Transfer programs are designed for students planning to continue their education at a 4-year institution.

**Cal Tech continues to manage JPL's contracts. According to a JPL section manager, the difference between the research conducted at Cal Tech's main campus in nearby Pasadena and that conducted by JPL is that JPL is product development-oriented whereas the research on the campus is primarily academic in nature.

As a NASA contractor, the principal focus of the laboratory's activities is lunar and interplanetary investigation—tracking and acquiring data from satellites and probes in NASA's deep space network. Currently operating at a funding level of just over $350 million, JPL concentrates on research, development, and design of products. Its manufacturing activity, therefore, is limited to the production of prototypes and is a proportionately small part of the lab's responsibilities. For this reason, JPL has little computer-aided production equipment; it does, however, have approximately 500 computers (ranging from mainframes to micros) which are primarily used for computer-aided design and other computer-aided engineering applications such as analysis and simulation of engineering data. *

According to JPL's Design and Mechanical Support Section manager, JPL's concentration on development, design, and "first article delivery" means that the laboratory uses computers and computer-aided systems primarily as analytical tools rather than as production tools. The current focus of the Design and Mechanical Support Section is to attempt to save money and other resources in the preliminary stages of manufacturing by infusing into the design process the ability to do simultaneous analysis, material selection, and selection of fabrication work in an attempt to create a product design that could be implemented without wasting material or having to reconfigure tooling in the manufacturing process.

JPL's Design and Mechanical Support Section participated in the Coordinated Funding Project partially because of its growing need for CAD/CAM operators since 1980, when the section installed its first Computervision CAD/CAM system. According to the section manager, the introduction of computer-aided design into the section enabled it to bid on and complete more work in less time and also-because the design engineers' time is considered to be too valuable to do detail and documentation work on their designs-created a need for a new category of employee- "CAD/CAM operators" who are skilled in drafting and in the operation of computer-aided design systems. *

Approximately two-thirds of the participants in the Coordinated Funding Project receive "work site training" at JPL—hands-on laboratory work on the Computervision terminals that both complements their classroom instruction at Glendale Community College and assists JPL engineers in the detailing and documentation of their designs. JPL has hired five trainees from the first cycle of the program and may hire some from the second phase.

Singer Librascope.–The remaining third of the original 12 Coordinated Funding Project participants received worksite training at Singer Librascope, a division of the Singer Co. engaged in the production of military equipment.

Like JPL, Singer Librascope required trained Computervision operators and looked on the Coordinated Funding Project as a means of acquiring employees trained to company specification; While all of the trainees received the same classroom instruction at GCC, their worksite training at Singer Librascope and JPL differed. Those who completed their laboratory training at Singer Librascope were trained to work on printed circuit board (PCB) designs, while the JPL trainees worked on mechanical designs.**

Computervision.—Computervision—for many years the largest producer of turnkey CAD/CAM systems—participated in the Coordinated Funding Project by providing free training for the GCC drafting instructor in its Los Angeles training center.*** The classroom instruction provided to the trainees was an adaptation of four of Computervision's customer training courses. Computervision also assisted by providing reduced-price training documentation.

Glendale Private Industry Council and the City of Glendale.—The Glendale Private Industry Council (PIC) was formed in 1979 under Title VII of the Comprehensive Employment and *Training* Act. Title VII, the Private Sector Initiative Program, was aimed at giving business and industry

*"Computer Aided Engineering (CAE) ., includes those computer systems designed to facilitate Computer Aided Design (CAD), Computer Aided Manufacturing (CAM). Computer Aided Business Systems (CABS), the Interactive Computer Graphis (ICG), and all those other systems that facilitate the solution of engineering problems. It plays a key role in areas such as design, analysis, detailing, documentation, N/C programing, tooling, fabrication, assembly, quality control, testing, and all aspects of management of the data base relevant to the particular product under consideration. " Donald D. Glower and Lindon E. Saline (cd.), ***A Response*** to ***Advancing Technologies*** (Washington, D. C.: American Society for Engineering Education, 1982), p. 7.

*Previous to the installation of the Computervision terminals, the section contracted drafting work to independent drafters or drafting firms. It is anticipated that the CAD systems and the new CAD/CAM operators will eventually replace the need for contract drafters.

**The students themselves were given a choice of industry site on the basis of their interest in either mechanical or PCB design.

*** Computervisionalso Supplied free training to two high school teachers, who became CAD instructors in a high school training program developed at approximately the same time as the Coordinated Funding Project's CAD/CAM operator program.

a major role in designing and implementing employment and training programs tailored to local private-sector needs.* Although the authority of business and industry representatives on a number of PICs across the country has sometimes been limited by the control of the local elected officials (designated as CETA Prime Sponsors) over PIC activities, the Glendale PIC has effected a viable working relationship between local government, education, and industry representatives.

In order to describe the role played by PIC in the Coordinated Funding CAD/CAM Operator Program, it is first necessary to provide a few paragraphs of background material on PIC itself and its relationship with its Prime Sponsor, the City of Glendale. PIC's board is primarily composed of business and industry representatives but also has representation from local government and community groups, including the Glendale Unified School District, the Employment Development Department, and the Department of Social Services. In 1981, PIC merged with the CETA Advisory Council (which was under the jurisdiction of the City of Glendale, in its role as CETA Prime Sponsor).

The merger occurred at a time when a number of other PICs and Prime Sponsors in other localities were also consolidating councils; in some locations, the mergers were seen by one or the other of the groups as "take-over bids" and were accompanied by vituperation on both sides. In Glendale and in some other locations, the consolidation of councils was seen as a reinforcement of an already effective cooperative relationship. According to the present PIC director, PIC and the city have yet to disagree on matters of program or policy, largely because there is general agreement that PIC should act as the policymaking body while the city acts as the administrative body.

Another factor that enhances PIC's ability to function in a coordinated manner is that it has eliminated duplication of services by designating specific types of training delivery to specific groups in the Glendale area. Glendale Community College, for example, provides classroom instruction and skills training under contract to PIC; another designated contractor is responsible for work experience for youth, for example, and yet another takes responsibility for in-school youth programs. PIC board members and staff believe that these measures have helped it to become the top-ranked council in terms of job placement in the DOL region covering California, Nevada, and Arizona.

PIC played two roles in the CAD/CAM Operators Program. Its formal role was to provide administrative services for the program, including contract compliance, recordkeeping, participant tracking and reporting, operational monitoring, and technical assistance. These services were formally subcontracted by Glendale Community College to the City of Glendale, which, as the administrative arm of the consolidated council, performs similar services for PIC-operated programs.

The other role played by PIC was informal but crucial to every aspect of the program from conception to delivery. The Glendale PIC defines its responsibilities in a broader context than the actual operation of training programs for economically disadvantaged participants. According to both the PIC director and the chairman, PIC must have a sense of–and be active in–the community as a whole in order to be effective in its formal function of delivering private-sector training programs for the community's disadvantaged residents. The board and staff members, therefore, perceive their function to be that of facilitators, or brokers, who can act to bring together representatives from business, education, and government to create the kind of working partnership they believe is the intent of CETA, Title VII, and its successor, the Job Training Partnership Act.

It was in its role as a facilitator that PIC had its greatest impact on the CAD/CAM Operator Training Program. The proposal that won the Coordinated Funding Project contract for Glendale Community College was conceived by the PIC director and was an adaptation of a computer-aided design program for high school students proposed by the PIC chairman, who is also the manager of JPL's Design and Mechanical Support Section and a member of the* school program, which

*The successor to CETA, the Jobs Training Partnership Act, retains the private-industry councils created under CETA and expands their responsibility and authority. In order to be certified under the new act—which requires a service delivery area with population of 200,000 or more—the Glendale PIC consolidated its council with the nearby Burbank PIC in 1983.

• Because the Glendale Coordinated Funding Project was not a PIC-sponsored program, the question of conflict-of-interest did not arise in relation to JPL's role. Conflict of interest is, however, a debated issue in the new Jobs Training Partnership Act. According to a report released by the National Governors' Association, "at least 15 states place total bans on designated officials from conducting business either with the State, or local municipalities, or other governmental entities of which they are members. " Some private-industry council members in some localities are, therefore prohibited from allowing PIC training programs to be operated in or for their places of business. A number of private industry councils, on the other hand, operate on the principle that PIC board members can have the most impact by opening up their own businesses or industries to PIC programs, thereby providing training and employment opportunities to eligible participants and, at the same time, illustrating by example that such programs can be effective for was designed to familiarize high school students with CAD/CAM technology and to encourage them to continue their education in computer-aided technologies.

The college program, on the other hand, was conceptualized as a means of serving the participating students and companies alike by training the students to fill immediate employment needs at JPL and Singer. Both programs were designed to serve their respective educational institutions by upgrading teachers, introducing new technological curricula, and providing courses that would eventually be incorporated into the ongoing curricula of both the college and the high school.

The CAD/CAM program, then, resulted from the synergistic relationship between PIC, the college, and industries like the Jet Propulsion Laboratory. It derives also from the leadership of individuals like the JPL section manager, whose activities in other arenas (as PIC chair and as School Board member) provided him with both the broad-based perspective and the position to effect the coordination called for in the State's Coordinated Funding Proposal.

CAD/CAM Operator Training Program

Goals and Objectives.–Overall goals of the CAD/CAM Operators' Program are: 1) to develop a training program in CAD/CAM which could be incorporated into the community college system in Glendale, and which could be replicated at other community colleges, and **2)** to train **24** participants to be CAD/CAM operators. Apart from those overall goals (which are primarily those of the college), PIC, JPL, and Singer Librascope each had additional objectives for their project participation.

Private Industry Council representatives viewed the Coordinated Funding Project as an opportunity to strengthen the bond between the college and local industries by demonstrating that the two entities could work together in a project that could benefit each while also helping the community by training and employing local residents. In particular, PIC hoped to showcase the college as a resource for local industries which could, by assuming industrial training responsibilities, help the companies save on training expenses. PIC also saw its participation in the project as a way to partake in an effort to build the community's capacity to engage in high-technology training which—in the opinion of key staff and board members—may not be appropriate for the majority of CETA-eligible residents without the necessary background skills. * By helping the community to establish a high-tech training capacity, PIC hoped to establish a training resource which could eventually be used by economically disadvantaged participants whom PIC would first provide with prerequisite skills such as drafting.

Although Jet Propulsion Laboratory and Singer Librascope had a major objective in common—that of obtaining employees specifically trained to their work requirements—their secondary objectives differed. One basic difference was that Singer required students trained as detailers-i.e., CAD/CAM operators who do detail work on designs created by others—whereas JPL wanted trainees who would do some basic design work and eventually become full-fledged designers.

Consequently, JPL informed all of the students who completed their worksite training at the laboratory that those who would be hired would be expected to continue their education (at company expense) at a 4-year college. A further objective held by JPL was to build the college's capabilities so that the lab could draw on it as a training resource in the future. Computervision's object in participating in the project was to support its customers–JPL and Singer Librascope–by assisting in the instruction of their future employees, and to assist the college by helping it to develop the capability to create an ongoing computer-aided design course utilizing Computervision equipment.

Planning and Development.—The State-level planning for the Coordinated Funding Project and much of the local-level planning for the Glendale program have been outlined in section I of this study. This section will, therefore, discuss the program development efforts that took place after the selection of Glendale as a contract recipient.

employers, In the NGA report cited above—which specifically addresses the question of conflict-of-interest in regard to the new Job Training Partnership Act–the Georgia Employment and Training Council specifically recommends that "Federal regulations concerning conflicts-of-interest which are presently being drafted exempt PIC members from prohibitions against conducting business in their own or any other service delivery area where: 1) such member notifies in writing his potential conflict of interest to the council or administrative entity; 2) such member refrains from voting or in any way participating in the decision to award contracts; and 3) the council or administrative entity makes as a part of its record the reasons for awarding the contract to one of its PIC members and why the award is in the public's best interest. " "Implementing the Job Training Partnership Act. Technical Brief: Conflict of Inter@ t," National Governors' Association, December 1982, Issue paper pre9ented for response.

*Because the CETA funds used in the Coordinated Funding Project were discretionary linkages funds earmarked for project administrative expenses, the project operators were not bound to meet CETA selection criteria, although they were urged to include as many CETA-eligible participants as possible.

Previous to the writing of the proposal, both JPL and Singer Librascope had made commitments to participate in the program. Once the proposal was accepted, PIC contacted Computervision and secured its commitment to provide training for the Glendale instructor. The school's engineering drafting instructor, who also works parttime at JPL as a senior engineer, was chosen as the CAD/CAM program instructor and was given the responsibility of designing the curriculum.

To prepare for his curriculum-writing and instructional duties, the instructor attended a summer-long upgrading program. He began his training by completing a week-long Computervision self-study course at JPL, followed by a week of on-the-job training in JPL's CAD/CAM operations. During the following 9 weeks, he attended 100 hours of training at Computervision's Los Angeles training center, completing customer courses in mechanical design and electromechanical design. The week-long courses at Computervision were supplemented by on-the-job training at both Singer Librascope and JPL. At the completion of his training, the instructor designed the classroom training curriculum for the program, aided by advice from JPL and Singer employees.

Because the students would be receiving classroom instruction at the college and laboratory training at one of the participating firms, much of the program development effort included setting up formal mechanisms for coordinating between JPL, Singer Librascope, PIC, and the school. That coordination involved logistics planning. Discussions between the college and the two companies resulted in a plan whereby students would attend 3-hour lectures at the college two mornings a week and laboratory training two late afternoons or evenings a week (to avoid students competing with employees for workstations).

Administrative and Instructional Staff. -As the primary program operator, Glendale Community College had fiscal responsibility for the project. It was also responsible for delivering classroom and laboratory training and for appointing a program counselor to act as liaison between the students, the college, and the participating companies. The college's director of special projects for vocational education served as the overall program administrator. Administrative services were subcontracted to the City of Glendale/Private Industry Council, while the college retained the activities of recruitment, screening and selection, counseling, and placement. The college's engineering drafting instructor was responsible for delivering the classroom instruction, overseeing the laboratory instruction at JPL, and coordinating with the two companies.

The instructor, a past graduate of Glendale Community College, has a bachelor's degree in industrial design from California State University at Los Angeles, a master's degree in industrial design from California State University at San Jose, and a vocational education teaching credential from the University of California at Berkeley. His previous industrial experience includes work at Columbia Broadcasting Corp. as a designer, at General Electric's Nuclear Engineering Division as a packaging engineer, and at IBM as a senior design engineer.

Facilities and Equipment.—Classroom instruction was delivered at Glendale Community College, which has a fully equipped traditional drafting classroom, but no computer-aided design stations. Eight of the initial class of 12 students attended the laboratory portion of their training at JPL, which has four Computervision terminals dedicated to training purposes. The remaining students had their laboratory instruction at Singer Librascope, which has four Computervision terminals in its engineering department for use by program trainees and Singer employees alike.

Program Funding.–Glendale Community College received $84,271 from the Coordinated Funding Project ($3,243 from CETA; $19,533 from CWETA; and $61,495 from VEA). The CETA funds and approximately half of the CWETA funds were subcontracted to the City of Glendale to cover administrative services, and the remainder of the CWETA funds paid for a portion of the instructor's retraining (4 weeks of on-the-job training at JPL and 4 weeks at Singer Librascope). The VEA funds were devoted primarily to covering the direct costs of the training for the 24 participants. In addition to the State funding, the participating firms provided the following in-kind contributions: 100 hours of computer-aided design training for the Glendale instructor (Computervision) and equipment-use-and-maintenance costs for the

CAD/CAM terminals valued at $97,200 (JPL and Singer Librascope). Glendale Community College contributed space and utilities totaling $3,800.

Recruitment and Selection / Participant Profile. —In May 1982, the college sent flyers announcing the CAD / CAM program to 2- and 4-year colleges and Employment Development Department in the Los Angeles County area. Applicants were required to be U.S. citizens; be 18 years old or over; have a high school diploma or general equivalency diploma; be able to pass a security clearance; and have completed the following college-level courses:

- one semester of basic mechanical drafting;
- one semester of advanced mechanical drafting;
- one semester of descriptive geometry; and
- or equivalent work experience.

Recommended but not required were the following:

- one semester of electronic drafting;
- one semester of machine design;
- one semester of basic electronics or machine shop;
- prior work experience in the above areas; and
- or equivalent work experience.

After making formal application for the program at the Glendale CETA office, the candidates took a written examination at the college on June 12. The applications contained questionnaires requesting information on the applicant's long- and short-term goals, attitude, and motivation. The formal examination contained practical drafting problems requiring a knowledge of tolerance, dimensioning, scaling, clearances, interferences, and electrical schematics. From the initial group of over 50 candidates, the college representatives selected 18 on the basis of both test scores and indications of practicality, willingness to do detailed work for long stretches of time, and motivation shown on the application questionnaires. Once the college made the initial selection, representatives from JPL and Singer interviewed the students and made the final selection.

The majority of the 12 students selected as program participants for the first session, which began September 13, had previous machine shop or drafting experience. Over half had 2-year drafting certificates, and five of those students also had 2-year certificates in electronics or machining. The average age of the group was 23. Two participants were female; one was Hispanic; four had incomes below the poverty level; one was a displaced homemaker; and four were veterans.

Similar selection and recruitment procedures were followed for the second group of 12 participants, who began the coursework in February 1983. The second group was approximately 50 percent female and included four Hispanics and three Orientals.

Classroom Instruction and Laboratory Training.—The students received 12 weeks of formal instruction (6 hours a week of classroom instruction and 6 hours of Computervision CADDS 3 terminal training per week). Because no terminals were available in the college classroom, the classroom instruction was strictly devoted to theory, which was then applied in practice in the company laboratories. The GCC instructor was responsible for classroom instruction and for monitoring the laboratory sessions at both JPL and Singer Librascope. instructional materials consisted of four Computervision training documents–CADDS 3 Pocket Reference, CADDS 3 Mechanical Basic Guide, CADDS 3 Mechanical Design Workbook, and the CADDS 3 Printed Circuit / Electrical Schematic Basic Guide*—and Computervision's self-study audio / print learning package, "Introduction to CADDS 3 Operation, " which teaches the basic concepts and commands needed to use CADDS 3 applications software.

Curriculum.–The curriculum was designed to include the introductory material covered in the self-study package plus three Computervision CADDS 3 customer courses: 1) Basic Mechanical Design, 2) Advanced Mechanical Design, and 3) Basic Printed Circuit / Electrical Schematic Design. The first week of class was devoted to an overview of CAD / CAM technology, during which the instructor lectured on CAD / CAM system hardware and software, turnkey CAD / CAM systems, computer-generated visualizations, computer-aided design and computer-aided manufacturing processes and applications, and the integration of CAD / CAM into industrial processes.

During the second week, students were introduced to the basic techniques for using CADDS 3 software, concentrating on terminology, log on / off procedures for entering and leaving the system, and basic command language. The lecture portions of the second week of study covered the format of command language syntax-made up of verb + noun + modifier strings which the operator uses to execute a command by inputting a function (verb), such as "insert," plus a geometric entity (noun), like "line," plus a modifier which describes the geometry, such as "parallel" or "perpendicular."

*CADDS is Computervision's "Computer-Aided Drafting and Design System. Students were required to purchase the pocket reference and the mechanical design workbook; the school supplied them with the two basic guides. (Computervision, which normally sells the basic guides for $75 each, provided them to the college for $30 each,) The students also learned how to use the system's online documentation feature, which aids the operator by prompting him or her with information on, for example, what "nouns" (line, circle, arc, fillet) go with specific "verbs" (insert, delete, or combine, for instance) and what modifiers can be used with particular verb/noun combinations. During the laboratory sessions, the students completed portions of the Computervision audio cassette/workbook course under the instructor's supervision.

Following the basic operations segment, the students spent 2 weeks (24 hours) learning to use the system for basic mechanical design. This segment included the fundamentals of part creation (i.e., how to use the system to create lines, circles, arcs, and fillets) and part filing (how to file a drawing of a part in the system); how to erase, modify, and manipulate elements; and basic projections (how to reproduce objects on planes or curved surfaces by projecting their points to create 3-D objects).

During the following 2 weeks, the students learned how to insert dimensions in mechanical drawings (including linear, angular, radial, and diameter dimensions, dual dimensions, and extension lines and arrows); how to use construction aids, such as grids and layers; how to size and scale part-drawings; "zooming" (focusing in on a small section of the drawing on the screen or widening the focus to include the full drawing); and how to insert textual notes and symbols to accompany their drawings. The laboratory work during this segment consisted of working through specified sections of the *CADDS 3 Mechanical Design Workbook* and completing individual projects involving the creation of 2-D and 3-D parts.

The next 3 weeks (weeks 7-9 of the course) were devoted to printed circuit/electrical schematic (PC/ES) applications. The first lecture in this segment covered the differences between mechanical and PC/ES applications and operations. The students then learned to create electronic symbols (called "nodal information" in Computervision terminology) and to digitize* and annotate electrical schematics, which the computer then converts into a "net list, " i.e., a list of all the start- and end-points for specific wire paths on the board. By the eighth week, the students were creating PC component diagrams, digitizing simple PC boards, and then using the system to merge the printed circuit boards and to automatically route the result.* They then learned to edit their PC boards** and to record the parts and computer files (i.e., to store both the PCB drawing and the schematic and net list information in the computer). As in the mechanical segment, the students were required to complete individual projects using the terminals in the laboratories.

During the next 2 weeks, the students worked on specific electro-mechanical design problems dealing with the design and packaging of printed circuit boards. The last week of the course was devoted to review and to the final examination.

Instructional Methods. -When he developed the curriculum, the instructor was faced with a problem intrinsic to the structure of the program: how to modify the Computervision courses, which were designed for students with 4-hour-a-day access to terminals, to be taught in the Glendale format (6 hours a week of classroom instruction; 6 hours a week of laboratory practice). A number of his teaching methods were therefore dictated by the peculiarities of the situation. A portion of the classroom time was devoted to lecture on, and class discussion of, the theory behind the laboratory work to be done in the following lab session. Because of the lack of equipment, the instructor used the chalkboard to demonstrate the basic principles, and the students completed pen-and-paper exercises simulating the terminal exercises they would perform in the laboratories.

The remainder of the classroom time was spent in group discussions of individual problems encountered in the laboratories. (Although a number of the students were reticent about discussing those problems in a group situation, all were required to do so in order to provide them with experience in communicating problems to co-workers and attempting to solve them in a group situation.) The instructor's object in this was to simulate the industrial environment to the greatest extent pos-

*'Digitizers' are instrumented surfaces on which the location of a point, selected with an associated cursor unit, is automatically converted into digital, x-and-y coordinate data suitable for transmission to a computer (Turnkey CAD/CAM Computer Graphics, A Survey and Buyer's Guide, pp. 3-22). In the PC/ES operation described above, "digitizing" means to use a stylus to locate points which will eventually be connected by wires on the finished circuit board.

● The "merge" process tells the system that all of the components that exist on the board must be hooked up, baaed on the net list, so that the information on the net list is actually merged into the printed circuit board design. In the "routing" process, the system automatically indicates to the operator the lines that physically connect the digitized points.

**The editing process is necessary because the system cannot always route every wire on every board. For example, if the system cannot get from point A to point B without intersecting another point and so grounding-out the wires, the human operator must drill a hole in the board, run the wire along the bottom side, and drill back up to the component side so that he can continue to run the wire on an unobstructed path.

sible. Students were expected to produce professional-level work; were expected to meet strict deadlines for their twice-weekly lab work and for the projects required at the end of each section; and were trained to solve the sort of practical problems they would face on the job.

Students worked two-to-a-terminal in the laboratory sessions, using the "partner system" that Computervision trainers use in their customer classes. Each student would work on the terminal for approximately 15 minutes at a time, while his or her partner would monitor the operation to make sure it was being done correctly and would provide assistance when necessary. This system, according to Computervision, allows each partner to both observe and perform specific operations and therefore reinforces the learning process. Because JPL had four terminals located in a dedicated training lab and because the laboratory operates on a flexible schedule, the students who did their laboratory work at JPL had 4 to 6 extra hours a week of terminal time. According to the instructor, the students were all so highly motivated that they had to be forcibly ejected from the laboratory at 11:00 p.m.

In addition to the classroom and laboratory work, the instructor arranged for two field trips—one to the Computervision Training Center in Los Angeles, and one to Weber Aicraft to observe the IBM/CADAM system in a production environment.

Examinations and College Credit.–Students were given an examination at the end of each major course segment (basic operations, mechanical application, and electrical applications) and took a 3-part final examination covering mechanical design, electrical design, and basic drawing. All but one of the students passed the final test and received three units of college credit for the course. *

Student Evaluations.—In written evaluations completed at the end of the classroom/lab portion of the program, the trainees gave both the instructor and the course high marks. Most, however, stated that the course would be improved by more terminal time and more time spent on printed circuit board design. (See "Results" section for more recent evaluations of the course by session I trainees now working at JPL and Singer Librascope.)

Worksite Training.–Once they completed the classroom/laboratory portion of the program, the 11 remaining students began worksite training at JPL and Singer Librascope. This portion of the training consisted of 200 hours of work, which in the case of the eight trainees, was divided into 10, 20-hour weeks. Because Singer Librascope was anxious to place its trainees on the permanent payroll as soon as possible, the 200 hours of training for the three Singer participants was condensed into 7 weeks. Trainees in both locations worked on actual production designs and were paid salaries of $5 per hour by the firms. (Customers were informed that the design or detail work was being performed by student trainees, and the savings—in terms of lower-than-average salaries paid during the training period—were passed on to the customers in form of decreased design-room costs.)

The Singer Librascope trainees spent the worksite training portion of the program primarily doing detailer work on printed circuit board (PCB) designs. This included digitizing PCB drawings to input the design into the computer, editing existing designs, creating detailed drawings from an existing database, and creating photo tools. The students who completed their worksite training at JPL were given some design responsibilities as well as detail work. Their specific task was to work on mechanical designs for support equipment and peripheral structures, such as inspection platforms, for the Galileo spacecraft.

Given a basic design created by a JPL engineer, it was the trainees' job to complete the design, making sure that it met both the design and manufacturing standards (part tolerance and material selection, for example) specified by the design engineer. In many instances, completing the engineer's design required the trainee to design a part or structure forming a portion of the total design. The design work done by the trainees, closely monitored during the worksite training period, is a significant aspect of the duties of those trainees who became permanent employees,

Related Services: Counseling, Placement, and Follow-up.–Counseling, placement, and follow-up services were formally assigned to the college. The college's special projects department has a full-time counseling staff, one of whom was assigned part-time to the Coordinated Funding participants. In effect, however, most counseling was informal and was provided by the instructor and the Singer and JPublic Law employees who oversaw the students at the laboratory sites. Although placement services were officially the responsibility of the college, PIC representatives aided GCC in placing those program graduates who were not

*The one student who did not pass the final exam was the only student who carried a full-time job while participating in the program. The combination of full-time work and program participation proved to be more than he could accommodate.

hired by either of the participating firms. Follow-up procedures, planned for 30-, 60-, and 90-day intervals after program completion, were conducted by the college.

Results

Placement.—Seven of the 11 trainees who completed both the classroom instruction and worksite training portions of the program were hired by either JPL or Singer Librascope. JPL's stated intention at the beginning of the program was to train eight participants in its lab and to hire the four who were best qualified. The laboratory exceeded its original intention by hiring five trainees at the completion of the worksite training in February 1983. The new JPL CAD/CAM operators received entry-level salaries of $6 to $7.50 per hour. Two of the JPL trainees were placed in other firms in design and drafting jobs which do not, however, involve CAD/CAM operation.

Singer Librascope had originally intended to hire all three of the students who trained at the firm. One of them, however, failed to pass the security clearance required for all Singer Librascope employees. That trainee has since been hired by Glendale Community College in a nontraining-related capacity. The other two were hired by Singer in January 1983, at starting salaries of $6.25 to $7.25 an hour.

Singer hopes to hire four trainees from the second session of the program, which at this writing has not yet entered the worksite training stage. Whether or not JPL will be able to hire any of the second-session trainees will depend on the laboratory's need and funding situation at the end of the summer.

The Investment in People Project.–One of the results of the CAD/CAM operator program was achieved well before the first group of participants completed their classroom instruction. In October 1982, the State Community College Chancellor's Office and the EDD announced that additional funds for innovative college programs would be available under the Governor's Investment in People Initiative. Glendale Community College, again with the help of PIC and the City of Glendale, submitted a proposal to expand the CAD/CAM operators' program to adapt it to a wider range of applications (including architectural, piping, and structural design); to recruit additional applicants and involve more local industry; and to provide further training for instructors from GCC to help the college expand its already developed CAD curriculum.

In December 1982, the college was awarded Investment in People funding totaling $55,885 to provide 10 weeks of combined classroom instruction at GCC and onsite laboratory work at the Electro Optic Systems Division of Xerox Corp. and Jacobs Engineering (an architectural and civil engineering firm).

Unlike the Coordinated Funding Project participants, 32 of the 40 Investment in People participants were company employees requiring upgrade training in computer-aided design. Because the Xerox Electro Optical Systems employees were to be trained for aerospace applications, a combined class serving the second-session Coordinated Funding participants and the Xerox Investment in People participants was planned for the winter-spring semester of 1983. The Jacobs employees, who were to be trained in architectural applications, attended a separate course, taught by an employee of Jacobs certified by Glendale College. All of the industry employees received laboratory training at their respective companies. The eight trainees who were not company employees joined the Coordinated Funding participants at Singer and JPL.

Benefits.–Aside from the obvious benefits to the trainees, the CAD/CAM Operator Training Program produced beneficial results for the sponsoring companies, agencies, and institutions. Both employers got CAD/CAM operators trained in their specific applications and operations for a fraction of the cost involved in company-operated training programs. Singer Librascope, which specifically seeks young, energetic drafters to be trained as detailers in computer-aided PCB applications, obtained young CAD operators whose laboratory training was closely monitored by company employees—thus providing the assurance that they were trained in a manner acceptable to the firm. As added benefits, Singer representatives also point to their participation in the selection of the trainees and the opportunity to observe them over an extended period of time.

JPL representatives look on the training program as a first step in reducing the laboratory's dependence on the contract drafting houses that traditionally performed the manual drafting function now being replaced by CAD/CAM. According to the manager of the Design and Mechanical Support Section, the section has been able to accommodate double its previous workload since the introduction of the CAD systems in 1981 and can accomplish much of the work done by the contract drafters with a smaller number of permanently employed CAD/CAM operators. Furthermore, since the systems themselves are extremely accurate tools, JPL can increase productivity and lower its price structure by hiring trained CAD/CAM operators at entry-level salaries and passing the savings along to its customers.

An added benefit from JPL's point of view is the future potential of the trainees. All of those who were hired by JPL accepted their positions with the understanding that they will continue their education by pursuing 4-year engineering degrees and eventually become part of the engineering design staff in the section. In this way, JPL hopes to achieve a number of long-term results: to prevent the CAD/CAM operators from becoming static; to "home grow" new engineers who will have a working knowledge of CAD/CAM operations and JPL requirements; and to keep a constant flow of new CAD/CAM operators coming into the laboratory by replacing the older operators who have moved up to engineering design positions.

Glendale Community College, by obtaining the Coordinated Funding and Investment in People grants, now has increased credibility at the State level, which may, in turn, help the school to obtain additional funding for further innovative programs. Of equal importance is the CAD/CAM experience gained by the drafting instructor during his summer-long upgrading program, which was reinforced by his delivery of the academic-year program. In addition, the college got the opportunity to integrate computer-aided design into its regular drafting curriculum—an opportunity that would have been greatly delayed had GCC been forced to wait until it could obtain its own equipment.

Benefits to the Private Industry Council and Computervision were less tangible, but were, nevertheless, significant. By acting as the broker bringing the major players together and developing the operating systems that helped the program to succeed, PIC demonstrated that it could fill the needs of the community at large while, at the same time, setting the stage for a PIC-funded program preparing disadvantaged residents to become drafters who could then take advantage of training programs concentrating on CAD/CAM skills.

The program also aided the Private Industry Council by reinforcing the PIC-built bridges between the college and local industries and by demonstrating the PIC philosophy in action, i.e., that industrial commitment and academic training resources can be combined to benefit industries, schools, and potential employees. Computervision, by participating in a program sponsored by JPL and Singer, demonstrated its willingness to support its customers in an innovative endeavor while also helping to provide those customers with trained Computervision operators.

Problems/Solutions.–The necessity of condensing the Computervision courses to fit the time frame of the college semester and the need to separate the classroom and laboratory segments presented ongoing problems. Although the Glendale students did have 12 weeks to complete four 1-week Computervision courses, students who attend courses at one of Computervision's customer training centers engage in intensive 8-hour-a-day classroom and laboratory work. In the case of the mechanical design and printed circuit courses, the Glendale students received almost as much terminal time as a regular Computervision customer; but in the case of the introduction to CADDS 3 operation course, the coverage was reduced from approximately **40** hours to 10.

It should also be noted that Computervision recommends that its customers' employees have from 60 hours of terminal time (for detailers) to 120 hours (for designers) after they take the basic mechanical design course to thoroughly familiarize them with the system before they proceed to advanced mechanical design. This, of course, was impossible for the Glendale students, who, because of time constraints imposed by the 12-week semester, had to proceed directly from the basic to the advanced course.

While the first group of students did not feel that the classroom/laboratory schedule was inconvenient, the students who are attending the second cycle of the course do have a problem in that regard. Those who do their laboratory work at Singer Librascope must attend labs from 11:00 p.m. to 2:00 a.m. because the systems are in constant use for production purposes during the first two shifts. This presents obvious difficulties for the second-cycle students but alleviates the problem noted by Singer employees during the first cycle of the program, when regular employees were occasionally forced to work overtime in order to make up for the periods during which the terminals were used for training purposes, A similar problem was mentioned by some JPL employees, who had been accustomed to use the terminals "dedicated" to training for production design work.

A final problem related to the course structure is that the instructor occasionally had difficulty filling the mandatory 6 hours a week of lecture time with constructive material. While the chalkboard demonstrations of terminal operations and the pen-and-paper exercises were helpful to some extent, the instructor now feels that 4 hours a week of lecture and 8 hours of terminal time would be more appropriate for a course of this type.

While the instructor found ways to address some of the above-mentioned problems in the second cycle of the program, others were less amenable to immediate solution. The 10 hours originally devoted to the basic operations segment has been expanded to 20 hours. To deal with the problem of excessive classroom time, the instructor has assigned a term project for the second cycle of trainees.

As part of the project, students will write papers dealing with the advantages and disadvantages of various CAD/CAM systems for specific types of design work, such as mechanical, printed circuit board, architectural and piping. Each student is assigned an in-depth research project on a specific system for a specific type of application, and the instructor has arranged for more field trips to enable the students to see different systems in operation. At the end of the course, the students will make class presentations on the results of their research, so that the entire class will have some familiarity with a wide variety of systems and applications. Because both cycles of the course were firmly locked in to the college's schedule by the time the difficulties associated with the classroom/laboratory ratio became apparent, it was not possible to make the adjustment to the 4-hour lecture/8-hour lab format which the instructor believes would be the best long-term solution to this problem.

Lack of adequate periods of time for terminal practice between the basic and advanced mechanical design segments is a problem which as yet has no solution in a course which is structured to fit into an academic semester. Even if the college had a well-equipped laboratory dedicated to training, it is unlikely that the students could have logged in 60 to 120 hours of terminal time to fully acquaint themselves with the system before proceeding from the basic to the advanced segments of the course. It should be noted, however, that the students did have the opportunity to work on the terminals for at least 20 hours a week during the worksite training portion of the program. Therefore, although they may not have been able to make use of the terminals at the optimum period in the learning process, they did have up to 200 hours of experience on the terminals in addition to the time spent in the laboratory sections of the formal course.

A final problem, one noted by Singer representatives and by the Glendale instructor himself, is that—while the summer-long upgrading course provided the instructor with a grounding in the Computervision courses he adapted for his own course and a familiarity with the work of the Singer and JPL departments the students would be working in—his training was "barely adequate" to the task of training the students in advanced techniques. The major difficulty here was not with the abilities of the instructor, who had years of experience as an industrial designer and a drafting teacher and is familiar with the operation of another CAD/CAM system. However, while he was evaluated by both Singer and JPL representatives to be fully competent in his field and an excellent teacher, he did not have enough "system time" on Computervision terminals to become thoroughly familiar with all of the operations required for both mechanical and PCB design.

This problem has decreased as the instructor has had more opportunity to work on the system himself and to observe the types of difficulties his students run into on the terminals, and it can reasonably be expected to be overcome entirely with time and experience. Because JPL and Singer designers were always on hand to aid the students with difficult problems, the students did not suffer because of the instructor's lack of extensive production experience on the system.

Evaluation of Present and Future Capacity

In spite of the problems noted in the previous sections, the CAD/CAM operator training program can be rated as an overall success. The two employers have gained trained employees who fill what they both term as a "void" in their occupational structure, and both Singer and JPL pronounce themselves to be very pleased with the program graduates they have hired. The majority of the other graduates have obtained jobs; the college has gained experience in teaching a CAD/CAM course and hopes to be able to integrate it into its regular curriculum; and the Private Industry Council has strengthened its position as a "broker" between industry, academia, and those in need of training and jobs.

Many of the problems cited, are in fact, are normal "startup" difficulties associated with the initial implementation of demonstration programs with limited development time-frames. The other problems—specifically those involved in coordinating the resources and schedules of the industries, on the one hand, and the college, on the other— are currently being addressed by PIC and the college and require both long-range planning and flexible short-term adjustments to achieve a workable solution (see below).

Perhaps more important than the program's success in meeting its stated goals, however, is its value in demonstrating that industries and educational institutions can work together to meet their individual needs and the needs of the community with mutually satisfactory results. The present and future potential for the cooperative endeavor in high-technology training initiated by the college CAD/CAM program and its sister high school program, along with student and employer evaluations of the first cycle of the college program, are discussed in the following paragraphs.

Employer Evaluations.–Many of the employers' reactions to the program and to the students have been touched on in previous sections of this study. This section summarizes and draws together the overall response of the two employers who participated as major sponsors of the program.

Singer Librascope.—Singer representatives interviewed-the manager of engineering and planning, the supervisor of the computer-aided design department who oversaw the laboratory portion of the formal course and the worksite training, and a PCB designer who worked closely with the students during the worksite training-all believe that the trainees did "a great job" and are fully satisfied with the work and motivation of the two trainees who were eventually hired. Even though the third trainee could not be hired for security reasons, the Singer employees said that he, too, did "very good work" and that they would have hired him had he been able to pass the security clearance.

The supervisor of computer-aided design was extremely direct in both his praise and his criticism of various aspects of the program. He felt that the problem created for Singer in the case of the trainee who was unable to get a security clearance could have been avoided if more time and effort had gone into the initial screening process. The classroom training, in his opinion, was "adequate" but could have been "more adequate" if the Glendale instructor had received a longer training course himself. His final criticism of the program was that, while the trainees got a good "basic taste" of CADDS 3 techniques, the instruction would have served Singer's purposes better had it been "more focused" on printed circuit board design.

On the other hand, he recognized the instructor's problem of having students who would eventually be working in two different applications (mechanical and PCB) in the same class and believes that some grounding in mechanical design techniques is necessary for PCB detailers.

Overcoming all of his criticism of the program, however, was the fact that the two trainees who were hired were, first of all, precisely the type of employees he was seeking (young, intelligent, and highly motivated) and, secondly, were tailor-trained to meet Singer's specifications. The program was especially valuable from Singer's point of view in that it trained students who had drafting experience but who did not have previous computer-aided design experience; they therefore did not have to "unlearn improper or unprofessional techniques" or techniques specific to another industry or another CAD/CAM system. Six of the trainees in the second cycle of the program are now receiving laboratory training at Singer Librascope, and the CAD supervisor hopes to hire four of them.

Jet Propulsion Laboratory .–Representatives interviewed included the manager of the design and mechanical support section and the technical group supervisor for computer-aided design. Because the CAD/CAM operator training program was conceived and fostered by PIC (which is chaired by the JPL section manager), JPL's evaluation may be partially perceived as a parent's report of his child's progress, On the other hand, the section manager, being very much a businessman as well as a scientist, is committed to seeing a return on his investment in the trainees, and to hiring employees whose work meets the standards of precision required in the aerospace industry.

Another factor to be considered in JPL's evaluation is its philosophy of community participation and its approach to employee training. The Jet Propulsion Laboratory is the largest employer in the Glendale area, and its managerial employees have implemented their sense of commitment to the community by serving on the board of education, educational task forces, and organizations like the Private Industry Council.

JPL's participation in the CAD/CAM training program, therefore, was motivated not only by its need for trained operators but by its desire to increase the college's focus on high-technology training so that the school could better serve the needs of both the industrial community and the residents of Glendale. Integral to this approach is the notion that industry should communicate its perspective to educational institutions and work with them to address educational needs.*

Aside from attempting to strengthen industry-education linkages in the community at large, the design and mechanical support section manager has institutionalized upgrade training for all of the employees in his section. Forty hours a year of upgrade training for each employee is built into the cost structure of the section, and completion of that training is an important factor in each employee's yearly appraisal. This procedure, which is in essence a mandate that every employee continually upgrade his or her skills, was instituted at approximately the same time that the CAD/CAM equipment was installed in the section and grows out of the manager's perception of the need for engineers and support personnel to keep up with the dynamic advances of the computer-aided tools of their profession.

The JPL representatives who participated in the selection of the trainees for the CAD/CAM operator program therefore looked for applicants who were highly motivated and indicated a desire to continue their education; and the five trainees hired by JPL were those whose motivation both to work at the lab and to continue their education was most apparent. As noted previously, JPL sought trainees who would eventually become fully fledged design engineers-whom the training would provide with sophisticated entry-level skills and who had potential for career growth.

When interviewed halfway through the worksite training period, JPL representatives were well-satisfied with the work, the motivation, and the potential for success of all eight trainees. At the end of the worksite training, the five trainees with the strongest desire to pursue engineering degrees were hired. Two months after they were hired as full-time employees, they were, according to the section's CAD supervisor, "doing very well" and continued to be enthusiastic and motivated. Ten trainees in the second cycle are now receiving laboratory training at JPL (eight from the Coordinated Funding Project and two funded by Investment in People).

Student Evaluations.—Individual interviews were held with five session I graduates-the two graduates hired by Singer Librascope and three of those hired by JPL. The students were uniformly positive about the instructor, appreciative of the experience they had received, and enthusiastic about the current work. All of the students gave the instructor an excellent rating, and some added that he was one of the best teachers they had ever worked with. They specifically noted his ability to provide clear and concise explanations; his attention to detail; his willingness to provide personalized assistance; and his patience and dedication.

While all of the students rated the course content highly, the new Singer hires would have preferred more class- and laboratory-time devoted to printed circuit board design. The other problem—one mentioned by the instructor himself and all of the students interviewed —was the ratio of classroom to laboratory time. While most of the students found the 6 hours of lecture per week helpful in the beginning of the course, all stated that more lab and less lecture would have been more appropriate during the second half. Two students noted that the small size of the class resulted in specific benefits: personalized instruction and an environment that encouraged the students to help each other to explore a variety of design techniques. Others mentioned that the instructional material, especially the ComputerVision workbook, were excellent and that the class projects were especially helpful as learning experiences.

Although many of the students were required to travel long distances-both to the college from their homes and between the college and the laboratory sites—only one mentioned traveling as a problem. None of the students felt that the time-lag between the classroom lectures and the laboratory practice sessions created undue difficulties. All of the graduates stated that the laboratory experience was the most beneficial aspect of the program-not because the lectures were not good, but because of the necessity to engage in hands-on practice on the equipment. Two of the JPL students specifically mentioned the helpfulness of JPL employees during the laboratory sessions.

When, however, the students were asked if they preferred the college-classroom/industry-lab-site set-up to a situation in which the lectures and laboratory work could have been centralized in one location, all but one said that it would have been preferable that the equipment be located at the college. The dissenting student (one of the few who had not had previous industrial experience) said that the industrial environment provided him with a greater incentive to work harder and learn more than would have been possible in a classroom environment. All of the students, on the other hand, felt that the 7 to 10 weeks of worksite experience after the formal coursework was extremely valuable, primarily because they were given "real"

*JPL, which is an outgrowth of an educational institution but which operates like a company, is perhaps uniquely structured to create the academic-industry linkages illustrated by the CAD/CAD program.

work rather than make-work and because it gave them an opportunity to learn about the specific working procedures of the two industrial laboratories.

All of the students expressed their intention of continuing their education at 4-year colleges or universities. One plans to pursue a mechanical engineering degree, and the others intend to work on degrees in industrial design.

Present and Future CAD/CAM Training Capacity of Glendale Community College.—At the completion of the first cycle of the CAD/CAM program, Glendale College, as the program operator, had met most of the objectives set out by the Coordinated Funding sponsors. The college, with the help of PIC and the sponsoring companies, had operated a vocational training program that met the needs of specific local employers; had involved the employers and "other appropriate entities" (PIC and ComputerVision) in planning, design, and implementation; and had provided the participants with effective job skills training and continuing employment with career advancement potential. The final objective of the Coordinated Funding Project–to incorporate the resulting curriculum into ongoing college vocational education programs-has proved to be more difficult to accomplish.

Operating a program combining classroom and worksite training produced a number of beneficial results, not the least of which were the availability of state-of-the-art equipment at the industry sites and the opportunity given to the trainees to acclimate themselves to an industrial environment. The use of industrial labs and the instructor upgrade training provided by project funds enabled the college to demonstrate its effectiveness in training vocational education students to meet industrial needs. The expansion of the program under Investment in People funding also demonstrated that the college could serve as a resource for training existing industrial employees as well as entry-level candidates.

The college, however, is painfully aware of the possible "self-destructing" nature of a CAD/CAM program operated by a school with no equipment of its own. By the end of the second cycle of the program, both Singer Librascope and JPL will be "saturated" with CAD/CAM operators, at least for the present. In order to keep the program running, and to truly incorporate it into the ongoing curriculum of the college, GCC will have to find other sources of equipment.

This potential problem was apparent from the inception of the program, and both PIC and the college's director for special projects have been actively working on a solution. College representatives believe that the least promising solution in the long run is to assume that they-will be able to perpetuate the program indefinitely by relying completely on industry laboratories for the hands-on p-ortion of the training. They are, consequently, exploring the possibility of obtaining donated or reduced-price equipment to be installed at the college to be used for the training of regularly enrolled drafting and design students and for operating upgrade programs for industry. *

Technical Training Center.–Another possibility, one which now looks extremely promising, is the creation of a centrally located technical training center, supported by-local industries, schools, and agencies and outfitted with equipment to address a wide variety of "high tech" skills including CAD/CAM, computer repair, and word processing. The center—which until recently was little more than an idea conceived of by the chairman of the Private Industry Council–is now beginning to look like it may-become a reality.

A recently closed junior high school in Glendale would provide the site; education and business leaders-and local government officials have informally agreed on the concept; and a major producer of CAD/CAM equipment has expressed interest in the possibility of donating equipment. The current thought is that the facilities would be shared by all of the schools in the district and would operate on a three-shift schedule, allowing for three, 3%-hour teaching units in each subject per day. Although such a center would be challenging to administer and maintain, and although students would still have to travel to laboratory sessions, the problems noted previously with regard to coordinating production and training use of industry equipment would be solved, and the college would have access to the equipment it needs to continue its CAD/CAM course and to expand into related areas.

Future Potential.–Glendale College vocational education instructors and administrators believe that a crucial element in the college's future potential to operate vocational education programs is the maintenance and expansion of the communication channel with local industries, established

*In mid-May 1983, the college made the decision to continue the CAD CAM training program through June 1984, funded with regular district funds. The lecture portion will remain at the college. The lab work will be conducted in the private sector at late night and early morning hours, In addition, the college administration is now developing a foundation which will be able to borrow money to be used, in part, to build new laboratories to house the equipment and to cover equipment maintenance costs, through such means as the school's association with PIC and the Coordinated Funding and Investment in People projects.

The open channel to industry representatives is seen as necessary for a variety of reasons. Glendale representatives believe that colleges are 5 to 10 years behind industry in technical expertise and sophistication of equipment; and they look on industry as a resource for instructor upgrading, information about new industrial advances and hiring requirements, and material and equipment to implement new courses.

The college drafting instructor, for example, believes that within the next few years mechanical and architectural drafting programs that do not incorporate computer-aided design will not be achieving their major goal, which is to produce job-ready graduates. In return for industry support, the vocational education division of the college is committed to institute whatever ongoing changes are reasonable and necessary to meet industrial needs and to serve as a training resource for local industries.

Although the college's present capacity to teach programs in computer-aided design and manufacturing is limited by its almost complete lack of equipment, the bridge-building activities of the past 4 years (participation in PIC programs and representation on the PIC board, recruitment of industrial representatives for college advisory committees, and participation in programs like the Coordinated Funding Project) seem destined to bear fruit in the near future. Local industries that have benefited from CETA training programs operated by the college now donate material, equipment, and funds. The success of the Coordinated Funding Project demonstrated the college's ability and may bring more industrial support, open more industrial labs, and help the school to win more State funds.

The Investment in People grant, which allowed the school to expand the CAD/CAM operator program, is but one example of the college's potential to build on the achievements gained through working with local industries and agencies. More recently, the college was chosen as one of the possible west coast sites for the General Motors/United Auto Workers retraining projects. The program proposed by GCC—a year-long electronics technician course—has been accepted in concept and will be implemented if it proves feasible for 20-laid off GM workers to either relocate to or travel to Glendale for the length of time it would take to complete the course.

The synergistic relationship between the college, the Private Industry Council, and the City of Glendale is a major key to the college's future potential. PIC has engaged the support of its board members to aid the college in obtaining equipment, This, in itself, becomes a very powerful resource because of the stature of the industries–including JPL, ITT, Pacific Telephone, and banking and financial organizations-represented on the PIC board. Whether the final result of the effort to build GCC's equipment and laboratory resources takes the shape of a training center to which the college has access, or laboratories located on the college campus, the partners in the school-city-PIC relationship seem committed to making use of whatever equipment is obtained to serve the broadest possible constituency.

The Glendale Private Industry Council.–While the formal role played by PIC in the operation of the CAD/CAM operator program was relatively minor, the importance of the Private Industry Council as an informal broker between educational, industrial, and governmental organizations cannot be overestimated. The idea for the CAD/CAM operator program originated with the PIC director and chairman; the PIC chair secured the cooperation of his own organization (JPL); the PIC director enlisted Singer Librascope and Computervision; and the PIC staff assisted in placing the cycle I graduates who were not hired by the participating firms.

Although PIC's formal mandate is to operate training programs for structurally unemployed and displaced workers, the philosophy of the Glendale council encompasses a much wider sphere of activity than the direct operation of government-funded training and employment programs. Integral to that philosophy is the creation of linkages between the industrial and educational committees to enhance the activities and resources of each and to serve the community as a whole.

In light of this philosophy, the role of the broker is profound, especially when one considers the difficulty of creating matches between the two ends of the labor market spectrum: on one end, technologically oriented industries requiring many workers to have ever-more sophisticated entry-level skills; and, on the other end, the structurally unemployed,* who may have few workplace skills,

*Structurally unemployed individual are those whose situation reflects long-term changes in economic conditions, in contrast to the "cyclically unemployed" who are periodically without work due to short-term changes in the general economy.

and displaced workers, who may be only semi-skilled.

Occupying the vast middle ground are colleges and high schools requiring assistance to update their curricula and upgrade their instructors so they can assist in the job training process; workers with outdated skills who do not meet the Federal poverty guidelines and are therefore ineligible for federally funded programs; and firms whose workers require upgrade training but which may not have the resources to provide that training in-house. By taking the broad approach and making the most of its formal and informal channels of communication between all of the sectors of the community, PIC hopes to have a pervasive effect which, in the long run, may create that match between industry's high-tech needs and the structurally unemployed.

At present, PIC is working on a number of fronts, which, when brought together, may enable it simultaneously to serve the needs of high-tech industries and the structurally unemployed. Although the CAD/CAM operator program did not serve the structurally unemployed, it did serve some displaced workers and some who were below the poverty level. It also strengthened the college's training capacity and aided local industries. In addition, the CAD/CAM program demonstrated the feasibility of bringing the various participants together to create a successful high-technology training program and set the mechanism in place for expanding it.

This type of activity–working both formally and informally to strengthen various segments of the education and training system and concentrating on strengthening the links between the segments—illustrates another tenet of the Glendale PIC philosophy, characterized by the following statement by the PIC chair: "There's a need to recognize that nothing is static—once you get into it, you've got to be willing to move. The way we've done that is to address needs that are peculiar and particular to industry now, and we ask industry to forecast needs downstream, so we can be ready to alter our training programs to be ready at the time that the need exists. My impression is that industry loves it if they're included and that school systems are now put in the position of preparing students for the real world. They're beginning to realize that they're both part of it and that the responsibility is a shared one. "

To further strengthen education's knowledge of industry, PIC is working to encourage local schools to substitute a work experience program for the traditional sabbatical leave for instructors and to provide appropriate promotion credits for such a program. To increase industry's recognition of the capacities of educational institutions, PIC encourages companies to look on vocational education teachers as a training resource and to contract out in-house training to the colleges. *

This system, according to the PIC chair, would cost the companies less than in-house training and would strengthen the schools' capacity to provide industrial-level technical training. While this notion would not necessarily work for all types of training in all companies, it is likely to work in a number of instances if well-managed and properly designed.

The CAD/CAM operator program illustrates that industry-education cooperative training endeavors can succeed, in spite of the difficulties that inevitably occur. The problem now facing Glendale Community College-how to continue the course when the two industrial sponsors are saturated and the equipment question is still up in the air—graphically illustrates the PIC chair's statement that "nothing is static. " PIC and the college, however, are ready to move—either to move to other companies to keep the program running until a permanent solution can be found, or to acquire equipment or establish a training center. This type of innovative approach to CAD/CAM training, which relies on mutual cooperation while recognizing that circumstances change and resources are limited, may not be guaranteed of certain success, but it is most certainly well worth the attempt.

*In many cases, this would involve providing industrial upgrade training to the teachers, as was done in the case of the GCC instructor.