# ARCHITECTURAL / ENGINEERING APPLICATIONS

INPUT

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X
CADA

AUTHOR

Improving the Productivity of
Engineering and Manufacturing

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INPUT Planning Services for Management

# IMPROVING THE PRODUCTIVITY OF ENGINEERING AND MANUFACTURING USING CAD/CAM ARCHITECTURAL/ENGINEERING APPLICATIONS

A MULTICLIENT STUDY

DECEMBER 1981

IMPROVING THE PRODUCTIVITY OF
ENGINEERING AND MANUFACTURING
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CONTENTS

# IMPROVING THE PRODUCTIVITY OF ENGINEERING AND MANUFACTURING USING CAD/CAM ARCHITECTURAL/ENGINEERING APPLICATIONS

## EXHIBITS

# I INTRODUCTION

# I INTRODUCTION

## A. RESEARCH METHODOLOGY

- This report, produced by INPUT as part of a five-volume CAD/CAM (Computer-Aided Design/Computer-Aided Manufacturing) multiclient study, analyzes the application of CAD systems to architecture and engineering.

- The research methodology is explained in the User Issues and Considerations volume of this study.

- Extensive reading of recently published books and articles relating to architectural/engineering (A/E) usage of CAD was performed.

- Vendor interviews were conducted with those turnkey vendors representing the majority of A/E installations plus two vendors specializing in A/E, Grafcon and Sigma Design.

- Vendor questionnaires were supplemented with questions concerning A/E applications for those vendors with current or future potential to serve the industry.

- Thirty-nine domestic users of CAD systems for A/E applications were interviewed using the questionnaire in Appendix D.

- Seventeen users were interviewed on-site and 22 by telephone.

- The following CAD vendors were reported being used by the respondents:

  . Auto-trol.

  . CADAM.

  . Intergraph.

  . Computervision.

  . Calma.

  . MCAUTO.

  . Applicon.

  . Cybernet.

  . Applied Graphics.

  . Koppers Company.

## B. ORGANIZATION

- Chapter II, "Executive Summary," presents the major findings in a brief overview. Readers are referred to following chapters for more detailed discussions.

- Chapter III describes the developments in CAD applications within the industry in historical-to-present perspective.

- Size of market and current usage of systems by A/E applications are discussed in Chapter IV followed by a chapter devoted exclusively to the economic issues relative to the industry.

- Trends for the next five years are examined in the final two chapters, one each for A/E users and vendors.

- Appendix A contains case studies; Appendix B, the data base; Appendix C, a glossary of terms; and Appendix D, copies of the questionnaires.

# II EXECUTIVE SUMMARY

## II EXECUTIVE SUMMARY

### A. DRIVING FORCES AND TRENDS

- Architectural/engineering (A/E) usage of computer-aided design (CAD) lags well behind the two major applications, electronic and mechanical engineering. The lag is evident in both absolute and relative terms. The major factors responsible for this lag are:

  - The optimum size of most turnkey systems, six to eight workstations, represents average capital investments of over $500,000; well beyond the reach of most A/E firms.

  - The absence of vertically integrated production functions, except in the few large firms, precludes a majority of A/E firms taking advantage of many of the potential benefits of CAD.

  - Until quite recently there has been little in the way of specialized software to support interactive graphics for A/E applications.

- Progress in the usage of CAD A/E applications has been made, however, especially among larger organizations.

- Following the leads of the Air Force and NASA, GSA has developed guidelines for agencies in the procurement of A/E services through federal contract authority.

- Shortages of qualified drafting personnel have created the need for productivity improvements among those remaining available to the industry.

- Competition demands faster and more accurate responses to requests for proposals.

- The prestige associated with a small-to-medium firm landing a main contract has justified the capital investment in many cases.

## B. CRITERIA FOR THE SELECTION OF CAD SYSTEMS VENDOR

- The most important feature to the A/E user when selecting among vendor product offerings is software, as shown in Exhibit II-1.

- System flexibility runs a close second among users surveyed and should be considered equal in importance on the basis of sample size.

- It may surprise some firms that system cost is among the less important factors for vendor selection, once the commitment to CAD is made.

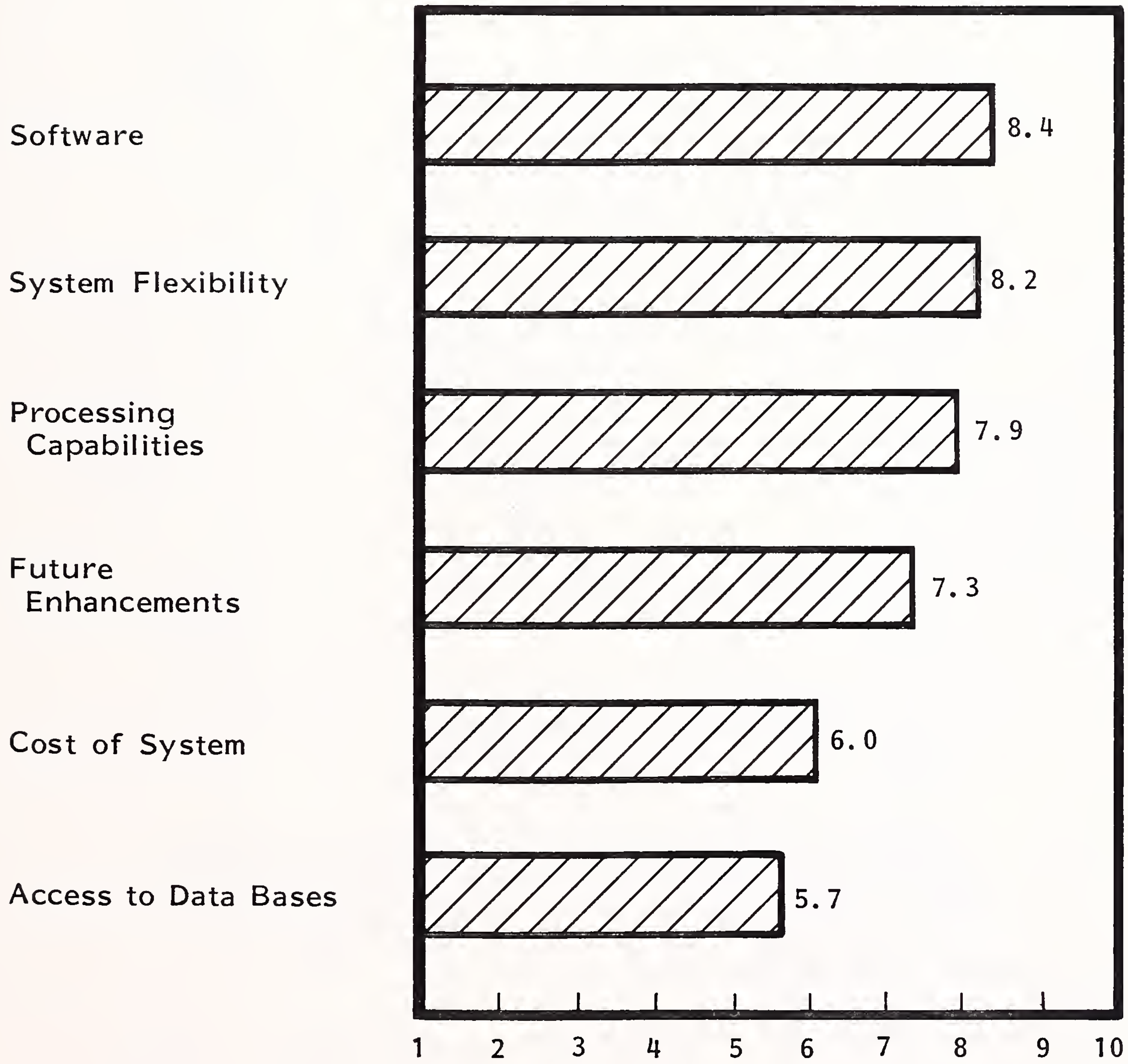
## C. THE FUTURE OF CAD IN ARCHITECTURAL/ENGINEERING APPLICATIONS

- By 1986, A/E CAD applications will represent a market of $895 million, as shown in Exhibits II-2 and II-3.

EXHIBIT II-1

CAD VENDOR SELECTION CRITERIA

(average responses)




SCALE: 1 = Not Important, 10 = Vital

EXHIBIT II-2

PROJECTED GROWTH OF CAD TURNKEY AND HARDWARE EQUIPMENT SALES IN ARCHITECTURAL/ENGINEERING APPLICATIONS

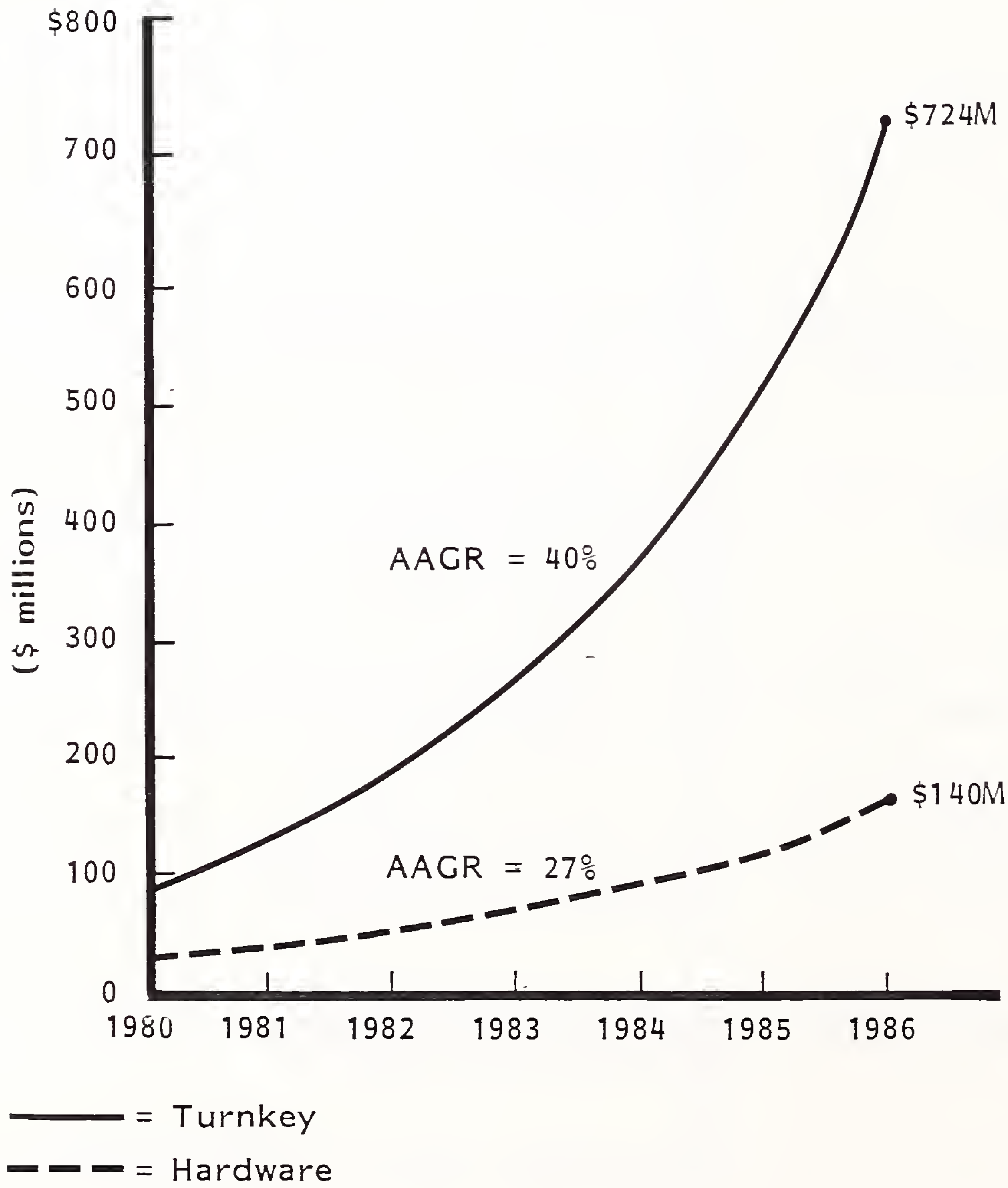
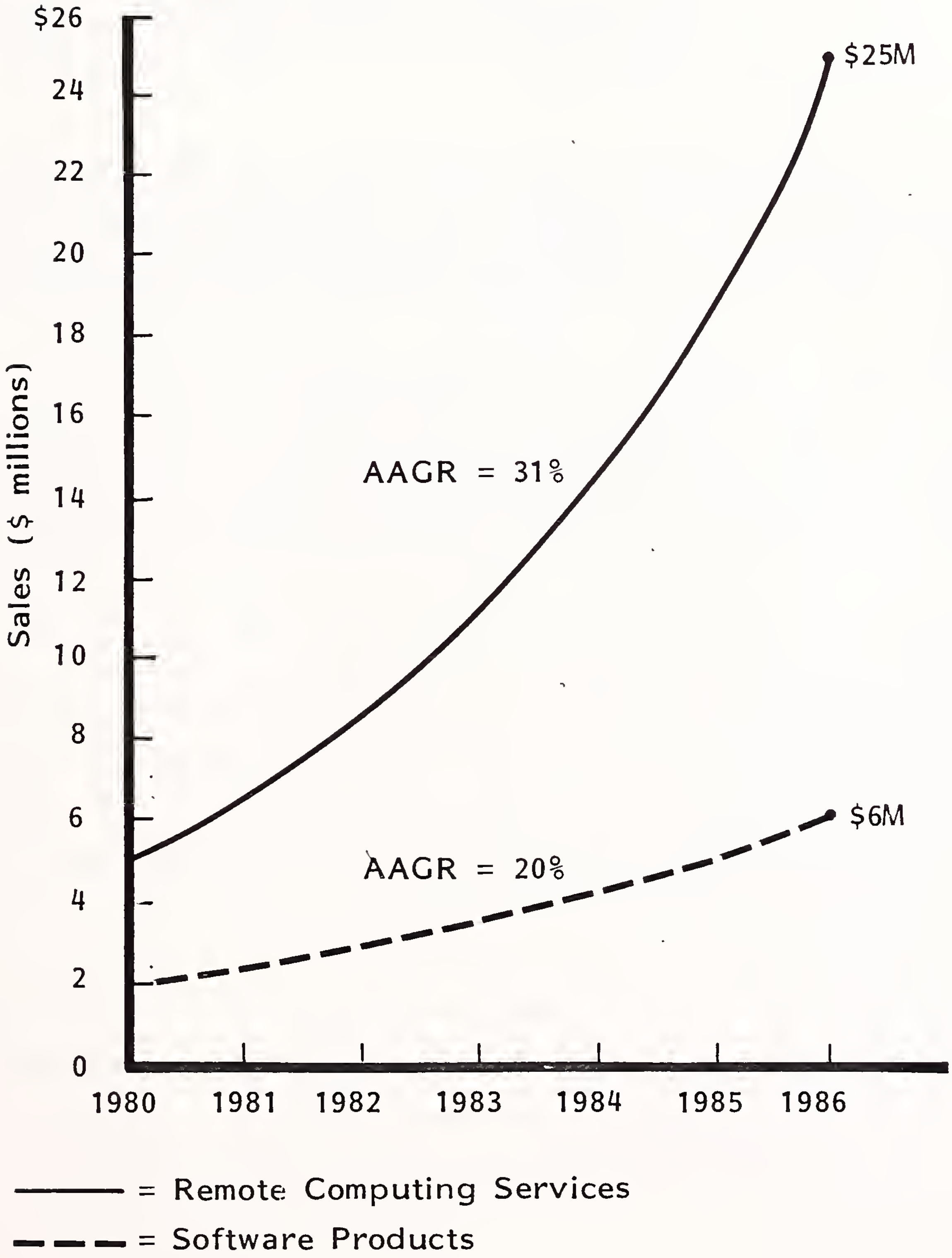


EXHIBIT II-3

PROJECTED GROWTH OF CAD SOFTWARE AND REMOTE COMPUTING SERVICES IN ARCHITECTURAL/ENGINEERING APPLICATIONS



- The cumulative investment in turnkey systems between now and the end of 1986 will be over $2.3 billion in A/E applications.

- The potential market, plus acquisitions of CAD expertise by the large DP vendors, will accelerate developments in A/E applications and, through economies of scale, make affordable interactive graphics available to the majority of A/E firms.

- The requirements for single, locally intelligent workstations for the small firms will be met with small systems having the capability of interfacing with larger systems as the need arises.

- CAD systems will become more widely used to increase the productivity of draftsmen, designers, and engineers. This will become an increasingly critical issue to firms of all sizes as the costs and shortages of skilled personnel increase.

- The current trend toward the development of small, full-function systems and intelligent workstations will continue. Benefits to A/E firms will be lower start-up costs and a more complete range of CAD systems to choose from.

- Some of the major CAD vendors and a number of small system vendors have targeted the A/E market because of its relatively untapped potential. The major vendors will round out their product lines (more application software and a wider range of systems) while the smaller vendors will concentrate on specific applications (specific building-type designs, drafting, specific material design and analysis, etc.).

- As the A/E CAD market develops, a wider range of special and general applications software will become available to better interface the design activity to other functions such as analysis, project scheduling and control, bills of materials, construction scheduling, management reporting, etc.

## D. RECOMMENDATIONS

- Vendors wishing to penetrate and grow with the architectural/engineering CAD market will do well to develop single workstation capability well below $100,000 for a fully configured drafting system.

- Architects and consulting engineers should become more involved in vendor/user organizations to have their needs brought more forcefully to the attention of vendors.

- Potential A/E users may find an easier entry into CAD via service bureaus or local cooperative organizations composed of several firms, none of which can individually afford the cost of large turnkey CAD systems.

- A/E firms should consider engaging the services of a qualified consulting firm prior to making a commitment to purchasing or leasing a CAD system, due to the complex nature of the products, the dynamics of the CAD industry, and the magnitude of the investment.

# III DRIVING FORCES AND TRENDS

## III DRIVING FORCES AND TRENDS

- Of the three application areas studied by INPUT (mechanical, electronics, and architectural), A/E makes the least use of automated design and engineering techniques. The A/E industry is being driven to consider CAD as one of the key tools for increasing productivity and streamlining internal operations to meet growing competitive and operational pressures.

### A. AVAILABILITY OF PERSONNEL

- The shortage of qualified draftsmen and engineers available to the A/E industry has grown more and more critical over the past decade.

- Increased requirements for good drafting personnel in the electronics and mechanical engineering fields have attracted potential A/E draftsmen away, creating an even more serious problem.

- The engineers' and architects' time has become too valuable to spend in drafting or other activities which may be performed by less qualified personnel.

## B. PRODUCTIVITY

- With a crisis looming in the availability of draftsmen and engineers, A/E firms have no choice but to turn to automated techniques to increase productivity.

- Computer-aided design systems have found a natural home in architectural and engineering applications by offering increased throughput of drawings:

  - Shared drawings historically required significant effort in reproduction and in the control of revisions to masters which had to be reflected in all associated drawings.

    - Revisions to masters may be called up on a CAD screen for reference or merged into the current background drawings on which engineers are working.

  - References to other drawings in a manual system can be a time-consuming and error-prone task.

    - CAD systems allow for the overlay of other current drawings for quick reference.

  - Archival drawings, reusable except for modernization alterations and minor customizing, had to be completely redrawn, saving only the original effort of conceptual design and some drafting setup time.

    - Once digitized, archival drawings may be called up on a CAD screen and modified as required with the only added effort being the actual modifications.

  - Except for templates and specialization through repetitive drawings, draftspersons essentially redesigned every symbol, window, door insert, etc. each time the same repetitive symbols were used.

- CAD systems have provided both standard and customized menus of drawing symbols which may be placed anywhere on the screen and drawn by quick reference of coordinates and symbols.

- Changes of scale in drawings or from inches to metric scales were historically tedious jobs requiring significant manual effort.

  - CAD systems have rescued the industry from this tedious activity by automating scale changes.

- Parallel line segments such as those found in dimensioned piping layouts or ductwork drawings added time to the drafting effort, but are easily defined and drawn by CAD systems.

- Manual drafting of isometrics and perspective drawings requires careful calculations and rotation of axes.

  - Given the base coordinates, CAD systems easily plot three-dimensional representations in either isometric or perspective form.

- Architects and engineers lose productive time checking various municipal codes for compliance throughout the design phases. Code checking is a potential benefit of CAD technology not currently integrated in a significant way.

## C. COMPETITIVE FORCES

- Turnaround time on competitive bids is probably more critical in the architectural, engineering, and general construction industry than in any other.

- The ability of a small to medium A/E firm to land a big competitive contract is worth far more in future credibility and referral business than the average cost of a turnkey CAD system.

- Accelerated costs for all elements of construction - materials, labor, interest rates, equipment, and land - have squeezed the architects and engineers into the position of requiring more accurate methods of estimating costs and profits before submitting bids; rules of thumb are too outdated.

## D. GOVERNMENT PRESSURE

- Various government agencies are increasing their demands that computers be used on their projects.

- In a 1980 report to Congress, the Comptroller General encouraged the use of architectural and engineering firms who are competent in the use of computer-aided design techniques. The report contains some very strong recommendations to impose certain requirements on procuring agencies; paraphrased excerpts follow:

  - "Require that architect-engineer contract negotiators routinely discuss and evaluate planned use of computers when negotiating contracts.

  - "Fee negotiations will be based on proposals which clearly identify tasks . . . and, when applicable, indicate how computers will be used on the project.

  - "Require computer capabilities and expertise to be considered and evaluated when selecting architects and engineers.

  - "Direct that computer use be required for those analyses and design functions which can be efficiently done only by computer aided methods. Also, encourage computer use in all areas where the quality of the design or the structure to be built can be improved when computer aids are used."

*(Source: REPORT TO THE CONGRESS by the Comptroller General of the United States, LCD -81-7; October 15, 1980)

- The U.S. Corps of Engineers has recently gone a step beyond the above recommendations and required graphic data compatibility with a specific CAD vendor in some contract bids.

## E. PROJECT ANALYSIS

- Analysis of alternative placements of plants on given topography historically required extensive redraw efforts and modeling. CAD offers a solution to this design effort.

- An accelerated need for feasibility analyses involving complex variables creates requirements for more sophisticated design tools. Consideration of the following and other variables could be significantly enhanced with computer aids:

  - Alternative materials available during projected construction phases.

  - Schedules of subcontractors during critical path activities.

  - Projected schedules of competitive activities with potential to impact the marketability of a project.

  - Financial commitments and projected interest rates during development.

  - Government intervention projections:

    . Environmental impact studies.

    . Building permit legal arguments.

- General marketing considerations.

    . Existing and projected demand for project benefits.

    . Changing sensitivity to prices.

    . Strategies and costs of reaching potential markets.

- A better method has been needed to aid in forcing designs or to use standard measurements of materials available in bulk quantities.

- Quality control of design, such as in matching a design against minimum bid specifications or against internal QC specifications, could be made more accurate and more timely during project analysis.

- Conceptual alternatives in master floor plan layouts are facilitated using CAD methods.

- Structural analysis with data taken from manual designs is time consuming, even if the analysis itself is performed by computer. CAD offers a means to transfer digital design data directly to analysis routines.

- PERT/CPM methods of project analysis and control are only as good as the input data. CAD offers a potential for capturing significant amounts of required data during design phases.

## F. PROJECT MANAGEMENT FORCES

- Requirements for quicker production of key working documents have created a greater need for CAD systems. Such documents are:

- Working drawings.

- Field addenda.

- Instructions and specifications.

- Materials and parts lists.

- Special equipment and tools lists.

• The need for smoother integration of design and feasibility analysis data into the project management data base has been increasing rapidly; for example:

  - The conversion of PERT/CPM analysis data into benchmarks and/or milestone charts for construction.

  - Contingent alternatives built into the design to be communicated to project management.

  - An established feedback loop to facilitate field addenda.

• Logistics of material orders and deliveries underlying design/feasibility assumptions could be greatly enhanced by CAD systems.

• Overall project productivity can be enhanced with integrated CAD feedback loops between design and construction entities with regard to assumptions and controls to level demands for scarce personnel and other resources critical to the success of the project.

## G. FORCES INHIBITING THE DEVELOPMENT OF CAD IN ARCHITECTURAL/ENGINEERING APPLICATIONS

- Prior to the recent introduction of microprocessor-based workstations, only very large architectural and/or engineering firms could afford CAD systems.

    - Most architectural and engineering CAD applications can be cost justified in the range of $50,000 to $125,000 per workstation.

    - Typical turnkey systems would require configurations of from four to six workstations per CPU to achieve these levels of investment.

    - A large majority of firms require no more than one or two workstations for start-up CAD systems.

- Even with the driving forces behind the evolving need for CAD in the architectural and engineering fields, these firms have traditionally avoided heavy capital investment in tools and equipment.

- The industry lacks a tradition of functional integration more typical to the manufacturing industries.

    - The stronger ties among the design, management, and production functions in manufacturing create better opportunities there than in architectural/engineering applications to expand the benefits of CAD beyond the drafting activity.

    - Architectural and engineering disciplines have a greater tradition of independence which has established a more general reluctance to changes in methods.

# IV CURRENT STATUS OF CAD

# IV CURRENT STATUS OF CAD

## A. PROJECTED MARKET FOR CAD IN ARCHITECTURAL AND ENGINEERING APPLICATIONS

- Turnkey sales of $97 million in 1980 are projected to increase over the next five years at a compound growth rate of approximately 40%, as shown in Exhibit IV-1.

  - Architectural and engineering applications will represent a turnkey systems market of over $700 million by 1986.

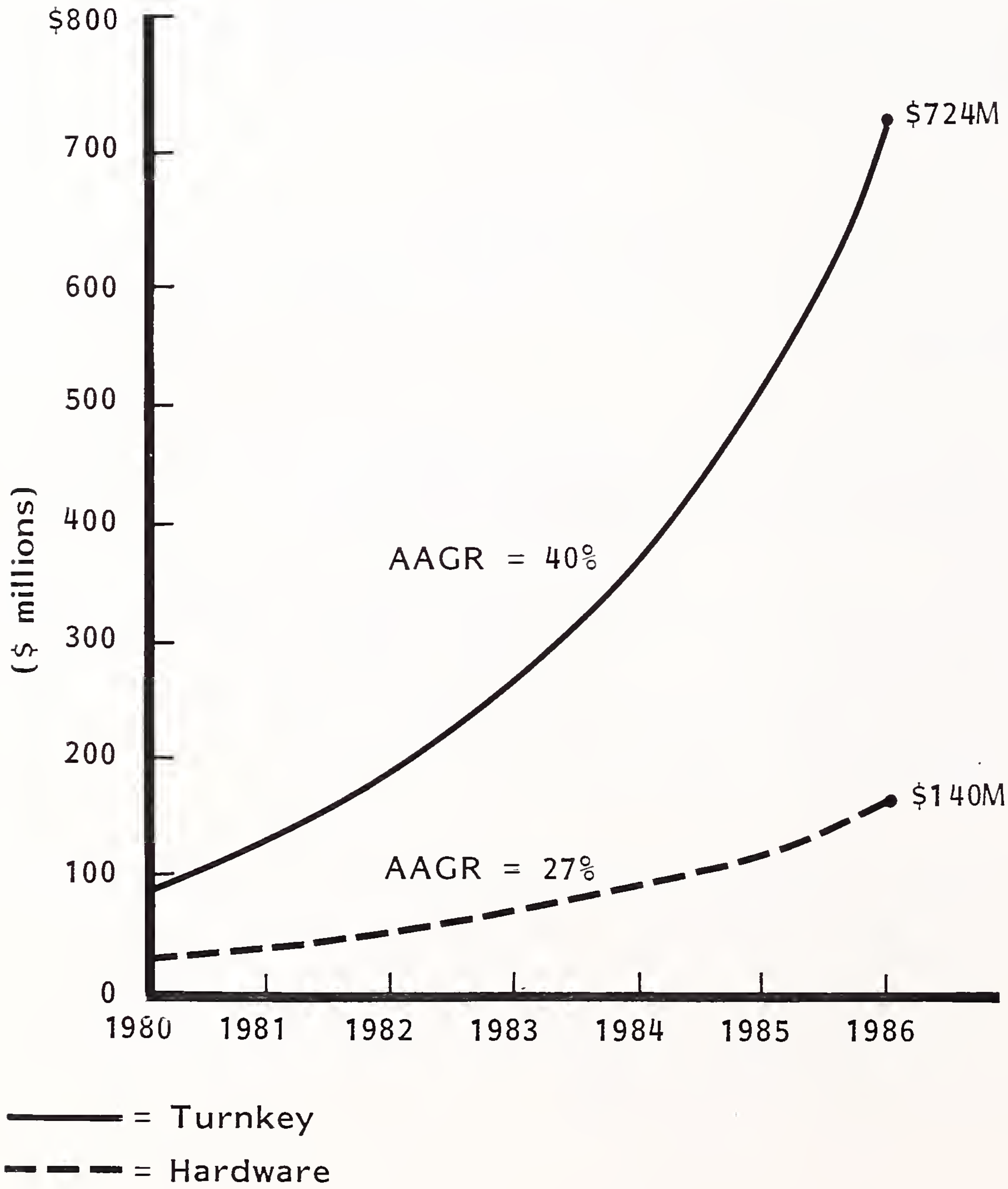
  - Even with an allowance for 100% depreciation of the currently installed equipment, by the end of 1986 the turnkey systems purchased by architectural and engineering firms will represent an accumulated investment of over $2 billion.

  - Turnkey systems will represent the primary method of delivering CAD capability to this industry for most of the decade.

- Sales of general hardware allocated or dedicated to CAD in A/E applications amounted to $33 million in 1980.

EXHIBIT IV-1

PROJECTED GROWTH OF CAD TURNKEY AND
HARDWARE EQUIPMENT SALES
IN ARCHITECTURAL/ENGINEERING APPLICATIONS



- INPUT forecasts of sales in general (nonturnkey) hardware are at a relatively moderate 27% annual growth rate, still an attractive market for any vendor.

- A/E hardware sales of $140 million in 1986 will cap a six-year cumulative investment of over $530 million.

• Remote computing services (RCS) are not projected to play a significant role in the growth of CAD within the A/E applications, as shown in Exhibit IV-2.

  - From a reference point of $5 million in 1980 sales, RCS sales will increase to $25 million in 1986.

  - The anticipated growth of 31% per year is based on increased demands for numerical analysis in complex engineering applications.

  - Some of the growth will also come about as small A/E operations use interactive remote workstations to get started in CAD.

• Software products to support general hardware and to augment turnkey systems will increase slightly to $6 million in 1986, growing at a compounded rate of 20%.

## B. USER ACTIVITIES

• A majority of A/E firms (79%) centralize their CAD operations, as shown in Exhibit IV-3.

  - Also, 69% of the firms are using CAD specialists on the graphic systems, as opposed to providing the terminals to all engineers and architects.

EXHIBIT IV-2

PROJECTED GROWTH OF CAD SOFTWARE AND REMOTE COMPUTING SERVICES IN ARCHITECTURAL/ENGINEERING APPLICATIONS

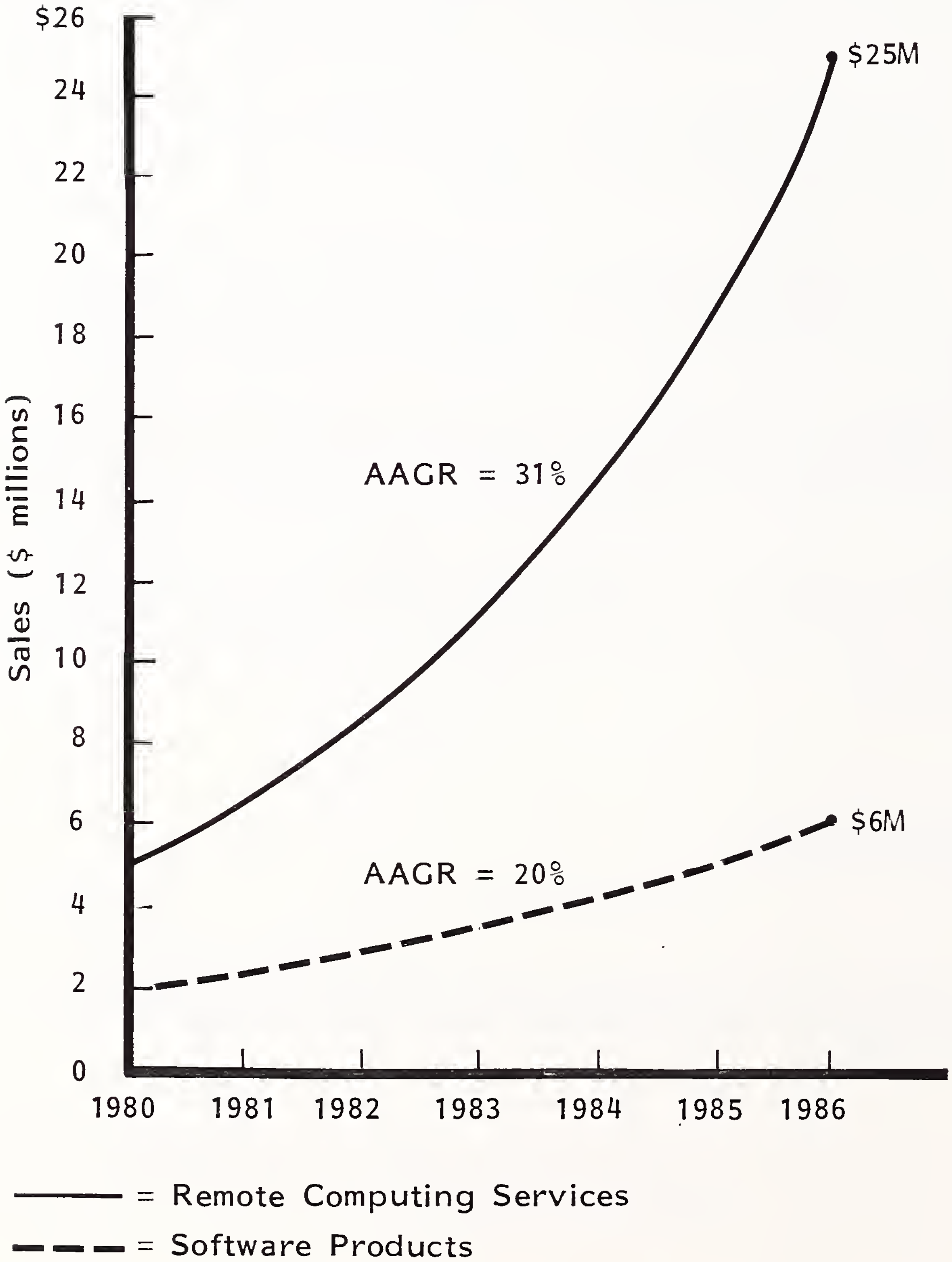


EXHIBIT IV-3

LOCATION AND USER OF CAD WORKSTATIONS IN ARCHITECTURAL/ENGINEERING APPLICATIONS

| USER | WORKSTATION LOCATION | | | TOTAL |
|---|---|---|---|---|
| | CENTRAL | DISTRIBUTED | BOTH | |
| Specialist (either CAD Trained Draftsman or Dedicated Engineer) | 63% | 6% | 0 | 69% |
| Project and/or Design Engineers | 13 | 3 | 3% | 19 |
| Both | 3 | 6 | 3 | 12 |
| Total | 79% | 15% | 6% | 100% |

- Sixty-three percent of the firms surveyed use specialists on centralized equipment exclusively.

- Only 3% of all firms surveyed had a complete mixture of specialists and designers using both centralized and distributed terminals.

• A large A/E firm in the southeastern U.S. interviewed by INPUT, has experimented with a program of training any design engineer or architect from any department to use the CAD facilities.

  - They found that the direct productivity improvements over conventional methods fall within the 2:1 range as opposed to the 3.5:1 ratios by specialists, because the casual operators do not spend a large share of their time on the terminals and do not become as proficient.

  - This firm is convinced, however, that the overall efficiency of the organization is improved for more subtle reasons:

    . The reluctance of engineers and architects to use automated design tools in these professions is significantly reduced after the designers become familiar with the benefits.

    . Broader familiarity with CAD creates an atmosphere in which conceptual sketches and approaches to drafting instructions are made which enhance the use of design aids and create even greater efficiencies in the central drafting pools.

    . Both of the factors above, while difficult to measure, contribute to the throughput of projects from bidding and conceptualization to completion.

• Drafting applications represent by far the most prevalent use of CAD systems in the A/E environment.

- Currently, the CAD systems are used more for nondimensional drawings than for other purposes in most A/E operations.

- Exhibit IV-4 is a reproduction of a nondimensional drawing benchmarked by Auto-trol at 4.5 hours versus 35 hours manually, a productivity ratio of 7.8:1.

    . Other examples of nondimensional drawings using a majority of standardized symbols would be for ductwork, electrical, lighting, etc.

    . Design engineers feel that productivity will be greatly improved when nondimensional drawings can be automatically converted to dimensioned working drawings for construction.

    . The ultimate use of CAD will be when the combined drawing data bases are used to automate the bill of materials takeoffs.

- Exhibit IV-5, furnished by Everett I. Brown Company, is detail work generated by their Intergraph system.

    . Because of the high repetition rates of these types of details, 10:1 productivity improvements are achievable once the common symbols are entered into the menu.

    . Since many structural details such as these are defined by municipal codes, the potential exists in the future for even greater productivity improvements by combining automated code compliance checking with detail drawings.

- The incidence of CAD for structural analysis and uses other than drafting is currently insignificant.

## EXHIBIT IV-4

## NONDIMENSIONAL DRAWING BY AUTO-TROL

AD/380
4.5 hrs.

Manual
35 hrs.

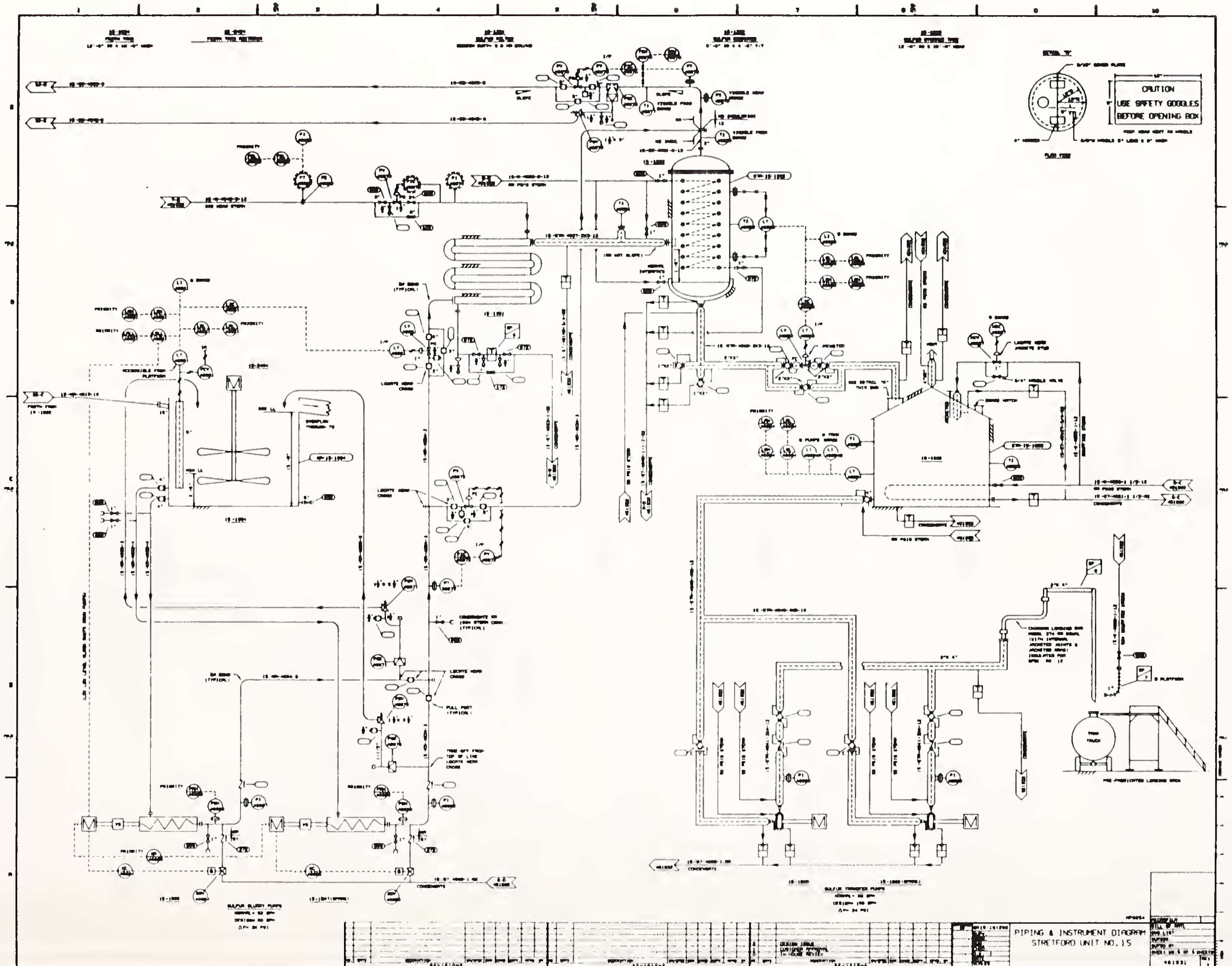
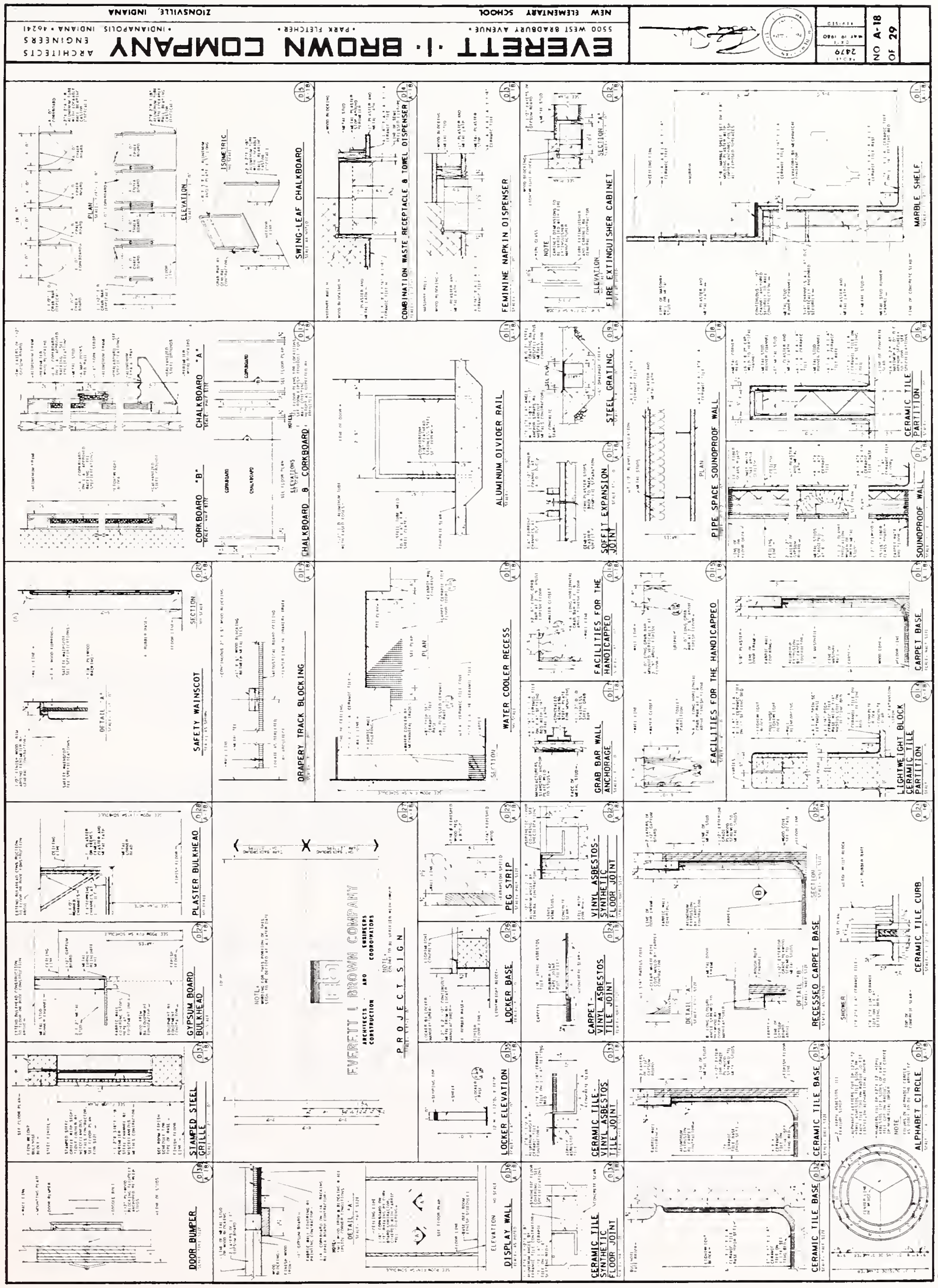


EXHIBIT IV-5

SAMPLE DETAIL DRAWING



- Engineering analyses of pressures and vessel integrity, as examples, are being accomplished at the moment by more traditional methods.

- When computers are used, the engineers are generally using manually transcribed design data for input into the analysis systems; there is practically no integration of the design data bases with engineering analysis programs.

- One of the engineering firms with over $1 billion in sales interviewed by INPUT reported that cut-and-fill calculations are being performed by slide rule or handheld programmable calculators.

- Remote computing services are being used for separate engineering analyses in most cases. MCAUTO and Cybernet were the most frequently mentioned resources.

• Only two of the users surveyed reported that they do not now belong to a CAD vendors' user group.

  - Most feel that the group association is worthwhile.

    . Some users expressed concern that their group meetings were being used too much for training newer users, a responsibility, in their opinion, of the vendors.

    . Several mentioned working with more experienced members to shift the emphasis of meetings toward bringing needed improvements to the attention of the vendors and toward the sharing of mutually beneficial suggestions among all experienced users.

• A/E firms are not significantly involved in standards groups, as are large industrial firms.

- Few respondents had any opinion about the ultimate influence of SIGGRAPH-CORE (a proposed standard of the Special Interest Group on graphics of the Association for Computing Machinery) versus the Initial Graphics Exchange Specification (IGES) of the National Bureau of Standards on final industry standards; those who do favor IGES.

- Only one of the A/E firms interviewed was familiar with the following government programs:

  . BSDS - Building Standard Design System (Corps of Engineers).

  . CAEADS - Computer Aided Engineering and Architectural Design System (Corps of Engineers).

  . CASDAC - Computer Aided Ship Design and Construction (U.S. Navy).

## C. VENDOR ACTIVITIES

- The current turnkey market in A/E applications is dominated by Computervision, Intergraph (formerly M&S Systems), and Auto-trol as shown in Exhibit IV-6.

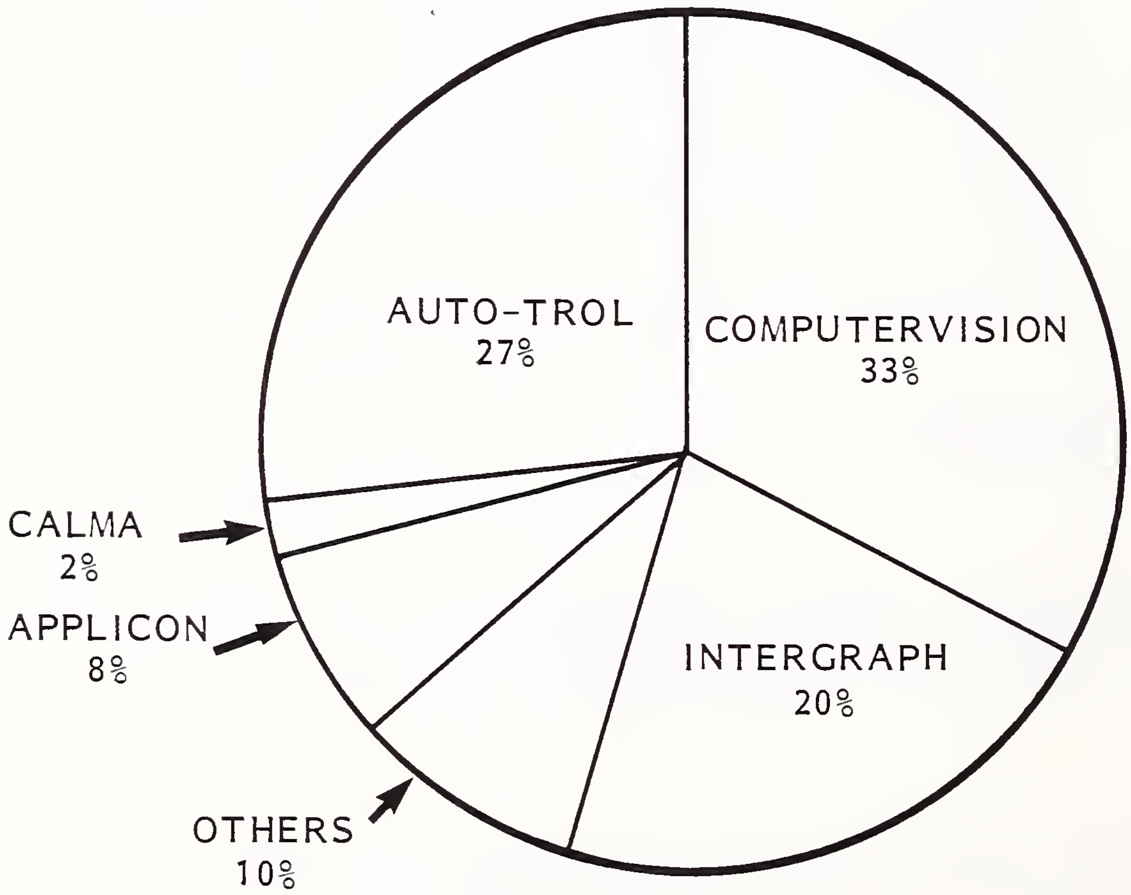
  - While Intergraph enjoys only 20% to Computervision's 33% of systems installed, it takes in 27% of the revenue, as indicated in Exhibit IV-7.

  - The cost of these major turnkey systems limits current use to large consulting firms and integrated construction companies.

- The "Designer System"T.M. by Computervision is a multiterminal turnkey system which may be customized for plant and building design purposes.

EXHIBIT IV-6

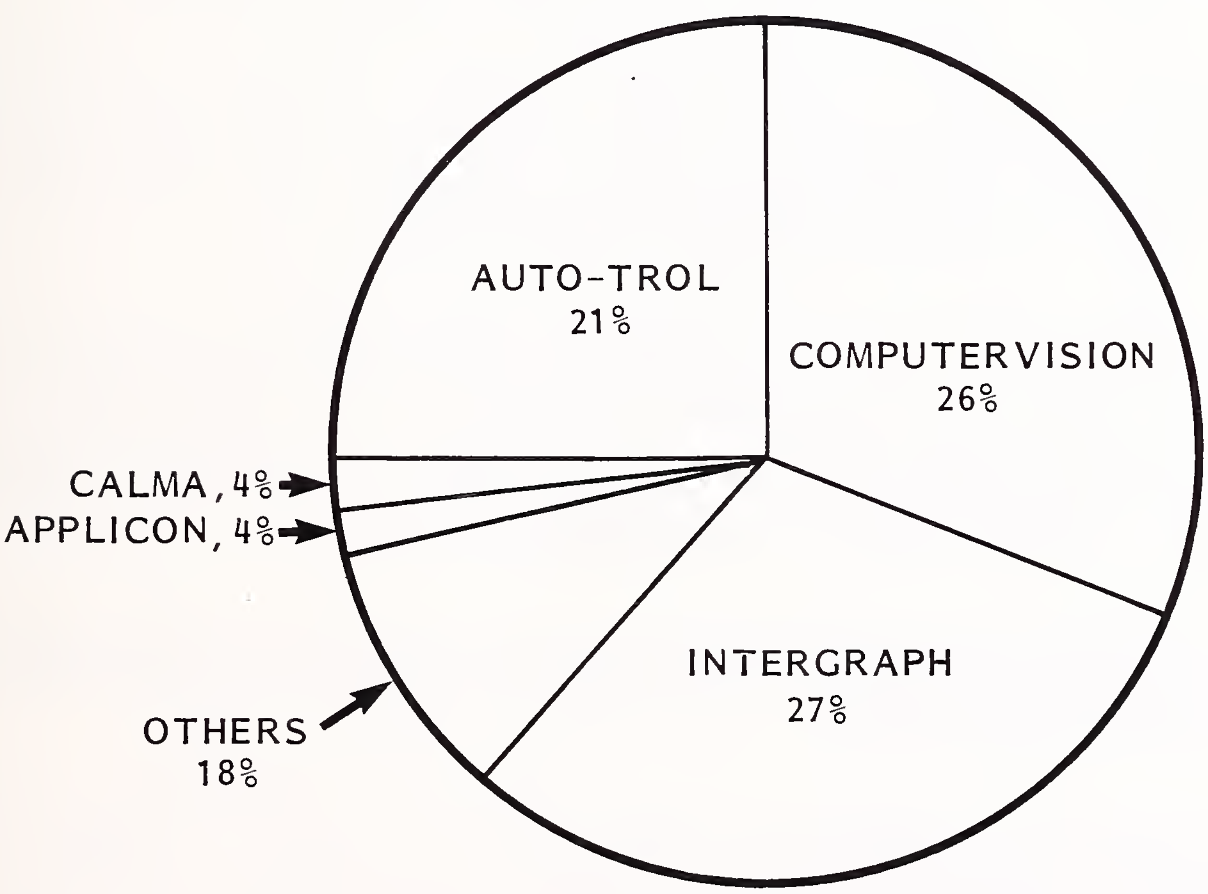
1980 VENDOR SHARES OF TURNKEY SYSTEMS INSTALLED
IN ARCHITECTURAL/ENGINEERING APPLICATIONS




TOTAL SYSTEMS - 558

EXHIBIT IV-7

1980 VENDOR SHARES OF REVENUE FROM ARCHITECTURAL/ENGINEERING TURNKEY INSTALLATIONS




REVENUE TOTAL = $97 MILLION, INCLUDING MAINTENANCE REVENUES OF $25 MILLION

- Features include facilities to work from the site plan, using mapping capabilities, through building design and detailing.

- A 3-D capability allows for easy routing of piping after laying all equipment in place, and for interference checking among layers of simultaneous design efforts.

- Relatively simple structural analysis routines like beam loading and deflections may be programmed in the CV "PEP" language.

- More complex structural analysis routines are run on larger mainframes with design data taken directly from the 3-D structural models.

- Reinforced concrete details, length, spacing, bending, etc., may be automated into the design process by instructions to the system and in conformance with standard engineering practices.

- The wiring diagram and instrumentation package used for jobs much more complex than most building designs (e.g., jet airliners) may be incorporated into the architectural system for producing wiring diagrams, ladder diagrams, routing drawings, etc.

• Auto-trol's AD/380 is a multipurpose and multi-workstation system which may be used in the A/E environment.

  - GS-1000, the general-purpose design software, makes it possible to operate in different applications areas; e.g., architectural and electrical, simultaneously from separate terminals.

  - Software packages support general architectural drafting applications, piping, facilities layouts, etc.

• Intergraph has built the IGDS system around the DEC PDP-11 using standard DEC operating software and appears to be the vendor most capable of responding to industry requirements for data base integration and portability of graphics data.

- Microprocessor based CAD systems, such as the ones manufactured by Grafcon and Sigma Design, are designed to penetrate the large market represented by the smaller architectural firms.

- Grafcon is the American counterpart of British architectural and engineering firms who developed systems to satisfy their own needs in the absence of early vendor response.

  - The firm of Boyd, Broach & Foster developed software to solve a potential overrun problem in a wall panel drawings contract.

  - Eventual savings from the system and potential savings to other firms prompted BB&F to found Grafcon to develop and market a general-purpose system for smaller architectural firms with less than 50 employees.

  - The system is based on the HP 9845B and offers a relatively low entry cost of less than $75,000.

- Sigma Design entered the CAD market with one of the most specialized efforts and limited its early development to fire protection and prestressed concrete users.

  - Their SIGMAGRAPHIC system is based on the Z80 microprocessor and starts at less than $50,000.

  - Displays with resolution exceeding 1,000 by 1,000 pixels are available.

  - SIGMAGRAPHICS II employs a dedicated processor to manage the display which gives good response times for a Z80-based system.

- Software packages for specific hardware integrated by the user, as opposed to the turnkey vendor, have been developed over the past few years by several British engineering firms.

  - "GIPSYS," developed by Scott Wilson Kirkpatrick is a 3-D CAD system for detailing reinforced concrete.

    . The system is interactive and builds drawing files from a natural architect-to-draftsman sequence of instructions and data.

    . Integration of drawing data with bending, pricing, delivery, optimization of densities, etc., is possible. Integration of effort is only practical where organizational integration is present or encouraged, however.

    . Macros can be built up from menu shapes or be otherwise created by the user.

    . The firm of SWK was also involved in the development of "BARD" which is discussed below.

  - "BARD," a system developed jointly under the auspices of the Cement and Concrete Association of Great Britain, is a standardized CAD system for detailing reinforced conrete slabs, beams, and columns.

    . The user has options of inserting local codes or using the British Standard, and the system will automatically flag any violations during detailing, prompting the detailer to make the corrections.

    . The developers claim economic productivity ratios up to 24:1.

  - "CAPS" (Computer Aided Production System) was designed to automate the design of connections in structural steel detailing.

- Since most structural steel designs are "one-offs," the prospects for productivity improvements must come from the automation of connection design within various shop specifications.

- CAPS, in conjunction with SWAG, provides a fabrication design aid to position bolts, weld joints, sawing points etc., as required by specifications.

- CADRAW is flexible enough to run on a DEC 10 in FORTRAN or HP 9845 desktop computer in BASIC. CADRAW is basically a layered architectural drafting system with macro capabilities.

- MCAUTO has imported two of the British software packages developed for A/E applications and is offering turnkey units based on the 32-bit VAX-11/780 and Prime models 150 through 750 minicomputers.

  - "BDS" (Building Design System) has been used in Europe for three years by:

    - Architects for modeling outer shells, interior walls, and floors.

    - Structural engineers for locating beams and columns.

    - Mechanical engineers for laying out heating and cooling equipment.

    - Electrical engineers for placing electrical fixtures, wires, and panels.

  - BDS will automatically take off bills of material, produce drawings and perspectives, and overlay drawing files to check for interferences.

- The GDS (General Design System), also marketed by MCAUTO, produces engineering drawings, architectural renderings, maps, and schematics with ink-on-mylar plots.

- Consulting engineering firms should know that MCAUTO is now offering Fastdraw/3, including the NASTRAN package, as a turnkey package to run on the VAX-11/780.

## D. USER RATINGS OF VENDORS

- Several users interviewed for this report were impressed by Calcomp's CAD system primarily designed for A/E applications.

  - Calcomp's market penetration is very small at present and no Calcomp systems were installed at respondent sites; therefore, comments of respondents to the INPUT survey were based on their perceptions of Calcomp capabilities and not actual experiences.

- Eighteen users were asked to rank the top four vendors in several categories. Exhibits IV-8 through IV-12 display the relative weighted average of perceived vendor capabilities among architectural and engineering respondents.

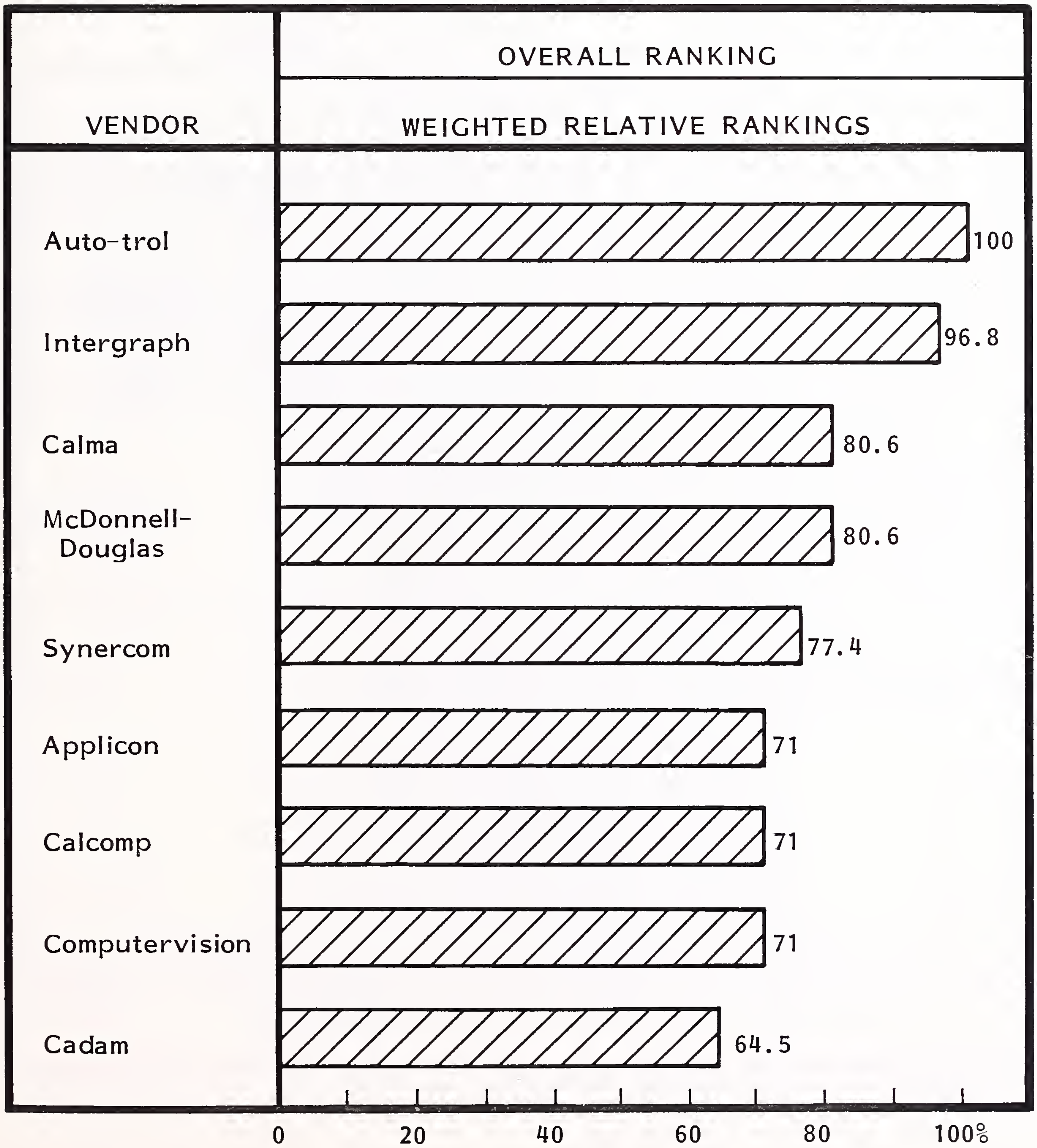
- Auto-trol and Intergraph were most frequently mentioned and most highly ranked overall, as shown in Exhibit IV-8.

  - In this exhibit and the ones that follow, the top ranked vendor is placed at 100%, and all others are adjusted relative to the leader according to their frequency of mention.

  - Intergraph is therefore practically equal to Auto-trol in the opinion of the users surveyed.

EXHIBIT IV-8

RESPONDENTS' RANKING OF VENDORS IN
ARCHITECTURAL/ENGINEERING APPLICATIONS
- OVERALL RANKING




N = 18

EXHIBIT IV-9

RESPONDENTS' RANKING OF VENDORS IN
ARCHITECTURAL/ENGINEERING APPLICATIONS - DRAFTING

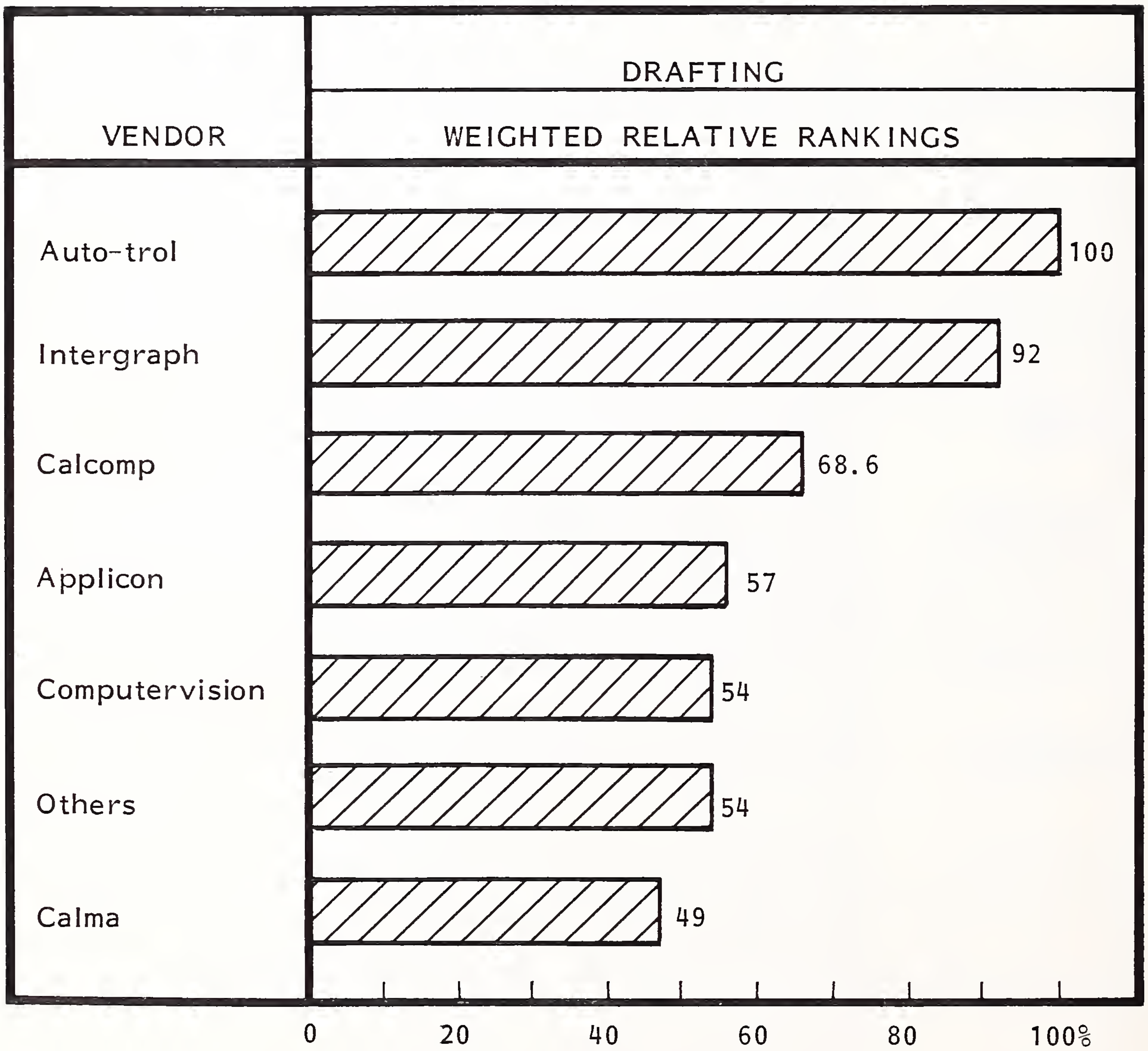



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EXHIBIT IV-10

RESPONDENTS' RANKING OF VENDORS IN ARCHITECTURAL/ENGINEERING APPLICATIONS - 3-D MODELING SIMULATION

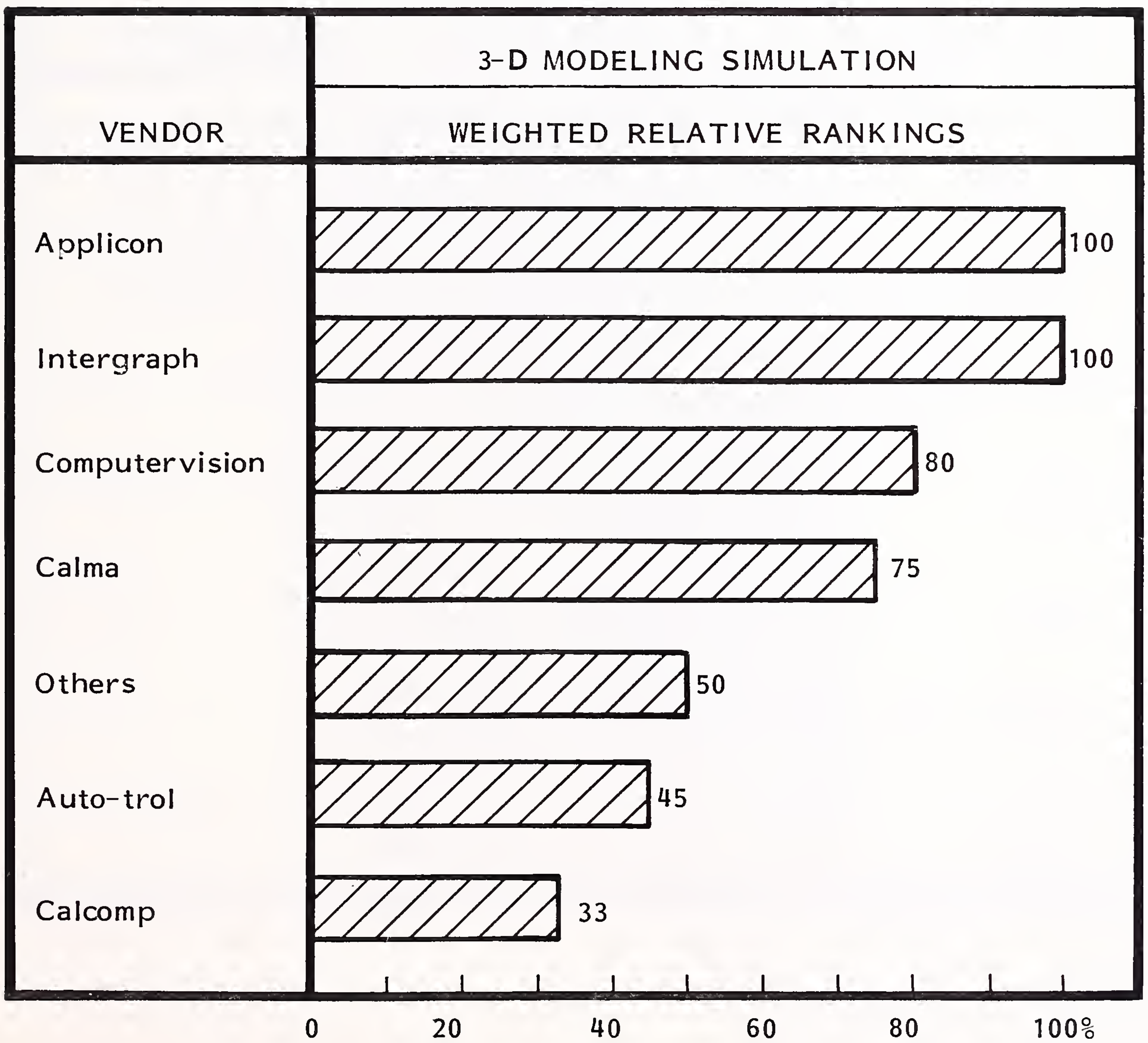


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EXHIBIT IV-11

RESPONDENTS' RANKING OF VENDORS IN ARCHITECTURAL/ENGINEERING APPLICATIONS - DRAWING NETWORK DATA BASE

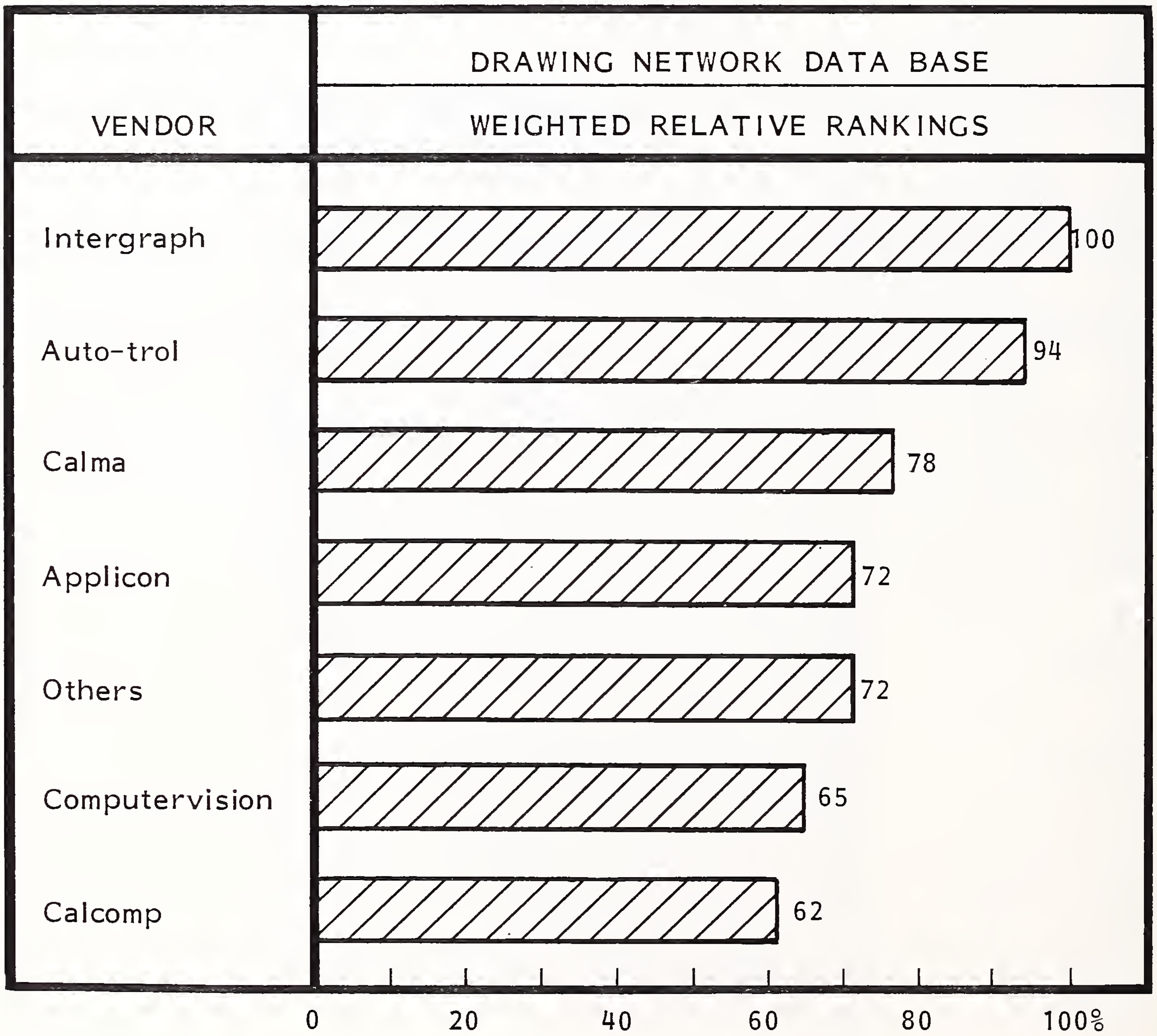


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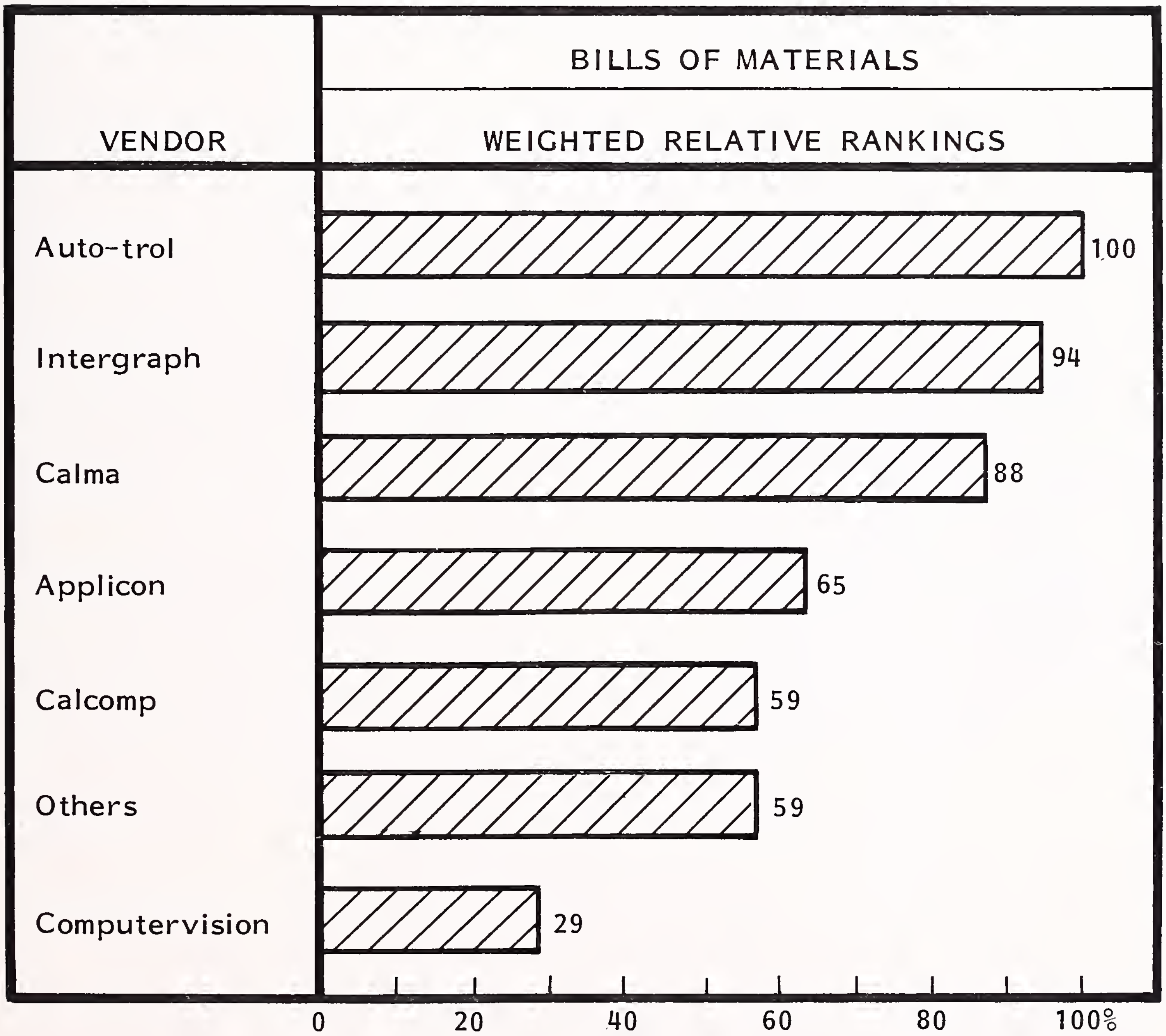
EXHIBIT IV-12

RESPONDENTS' RANKING OF VENDORS IN
ARCHITECTURAL/ENGINEERING APPLICATIONS-
BILLS OF MATERIALS




N = 18

- Auto-trol and Intergraph are most popular choices for 2-D drafting applications, as shown in Exhibit IV-9.

- Auto-trol is replaced by Applicon and Intergraph 3-D modeling and simulation capabilities, as perceived by A/E users, and shown in Exhibit IV-10.

- As shown in Exhibits IV-11 and IV-12, Auto-trol and Intergraph hold their positions as the two most popular vendors of turnkey systems in Drawing Network Data Bases and Bills of Materials.

# V MANAGEMENT AND ECONOMIC ISSUES

# V MANAGEMENT AND ECONOMIC ISSUES

## A. PRODUCTIVITY

- Because of shortages of qualified drafting personnel, personal productivity remains important even when the economic productivity ratios remain at 1:1, or, in some cases, lower.

- A/E respondents, as a group, have expected labor productivity improvements of an average 3.2:1, as shown in Exhibit V-1.

  - Actual productivity improvements are averaging 3.6:1, slightly better than users expected.

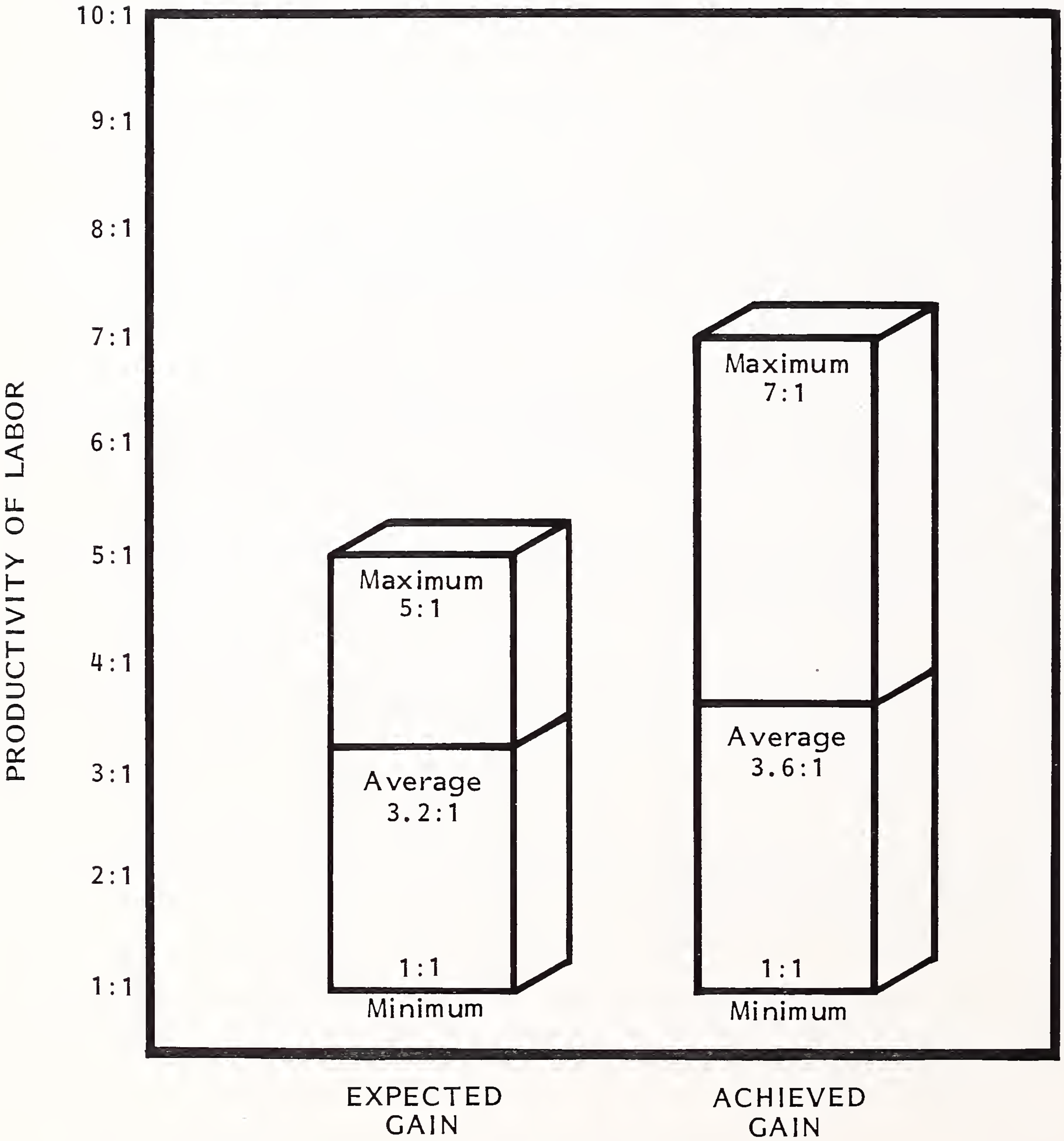
  - The range of improvements throughout the disciplines of architectural and engineering applications vary considerably, from just over 1:1 to a high of 7:1.

- Drafting, which accounts for the greatest single use of CAD, averages around 6:1 among A/E users surveyed.

  - Activities employing the use of shared and layered drawings among several designers or draftsmen show throughput improvements averaging nearly 10:1.

EXHIBIT V-1

PRODUCTIVITY GAINS EXPECTED AND ACHIEVED BY CAD IN ARCHITECTURAL/ENGINEERING APPLICATIONS



- Engineering analysis and conceptual designing at the workstations appeared to bring down the overall productivity ratios; however, standards for these tasks are not well defined, making productivity gains difficult to measure.

- In reporting the above productivity ratios, users relied heavily on throughput of drawings on the CAD system compared to manual drafting standards.

  - No adjustments were made for labor associated with implementation of the systems. These costs are to be absorbed and amortized over the payback method used when accounting for the economic productivity gains or losses.

  - Users did make adjustments for various levels of experience during the first six months or so for new operators.

## B. COSTS

- Most current users have capital investments (or lease obligations representing capital investments) of between $450,000 and $650,000 per CAD system.

- Capital assets invested in A/E CAD applications average a little over $75,000 per workstation.

  - While an average of eight workstations per system approaches an optimum capital investment, such density remains responsive only in a pure drafting environment.

  - High use of analysis in an interactive graphics environment can significantly impact the responsiveness of most turnkey systems with over four workstations.

- Users reported hourly operating costs of CAD workstations ranging from a low of $27 to a high of $100.

  - The lower figures were reported by companies who had expensed all implementation costs and who accounted only for direct costs for internal transfers.

  - The higher rates were used as external billing rates and included adjustments for computed profit margins.

  - Users who accounted for hourly costs with conventional cost accounting methods tended to fall within the $40- to $60-per-hour range. The accounting methods included all costs of owning and operating the systems over the expected useful life plus standard cost burdens and labor.

- It takes from two to four weeks to train a qualified draftsman to use the CAD systems, according to most users.

  - At this level, they are considered qualified to produce drawings at nearly a 1:1 ratio.

  - Users reported a wide range of qualifying times for new operators to be considered proficient enough to charge the fully burdened rate for their services; times ranged from six to 36 weeks.

## C. JUSTIFICATION

- Many of the users surveyed were quick to caution firms who are considering the implementation of CAD not to overlook hidden implementation costs associated with:

- Slow acceptance of a centralization of drafting services.

- Internal resistance to the "systems analysis" approach to business which questions traditional methods.

- Resistance by older employees who fear either displacement or the loss of acquired skills and the need to learn a new technology.

- Hypercritical attitudes of engineers and architects expecting perfection from computerized outputs.

- Negative attitudes toward the elimination of drawing "aesthetics"; e.g., personal signature flourishes of experienced and established draftsmen.

- Direct productivity ratios translated into economic returns carry the most weight in the justification of the investment in CAD, as shown in Exhibit V-2.

  - Users reported that most controllers like to see this sort of investment "payback" in two to three years. Using round number averages from survey data, the following typical payback analysis emerges:

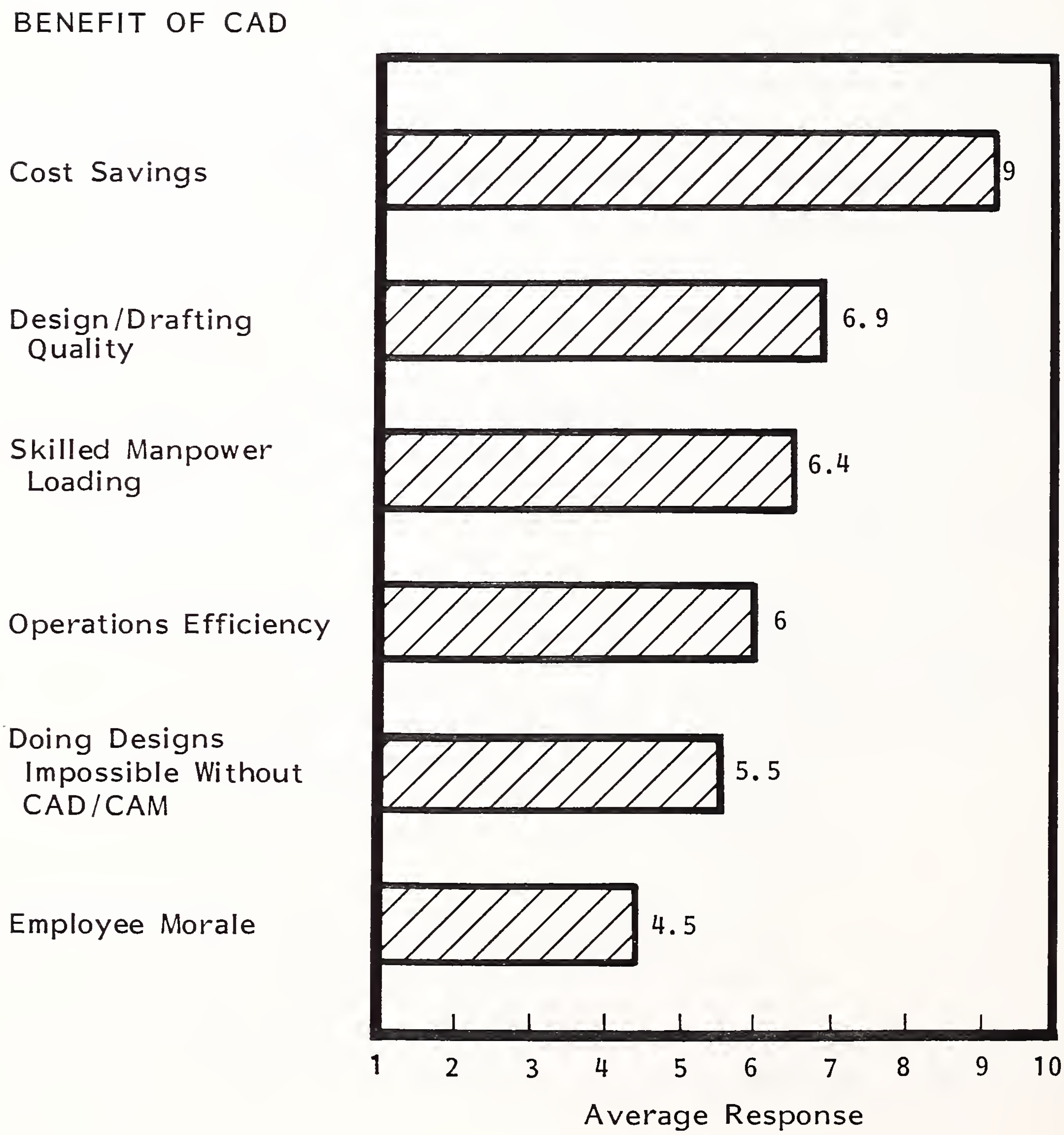
    . Consider the average $75,000 workstation burdened with an additional $29,000 start-up cost to be paid back.

    . In a single-shift environment of 2,080 hours utilized per year per workstation, the payback amortization factor for 2.5 years is $20 per hour.

    . Further assume an average operating cost per workstation of $50 per hour including labor, overhead, maintenance, etc., but excluding depreciation and amortization of implementation costs.

EXHIBIT V-2

IMPORTANCE OF BENEFITS IN
JUSTIFICATION OF CAD




SCALE: 1 = Not Important, 10 = Vital

- Add the "payback" factor of $20 to $50 and divide by the average operating cost of manual methods to find the required productivity ratio for a 2.5-year payback.

- Example: Standard burdened labor rate of $20 for drafting ($50 + $20)/$20 = 3.5 productivity ratio at assumed utilization to achieve payback in 2.5 years.

- More exotic methods of cost-justifying a CAD system from productivity expectations include reducing all net costs and benefits to a present value with appropriate interest rates to equalize alternative employment of capital.

- Factors other than direct productivity ratios are entering into the justification of CAD systems in architectural and engineering applications, as shown in Exhibit V-2.

  - Design quality expected from CAD runs a close second to productivity improvement as reported by current users.

  - Operations efficiencies, especially in more rapid preparation of cost estimates complete with conceptual drawings in job proposals, represent some of the hard-to-measure intangible benefits. A demonstration of these benefits turns the heads of executive decision-makers while escaping the controllers' more conservative scrutiny.

  - The acquisition of contracts requiring turnaround times achievable only through the use of CAD represents a significant reason for consideration of the investment. As reported earlier, the federal government has encouraged an emphasis on CAD in bidding for GSA contracts.

  - Other factors justifying investments in CAD are expected future benefits from the total integration of data bases creating greater efficiencies in purchasing, construction, and marketing.

# VI USER PREFERENCES AND NEEDS

# VI USER PREFERENCES AND NEEDS

## A. LOCAL VERSUS CENTRAL INTELLIGENCE

- Small architectural and engineering firms of under 50 production personnel can justify CAD systems in quantities of one or two workstations at a time.

  - Needed for the A/E industry are locally intelligent workstations (able to provide a limited range of design and drafting functions) such as the example shown in Exhibit VI-1.

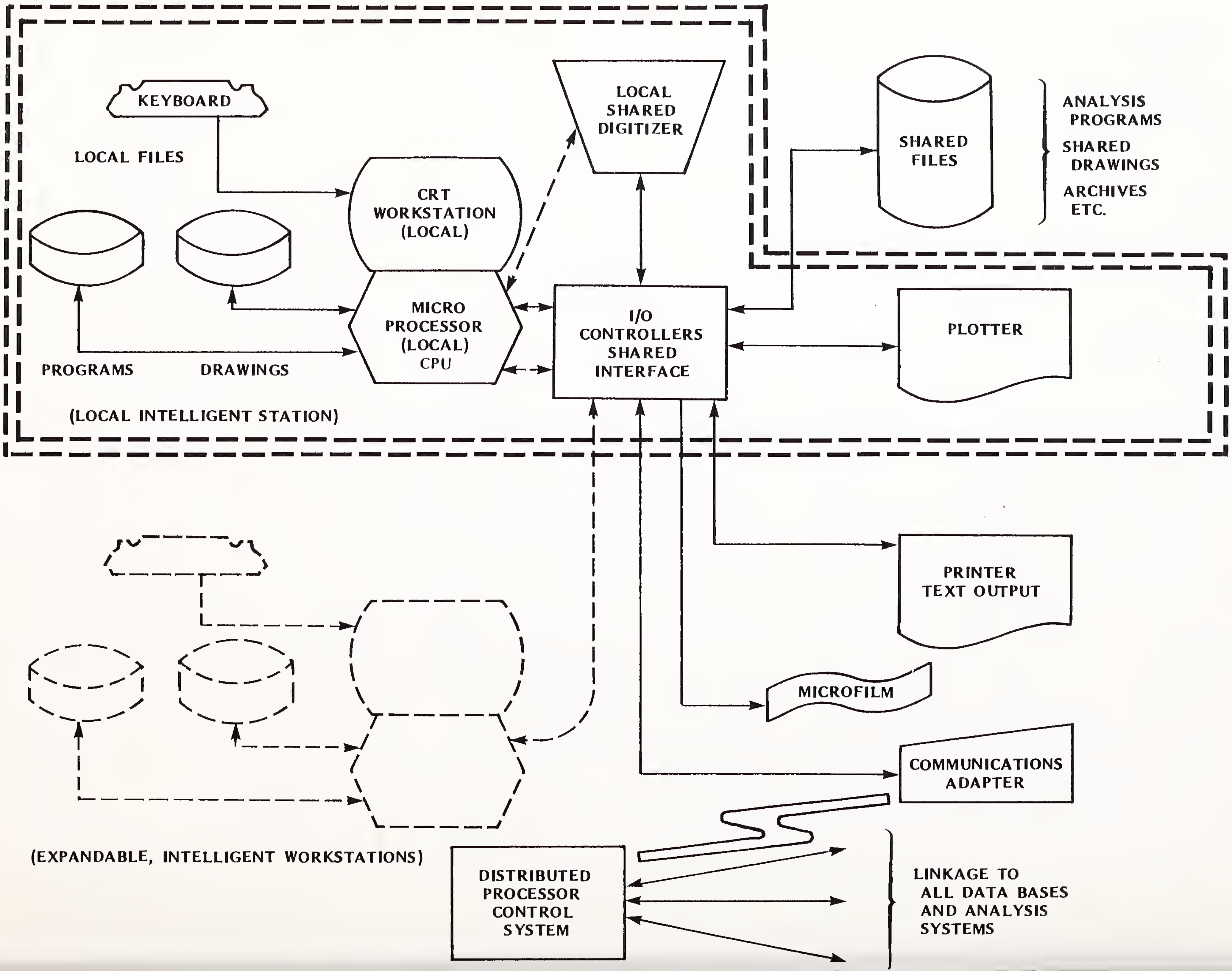
    - Such a package would start as low as $60,000 for the minimum configuration outlined in the exhibit.

    - Ideally, the package would be modular allowing a first level expansion to two or more workstations sharing common input/output devices.

    - Ultimately, this level of system could expand to communicate with other terminals and with remote computer service processors to handle analysis, code compliance, materials logistics, and other data processing routines accomplished more efficiently on large mainframes.

EXHIBIT VI-1

LOCAL INTELLIGENT WORKSTATION FOR ARCHITECTURAL CAD/CAM APPLICATIONS
(EXPANDABLE TO SHARED CENTRAL INTELLIGENCE)



- Medium to large (50 to 1,000 employees) architectural and engineering firms can afford the additional computing power and potential for economies of scale offered by systems such as the ones represented by Exhibit VI-2.

  - By convention, Exhibit VI-2 displays a centrally intelligent CAD system. Although the intelligence does not reside at the workstation, it is present in a self-contained local turnkey system controlled by a minicomputer.

    - Ideally, this type of system would be offered with enough central processor capacity to serve a number of workstations sufficient to lower the cost per workstation to a range of $50,000 to $60,000.

    - This type of system should be expandable to two or more systems with shared and dedicated files.

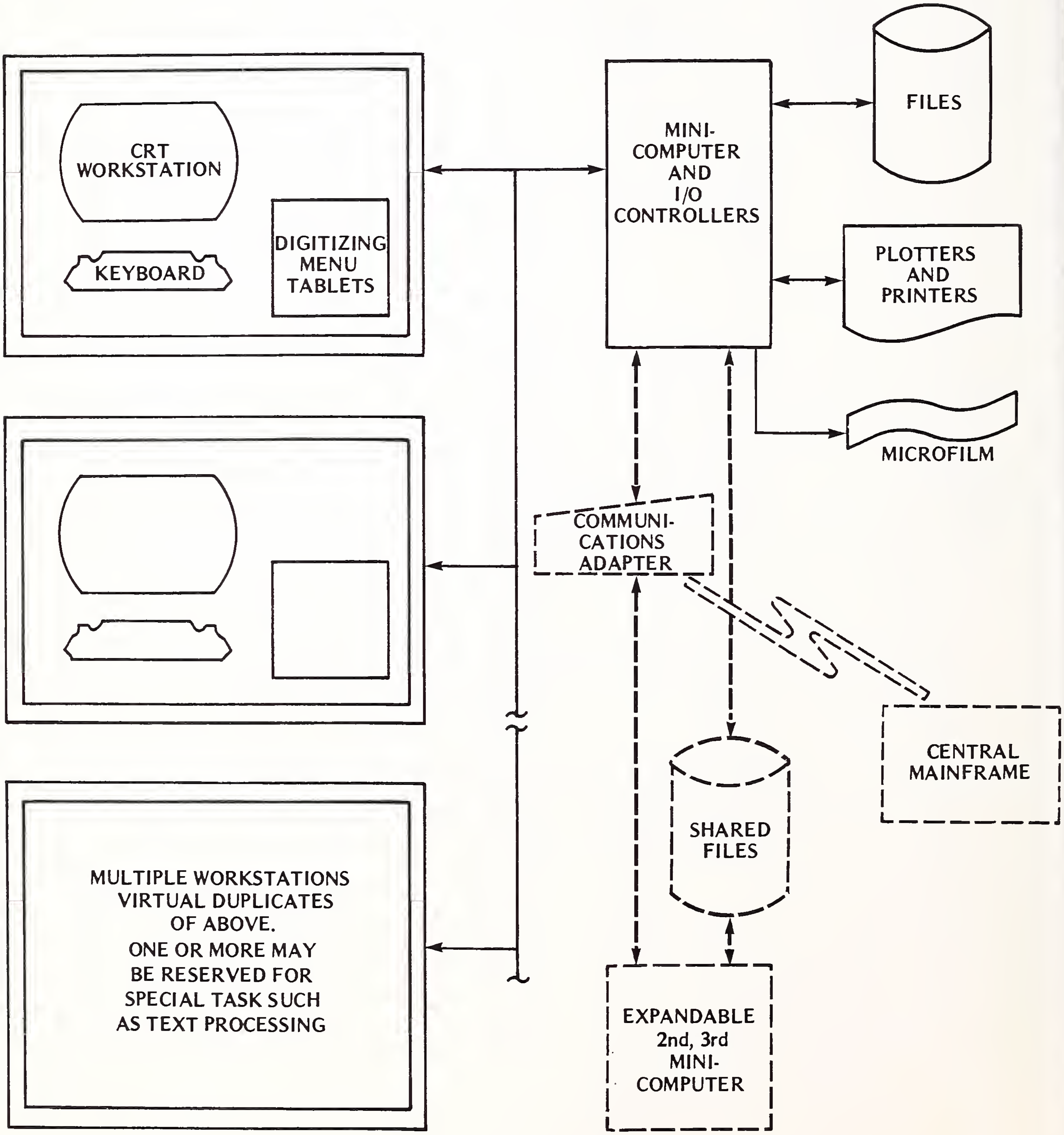
    - The range of expansion should be sufficient to ensure that all drawings for any given project may be brought on-line and be available to any designer or draftsperson simultaneously with all other priority work being performed on the CAD system.

    - Also, the system should contain enough processing capability to perform design and project-oriented analysis work.

    - In order to be responsive to expanding user needs, the system could interface with a hierarchical network for progressively more complex analysis.

EXHIBIT VI-2

TYPICAL CENTRALLY INTELLIGENT MULTIPLE WORKSTATION CAD/CAM SYSTEM USED BY LARGE ARCHITECTURAL/ENGINEERING FIRMS



## B. INTEGRATION

### 1. DIRECT DESIGN-TO-CONSTRUCTION INTEGRATION

- The integration of design with construction data bases, while desirable, will depend more on issues internal to the industry than on technological developments in CAD.

  - A tradition of functional integration within the architectural, engineering, and general construction industry is lacking except in a few large, vertically integrated firms.

  - It remains to be seen over the next two to three years whether the demand for integrated design and construction data bases by the large companies will be sufficient to encourage their development.

  - With the industry largely represented by loose associations of independent professional groups and partnerships, it will require a much stronger national association of interests in computer aided technology for architects and engineers than now exists to consolidate design and construction data bases.

- The potential benefits of overcoming the lack of traditional vertical integration in this industry and moving ahead with design/construction integration in CAD should be sufficient to accelerate interest in exploiting the 1980's developments in computer-aided engineering and design. A sample of potential benefits follows:

  - PERT/CPM analyses jointly developed during the design phase could be fed directly into the construction management data base.

  - Materials and equipment lists could be produced directly from integrated design and project planning data bases.

- Real time feedback and control of field addenda and bulletins could be made as a project proceeds.

- Direct on-site working drawings and other documentation used in the construction process could be produced.

- Feasibility analyses could be tied directly into projected requirements for skilled personnel and other tightly scheduled resources.

- Real time analysis of the dynamics of projects under construction could enhance ongoing design efforts by taking advantage of innovations as they occur and by avoiding unforeseen pitfalls in subsequent projects.

## 2. THE INTEGRATION OF OTHER DATA BASES WITH CAD

- Access to municipal building codes through some centralized data base holds great potential for improving the productivity of designers and quality control checking of designs.

- The integration of CAD systems with materials purchasing and planning is a desirable feature. Designers would be able to work with material types forecasted to be available in bulk purchase quantities within the project schedule, or access libraries of materials and components standards and characteristics for both design and analysis tasks.

- Engineers need better access to general data bases containing locally relevant data such as:

  - Topographical data.

  - Percolation tests and hydrological data.

  - Cut and fill considerations.

- Subterranean data for foundations.

- Seasonal wind pressures.

- Earthquake hazards.

- Temperature and humidity ranges.

- Noise levels.

## 3. PROGRESS TOWARD INTEGRATION

- Respondents were asked to rate the progress of integration in the A/E industry in 1981 and 1986. The questions were broadly phrased as integrating CAD and CAM where CAM is defined in the A/E context as all functions dependent on, but separate from, the actual design function (such as project management, cost estimating, etc.).

  - Integration may involve the linking of data bases or merely the formatting and transmission of design data to an application program; in either case, it is critical that the CAD system is capable of extracting and moving data between functions without the need for manual transformation of the data.

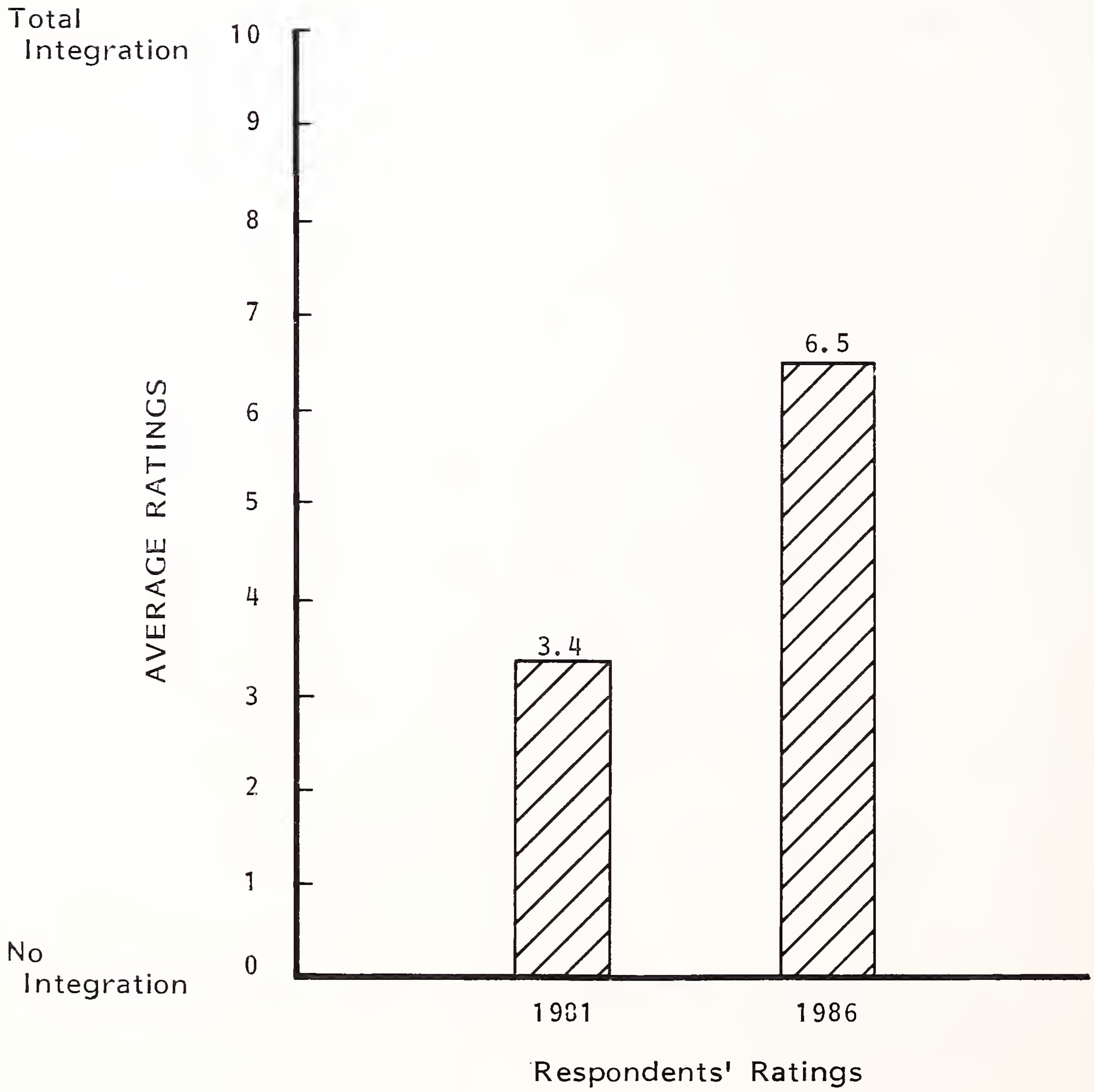
  - The first integration question dealt with overall progress in A/E. The results are shown in Exhibit VI-3.

  - Several users went so far as to say that the industry will be completely integrated by 1986.

- There was general optimism among architects and engineers about the overall prospects for integration of CAD functions by 1986, as shown in Exhibit VI-4.

EXHIBIT VI-3

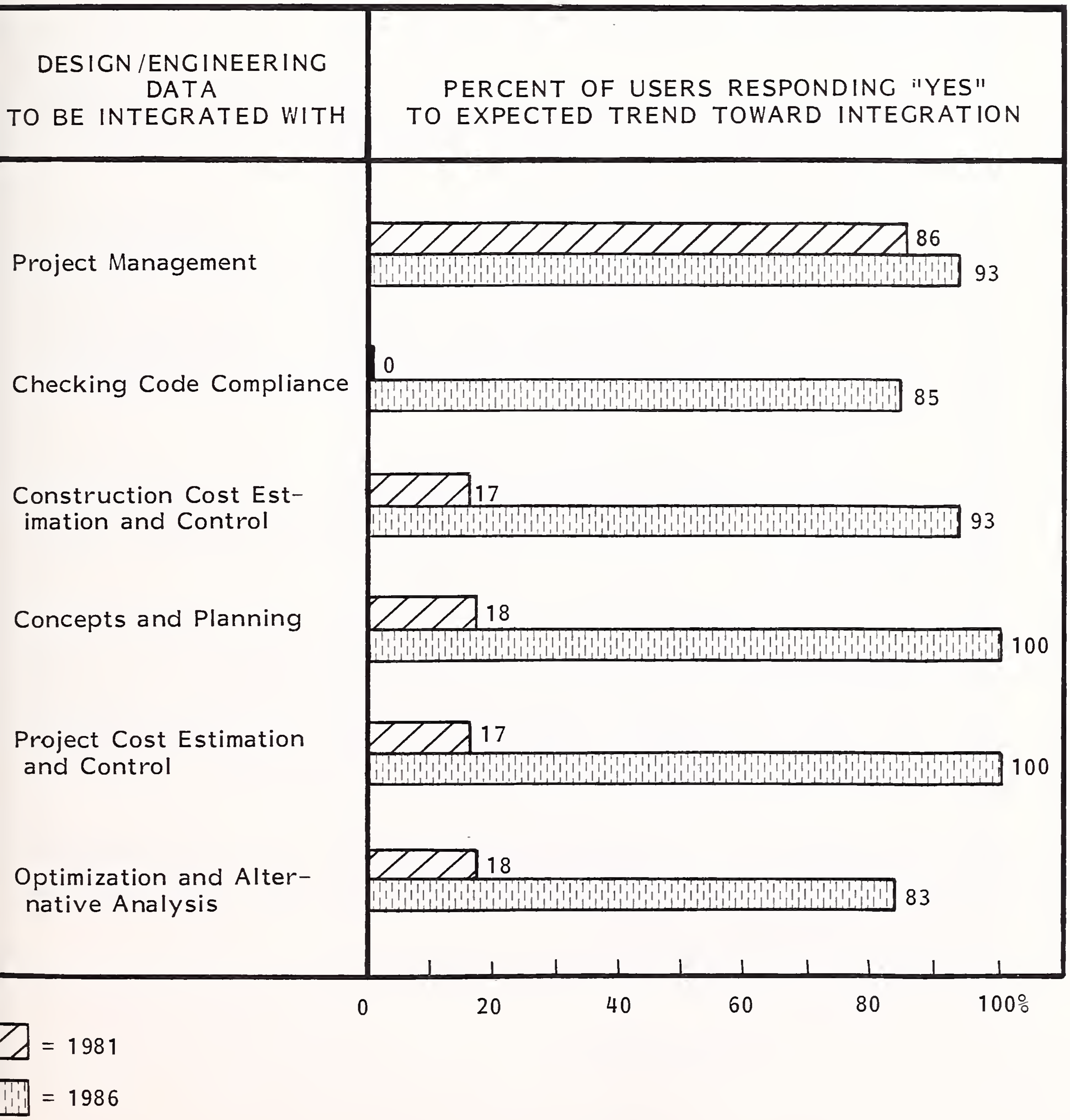
PROGRESS IN CAD/CAM INTEGRATION
FOR ARCHITECTRUAL/ENGINEERING APPLICATIONS




*SEE APPENDIX B FOR DETAIL

EXHIBIT VI-4

TRENDS TOWARD THE INTEGRATION OF DESIGN/ENGINEERING DATA BASES WITH SPECIFIC, RELATED FUNCTIONS



- Every respondent agreed that there is no evidence of building code compliance checking built into CAD at present.

- Less than 20% of INPUT's respondents see any real progress toward integration in any areas other than project management.

## 4. OBSTACLES TO PROGRESS IN INTEGRATION

- INPUT agrees with respondents in saying that a lack of data base standards within the architectural and engineering disciplines is a major obstacle to integration, as indicated in Exhibit VI-5.

- As the ratings indicate, respondents were concerned that organizational conflicts will present one of the more significant obstacles to integration. This barrier will only be eliminated through informing the other organizations of the benefits inherent in integrating functions and proving the effectiveness of the CAD system.

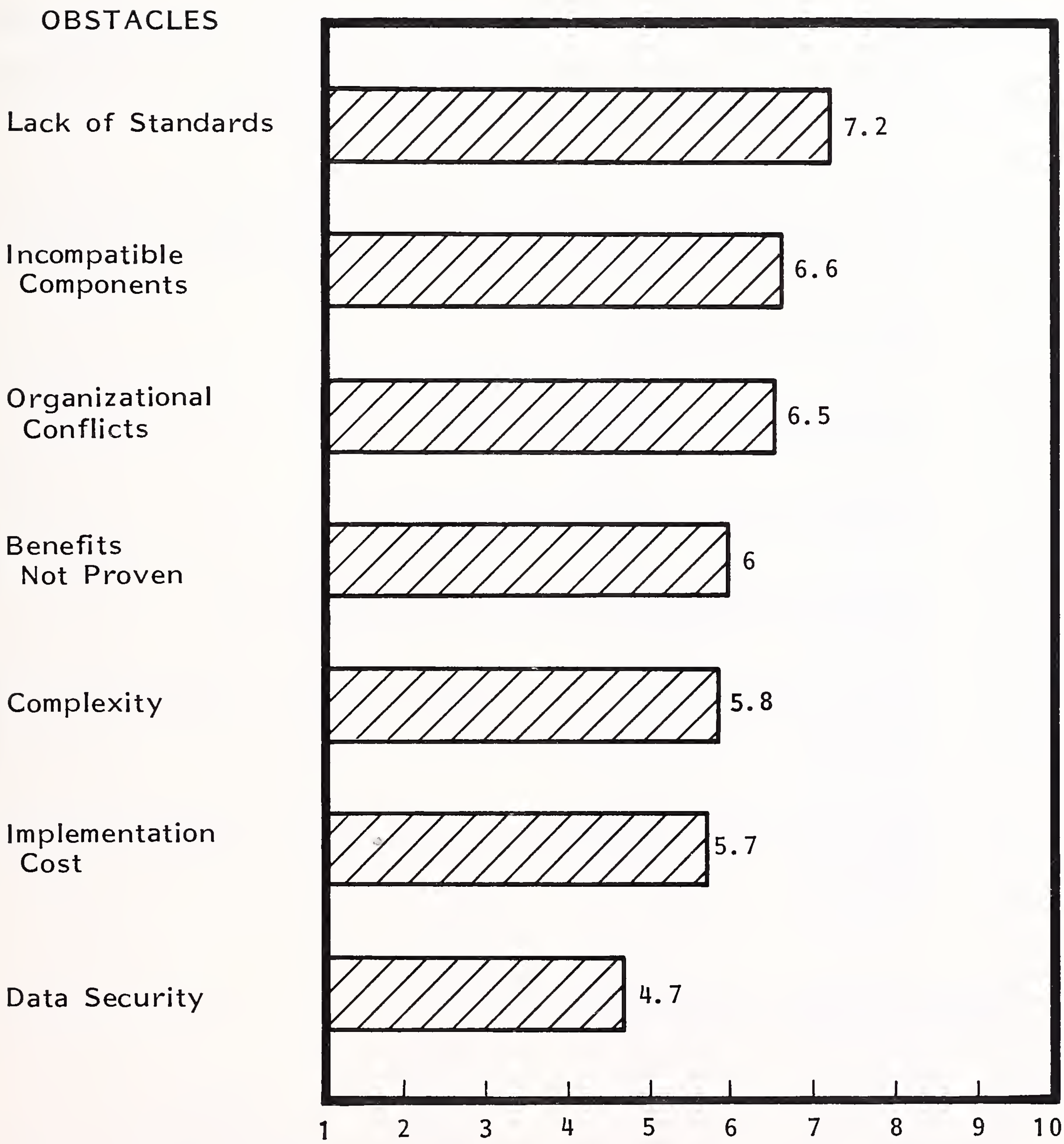
- As with all CAD applications, system components are incompatible among various vendors which creates a substantial obstacle for progress toward integration.

- Respondents are concerned that the benefits of CAD integration have not been proven sufficiently to the decision-makers and other organizations. Vendors as well as users must take every opportunity to clearly demonstrate and prove the benefits and effectiveness of CAD to remove this obstacle.

- Those users indicating concern with data security as an obstacle to integration are primarily concerned with competitively sensitive data rather than the physical destruction of data.

EXHIBIT VI-5

PERCEIVED OBSTACLES TO INTEGRATION




SCALE: 1 = No Obstacle, 10 = Large Obstacle

*SEE APPENDIX B FOR DETAIL

## C. DATA SECURITY

- Users of CAD express some concern for data security, but expect the vendors to take care of the problems.

- The users are less concerned about security in 1986 than at present, a fact which supports their feeling that the vendors will take care of any problems in hardware and software developments as a matter of course.

- Methods used by architects and engineers to provide for the security of CAD data are the same as those found in most other data processing applications:

  - The use of passwords.

  - Off-site vault storage of backup files.

  - Controlled entry to computer facilities.

  - Not allowing trainees to have access to critical files.

  - Special keys and codes to update permanent graphics files with revisions.

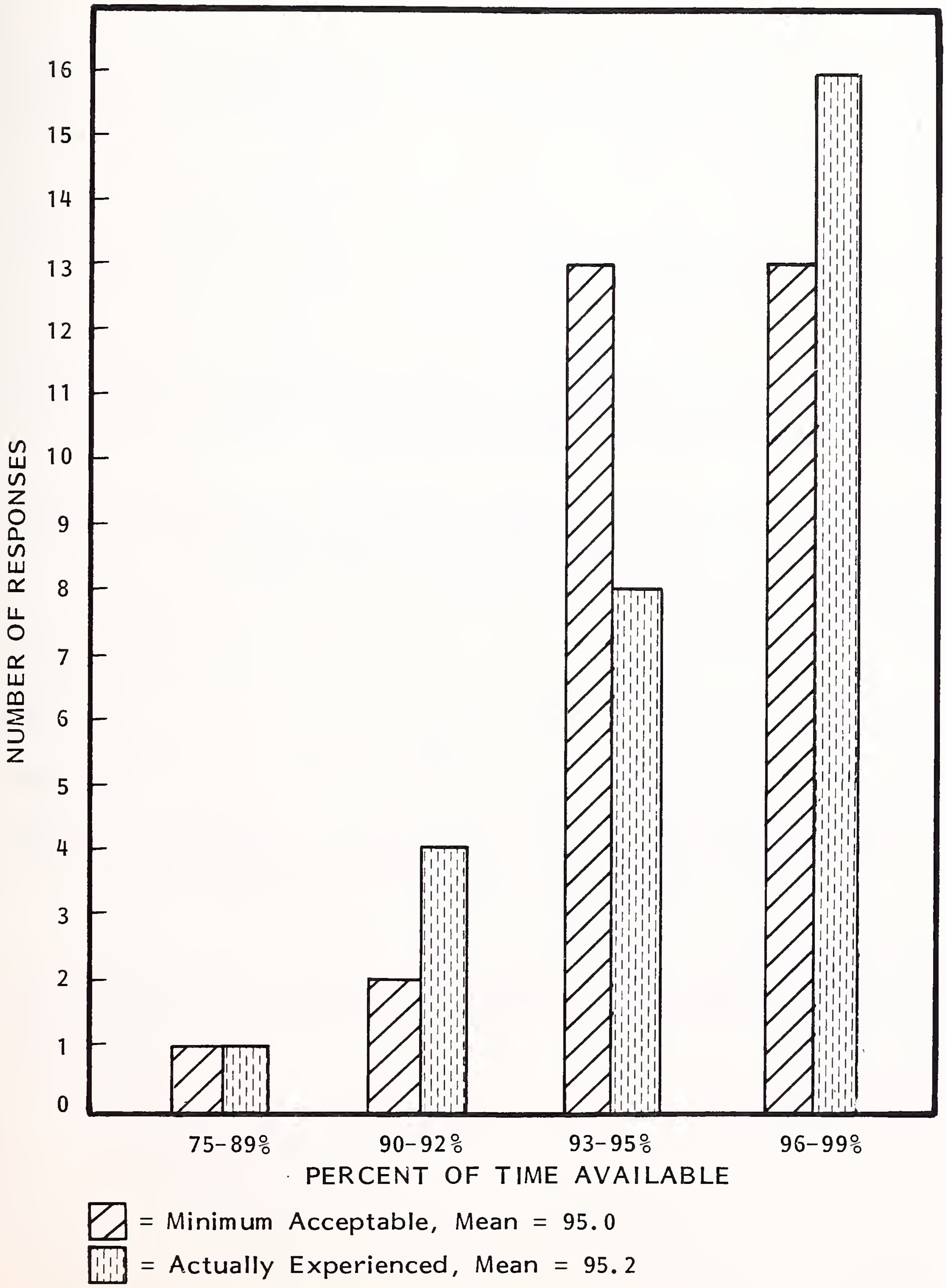
  - Requiring manual intervention to load highly sensitive files into systems.

## D. SYSTEM RELIABILITY REQUIREMENTS

- Users expect their CAD systems to be available over 95% of the time on the average, and that is what they are getting, as shown in Exhibit VI-6.

EXHIBIT VI-6

CAD/CAM SYSTEM AVAILABILITY EXPECTED AND RECEIVED



- One user, who accounts for system availability only when all components are working, expects and receives 75% availability.

- All other users measure CAD system availability as a weighted average of the impact on idle workstations versus scheduled time.

  - One workstation down in a configuration of five workstations would therefore be calculated as 20% system downtime if the workstation was scheduled to be used.

  - Users who calculate system availability by the above method expect and receive over 90% uptime.

- Architects and engineers expect the reliability of hardware to improve over the next few years and feel confident that problems due to hardware will not keep systems down more than 5% of scheduled time.

- Functional reliability, the reliability of the total hardware and software system, is the area in which INPUT found the most concern.

  - Architects and engineers are at the mercy of vendor reliability much more than are other users with years of experience in data processing.

  - INPUT expects that the architectural and engineering CAD applications will be sold and delivered as specialized turnkey packages in greater proportions than in mechanical and electronic applications because of this greater current A/E industry dependency on vendor expertise.

- Maintenance issues relative to total system reliability are common to all application areas and are discussed in detail in the User Issues and Considerations volume.

## E. DESIRABLE SYSTEM FEATURES

- Architects and engineers interviewed by INPUT indicated it is very essential to add intelligence to graphics, as shown in Exhibit VI-7.

  - Variable pitch, variable font printing capability is required for labels and descriptions at any location on the drawings.

  - Forced drawing numbers for documentation control is very desirable.

  - Most users realistically expect to use customized menu symbols for firm logos, signatures, ruled and slanted alphanumerics.

- Most users consider it an absolute requirement that 1986 CAD systems provide for the interface of CAD to project management and CPM scheduling.

- The second heaviest shift of emphasis on features between current systems and 1986 systems is in the increased desirability of the transportability of graphics among various CAD vendors. This is important for both internal and external communications.

- Dynamic motion is not a feature that architects and engineers expect to have much need for, even by 1986.

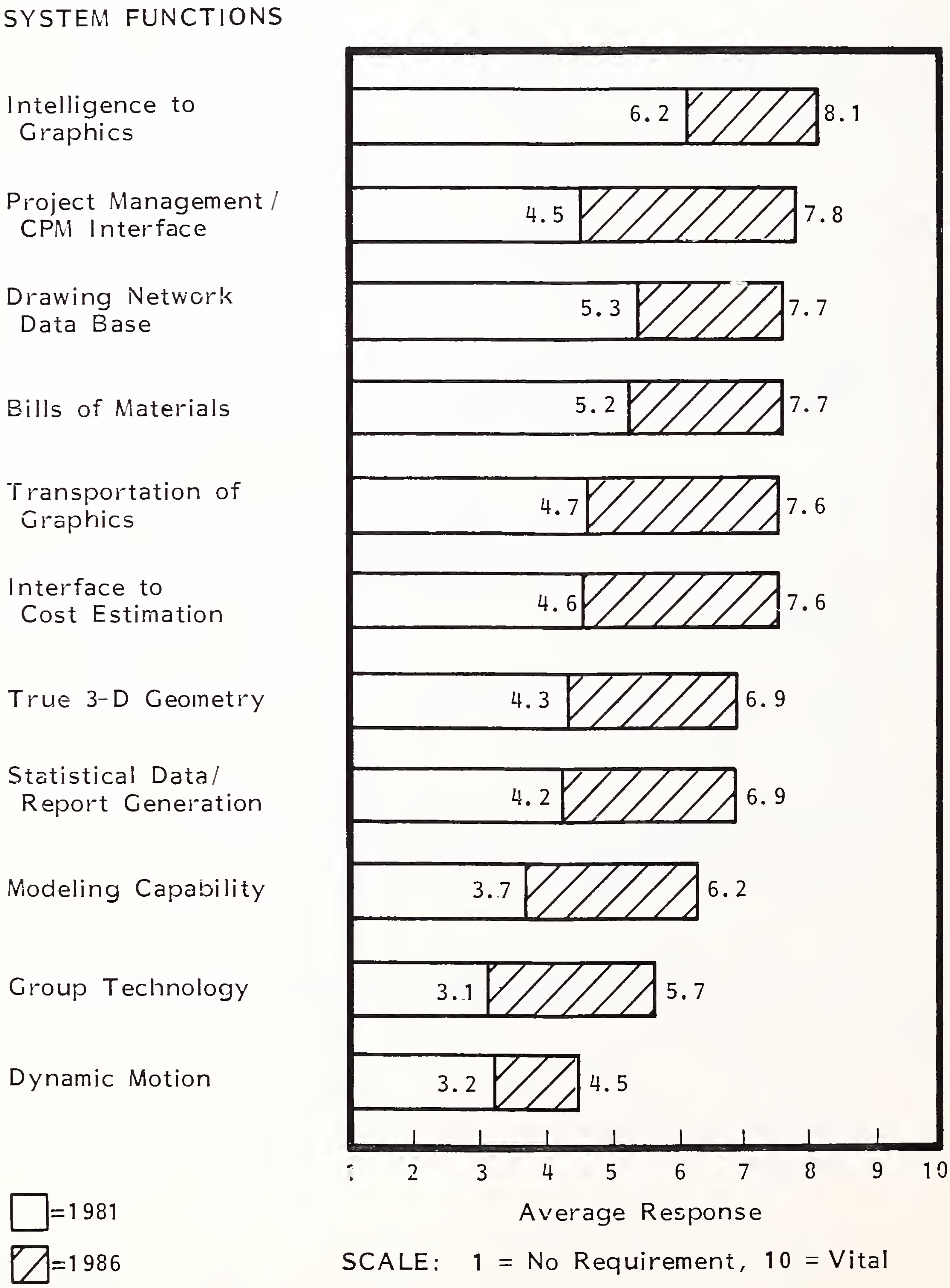
- Users expect to become more dependent on CAD systems capable of controlling and retrieving drawing network data bases.

- They desire features in the next few years to control parts lists, bills of materials, and special equipment specifications required to construct projects.

- There is also a very heavy shift of emphasis between now and 1986 on the preference for CAD systems which allow the interface of CAD to cost estimation.

EXHIBIT VI-7

RESPONDENTS' RATINGS OF IMPORTANCE OF SYSTEM FUNCTIONS




*SEE APPENDIX B FOR DETAIL

- To aid in cost estimation and in project cost control, future CAD systems designed for use by architects and engineers should provide routines for statistical data analysis and report generation.

- Users are somewhat less enthusiastic about true three-dimensional geometry, but do find it more desirable in 1986.

- There were mixed feelings among respondents about modeling capabilities, but most engineering firms see the need to advance beyond current technology by 1986.

- Group technology, the classification and coding of part or component attributes, is not a term familiar to most architects and engineers, but when INPUT explained the use in manufacturing terms, many found the concept to be desirable.

## F. DISPLAY TECHNOLOGY

- Current architects and engineers find storage tube technology to be adequate for most applications, as shown in Exhibit VI-8.

  - Resolution is good and repaint time has not been a significant problem in most applications before now.

  - Storage tubes will be considered obsolete by 1986, according to the respondents.

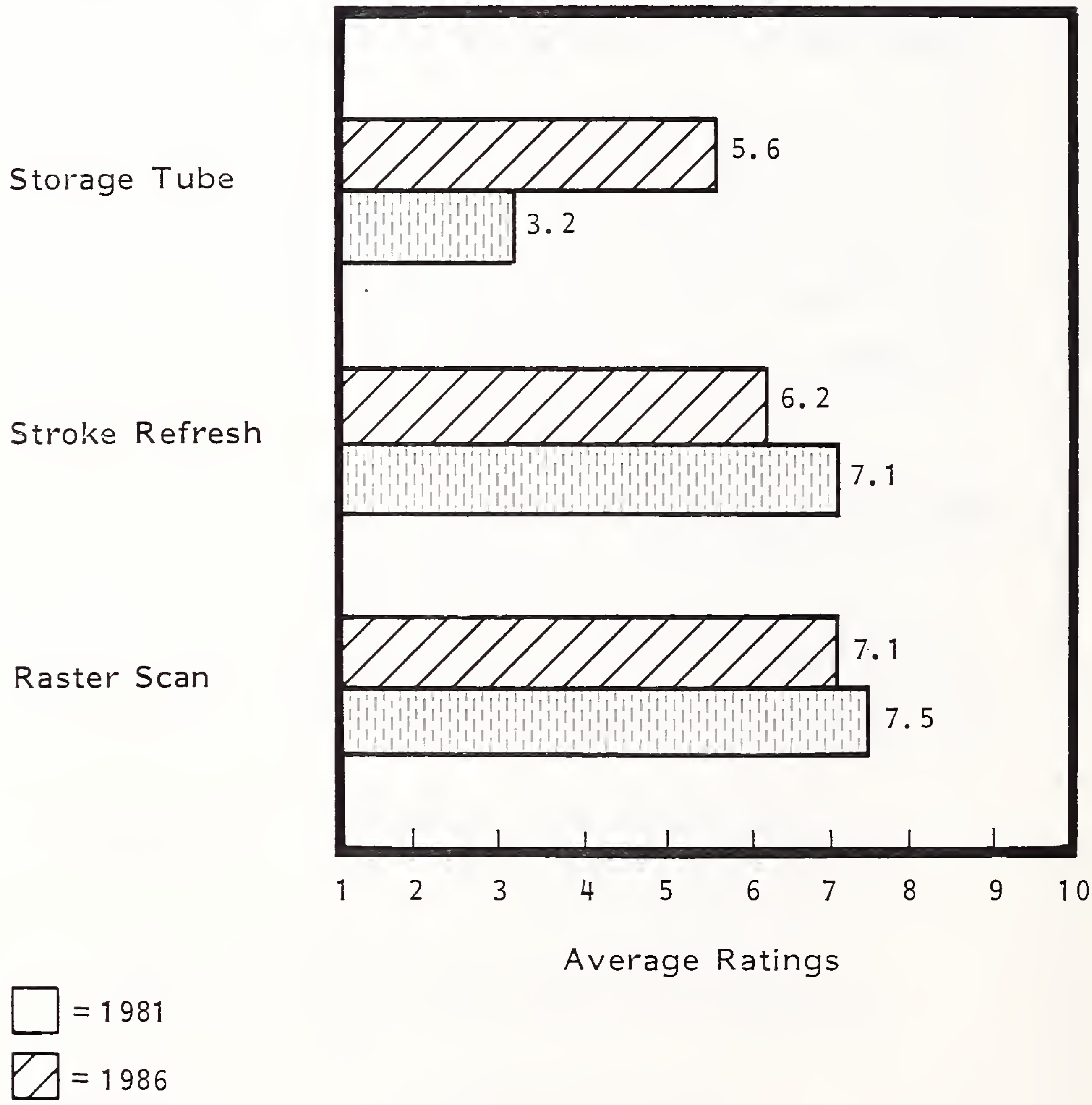
- Stroke refresh is perceived as being beyond current requirements in most applications, but may be the best answer for some users in 1986.

  - Users with dense drawing requirements believe that stroke refresh will not serve them adequately due to the time required to paint a full

## EXHIBIT VI-8

### RESPONDENTS' RATINGS OF DISPLAY TECHNOLOGIES

DISPLAY TECHNOLOGIES




SCALE: 1 = Inadequate, 10 = Exceeds Needs

*SEE APPENDIX FOR DETAIL

screen. Continued advances in local display memories and processors should remove the objection.

- Those applications with high resolution drawings which are relatively uncluttered expect stroke refresh to be exactly what they will need over the next five years or more.

- Raster scan technology is expected to remain the most preferred overall for the next five years due to its speed and cost. Higher resolution displays have the potential for making this technology even more popular than the ratings indicate.

## G. THE PAPERLESS ENVIRONMENT

- Along with expectations that many A/E industry functions will be integrated with CAD data bases, architects and engineers expect that there will be a considerable decrease in the amount of paperwork flowing among administrative functions.

- When asked to rate their expectations that conventional drawings would be rendered obsolete by CAD, users were a little more conservative, as shown in Exhibit VI-9.

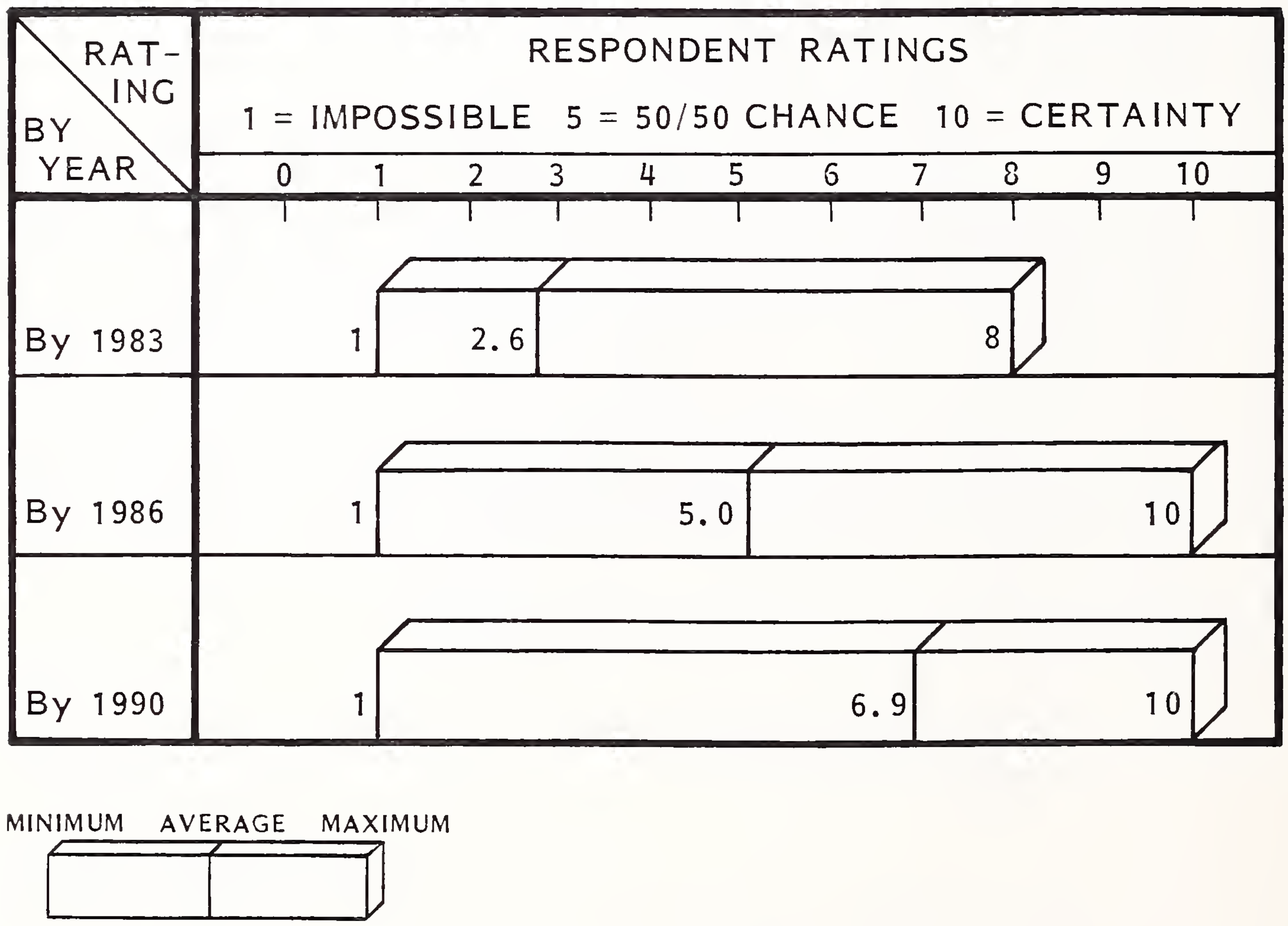
  - There is only a 30% chance that mylar/vellum drawings will be obsolete by 1983.

  - One respondent believes that it is impossible that this could happen by 1990.

  - A consensus believes that it is 70% probable that conventional drawings will be replaced by digital storage quickly reproducible for fieldwork and on microfilm.

EXHIBIT VI-9

PERCEPTIONS OF THE LIKELIHOOD THAT
CAD/CAM SYSTEMS WILL RENDER
CONVENTIONAL MYLAR/VELLUM DRAWINGS OBSOLETE



- Municipal regulations will need to be revised significantly to accommodate changes in storage of archival, certified drawings.

- The personal nature of many projects introduces a greater number of people who must be converted to believe that designs exist even if they cannot see them on paper.

## H. OTHER FEATURES

- The importance of color displays to A/E respondents was rated lowest of the three application groups surveyed by INPUT. A/E respondent ratings are shown in Exhibit VI-10. It is a reasonable assumption that the visual separation available with color would be a definite asset in A/E to distinguish various elements in a design layout (piping types, electrical components, wiring, valve types, etc.).

  - It is INPUT's opinion that most of the respondents have not developed far enough in their use of CAD to be able to appreciate or need this level of sophistication.

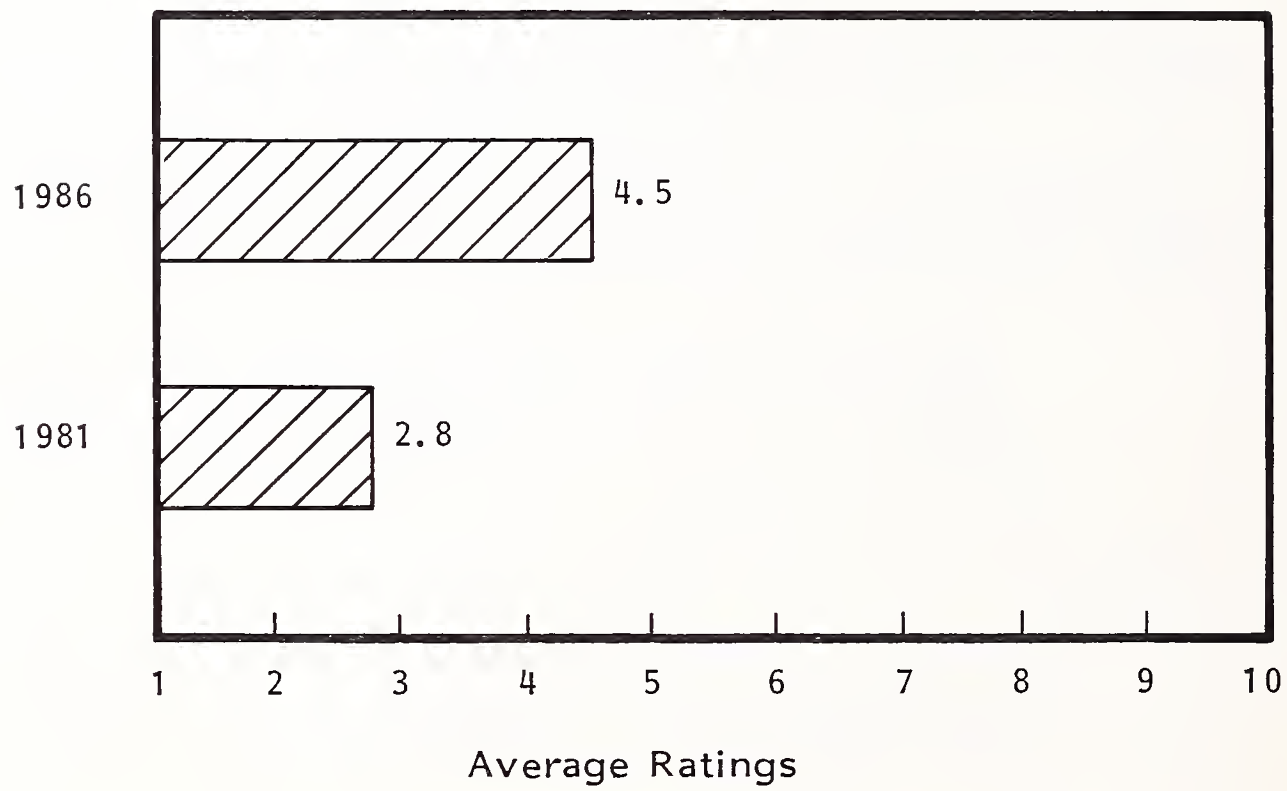
  - One-third of the respondents rated the importance of color in 1986 at 6 or above. These were firms who have been using CAD for several years and are making more extensive use of their system than just basic drafting.

  - Some respondents also expressed concern that the use of color displays would create the need for more expensive and slower color hardcopy.

- Practically all users would like to see a text processing capability built into CAD systems. One user stated that the text features of his system were so cumbersome to use that his draftsmen could letter faster by hand (and were doing so).

EXHIBIT VI-10

RESPONDENTS' RATINGS OF THE IMPORTANCE OF COLOR DISPLAYS




SCALE: 1 = No Requirement, 10 = Essential

- User friendliness and programmer friendliness are expected to increase over the next few years.

  - Users expect to see more consideration given to minimizing eye and hand motion when interacting with CAD systems.

  - Additional interfaces, such as voice recognition, digitizing of archival drawings, and audio responses are considered to be desirable features.

  - None of the architectural or engineering firms want to be left completely at the mercy of vendor programmers; they expect to see more ability to hook into both systems and applications programs using common higher level languages.

  - Finally, users expect to be able to upgrade programs and graphics data bases without traumatic conversion problems every time a new revision or model is introduced.

# VII VENDOR TRENDS OF INTEREST TO ARCHITECTURAL/ ENGINEERING USERS

# VII VENDOR TRENDS OF INTEREST TO ARCHITECTURAL/ENGINEERING USERS

## A. LOCAL VERSUS CENTRAL INTELLIGENCE

- For the small architectural/engineering firm of under 50 employees, intelligent workstations with communications capabilities for accessing remote computing services for analysis work, specialized applications, and more sophisticated design packages hold some promise in the near future.

- The major CAD/CAM turnkey vendors will probably continue the strategy of holding cost per workstation fairly constant by adding features as hardware technology becomes less expensive.

  - This strategy, while advantageous to large electronics and manufacturing companies, offers little to the A/E firms unable to purchase optimum configurations of six or more workstations per system.

  - These pricing strategies of CAD turnkey vendors will encourage further developments in locally intelligent workstations with highly specialized applications.

  - The keys to the success of dedicated A/E CAD systems will be:

    - Price.

- Compatibility with other CAD systems and mainframes (both local and remote).

- Increased user friendliness to reduce training times and encourage use.

- Upgrade capabilities, both for future expansion and for processing current output using higher level systems.

- Improved vendor support, structured to better respond to this typically computer-unsophisticated market.

## B. INTEGRATION

- CAD/CAM business in general has become so attractive that large data processing companies are accelerating their market plans through acquisition of CAD/CAM vendors.

  - INPUT expects that all major DP vendors will be offering CAD/CAM products and services before 1986, primarily through product acquisitions or mergers with existing CAD/CAM vendors.

  - These vendors typically have more extensive experience in system integration and data base management than the dedicated CAD vendors.

  - The broader geographic market coverage of the large DP companies will allow them to be more responsive to the smaller A/E firms, an attractive market when viewed in the aggregate.

- The A/E industry will find that the hardware and software solutions to integration will move more rapidly than the users' ability to consolidate and integrate among their various disciplines.

- Simultaneous pressures of small firms under 50 employees to meet the competition of larger A/E firms employing CAD will create a greater demand for developments in integration.

  - The smaller firms will discover the advantages of pooling development efforts through joint ventures in specialized A/E CAD/CAM Service Bureaus.

  - Common usage, such as engineering standards within given environments, will be shared as no real competitive secrets are threatened.

- Exhibit VII-1 depicts an integrated data base for A/E applications. This example represents the ultimate integration of application or functional data with a corporate data base for management information and control. Considering the present state of integration within the A/E industry, this concept will probably not be fully implemented until the late 1980s.

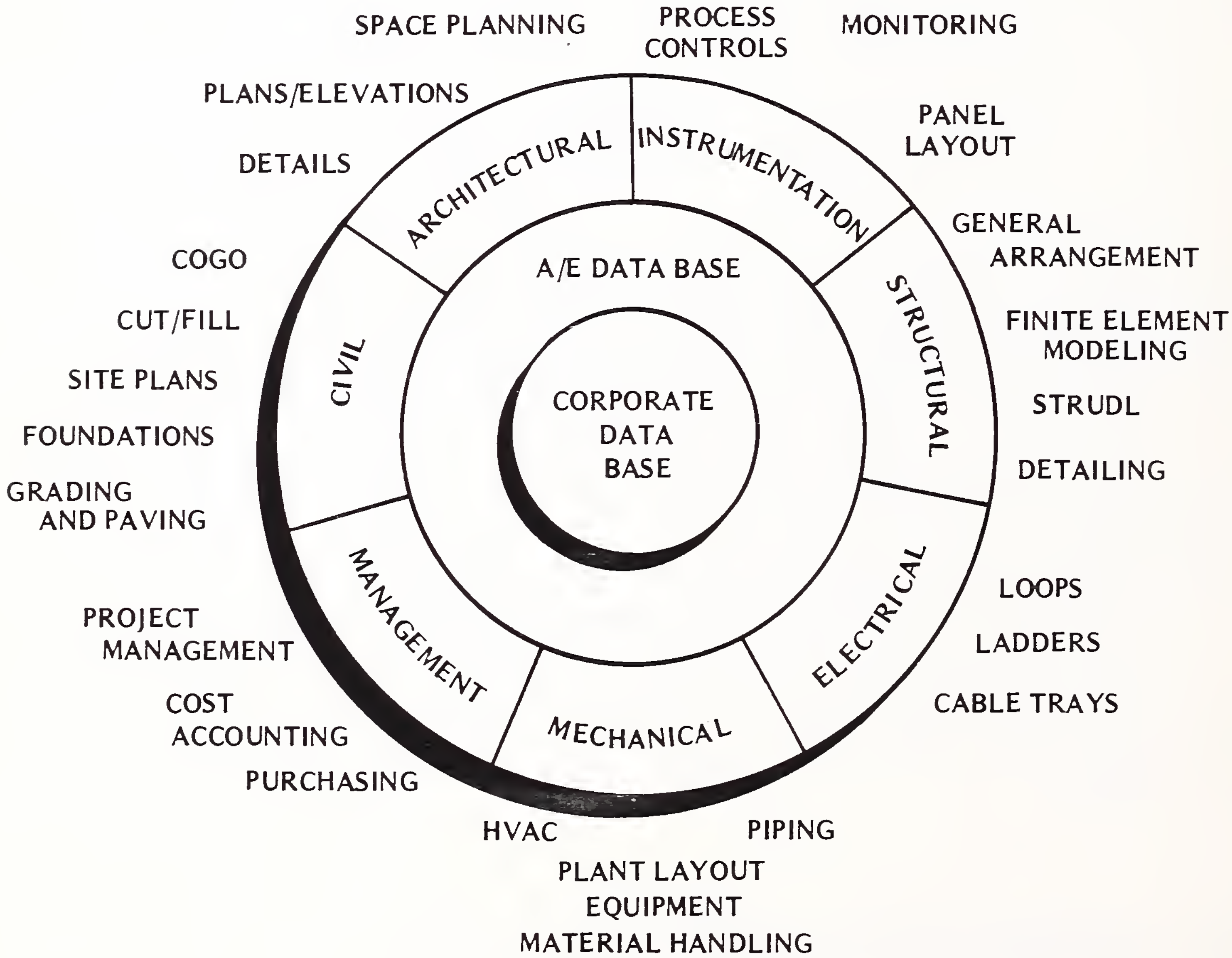
- The need for a totally integrated information system is clear, but there are many issues of technology, resources, user acceptance, and user sophistication to be resolved before progress can be made. Users and vendors will have to work closely together for integration to proceed - it will not be a unilateral effort.

## C. RELIABILITY AND MAINTENANCE

- The trend toward acquisition of the smaller firms by large firms will also introduce the economies of scale in maintenance which should improve maintenance response times and provide a higher incidence of spare parts availability.

EXHIBIT VII-1

SAMPLE INTEGRATED DATA BASE FOR ARCHITECTURAL/CIVIL ENGINEERING APPLICATIONS




COURTESY APPLICON, INC.
32 SECOND AVE.
BURLINGTON, MA

- As users become more comfortable with CAD/CAM systems, software maintenance will improve through better user/vendor communications.

- All hardware continues to become more and more reliable as the manufacturing costs of backup circuitry becomes less than the costs of traditional product-life maintenance support.

- Remote diagnostics will be available for CAD systems equipped with communications adapters by 1986. Users will replace major modules with advice from engineers located at centralized support centers. Remote access capabilities will also enhance the vendors' software support by allowing remote troubleshooting.

## D. PRODUCTS AND FEATURES

- "User-friendly" devices will be in abundance by 1986.

  - Voice recognition circuitry should control, at a minimum, the number of commands available through current menu tablets and light pen commands. Voice recognition will also introduce an additional security measure for access to design data bases.

  - Significant movement toward the portability of graphics data between systems using standard protocols will be evident over the next few years.

  - User pressures will force the majority of CAD/CAM vendors to offer programs in one or more of the common compiler languages providing "hooks" for the interface of custom user programs.

- None of the vendors interviewed is seriously considering devices or algorithms to facilitate the digitizing of archival drawings, although some companies have active development programs underway in this area.

- All vendors expect color displays to provide today's best monochrome resolutions at today's prices by 1986.

- The ability of hardware to store and retrieve digitized drawing files will continue to remain ahead of the general acceptance of substitutes for traditional "hard copy" drawings for all purposes.

# APPENDIX A: CASE STUDIES

## APPENDIX A: CASE STUDIES

- The case studies in this appendix are profiles of CAD/CAM users interviewed on-site by INPUT. Minor license is employed to protect the identity of the actual users.

## A. A LARGE ARCHITECTURAL, ENGINEERING, AND CONSTRUCTION FIRM (COMPANY A)

- Company A has annual sales of over $1.5 billion and employs over 4,000 personnel in all of its operations.

- Using an Auto-trol CAD system employing seven workstations, Company A experienced first-year productivity in drafting equal to 4.75 times the output of equally qualified drafting personnel using conventional drawing boards.

  - A spokesman for Company A said that 18 draftsmen working three shifts on six production workstations produced the same volume as 90 draftsmen on the boards.

  - Productivity improvements of 5:1 are suggested by this statement, but an adjustment is made for the fact that one of the seven workstations is dedicated to CAD development; i.e., entering library symbols and other development activities.

- Training consisted of two weeks of intensive vendor training plus one week at Company A workstations.

  - At the end of three weeks, draftsmen were reasonably proficient on nondimensional, nonscaled drawings.

  - Within three months, all draftsmen were handling all complex work at nearly full proficiency.

- The system experienced 94.7% availability during the first year of operation.

- Subsequently, Company A has added a second AD/380 system from Auto-trol with nine new workstations, 160K of memory, two new CC-80 workstations, and GS-1000 software.

  - The new intelligent workstations and improved software are credited with providing a 20% boost in productivity.

- The CAD service was installed at Company A with the expectation that most divisions would retain their own draftsmen using conventional methods for the largest part of the work, and that the CAD group would serve as an engineering services and support group.

  - Project managers have been free to use the service or to use their own staff of draftsmen.

  - The criteria for selecting CAD to be used for certain projects have been lead time constraints and job complexity.

  - Project managers with profit and loss responsibility for construction projects have gradually discovered the economic benefits of using CAD services in critical situations.

- Company A was contracted to rebuild a refinery recently damaged by an explosion and spent over $100,000 on messenger service delivering field changes to the construction site within the same metropolitan area, and concluded that it would be quite easy to justify a mobile workstation and plotter on these potential savings alone.

- Although Company A did not specify the anticipated payback from the investment in CAD, a spokesman informed INPUT that the actual payback has been significantly better than their original estimates used to justify the first system.

## B. COMPANY B

- Company B is an A/E firm with annual sales of $3.5 million and less than 100 employees.

- After reviewing several systems for use in automated graphics for A/E applications, Company B decided on an Information Displays, Inc. System 150. Company B had established selection criteria as follows:

  - The vendor had to supply source code for the operating system and graphics system in FORTRAN to facilitate local modifications and the integration of engineering and graphics data bases by Company B's program development staff.

  - Disk storage capacity had to be sufficient to contain all drawings for any single project; capacity of 80 megabytes was considered sufficient.

  - High-density mag tape was needed for storing archival drawings.

  - Only systems offering refresh CRT workstations were considered.

- Two CRTs per workstation were not required in the production-line environment. Management at Company B considered the designer detail sketches to be of adequate quality to provide the overview normally provided by the second CRT in most turnkey workstations.

- "Operator-friendly" interface, such as software-prompted light pen input, was considered a requirement.

- On-line microfilm processing was not a requirement as Company B would use a service bureau to produce microfilm copies from mag tape when needed.

- The availability of a mechanical cartridge pen plotter was required as a cost-saving measure. Company B could add a second plotter if drawing output volume created a permanent bottleneck.

- The CPU had to be useful for purposes other than automated graphics to be affordable by Company B; e.g., capable of running engineering analyses and accounting.

- The large number of "layers" offered by many turnkey vendors was not a consideration by Company B since it had developed a plan to implement control over multiple drawings and the ability of any draftsman to reference the latest version of architect's masters and other drawings.

• Company B implemented a production-line approach to drafting with centralized services.

  - It was determined that one reason drafting personnel were leaving was because they were so bogged down in drafting, they were not learning designing as rapidly as expected.

- Less expensive and less qualified personnel could be used to finalize the drafting procedure if designer apprentices being used for the conventional drafting assignments could be used to provide the detailed sketches.

• Because Company B took a systems approach to redesigning the procedures from concept to finished drawing, the only legitimate measure of productivity is the total time saved through the entire pipeline.

  - When diluted by the entire pipeline, productivity is still a healthy 2:1 using the IDI 150 system.

  - In justifying the system, Company B estimated breakeven would occur at a productivity improvement ratio of 1.67:1.

  - The 2:1 ratio represents a net $43,000 to profits per year for this relatively small business.

# APPENDIX B: DATA BASE

## EXHIBIT B-1*

### PROGRESS IN INTEGRATION FOR ARCHITECTURAL/ENGINEERING CAD APPLICATIONS

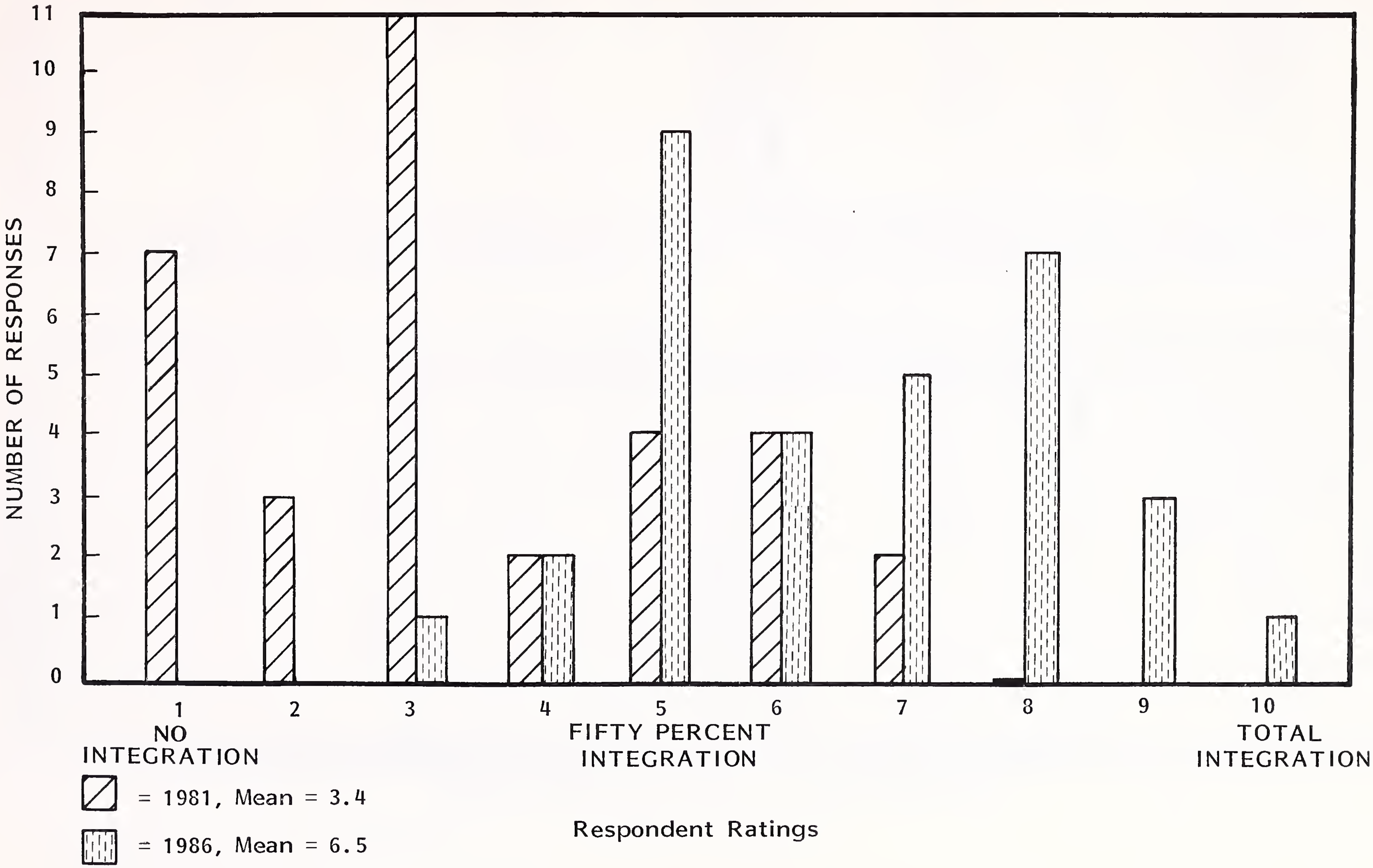
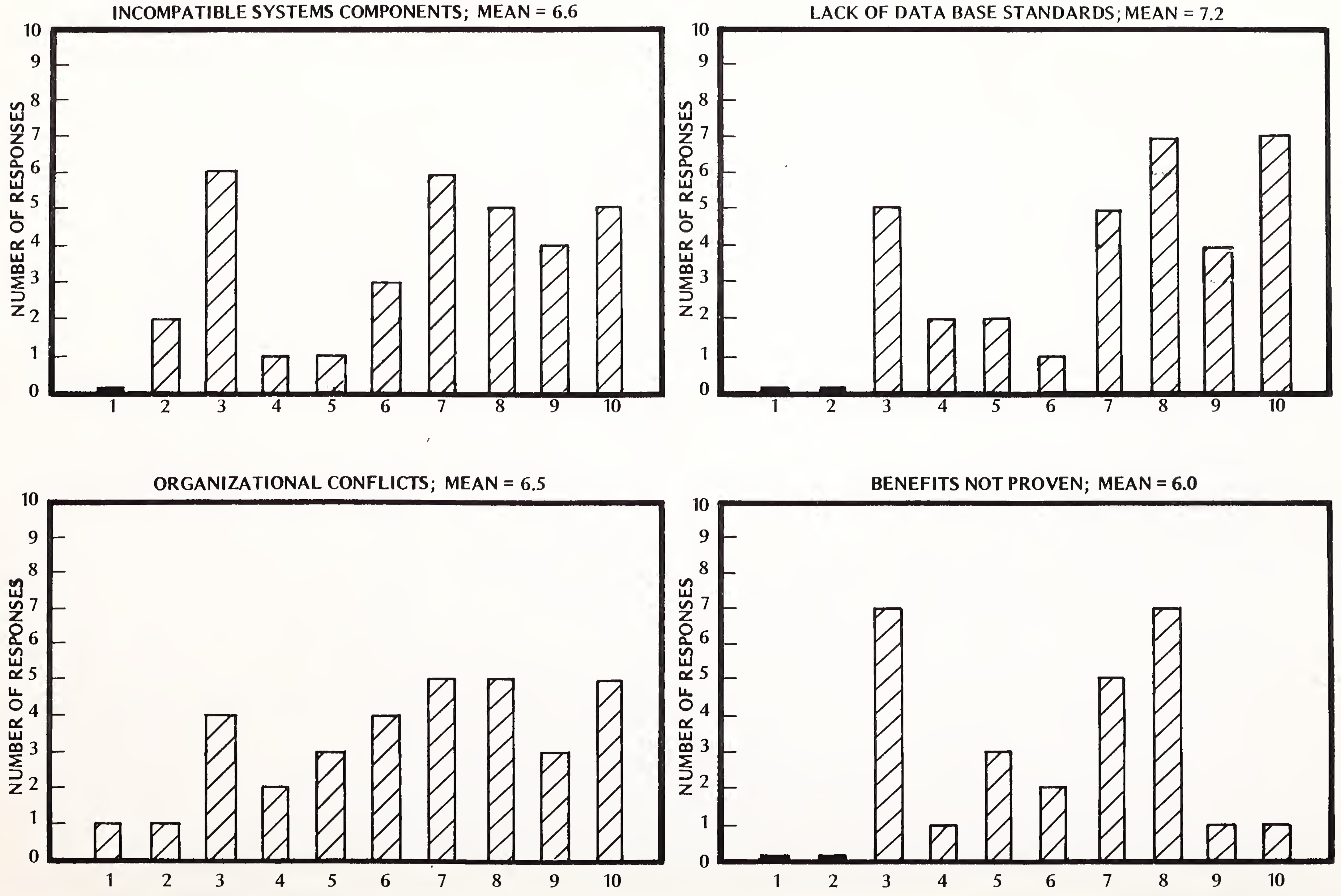



*EXHIBIT VI-3 — Detail

## EXHIBIT B-2*

## PERCEIVED OBSTACLES TO INTEGRATION




1 = NO OBSTACLE, 10 = LARGE OBSTACLE

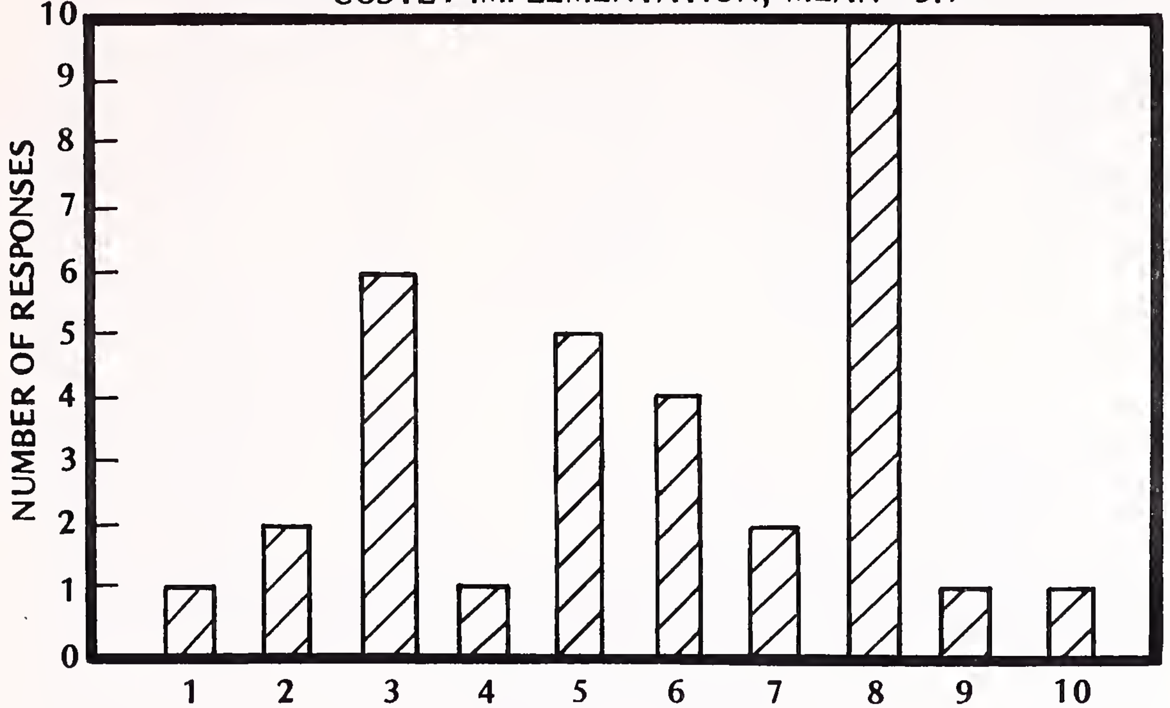
*EXHIBIT VI-5 – Detail

Continued

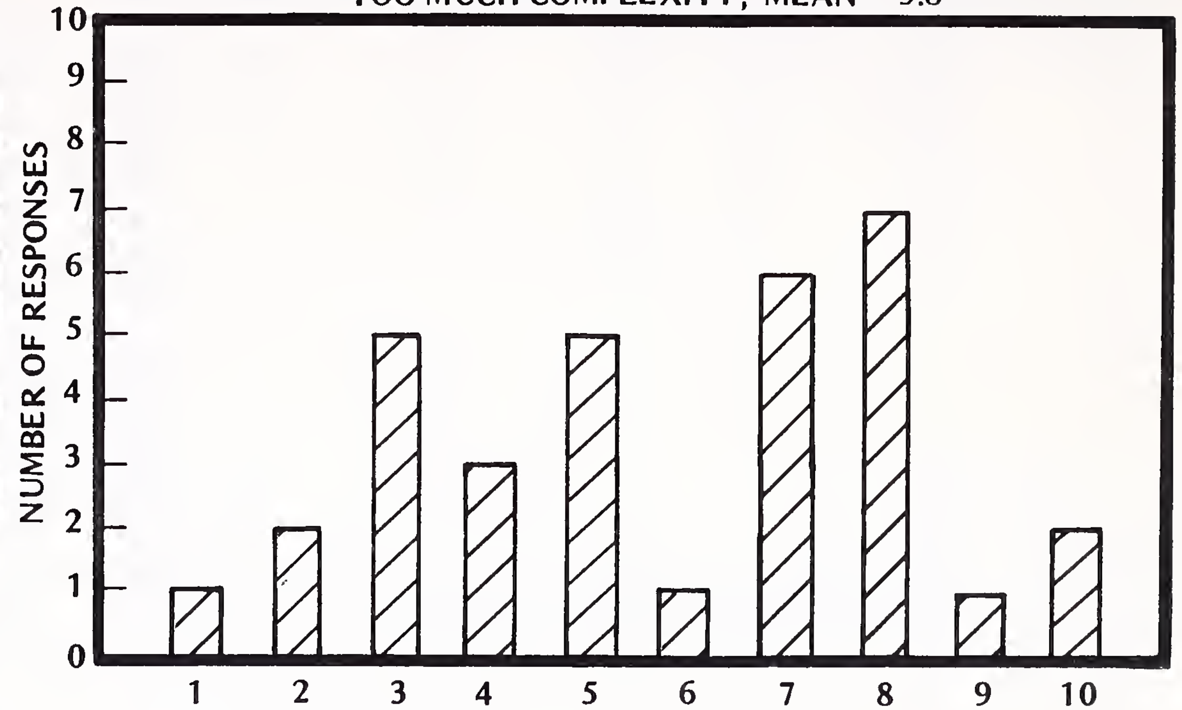
## EXHIBIT B-2 (Cont.)*

## PERCEIVED OBSTACLES TO INTEGRATION

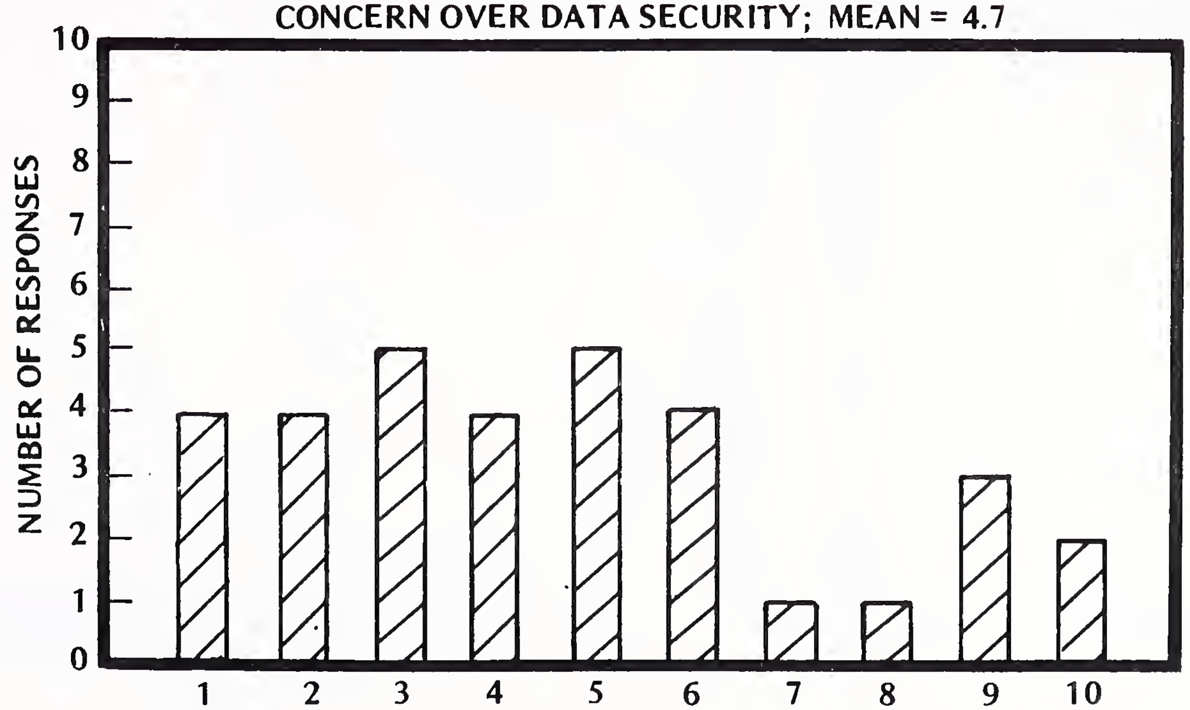
COSTLY IMPLEMENTATION; MEAN = 5.7




TOO MUCH COMPLEXITY; MEAN = 5.8




CONCERN OVER DATA SECURITY; MEAN = 4.7

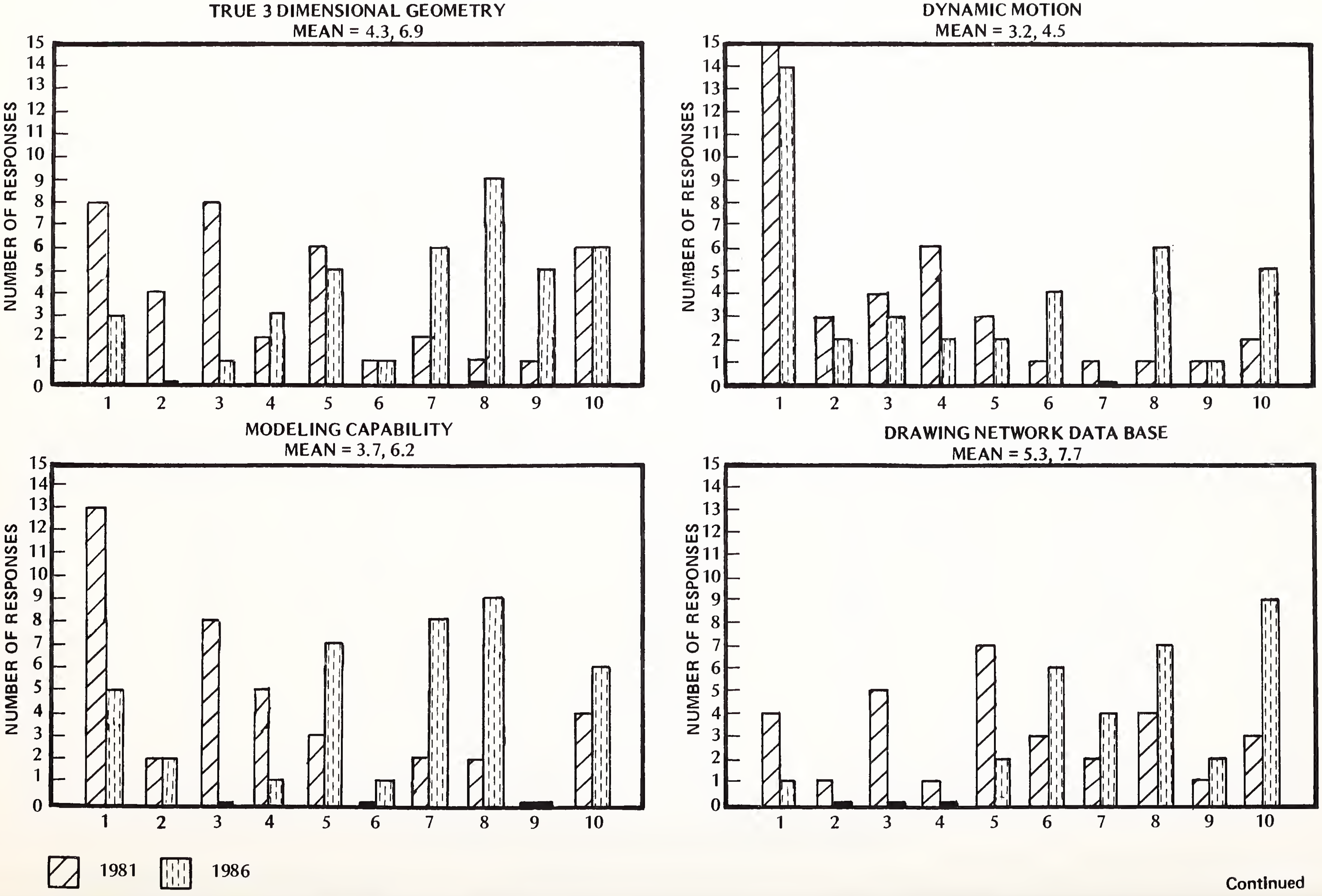



1 = NO OBSTACLE, 10 = LARGE OBSTACLE

*EXHIBIT VI-5 – Detail

## EXHIBIT B-3*

## USERS' RATINGS OF CAD/CAM FUNCTIONS




Continued

1 = NO REQUIREMENT, 10 = VITAL *EXHIBIT VI-7 — Detail

EXHIBIT B-3 (Cont.)*

USERS' RATINGS OF CAD/CAM FUNCTIONS

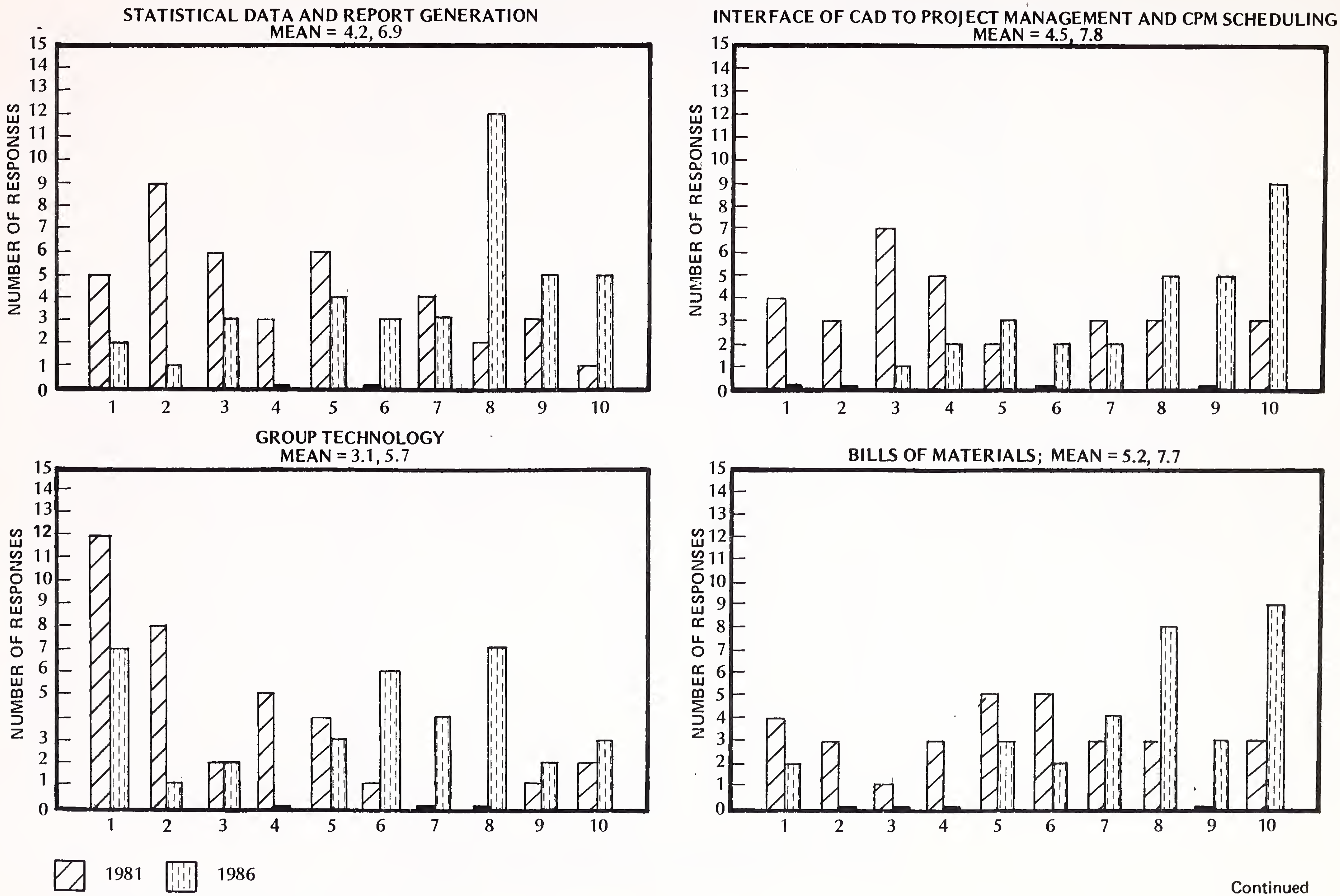
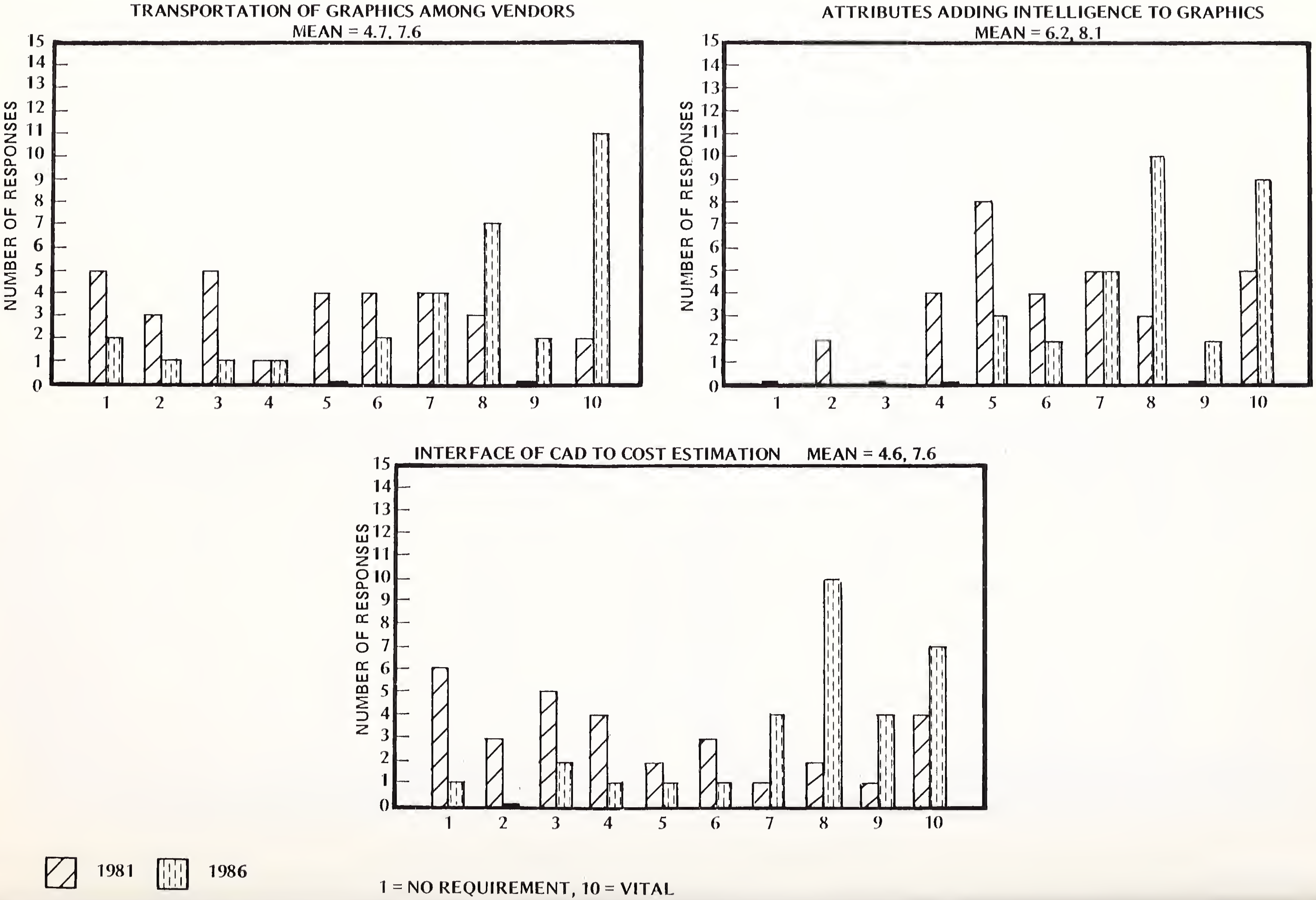



*EXHIBIT VI-7 — Detail

Continued

EXHIBIT B-3 (Cont.)*

USERS' RATINGS OF CAD/CAM FUNCTIONS

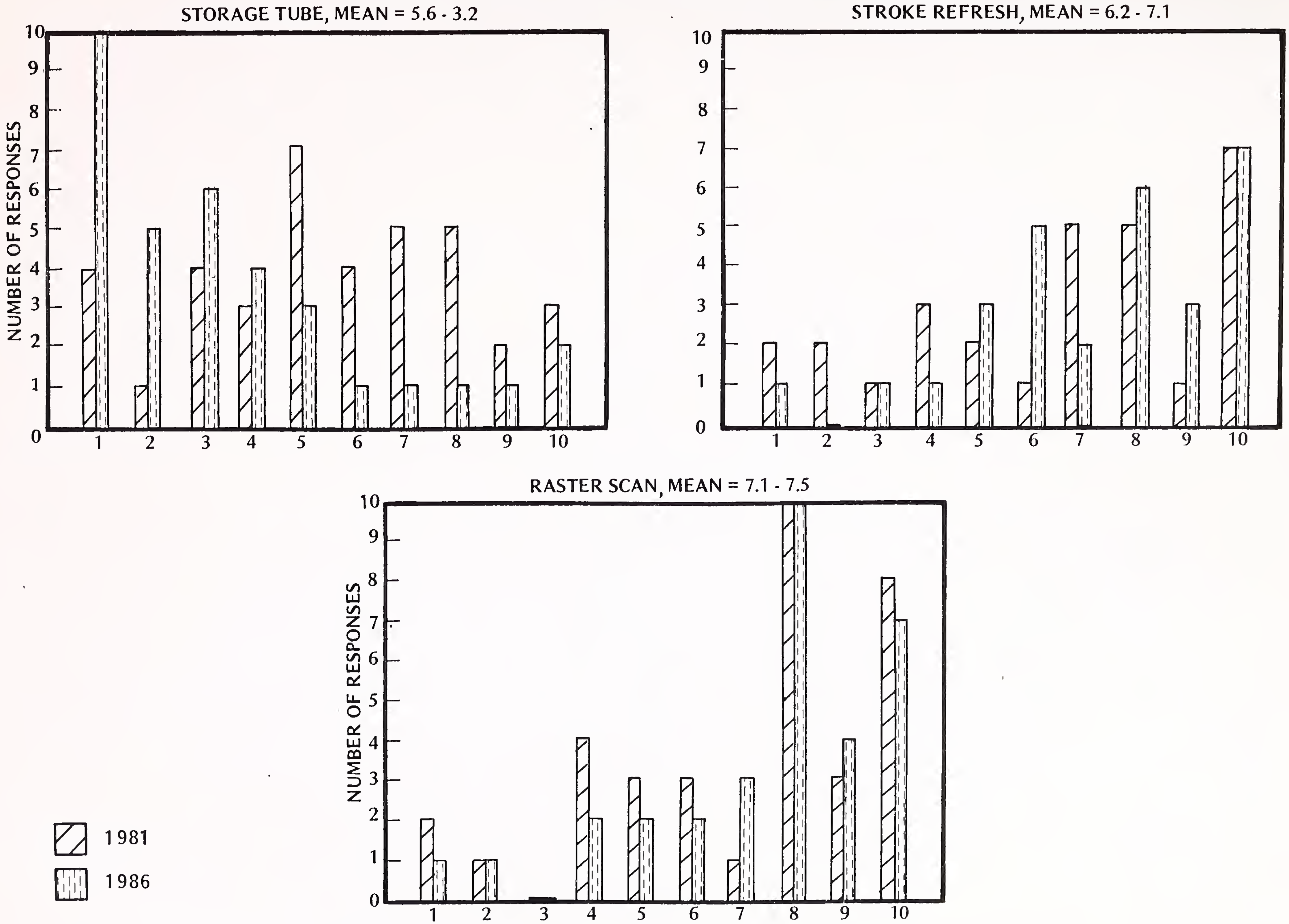



1 = NO REQUIREMENT, 10 = VITAL

*EXHIBIT VI-7 — Detail

## EXHIBIT B-4*

### DISPLAY TECHNOLOGY REQUIREMENTS, 1981-1986




1 = NO 1 = INADEQUATE, 10 = EXCEEDS NEEDS

*EXHIBIT VI-8 — Detail

# APPENDIX C: GLOSSARY OF TERMS

## APPENDIX C: GLOSSARY OF TERMS

AEROSPACE (product category). The subgroup of mechanical CAD/CAM users producing aerospace products such as airplanes, missiles, and aircraft engines.

ARTICULATION. Analysis of the movement of connected parts in complex assemblies.

BILL OF MATERIAL (BOM). A listing of all subassemblies, parts, and materials that go into an assembled part showing the quantities of each.

CAD (Computer-Aided Design). Application of computer and graphic technology to engineering, design, and drafting.

CAD/CAM. The integrated application of CAD and CAM.

CALLIGRAPHIC DISPLAY. A cathode ray tube display which writes each vector and character in the sequence of its commands. This display type provides high quality and good dynamics.

CAM. Application of computer and graphic technology to manufacturing engineering, planning, and control.

Computer Output Microfilm (COM). The technology for accepting digital data and recording it on microfilm at high reduction ratios and very high speeds. Useful for recording drawings as well as data.

CORE (SIGGRAPH). A proposed standard for software driving graphic devices, established by SIGGRAPH.

DATA BASE. A set of data records and files structured for a particular operating environment.

DATA BASE MANAGEMENT SYSTEM (DBMS). A software system that allows a user to structure a data base by defining the data, its organization, and the association between data elements. It also includes a data manipulation language (for access, sorting, merging, etc.) and controls for concurrent use (security, request, queueing, etc.). Functions as a common interface to multiple applications.

DATA TABLET. A device consisting of a pad and stylus used to input commands, designate elements, or to digitize drawings for a CAD system.

DISCRETE (product cateogry). The subgroup of mechanical CAD/CAM users producing discrete products such as conveyors, hand tools, electric motors, and air filters.

DISPLAY. A simple graphics terminal or the graphics display component of a more complex terminal.

DISTRIBUTED DATA BASE. A data base which is physically located at multiple sites, with each site having a part of the total data base. The sites are usually linked to a central site as well as having access to each other.

DISTRIBUTED PROCESSING. Multiple computers simultaneously processing elements of a CAD or CAM task.

DYNAMIC MOTION (display). A capability of a display to rapidly and continuously change the viewpoint under operator command.

ENGINEERING/MANUFACTURING DATA BASE. A combined CAD/CAM data base used by both engineering and manufacturing.

FAMILY OF PARTS. A process for defining generic part attributes which, when combined with user-specified parameters, will perform automatic CAD or CAM operations such as drawing, NC programming, or testing and simulation.

FINITE ELEMENT ANALYSIS. As used in this report, this includes all tasks involved in structural analysis using finite element methods: preprocessing or mesh generation, finite element analysis processing, and post-processing.

GKS (Graphic Kernel System). A proposed European standard for interchange of data between CAD systems.

GROUP TECHNOLOGY. The application of classification and coding technology to search a data base for information on similar parts and to apply this to CAD and CAM tasks.

ICAM. U.S. Air Force Integrated Computer Aided Manufacturing program for manufacturing technology.

IGES (Initial Graphics Exchange Specification). A proposed standard for the interchange of data between CAD systems. Developed by the National Bureau of Standards under contract from the ICAM program.

INTELLIGENT WORKSTATION. A CAD or CAM workstation which performs many tasks internally and independent of the host computer.

IPAD (Integrated Programs for Aerospace Vehicle Design). A NASA program to develop an integrated CAD/CAM system for aerospace applications.

KINEMATICS. Analysis of articulated assemblies.

KINETICS. Analysis of dynamic loads.

LAYERING. A technique to assign geometric and other data to spatially related layers, which can be viewed or plotted independently.

LIGHT PEN. A device used to input commands and to designate elements by pointing at or touching the display.

MANAGEMENT INFORMATION SYSTEM (MIS). A data processing system specifically designed to provide business managers with company, financial, project, or program data.

MASS PROPERTIES. Calculation of weights, centers of gravity, and moments of inertia for a closed volume.

MOBILE/TRANSPORTATION (product category). The subgroup of mechanical CAD/CAM users producing products for transportation or similar products, such as automobiles, tractors, and construction machines.

NUMERICAL CONTROL (NC). CAM technology and systems for programming and controlling numerically controlled machines.

NCGA. National Computer Graphics Association.

NC POST PROCESSORS. Computer programs to adopt generic NC commands to drive specific NC machines.

NESTING. Software to automatically or interactively arrange patterns for parts within stock material boundaries.

NETWORKING. The interconnection and control of remotely located systems and devices over communications lines.

RASTER DISPLAY. A CAD display using television technology. Currently has less resolution than Calligraphic, better dynamics than memory tubes, and lower cost.

SHOP FLOOR CONTROL. Control of the progress of each customer order or stock order through the successive operations of its production cycle and the collection of data regarding actual completion results or status.

SIGGRAPH. Special Interest Group on Graphics, an organization within ACM (Association for Computing Machinery).

SOLID MODEL. A computer based representation of a complete, enclosed object or part; the same as a volumetric model.

STORAGE TUBES. A graphics display in which the image is stored on an element behind the viewing screen. Graphics elements can be added to the stored image, but the entire screen must be erased and repainted if elements are deleted. Since this image is not refreshed as in raster or stroke tubes, there is no flicker; however, repaint time for large amounts of data can be significant compared to other technologies.

STROKE REFRESH. A calligraphic display.

SURFACE MODEL. A computer based representation of a surface patch. The surface may be of many types, including ruled, tabulated cylinders, and sculptured.

TRIMMING. The operation of removing the parts of a geometric model which extend past a designated boundary.

TRUE 3-D GEOMETRY. A geometry model for a part which can be viewed from any direction with automatic generation of correct perspective or orthographic views.

TURNKEY CAD. A complete packaged CAD system including all software, computer and other hardware, and user support and training.

VECTOR STROKE. A calligraphic display.

VOLUMETRIC MODEL. The same as a solid model.

WIRE FRAME. A 3-D representation of edges made up of line segments.

# APPENDIX D: QUESTIONNAIRES

# ARCHITECTURAL/CIVIL ENGINEERING USER OUTLINE

I. GENERAL

II. TECHNOLOGY ISSUES

III. PRODUCTIVITY IMPROVEMENTS

IV. SOFTWARE

V. CAD/CAM INTEGRATION

VI. MAINTENANCE

VII. CAD/CAM SUPPORT OF BUSINESS GRAPHICS

# I. GENERAL

1. For the purpose of this study, INPUT defines "CAD" as the utilization of computer aids for graphics, analysis, simulation, modeling requirements, documentation and configuration control in the support of the design function. "CAM" is defined as the utilization of computer aids in the linkage of outputs from design into the construction process and facilities management through bills of material, quality control and the mutual exchange of data between design, construction and maintenance.

2. What type(s) of CAD systems do you have or plan to get in the near future?

   a. Turnkey system (Applicon, CV, etc.) ______ 10

   b. Software packages for in-house computer ______ 11

   c. Custom-built system ______ 12

   d. System from a major computer supplier: (IBM, CDC, DEC, PRIME) ______ 13

   e. Remote Computing Services ______ 14

3. How many total workstations are (or will be) employed?

   ______ Number
   15

4. Are the analysis and processor-intensive functions performed via workstations linked with:

a. An in-house mainframe ______ 16

b. A processor in a turnkey system ______ 17

c. A remote computing company processor ______ 18

d. Distributed processors ______ 19

e. Other (describe) ______________________ 20

______________________________ ______ 21

Comments: ______________________________

______________________________

5. What vendors are you currently using for CAD/CAM?

a. Turnkey Systems (stand-alone)

| | Vendor | Model | System Cost |
|---|---|---|---|
| 1. | ______ 22 | ______ 23 | $______ 24 |
| 2. | ______ 25 | ______ 26 | $______ 27 |
| 3. | ______ 28 | ______ 29 | $______ 30 |
| 4. | ______ 31 | ______ 32 | $______ 33 |
| 5. | ______ 34 | ______ 35 | $______ 36 |

b. In-house systems:

| | | | |
|---|---|---|---|
| 1. | ______ 37 | ______ 38 | $______ 39 |
| 2. | ______ 40 | ______ 41 | $______ 42 |
| 3. | ______ 43 | ______ 44 | $______ 45 |
| 4. | ______ 46 | ______ 47 | $______ 48 |
| 5. | ______ 49 | ______ 50 | $______ 51 |

5. (Cont.)

c. Remote Computing Services:

| | Vendor | Product | Monthly Cost |
|---|---|---|---|
| 1. | 52 | 53 | $ 54 |
| 2. | 55 | 56 | $ 57 |
| 3. | 58 | 59 | $ 60 |
| 4. | 61 | 62 | $ 63 |
| 5. | 64 | 65 | $ 66 |

d. Independent Software Packages:

| | Vendor | Product | System Cost |
|---|---|---|---|
| 1. | 67 | 68 | $ 69 |
| 2. | 70 | 71 | $ 72 |
| 3. | 73 | 74 | $ 75 |
| 4. | 76 | 77 | $ 78 |
| 5. | 79 | 80 | $ 81 |

6. Please rate the following factors in terms of their impact on your system selection decision. Rate (On a scale of 1 to 10, where 10 is major impact, and 1 is no impact)

| FACTOR | TURNKEY SYSTEMS | IN-HOUSE SYSTEMS | REMOTE COMPUTING SERVICES | INDEPENDENT SOFTWARE PACKAGES |
|---|---|---|---|---|
| a) Cost | 82 | 83 | 84 | 85 |
| b) Processing Capability | 86 | 87 | 88 | 89 |
| c) Software | 90 | 91 | 92 | 93 |
| d) System Flexibility | 94 | 95 | 96 | 97 |
| e) Access to Data bases | 98 | 99 | 100 | 101 |
| f) Future enhancements | 102 | 103 | 104 | 105 |
| g) Other ________ 106 | 107 | 108 | 109 | 110 |
| h) Other ________ 111 | 112 | 113 | 114 | 115 |
| i) Other ________ 116 | 117 | 118 | 119 | 120 |

Comments: ____________________________________________

____________________________________________

____________________________________________

7. In your opinion, which vendors have the best systems for your applications meeting the following requirements? (Please rank vendors, starting with the best, in the first column)

| RANK<br>APPLICATION | VENDOR #1 | VENDOR #2 | VENDOR #3 | VENDOR #4 |
|---|---|---|---|---|
| a) Drafting (2D) | 121 | 122 | 123 | 124 |
| b) Design Analysis (Purchasable) | 1C | 126 | 127 | 128 |
| c) 3D-Modeling, Simulation | 129 | 130 | 131 | 132 |
| d) Drawing network data base | 2C | 134 | 135 | 136 |
| e) Direct process control | 137 | 138 | 139 | 140 |
| f) Design Analysis Development-ability | 3C | 142 | 143 | 144 |
| g) Bill of Materials | 145 | 146 | 147 | 148 |
| h) Other (specify) | | | | |
| ______ 149 | 150 | 151 | 152 | 153 |
| ______ 154 | 155 | 156 | 157 | 158 |

Comments: ______________________________

______________________________

______________________________

8.a. Please rate your total CAD/CAM installation in terms of it meeting your expectations at the time of purchase (on a scale of 1 - 10)

1 - 10

1 = totally fails to meet expectations

5 = equals expectations

10 = far exceeds expectations

Rating ______ 159

b. Explain all scores of 4 or less: ______________________________

______________________________________________________________

______________________________________________________________

c. If you were to start over again today, would you buy from the same vendor(s)?

Yes _____ No _____ 160

d. If "no", why not? ______________________________

______________________________________________________________

9. Please rate the importance of the following benefits of CAD in cost justifying the system. Rate on a scale of 1 to 10, where 1 is not important and 10 is of vital importance.

| Benefit | Rating |
| --- | --- |
| a. Productivity improvement due to cost savings. | ______ 161 |
| b. Improved design/drafting quality (better product) | ______ 162 |
| c. Increased capabilities to acquire projects that cannot be done without CAD/CAM | ______ 163 |
| d. More efficient skilled manpower loading | ______ 164 |
| e. Increased operations efficiency | ______ 165 |
| f. Employee morale | ______ 166 |
| g. Better addendum, bulletin and field maintainability | ______ 4C |
| h. Standardization and visability of libraries | ______ 5C |
| i. Centralized building data base | ______ 6C |

10.a. What are your planned expenditures for external CAD/CAM products and services for the following time periods? ($ in thousands-K or millions-M)

| ITEM OF EXPENSE | 1981 | 1982 | 1983 |
|---|---|---|---|
| a) Hardware | 168 | 169 | 170 |
| b) Software | 171 | 172 | 173 |
| c) Remote Computing Services | 174 | 175 | 176 |
| d) Turnkey Systems | 177 | 178 | 179 |

b. What is the average cost per workstation for your CAD/CAM system?

$______K 1981 (180)    $______K 1986 (181)

c. What is the average cost per hour per workstation for use of the system?

1981    1986

______$/hr/workstation (182)    ______$/hr/workstation (183)

11. What additional external CAD/CAM purchases for products or services do you expect to make by 1986?

a. Hardware ____________________
184

b. Software ____________________
185

c. Remote Computing Services ____________________
186

d. Turnkey Systems ____________________
187

e. Other ____________________
188

12. In your opinion, what will be the average annual growth rate for dollars spent on CAD systems and services in the U.S. between 1981 and 1986?

_____ $ AAGR
189

II. TECHNOLOGY ISSUES

13.a. What display terminal technology best serves your applications needs today and in 1986. Please rate on a scale of 1 to 10, where 10 is far exceeding application needs and 1 is totally inadequate for application needs.

| TYPE | RATING 1981 | RATING 1986 |
|---|---|---|
| STORAGE TUBE | ____ 190 | ____ 191 |
| REFRESH: | | |
| VECTOR STROKE (Calligraphic) | ____ 192 | ____ 193 |
| RASTER SCAN | ____ 194 | ____ 195 |
| HYBRID | ____ 196 | ____ 197 |

b. In rating the types of display, considering the ability of the display to meet your application needs, how important are memory requirements? Please rate on a scale of 1 to 10, where 10 is very important and 1 is not a consideration at all.

| | 1981 | 1986 |
|---|---|---|
| Rating | ____ 198 | ____ 199 |

c. How important is price in the decision to select a particular display technology?

| | 1981 | 1986 |
|---|---|---|
| Rating | ____ 200 | ____ 201 |

d. What major changes in display terminals do you expect over the next 5 years, and why will the changes come about?

______________________________
202

______________________________

______________________________

14. IMPORTANCE OF COLOR

a. Are color displays a requirement?

1981 _____ Yes _____ No 203

1986 _____ Yes _____ No 204

Why? ______________________________________________

______________________________________________

______________________________________________

b. On a scale of 1 - 10, how important is color to your application needs? (1 = no requirement, 10 is absolutely essential)

| | Rating |
|---|---|
| 1981 | _____ 206 |
| 1986 | _____ 207 |

Comments: ______________________________________________
208

______________________________________________

______________________________________________

c. On a scale of 1 - 10, how important would color be if high quality, fast response color reproduction were available for a reasonable price over monochrome?

| | |
|---|---|
| 1981 | _____ 7C |
| 1986 | _____ 8C |

15. What is the CAD workstation display resolution of your present system?

_____________ 209 by _____________ 210

_____________ 211 by _____________ 212

_____________ 213 by _____________ 214

16. RESPONSE TIMES

a. What response times are you presently experiencing on your present system?

_____ Seconds
215

b. Is this adequate?

Yes _____ No _____ 216

c. If no, what are your requirements?

_____ Seconds
217

d. Comments: _______________________________________
218

_______________________________________

_______________________________________

17. 3D MODELING

a. Do you currently use 3D modeling techniques at your CAD workstations?

Yes _____ No _____ 219

Why or why not? _______________________________________
220

_______________________________________

b. Do you expect to be using 3D modeling techniques at your CAD/CAM installation by 1986?

Yes _____ No _____ 221

17.c. On a scale of 1 - 10, rate the importance of 3D for:

| | 1981 | 1986 |
|---|---|---|
| i. Structural Finite Element | ____ 9C | ____ 10C |
| ii. Mechanical Systems | ____ 11C | ____ 12C |
| iii. Electrical Systems | ____ 13C | ____ 14C |
| iv. Architectural Space Analysis | ____ 15C | ____ 16C |
| v. Interference Checking | ____ 17C | ____ 18C |
| vi. Site and Building Analysis | ____ 19C | ____ 20C |
| vii. Model Making | ____ 21C | ____ 22C |
| viii. Renderings | ____ 23C | ____ 24C |

18. How essential to your application, now and in 1986, are the following functions of CAD/CAM systems. Please rate on a scale of 1 to 10, where 10 is absolutely vital and 1 is no requirement.

| FUNCTION | RATING | |
|---|---|---|
| | 1981 | 1986 |
| a. True 3-dimensional geometry | ___ 222 | ___ 223 |
| b. Dynamic motion | ___ 224 | ___ 225 |
| c. Modeling capability such as Finite Element Modeling | ___ 226 | ___ 227 |
| d. Drawing network data base | ___ 25C | ___ 26C |
| e. Statistical data and report generation | ___ 230 | ___ 231 |
| f. Interface of CAD to project management and CPM scheduling | ___ 27C | ___ 28C |
| g. Group technology for classifying groups of parts | ___ 234 | ___ 235 |
| h. Bills of materials | ___ 236 | ___ 237 |
| i. Transportation of graphics among vendors | ___ 29C | ___ 30C |
| j. Attributes adding intelligence to graphics | ___ 31C | ___ 32C |
| k. Interface of CAD to cost estimation | ___ 33C | ___ 34C |

19. How likely is it that CAD/CAM systems will render conventional mylar/vellum drawings obsolete, such as through the use of electrostatic media and/or microfilm.

1 - 10

1 = impossible

5 = 50/50 chance

10 = absolutely certain

1983 ___ 242

1986 ___ 243

1990 ___ 244

20. How long does it take to train a new user of the CAD/CAM system?

a. To initial use ________ weeks
245

b. To complete proficiency ________ weeks
246

21. Would lower CAD/CAM system prices enable you to use these systems more extensively?

Yes _____ No _____ 247

Why or why not? ________________________________
248

________________________________________________

________________________________________________

22. USE OF CAD

a. Where are your workstations located?

I. Central design facility _____
249

II. Co-located with design groups _____
250

b. Who operates CAD?

I. Specialist _____
251

II. Engineer _____
252

## III. PRODUCTIVITY IMPROVEMENTS

23.a. What percent productivity improvement did you <u>expect</u> from your system?

_____% 253

b. Overall, what percent productivity improvement has your CAD/CAM system provided over the previous method?

_____% 254

c. How do you measure productivity gains associated with CAD/CAM implementation?

______________________________ 255

______________________________

______________________________

______________________________

______________________________

24. What has been the productivity gain associated with the following components of the product development cycle which are attributed to your CAD/CAM system?

a. The most productivity gain

1. Design _____% 256 2. Drafting _____% 257 3. Engineering Analysis _____% 258

4. Production planning _____ 259 5. Shared Drawings _____% 35C

6. Library standards _____% 36C

7. Other (specify) ______________________________ 262 _____% 263

b. Comments: ______________________________

______________________________

______________________________

# IV. SOFTWARE

## 25. ENHANCEMENTS

a. How are systems and applications software enhancements provided for your CAD/CAM system? Please rank in order of importance on a scale of 0 to 1, where 1 is most important.

| | Ranking |
|---|---|
| 1. In-house software development group | ____ 264 |
| 2. Vendor software releases | ____ 265 |
| 3. Software consulting services | ____ 266 |

b. Do you belong to a users group?

Yes ____ No ____ 267

if yes;

- What is the name of the group?

  ____________________ name
  268

  Describe the group's goal/function: ____________________

  ____________________

- How would you rate the overall effectiveness of the group in achieving its goals? (On a scale of 1 to 10, 10 = totally effective, 1 = totally ineffective) ____ rating
  269

c. What degree of participation do you have in IPAD?

- None ____ 270
- Observer status ____ 271
- Participant ____ 272
- Contributor ____ 273

25.c. (Cont.)

What degree of participation do you have in:

| | *BSDS | CAEADS | CASDAC |
|---|---|---|---|
| • None | 37C | 38C | 39C |
| • Observer status | 40C | 41C | 42C |
| • Participant | 43C | 44C | 45C |
| • Contributor | 46C | 47C | 48C |

Comments: ____________________

____________________

* Building Standard Design System (Corp. of Engineers)

Computer Aided Engineering and Architectural Design System (Corp. of Engineers)

Computer Aided Ship Design And Construction (U.S. Navy)

d. Between the National Bureau of Standards' ANSI standard (Initial Graphics Exchange (IGES)), and the SIGGRAPH-CORE standard, which do you feel will become the final standard?

| IGES | SIGGRAPH-CORE | COMBINATION OF BOTH |
|---|---|---|
| ☐ 278 | ☐ 279 | ☐ 280 |

Comments: ____________________

____________________

____________________

____________________

26. Please identify which CAD/CAM software packages and documentation you use (or utilities used in CAD/CAM environment). Rate them on a scale of 1 to 10, where 10 is outstanding and 1 is completely inadequate.

| SOFTWARE PACKAGE | USE | | RATING APPLICATION |
|---|---|---|---|
| | YES | NO | |
| a) CADAM 281 | | | ___ 282 |
| b) BOSOR (strucutral) 283 | | | ___ 284 |
| c) NASTRAN (structural) 285 | | | ___ 286 |
| d) SINDA (thermal) 287 | | | ___ 288 |
| e) AD 2000 289 | | | ___ 290 |
| f) OTHER 291 | | | ___ 292 |
| g) 293 | | | ___ 294 |
| h) 295 | | | ___ 296 |
| i) 297 | | | ___ 298 |

27. OVERALL SOFTWARE EVALUATION

a. Please rate the overall adequacy of your CAD/CAM software today and what it is expected to be in 1986. Rate on a scale of 1 to 10, where 10 is excellent and 1 is very poor.

___ 1981 ___ 1986
299 300

b. What software requirements of your application are not being met by vendors, or by your in-house software development group?

___
301

___

___

___

## V. CAD/CAM INTEGRATION

### 28. STATUS OF CAD/CAM INTEGRATION

a. How far has industry progressed toward CAD/CAM integration now, and how far do you expect it to be in 1986? Please rate on a scale of 1 to 10, where 10 is completely integrated systems and 1 is no progress at all.

| | 1981 | 1986 |
|---|---|---|
| Rating | ____ 302 | ____ 303 |

b. To your knowledge, what results have actually been obtained towards integrating CAD and CAM?

______________________________
304

______________________________

29. Is there or will there be a trend towards integrating design engineering data bases with:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| a) | Project Management | 49C | Yes ____ | No ____ | Yes ____ | No ____ | 50C |
| b) | Checking Code Compliance | 51C | Yes ____ | No ____ | Yes ____ | No ____ | 52C |
| c) | Construction cost Estimation and Control | 53C | Yes ____ | No ____ | Yes ____ | No ____ | 54C |
| d) | Concepts and Planning | 55C | Yes ____ | No ____ | Yes ____ | No ____ | 56C |
| e) | Project cost estimation and control | 57C | Yes ____ | No ____ | Yes ____ | No ____ | 58C |
| f) | Optimization and alternative analysis | 59C | Yes ____ | No ____ | Yes ____ | No ____ | 60C |
| g) | Other | 318 | Yes ____ | No ____ | Yes ____ | No ____ | 319 |

______________
317

Why will this design engineering data base (not) take place with other functional data bases?

______________________________
320

______________________________

30. How will the trend towards design and operations data base integration change organizational responsibility in:

a) design engineering ______ 321

______

b) Project planning and control ______ 322

______

c) operations ______ 323

______

d) traditional DP functions ______ 324

______

31. Please rate the following in terms of their being an obstacle to an integrated CAD/CAM data base. Please rate on a scale of 1 to 10, where 10 is a very large obstacle and 1 is no obstacle at all.

lack of standards ______ 325

too much complexity ______ 326

incompatible systems components ______ 327

concern over data securiy ______ 328

costly implementation ______ 329

organizational conflicts ______ 330

benefits not proven ______ 331

other (please specify) ______ 332 ______ 333

32. Will distributed data bases for design engineering data, cost data, construction data, and facilities management data be developed for integrated CAD/CAM installations?

| | | | | |
|---|---|---|---|---|
| 1981 | Yes ______ | No ______ | Don't know ______ | 334 |
| 1986 | Yes ______ | No ______ | Don't know ______ | 335 |

33. How important is it to make provisions for data security in CAD/CAM systems? Please rate on a scale of 1 to 10, where 10 is essential and 1 is of no importance.

| | 1981 | 1986 |
|---|---|---|
| Rating | ____ 336 | ____ 337 |

b. What are the needs for data security?

______________________________________________
338

______________________________________________

______________________________________________

c. What provisions do you expect to utilize for CAD/CAM data security?

______________________________________________
339

______________________________________________

______________________________________________

______________________________________________

34. Will text processing capabilities have to be included in CAD/CAM systems?

Yes ____ No ____ Why or why not? ____________________
340

______________________________________________

______________________________________________

______________________________________________

## VI. MAINTENANCE

35.a. Is your hardware maintained through:

_____ (341) A monthly maintenance contract $_____ (342) /month

_____ (343) A time and materials arrangment $_____ (344) /month averaged

_____ (345) In-house personnel _____ (346) number

b. Is the software supported through:

_____ (347) A monthly maintenance fee $_____ (348) /month

_____ (349) A time and materials arrangement $_____ (350) /month averaged

_____ (351) In-house personnel _____ (352) number

_____ (353) No charge

36. How would you rate the overall quality of the maintenance you receive? Please rate on a scale of 1 to 10, where 10 is superior and 1 is completely inadequate.

Hardware _____ (354) Software _____ (355)

If less than 4, comment. (What has the vendor promised to do that he is not doing?)

_______________________________________________

_______________________________________________

_______________________________________________

37. What levels of response are you presently receiving for the following maintenance characteristics?

| | Actually Experienced | | Minimum Acceptable | |
|---|---|---|---|---|
| | Hdwre | Sftwre | Hdwre | Sftwre |
| a. Mean time to respond (hours) | 356 | 357 | 358 | 359 |
| b. Mean time to repair (hours) | 360 | 361 | 362 | 363 |
| c. MTBF (hours) | 364 | 365 | 366 | 367 |
| d. Percent uptime (%) | 368 | 369 | 370 | 371 |

38. What percent of the total purchase decision for future CAD/CAM systems will be based on the quality of maintenance service a vendor provides?

______%
372

## VII. CAD/CAM SUPPORT OF BUSINESS GRAPHICS

### 39. COMPUTER BUSINESS GRAPHICS

a. Please rate the importance of CAD/CAM as the basic capability that allows an extension into computer business graphics, now and in 1986. Please rate on a scale of 1 to 10, where 10 is most important and 1 is not important at all.

| | 1981 | 1986 | Don't know |
|---|---|---|---|
| Rating | ____ 373 | ____ 374 | ____ 375 |

b. Is your company using computer business graphics today? If not, will business graphics be in use in 1986?

| | 1981 | 1986 |
|---|---|---|
| Yes | 376 ____ | ____ 377 |
| No | ____ | ____ |

CATALOG NO. XCAD

# MECHANICAL VENDOR OUTLINE

I. GENERAL

II. MARKET GROWTH

III. TECHNOLOGY ISSUES

IV. PRODUCTIVITY IMPROVEMENTS

V. SOFTWARE

VI. CAD/CAM INTEGRATON

VII. MAINTENANCE

CATALOG NO. X C A D

I. GENERAL

1. For the purpose of this study, INPUT defines "CAD" as the utilization of computer aids for graphics, analysis, simulation, modeling requirements, documentation and configuration control in the support of the design function. "CAM" is defined as the utilization of computer aids in the linkage of outputs from design into the manufacturing process through direct control of numerical control equipment, documentation to aid N/C programmers, bills of material, quality control and the mutual exchange of data between manufacturing and design requirements.

2. What type of CAD/CAM systems, services, or software do you offer?

| TYPE | PROVIDED (X) | RATING | |
|---|---|---|---|
| | | 1981 | 1986 |
| a. Standalone turnkey system | 10 | 11 | 12 |
| b. Integrated system tied to data base | 13 | 14 | 15 |
| c. Software for in-house host system | 16 | 17 | 18 |
| d. Remote computing services | 19 | 20 | 21 |
| e. Independent CAD/CAM software packages | 22 | 23 | 24 |
| f. Other ______________ 25 | 26 | 27 | 28 |
| g. Other ______________ 29 | 30 | 31 | 32 |

Please rate the above type of systems with respect to what you believe will be the most dominant method of delivering CAD/CAM capability, now and in 1986. Rating on a scale of 1 to 10, where 10 is most prevalent method and 1 is least prevalent method

Comments: ______________________________

______________________________

3. Will you please send a copy of your latest product/services literature and price list to:

INPUT
2471 East Bayshore Road, Suite 600
Palo Alto, CA 94303

4. Will you please furnish us with a list of your users?

5. What percentage of your products/services do you sell directly to end-users?

33 _______%

CATALOG NO. XCAD

II. MARKET GROWTH

6. What is the distribution of your installed CAD/CAM systems in the U.S.A. for the following applications:

| APPLICATION | 1981 | 1986 |
|---|---|---|
| ELECTRONIC | 34 ______ % | 35 ______ % |
| MECHANICAL | 36 ______ % | 37 ______ % |
| CIVIL/STRUCTURAL | 38 ______ % | 39 ______ % |
| MAPPING | 40 ______ % | 41 ______ % |
| OTHER ______________ | 42 ______ % | 43 ______ % |
| | 100 % | 100 % |

7. What is your presently installed base of CAD/CAM systems today.

| APPLICATION | NUMBER OF SYSTEMS/ SERVICES | $ VALUE OF SYSTEMS/ SERVICES |
|---|---|---|
| ELECTRONIC | 44 | 45 |
| MECHANICAL | 46 | 47 |
| CIVIL/STRUCTURAL | 48 | 49 |
| MAPPING | 50 | 51 |
| OTHER 52 ______________ | 53 | 54 |
| TOTAL | 55 | 56 |

8. In your opinion, what will be the average annual growth rate (AAGR) for dollars spent on CAD systems and services in the U.S. between 1981 and 1986.

| | AAGR |
|---|---|
| Electronic 57 | ____% |
| Mechanical 58 | ____% |
| Civil/Structural 59 | ____% |
| Mapping 60 | ____% |
| OVERALL 61 | ____% |

Comments: 62 ______________________________

______________________________

______________________________

9. For your product/service segment, what share of the market do you have/expect to have?

Present share 63 ____% 1986 share 64 ____%

10. What is the average cost per workstation for your system?

65 $____ K's 1981 66 $____ K's 1986

11. What is the average cost per hour per terminal for use of the system?

67 ____ $/hr/terminal 1981 68 ____ $/hr/terminal 1986

12. Please rate the importance of the following benefits of CAD in cost justifying the system. Rate on a scale of 1 to 10, where 1 is not important and 10 is of vital importance.

| Benefit | Rating |
|---|---|
| a. Productivity improvement due to cost savings. | ______ 1M |
| b. Design quality (better product) | ______ 2M |
| c. Designs cannot be done without CAD/CAM | ______ 3M |
| d. More efficient plant loading | ______ 4M |
| e. Manufacturing efficiency | ______ 5M |
| f. Employee morale | ______ 6M |
| g. Better field maintainability | ______ 7M |
| h. Other ______________________ | ______ 8M |
| i. Other ______________________ | ______ 9M |
| j. Other ______________________ | ______ 10M |

13. Who are your top three competitors today and in 1986. Please rank in order from 0 to 1, with 1 being foremost competitor.

| COMPETITOR (NAME) | RANK |
|---|---|
| 69 | 70 |
| 71 | 72 |
| 73 | 74 |

Comments: 75 ____________________________________________

____________________________________________

____________________________________________

CATALOG NO. XCAD

## II. TECHNOLOGY ISSUES

14. What display terminal technology best serves your applications needs today and in 1986. Please rate on a scale of 1 to 10, where 10 is far exceeding application needs and 1 is totally inadequate for application needs.

| TYPE | RATING 1981 | RATING 1986 |
|---|---|---|
| STORAGE TUBE | ___ 76 | ___ 77 |
| REFRESH: | | |
| VECTOR STROKE (Calligraphic) | ___ 78 | ___ 79 |
| RASTER SCAN | ___ 80 | ___ 81 |
| HYBRID | ___ 82 | ___ 83 |

b. In rating the types of display, considering the ability of the display to meet your application needs, how important are memory requirements? Please rate on a scale of 1 to 10, where 10 is very important and 1 is not a consideration at all.

| | 1981 | 1986 |
|---|---|---|
| Rating | ___ 84 | ___ 85 |

c. How important is price in the decision to select a particular display terminology?

| | 1981 | 1986 |
|---|---|---|
| Rating | ___ 86 | ___ 87 |

d. What major changes in display terminals do you expect over the next 5 years, and why will the changes come about?

______________________________ 88

______________________________

______________________________

15. How important is the use of color in workstation display for the following applications? Please rate on a scale of 1 to 10, where 10 is of paramount importance, and 1 is not important at all.

| APPLICATION | RATING | |
|---|---|---|
| | 1981 | 1986 |
| Electronic Design | 89 | 90 |
| Mechanical Design | 91 | 92 |
| Civil Engineering | 93 | 94 |
| Mapping | 95 | 96 |

16. What response times are users of your systems generally experiencing?

97 ______ seconds

b. Is this adequate?

98 Yes _____ No _____

c. If no, what are the requirements?

99 _______ Seconds

d. Comments:

100 ____________________________________________

____________________________________________

____________________________________________

17. For CAD/CAM design applications, which application input devices are most likely to be used in 1986 systems? (List percent of installations using these devices)

light pen _____%101 joystick/ball _____%102

keyboard _____%103 tablet _____%104

touch panel _____%105 digitizer _____%106

touch recognition _____%107 other _______________108 _____%109

18. What will be the prevalent system architecture now and in 1986. Please rank in order of relative importance from 1 to 10, where 1 is most important.

| CONFIGURATION | RANK ORDER | |
|---|---|---|
| | 1981 | 1986 |
| A. CPU AND GRAPHICS PROCESSOR CO-RESIDENT WITH THE WORK-STATION | _____110 | _____111 |
| B. CENTRAL MAINFRAME HOST AND REMOTE GRAPHICS PROCESSOR | _____112 | _____113 |
| C. DISTRIBUTED SYSTEMS | _____114 | _____115 |
| D. REMOTE COMPUTING SERVICES | _____116 | _____117 |

19. What are the cost effective balances of intelligence between terminal, local processor and central processor:

Now 118 ______________________________

______________________________

______________________________

And in 1986 119 ______________________________

______________________________

______________________________

Comments: 120 ______________________________

______________________________

______________________________

20.a. Do you offer end-user training on your CAD/CAM system?

Yes _____ No _____ 121

b. How long does it take to train a new user to:

1. Initial use _____ weeks 122

2. Complete proficiency _____ weeks 123

## IV. PRODUCTIVITY IMPROVEMENTS

21.a. What percent productivity improvements do users expect from your system?

_______% 11M

b. Overall, what percent productivity improvement has the CAD/CAM system provided over previous methods?

_______% 12M

c. How do users measure productivity gains associated with CAD/CAM implementation?

13M ______________________________

______________________________

______________________________

______________________________

______________________________

22. For which components of the product development cycle does the CAD/CAM system provide the most productivity gain?

| | | Percent of productivity gain | |
|---|---|---|---|
| a. | Design | _______% | 14M |
| b. | Drafting | _______ | 15M |
| c. | Engineering Analysis | _______ | 16M |
| d. | Production planning | _______ | 17M |
| e. | N/C programming | _______ | 18M |
| f. | Documentation | _______ | 19M |
| g. | Configuration control | _______ | 20M |
| h. | Other (specify) _______ 21M | _______ | 22M |
| | TOTAL | 100 % | |

23. In what fields have improvements in productivity been the greatest? Please rank order on a scale of 0 to 1, where 1 is the greatest improvement.

| FIELD | RANKING |
|---|---|
| ELECTRONIC | ______124 |
| MECHANICAL | ______125 |
| CIVIL/STRUCTURAL | ______126 |
| MAPPING | ______127 |

## V. SOFTWARE

24. What application software do you currently offer for your turnkey CAD systems? (Please list by name and give end-user's purchase pricing)

Electronic 128 ______________________________

______________________________

______________________________

Mechanical 129 ______________________________

______________________________

______________________________

Civil/Structural 130 ______________________________

______________________________

______________________________

Mapping 131 ______________________________

______________________________

______________________________

25. What do you believe the major new software developments will be in 1986?

a. System software 132 ______________________________

______________________________

______________________________

b. Application software 133 ______________________________

______________________________

______________________________

26. Will independent software vendors have any impact upon CAD systems during the next several years?

Yes _____ No _____ 134

Rated on a scale of 1 to 10, how important are these vendors to the future of CAD/CAM systems?

_____ Rating 135

Comments: 135 _____

27.a. What impact, if any, will government-funded software development have on industry software developments? Please rate on a scale of 1 to 10, where 10 is a major impact and 1 is of no importance.

_____ Rating 23M

b. What software development programs are you aware of that have been sponsored by the U.S. Federal Government?

24M _____

c. Between the National Bureau of Standards' ANSI standard (Initial Graphics Exchange (IGES)), and the SIGGRAPH-CORE standard, which do you feel will become the final standard?

| IGES | SIGGRAPH-CORE | COMBINATION OF BOTH |
|---|---|---|
| ☐ | ☐ | ☐ |
| 137 | 138 | 139 |

Comments: _____

28. How likely is it that CAD/CAM systems will render conventional manufacturing drawing obsolete?

1 - 10

1 = impossible
5 = 50/50 chance
10 = absolute certainty

1983 ______________________ 25M

1986 ______________________ 26M

1990 ______________________ 27M

## V. CAD/CAM INTEGRATION

### 29. STATUS OF CAD/CAM INTEGRATION

a. How far has industry progressed toward CAD/CAM integration now, and how far do you expect it to be in 1986? Please rate on a scale of 1 to 10, where 10 is completely integrated systems and 1 is no progress at all.

| | 1981 | 1986 |
|---|---|---|
| Rating | ______ 140 | ______ 141 |

b. To your knowledge, what results have actually been obtained towards integrating CAD and CAM?

142 ______________________________________________

______________________________________________

______________________________________________

CATALOG NO. X C A D

30. What will be the requirements for design data and manufacturing operations data to be integrated to CAD data files. Please rate on a scale of 1 to 10, where 10 is absolute and 1 is not required.

Rating ______ 1981 ______ 1986
28M 29M

31. What engineering and manufacturing functions are most likely to utilize an integrated data base for CAD/CAM first in the mechanical industries? Please rate on a scale of 1 to 10, where 10 is most likely and 1 is very unlikely.

design _____ 30M

assembly _____ 31M

drafting _____ 32M

test and inspection _____ 33M

planning and control _____ 34M

materials handling _____ 35M

fabrication _____ 36M

other (specify) _____________ 37M

_______________________________

Comments: 38M _______________________________________________

_______________________________________________________________

_______________________________________________________________

_______________________________________________________________

32. How will the trend towards engineering and manufacturing data base integration change organizational responsiblity in:

a) design engineering 39M ______________________________________

_______________________________________________________________

b) production planning and control 40M __________________________

_______________________________________________________________

c) factory operations 41M ______________________________________

_______________________________________________________________

d) traditional DP functions 42M _________________________________

_______________________________________________________________

33. Please rate the following in terms of their being an obstacle to an integrated CAD/CAM data base. Please rate on a scale of 1 to 10, where 10 is a very large obstacle and 1 is no obstacle at all.

lack of standards _____ 43M too much complexity _____ 44M

incompatible systems components _____ 45M concern over data securiy _____ 46M

costly implementation _____ 47M organizational conflicts _____ 48M

benefits not proven _____ 49M

other (please specify) __________ 50M _____ 51M

34. Will distributed data bases for design engineering data and manufacturing operations data be developed for integrated CAD/CAM installations?

1981 Yes _____ No _____ Don't know _____ 52M

1986 Yes _____ No _____ Don't know _____ 53M

## VII. MAINTENANCE

35. Do you offer hardware maintenance through:

_____ 143 A monthly contract $_____ 144 /month

_____ 145 A time and materials arrangement $_____ 146 /month averaged

_____ 147 Contract with third party

_____ 148 Do not offer hardware maintenance

_____ 149 Other (please specify) 150 __________

__________

36. Is the software supported through:

_____ A monthly maintenance fee $_____/month
151 152

_____ A time and materials arrangement $_____/months averaged
153 154

_____ No charge
155

_____ Do not offer software maintenance
156

_____ Not applicable to our products/services
157

_____ Other (please specify) 159 _____________________________
158

_____________________________________________

37. How would you rate the overall quality of the maintenace you provide? Please rate on a scale of 1 to 10, where 10 is superior and 1 is complete inadequate.

Hardware _____ Software _____
160 161

If less than 4, comment. (What do the users request that is not being provided)

162 _____________________________________________

_____________________________________________

_____________________________________________

38. What levels of response are you presently providing for the following maintenance characteristics?

| | Actually Experienced | | Minimum Acceptable | |
|---|---|---|---|---|
| | Hdwre | Sftwre | Hdwre | Sftwre |
| a. Mean time to respond (hours) | 163 | 164 | 165 | 166 |
| b. Mean time to repair (hours) | 167 | 168 | 169 | 170 |
| c. MTBF (hours) | 171 | 172 | 173 | 174 |
| d. Percent uptime (%) | 175 | 176 | 177 | 178 |

39. What percent of the total purchase decision for future CAD/CAM systems will be based on the quality of maintenance service a vendor provides?

_____ %
179