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DEFENSE SYSTEMS MANAGEMENT COLLEGE

PROGRAM MANAGEMENT COURSE
INDIVIDUAL STUDY PROGRAM

INTERACTIVE COMPUTER GRAPHICS
APPLICATIONS
for
PROGRAM MANAGEMENT

STUDY PROJECT REPORT
PMC 76-2

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DEFENSE SYSTEMS MANAGEMENT COLLEGE

STUDY TITLE: INTERACTIVE COMPUTER GRAPHICS APPLICATIONS FOR PROGRAM MANAGEMENT

STUDY PROJECT GOALS: Three specific research objectives were established to limit the scope of this project:

1. To identify off-the-shelf interactive computer graphics hardware and software which can be used in managerial applications.
2. To determine how interactive computer graphics is being used in industry for managerial purposes.
3. To derive implications concerning potential use of interactive computer graphics for management functions.

STUDY REPORT ABSTRACT: PURPOSE: To determine the current availability of interactive computer graphics systems and components which could be used in support of DOD major weapons system acquisition program management planning and control activities. RESEARCH METHODOLOGY: Survey of literature and telephone interviews. CONTENTS: Part I addresses the question: "Why interactive computer graphics?" and underscores the needs of management which this advance in computer technology can fulfill. Part II provides historical insight to the current status of interactive graphics in terms of systems developed together with a brief description of the input and output devices most commonly available in systems developed to date. Part III contains examples of how industry is currently using interactive computer graphics to fulfill its managerial needs. Implications for the future of interactive graphics based on developments to date and comments on potential applications in the area of program management planning and control are discussed in Part IV. RESEARCH RESULTS: While the use of interactive graphics is fairly well established in the scientific field, managerial applications are still in an embryonic stage of development. Two reasons for this became apparent. First, there has been a general reluctance on the part of managers, themselves, to become involved in the design of application software. Second, the cost of most computer systems has been too high, in the past, to allow for the acquisition of unproven computer capabilities in the budgets of all but the largest companies. Research results also indicate that the computer industry is placing its emphasis on improvements in hardware technology rather than on software design. Marketing brochures underscore the widespread availability of equipment and a disheartening lack of commercially available business application software. Until management becomes convinced that interactive graphics capabilities can be a practical and economical aid to decision-making and becomes involved in the development of software packages, we will not see rapid and widespread growth in this area. SUBJECT DESCRIPTORS: Interactive Graphics; Information Display Systems; Interactive MIS.

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INTERACTIVE COMPUTER GRAPHICS APPLICATIONS for PROGRAM MANAGEMENT

Study Project Report

Individual Study Program

Defense Systems Management College

Program Management Course

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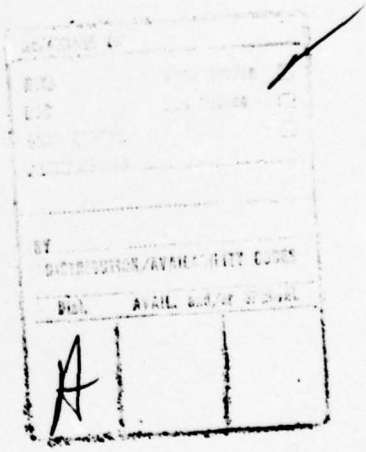

By

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November 1976

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EXECUTIVE SUMMARY

This report presents the findings of a research project conducted at the request of the Defense Systems Management College. The purpose of this research project was to determine the current availability of interactive computer graphics systems and components which could be used in support of Department of Defense major weapons system acquisition program management planning and control activities.

Three specific research objectives were established to limit the scope of this project:

1. To identify off-the-shelf interactive computer graphics hardware and software which can be used in managerial applications.

2. To determine how interactive computer graphics is being used in industry for managerial purposes.

3. To derive implications concerning potential use of interactive graphics for management functions.

Part I of this report addresses the question: "Why interactive computer graphics?" and underscores the needs of management which this advance in computer technology can fulfill. Part II provides historical insight to the current status of interactive graphics in terms of systems development together with a brief description of the input and output devices most commonly available in systems developed to date. Part III contains examples of how industry is currently using interactive computer graphics to fulfill its managerial

needs. Implications for the future of interactive graphics based on developments to date and comments on potential applications in the area of program management planning and control are discussed in Part IV.

The results of research conducted for the purpose of this report indicate that, while the use of interactive graphics is fairly well established in the scientific field, managerial applications are still in an embrionic stage of development. Two reasons for this have become apparent. First, there has been a general reluctance on the part of managers, themselves, to become involved in the design of application software. Second, the cost of most computer systems has been too high, in the past, to allow for the acquisition of unproven computer capabilities in the budgets of all but the largest companies.

Results of the author's research also indicate that the computer industry is placing its emphasis on improvements in hardware technology rather than on software design. Marketing brochures collected during the research effort underscore the widespread availability of equipment and a disheartening lack of commercially available business application software.

Until management becomes convinced that interactive computer graphics capabilities can be a practical and economical aid to decision-making and becomes involved in the development of software packages, we will not see rapid and widespread growth in this area.

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PURPOSE OF THE REPORT

This report presents the findings of a research project conducted at the request of the Defense Systems Management College. The purpose of this research project was to determine the current availability of interactive computer graphics systems and components which could be used in support of Department of Defense major weapons system acquisition program management planning and control activities.

SCOPE OF THE REPORT

Three specific research objectives were established to limit the scope of this project:

1. To identify off-the-shelf interactive computer graphics hardware and software which can be used in managerial applications.

2. To determine how interactive computer graphics is being used in industry for managerial purposes.

3. To derive implications concerning potential use of interactive graphics for management functions.

RESEARCH METHODOLOGY AND REPORT LIMITATIONS

The research effort, as originally structured, would have included the following three steps:

First, a survey of literature on interactive computer

graphics available through the Defense Systems Management College library to develop background information on systems description and historical development.

Second, a survey of at least five major and ten minor computer equipment/software firms by telephone and/or personal interview to develop state of the art data.

Third, a survey of at least ten business firms by telephone and/or personal interview to develop current application data.

Due to the time constraints encountered, it was necessary to forgo the third step in the research effort and to utilize information gathered during the preceding two steps as a substitute. Future student efforts might well focus on step three to round out the usefulness of this research project.

REPORT STRUCTURE

Part I of this report addresses the question: "Why interactive computer graphics?" and underscores the needs of management which this advance in computer technology can fulfill. Part II provides historical insight to the current status of interactive graphics in terms of systems development together with a brief description of the input and output devices most commonly available in systems developed to date. Part III contains examples of how industry is currently using interactive computer graphics to fulfill its managerial needs. Implications for the future of interactive graphics based on

developments to date and comments on potential applications in the area of program management planning and control are discussed in Part IV.

PART I: WHY INTERACTIVE GRAPHICS?

Over the past few decades, the development of computerized management information systems has greatly added to the amount of data made available. However, the use of computer processing has inevitably followed the easily observed rule that paperwork expands in proportion to the ability to generate it, rather than the ability to utilize it. Who has not wished, when pouring over thick reports, that he could command the information system to give him answers as fast as the job of managing gives him questions? The tremendous output of the high-speed computer has far outstripped the modern manager's ability to examine, absorb, and use all the available data in his day-to-day decision making. Obviously, data must be presented to decision makers in some readily comprehensible form if it is to be useful.

Interactive computer graphics is a medium that offers a new way of examining, handling, and communicating data. It is a new way of developing information. Far from being a management frill or gimmicky aid to decision making, interactive computer graphics makes it possible for executives to attain an interpretation and understanding of data that might other-

wise be impossible to achieve. Computer graphics is a general term referring to the equipment and programs used for visual output rather than the usual high-speed printer output. If the user can control the pictorial display in real-time (the picture changes immediately when so commanded), the system is said to have interactive graphics capability. Most applications of interactive computer graphics are currently to be found in the scientific field; however, many business applications are beginning to appear, especially since third generation hardware has made interaction economically feasible.

The use of interactive computer graphics for business decision making is a relatively new technique whereby an executive creates and analyzes graphs relating to business decisions by direct interaction with a computer that has been programmed to produce data on a visual output screen. The interactive graphics system provides a problem-solving, decision-making, continuous feedback loop where real-time executive participation is needed to complete the information processing cycle. This personal interaction between man and computer overcomes two traditional obstacles to effective decision making:

The deteriorating effect of time on data. The freshness of carefully compiled data deteriorates rapidly with time, so that current decisions often do not result from current data. Nor do raw data become usable intelligence until feedback has been received and analyzed. This can take months in a

traditional management information system--or a fraction of a second with interactive computer graphics. Time has a further debilitating effect when a final decision is to be reached by the process of eliminating all other alternatives. Only when the decision is made and implemented can one answer the question: "What if we had done something else?" But, by then it is too late. The simulation techniques available through interactive computer graphics can provide realistic answers to the alternatives before any decision is made.

The lack of opportunity for private reflection by the decision maker. The term "private" refers to the climate in which the intuitive insights of the executive can be brought to bear on the implications of quantitative data. The executive needs a quiet method whereby he alone can anticipate, develop, and test the consequences of following various of his intuitive hunches before publically committing himself to a course of action. When he can do this, he develops a confidence born of the ability to test a decision before implementing it. In the privacy of his own office, an executive can experiment on a computer display screen with operating graphs that represent business decisions about sales, prices, inventory, and production. (7:121-2)

The system that converts quantitative data into graphs consists of a display console attached to a digital computer capable of receiving, storing, and retrieving large amounts of data. The display console is an input/output device that

provides two-way communications between the man and the computer. The console contains a TV-like display screen and an alphanumeric keyboard to enter information. The screen is linked to a central computer programmed so that when the executive indicates the changes he desires, the computer revises the graphs immediately. Changes may also be made with a light pen which is a hand-held accessory device used by the executive to point to a particular area of interest on the display. Touching this area with the pen allows instructions to be input which cause the performance of new computations relative to the chosen area of interest and the production of a revised display--a decision that is a result of the joint efforts of man, program, and machine. Through this interactive technique or "conversation" with the computer, the decision maker tests his intuitive judgement by simple analysis of quantitative data and develops confidence in his decision, knowing that he has rationally considered all alternatives and selected the best one. The technique can also facilitate and speed discussion in small groups of executives because they can order up and revise current data with a minimum of effort. (7:123-4)

The interactive graphics display concept goes a long way toward bridging the communications gap between the user and the computer. The computer does not replace executive judgement, but rather enhances it by providing immediate feedback to intuitive questions about the operations of the

business. The advantages of interactive computer graphics include:

1. On-hand control during program execution.

2. A decrease in the calendar time to complete the decision making cycle due to the immediate visual display of results as they are being computed.

3. Reduced computer run time by being able to interupt diverging processes.

4. The evaluation of many alternatives during one session at the console by taking a quick look at various "what-if" situations.

5. The ability to test alternatives in private or to call in a team of people to participate in the real-time decision making process. (11:21)

In short, rather than submitting data for batch processing and having to wait for the results, the user can input and output desired data by means of the display console. Input and output can be displayed in user defined format which may be alphanumeric or pictorial. The user is placed in the loop to monitor the process and is also given control to interrupt, manipulate, or modify it. Real-time data becomes real-time information.

PART II: HOW WE GOT WHERE WE ARE

HISTORICAL DEVELOPMENT

Interactive computer graphics has been with us since the early 1960's when Doctor Ivan E. Sutherland developed "Sketchpad," the first interactive system for computer aided design. During the gradual evolution of computer graphics technology which followed, there have been various shifts of interest among those involved in interactive graphics systems development.

Originally, the principal concern was to develop the interactive graphics system capabilities to the point where they could perform a useful task. That point was reached in the mid-1960's when graphics systems were introduced into the automobile and aircraft industries for use in computer aided design by such companies as General Motors, Lockheed, McDonnell-Douglas, and Boeing. Once these systems had demonstrated that interactive graphics was indeed useful, interest shifted towards reducing the cost. Many graphics system designers believed that time-sharing offered the cheapest approach to interactive computing. Their initial approach was to modify operating systems originally designed for teletypewriter terminals. However, graphics systems tended to be very complex and depended on expert programmers to write the application programs. As a result, very few really successful time-shared graphics systems were built. The interactive graphics systems that were successful tended to be

based on large, expensive, and specialized hardware with application programs written for specific users. Experimental and operational systems were developed for use in such areas as university research, design automation, simulation, seismic data analysis, molecular analysis, medical treatment research, process control, and text processing. Use of interactive graphics in business applications during the period was virtually non-existent.

By the late 1960's, computer manufacturers began to realize the economic and technical potential of the interactive graphics market and more readily supported graphics requirements in their hardware design. In addition, hardware costs came down as computer memory technology advanced, resulting in the emergence of smaller and faster machines. This was essential for the widespread use of computer graphics since interactive displays require large amounts of cheap processing power to perform picture transformation.

Since the early 1970's, we have seen the development of interactive graphics systems that combine hardware, software, and service from a single source. The period 1970, to present has been a new era in both products and customers for interactive computer graphics. The research of the 1960's spawned many new companies that had ideas on how to turn the promise of theories and prototype systems into practical tools. A new type of company has come into being which sells a turn-key system for a given application of interactive graphics.

Representative applications include drafting automation, medical treatment planning, production control, graphic arts, and cartography. Interactive computer graphics, after years of research and development, is now entering a phase in which it promises to become very widely used. The chance for this to happen has been created by a combination of the recent work in computer languages and system design plus the sharp drop in the cost of computing hardware. In the future, we can expect to see more and more use of specialized hardware to provide faster and cheaper interactive graphics systems. Continued development of high order languages will permit easy use of these systems by management and staff personnel who have little or no previous computer knowledge.(4:148)(8:xxvii)(13:50)

INPUT/OUTPUT DEVICES

There are a number of computer driven input and output devices currently available for use in systems which have an interactive graphics capability. The most common are discussed below.

CATHODE RAY TUBE TERMINALS: The cathode ray tube, or CRT as it is called, is the primary output media for interactive computer graphics systems. The cathode ray tube itself is classified into two main types. These are the storage tube and the refreshed scope. The storage tube is a CRT which will retain an image on the screen for approximately an hour or until the image is electronically erased. New information may be added to the image displayed on the screen; however,

generation of the complete display is slow. The storage tube type of CRT usually has a small screen, can be located quite far from a computer, and is relatively inexpensive. Because of its characteristics, it does not occupy the core space of a large computer, but usually does have a mini-computer attached to it.

The refreshed scope is a standard type CRT with a very fast decaying phospher. The image fades within a fraction of a second after being drawn, and unless redrawn at a rate greater than about 24 times per second, will tend to display a flickering image. Flicker may also develop if the information to be displayed is excessive. The amount of display is limited by the power of the graphics processor. The refreshed scope has a large screen, the display occupies core space, and the computer must be fairly close. The cost of these scopes and supporting computer equipment is relatively expensive. However, the cost is overshadowed by the ability to display dynamic phenomena and the ability to change almost any part of the image without erasing the entire picture. Since both types of CRT terminals provide temporary pictures, hard copy output must be obtained from other devices.

PLOTTERS: At the present time there are flatbed, drum, and electronic digital plotters which can operate as either off-line or on-line hardcopy output devices. Flatbed plotters are used for applications where total visibility of the output during the processing is a prime concern. They can be as large

as several feet in each direction and are often used in the manufacturing and building industries. They can also handle a variety of preprinted forms and special materials not practically handled by a drum type plotter.

Drum plotters present computer output data in an uninterrupted manner. Continuous plots up to 120 feet in length are produced on a 12-inch or 30-inch drum by the rotating motion of the drum and the lateral motion of the pen carriage.

The third type of plotter is the electronic digital. These plotters are employed for ultra high-speed plotting and microfilm recording of computer output data. They operate on the same basic incremental principle as the ink-on-paper plotters described above. The plot is generated electronically on the screen of an 8 x 10 inch CRT and automatically recorded on microfilm or paper.

COMPUTER OUTPUT TO MICROFILM: Due to the paper shortage and corresponding mushrooming cost of paper, computer output to microfilm (COM) has become very popular. The system of the microfilm recorder is a peripheral one which processes a specially coded magnetic tape obtained as output from a computer program to produce graphical, pictorial, or alphanumeric output. The equipment offers a choice of 16mm, 35mm, 70mm or 105mm film in single exposure or movies. Output from microfilm recorders can be stored in less space than any other form of computer output, thus saving storage space. Many COM

recorders can produce paper copies as well. (10:44-6)(12:52-6)

GRAPHIC INPUT DEVICES: Input devices used to change the graphic and/or alphanumeric output displayed on the CRT may be integral to the CRT terminal itself or available as an accessory. The most common types of input devices are keyboards and cursors. A keyboard can be used to input alphanumeric information to the display or, through the use of special function keys, modify a designated portion of the graphic image when depressed. Cursors are lines, usually one vertical and one horizontal, which appear on the CRT display and which can be moved across the face of the screen by turning two control dials or a single "joystick." The computer driving the CRT unit can be programmed to move an object around on the screen in response to the movement of the cursors. Light pens are also available which provide several methods for communicating with the computer. In one case, the computer is programmed to move objects around on the CRT screen in response to the light source in the pen. In another, the light pen can be used to create images by drawing directly on the display screen. A light pen used in conjunction with menus displayed on the screen is a third method which allows the user to pick and choose among the various sets of data for further analysis and display. Graphic inputs can also be generated on the CRT through the use of a graphic tablet which allows one to trace a paper drawing into the computer's memory. (2:86)

SYSTEMS CONFIGURATION

It is difficult to establish catagories for interactive computer graphics systems by mode of operation. Rather, the modes can be represented by a continuum. At one end is the user who communicates with a remote computer using only a storage CRT terminal. This user pays a little over $200 per month for the rental of the terminal and can perform only relatively simple graphics applications because of the data transmission limitations of telephone lines. A reasonably complex picture, for example, can take over ten minutes to generate if sent over voice-grade telephone lines. The leading manufacturer of the storage CRT is Tektronix, which has over 10,000 terminals in the field representing a little less than 90% of the total market. Uses encompass just about every application, but can be approximated as 75% scientific and 25% business. Many of the business applications are provided by time-sharing companies which not only support the storage CRT, but offer valuable econometric data bases as well.

At the other end of the spectrum are state of the art refresh-type systems consisting of sophisticated self-contained, stand-alone units, with three-dimensional and color graphics capabilities. These single station systems contain a large processor and are capable of continuous dynamic motion, zooming, perspective generation, and other

functions. The costs of the display processors alone usually start in excess of $125,000. The leading manufacturers of state of the art systems are Evans & Sutherland, Adage, and Vector General. Together there are probably less than 200 such systems in use. Because of their unique capabilities and high price, most are used for basic research, modeling and simulation, and to an increasing degree, for computer aided design applications.

Somewhere in between these two extremes lie one of the more successful recent developments in the computer graphics industry--the minicomputer based integrated turnkey system. The typical system will cost approximately $125,000, and consists of a graphics input station (digitizer, tablet, function keys, joystick or keyboard), an output station (flatbed, drum, electrostatic plotter or microfilm recorder), an interactive CRT work station, a large secondary mass memory (disc, tape or drum) for storing large data bases, the minicomputer, and, in come cases, a communications interface to a remote processor. Software for turnkey systems include both systems and applications capabilities for at least two-, and sometimes three-dimensional, graphics data bases. Although the hardware varies greatly from system to system, they are all alike in that both hardware and software support is provided by the same company. There were about 500 such systems in operation at the end of 1975. Of these, almost half were sold during that year. It is estimated that

by 1980, the number of systems in use will have doubled. The systems are currently produced by about a dozen firms with Computervision, Applicon, and Calma reportedly sharing over 75% of the market. Most of these systems are used for applications relating to electronics (75%), drafting (15%), and cartography (5%), with architecture, engineering, plus university and government research making up the remaining 5%.(13:50-3)

PART III: WHERE ARE WE, REALLY?

The direction which the business community is currently taking in the use of interactive computer graphics is exemplified by Gould, Inc., a Chicago-based company, with sales of $1.3 billion. Gould has recently installed a system to aid top-level decision makers which combines a large computer-driven display screen with a computerized management information system. Information on everything from inventories to receivables taken directly from the computer is displayed in an assortment of charts and tables which make comparisons easy and lend instant perspective. Individual CRT terminals will eventually be installed in offices of managers both at corporate headquarters and in the field. A manager will then be able to tap three-digit codes into a 12-button box resembling the keyboard of a telephone. "SEX" will get him sales figures. "GIN" will call up a balance sheet. "MUD" is the keyword for inventory. About 75 such catagories will be

available, and the details will be displayed for the company as a whole, for divisions, for product lines, and for other breakdowns, also specified by simple digital codes. In the near future, the system will automatically show significant deviations from operating plans to facilitate management by exception. Ultimately, directors and executives will be able to ask "what if" questions and to see the anticipated consequences of various alternatives.

Gould, Inc. was able to link its elaborate display to its data base because it already had spent considerable effort in fine-tuning its reporting system. Gould has rebuilt the charts of accounts for each of its operations, which range from its original battery business to electronics and metallurgy, so that financial data are correlated among all divisions. Eight years ago, when sales were $115 million and earnings $2.8 million, top executives made do with monthly summaries of such factors as sales, backlogs, receivables, and payables for each operation. Before installation of the new system, with sales at $891 million and earnings at $45 million, these summaries began coming out weekly instead of monthly. Now, with the new system, the information will be available instantaneously, either on CRT screens at various Gould offices or on the big 4 x 5.5 foot screen in the boardroom.(3:65)

Computerized management information and decision-making systems, such as the one used by Gould, Inc. include software produced by companies like Tektronics and IBM. The "Plot-10/

Decision-Maker," for example, is a business graphics software package marketed by Tektronics since mid-1973. It is a conversational, graphics assisted system with applications in corporate planning, production scheduling, investment portfolio management and other management areas. This system took two years to develop and was designed to meet the following seven major objectives:

1. Ease of use--not just a conversational, one-step-at-a-time system, but one that actually lets the user know what his choices are.

2. Availability of different analysis modes, to be combined at will.

3. Liberal use of graphing for ease of comprehension.

4. Ease of interfacing with the user's own routines.

5. A work-file structure to facilitate saving and recalling results.

6. Extensive report generation capabilities.

7. Absolutely no programming requirement for the user.

The company reports that Plot-10 has met all seven objectives and is available for use on computers manufactured by several companies at nominal rates. (14:n.p.)

"TREND ANALYSIS 370," expected to be ready this fall, will be the fifteenth software package that IBM has developed in the past five years for management information systems and the first capable of producing color graphs. IBM has worked for a period of nearly four years with First Chicago Corporation to

construct an executive information system which will serve as a prototype for the Trend Analysis 370 package. Much of that time was spent analyzing the information that First Chicago executives asked for and how they asked for it. The resulting system, which has been tested for a year at First Chicago, provides easy access to large banks of data in forms that executives can use and permits fast comparisons of different sets of data. It can store everything from Federal Reserve data on all banks to economic statistics on various industries as well as information on First Chicago's own customers.(3:65-7)

Software packages previously made available by IBM include IMS (Information Management System) used by such companies as Diamond Shamrock inthe chemical industry. The Diamond Shamrock system can process a customer's order from its receipt to authorization for shipment in 15 minutes. This includes a credit check, scheduling, product rating, and routing. With this system, an order received at a Diamond regional sales office in the morning can be shipped the same afternoon and billed that evening--a big plus for service and cash flow. Diamond's experience with the system is an indication of what can be expected. In early 1972, there were two large-scale computer systems in operation at the company's Cleveland data center. Now, with only one computer, an IBM System 370/Model 158, the company has expanded data processing and reduced average monthly computer processing time. In the previous batch processing system, there were 24 visual display

units and 40 hard copy terminals linked to the computer center. Now, 60 display units and 100 hard copy terminals are on-line. In 1974, the firm announced that it was implementing an on-line financial information system which would automatically handle all upper-level accounting on a company-wide basis. This additional system would include provision of interactive CRT display consoles which would allow corporate and division officials to obtain instantaneous information on the current financial situation such as expenses vs. budget, revenues vs. goals, and profits vs. plan. Future expansion plans, announced at that time, would also provide production management with information needed to plan, schedule, and control production. (9:38)

Many computer industry companies which initially produced interactive graphics systems solely for the scientific community are now expanding their systems' capabilities to include other applications. For example, the management information system used by D.W. Phillips International and Westinghouse Electric Corp. are based on the Information Display, Inc. produced "IDDIOM"--a complete interactive graphics display system which can be used for such applications as computer aided drafting and design, computer assisted instruction, simulation, on-line process control, management information, command and control, information retrieval, human factor studies, and medical research. (5:n.p.)

D.W. Phillips International manages 24 subsidiaries with over 1,400 retail outlets in 17 countries. Such an operation

could become top heavy with managers and submanagers. Phillip's goal, however, has been to maintain aggressive international growth while keeping its profits high by cutting the management overhead through more effectiveness. One measure of the success of this approach is that with sales of over $24 million and an annual growth rate exceeding 25%, the company still averages less than one general management executive per country. An early decision by Phillips International was to separate the management communications system from the normal data processing flow. The concept was that the information needed for a human decision differs sharply from the data required for a computer decision. The emphasis is therefore on interactive visual displays that will allow the managers to grasp the problem (or opportunity) at a glance and to work directly with the computer by light pen. Equally important, the system incorporates a method for recording and communicating the decision making process. Primary communications between management centers is via video tape. The tape carries a recording of the basic discussion that led to each decision and illustrates any charts, graphs, or other graphic display used during the discussion. At the central headquarters, where key decisions evolve, a minicomputer marshals the information stored in the computer together with that stored in system data banks. In most cases, these "data banks" consist of microfiche records, 35mm slides, and previous video tapes. All of these can be extracted, on demand, and viewed on appropriate

display equipment. One of these is an interactive display that allows executives to adapt the data to various production, inventory or marketing strategies and gives the manager an immediate prediction on the likely effect of a new policy decision. While this is going on, a video camera is recording the event, and the resulting video tape is mailed to the branch offices that are directly involved.(4:56)

Westinghouse Electric Corporation chose to implement a management information system in a middle-management area that dealt with large amounts of data and required judgement and computation in decision making--monthly sales forecasting and production scheduling for one of their major appliance products--the Laundry Division. In the Westinghouse application, all parameters of the problem are initially presented to the manager in the form of a light pen menu. By pointing the light pen at the information on a CRT, the manager can choose the information content and form he wants displayed. The display data can be manipulated by light pen and keyboard. In this way, the manager conveniently moves back and forth within the data base, asking "what if?" and making decisions. Although the data is computer generated, it is presented in a form with which the manager is intimately familiar. He need not learn a new language in order to communicate with the computer and the response from the computer is fast enough so that he does not forget the original "what if" question. Westinghouse concludes that the system is a practical tool and

the prototype of future manager-computer interactive systems for planning and control activities.(4:56-8)

The forgoing examples of interactive graphics applications in business are typical of the manner in which large companies, with their own computer facility, have taken advantage of graphics capabilities currently available. Smaller companies can also have access to the potential of interactive computer graphics through time-sharing services companies.

"PLOT***" is an interactive business graphics package available on the General Electric Information Service Business Division's MARK III time-sharing network. "PLOT***" uses simple English commands to generate a variety of graphic outputs to include line graphs, bar graphs, and scatter diagrams. The package can be run with customer supplied data, but is also designed to interface with General Electric's "FAL II"--a financial analysis language. Elimination of the time consuming job of manual preparation of graphs was high on the list of design goals for "PLOT***". The package does not require familiarity with a programming language to use, making it ideal for non data-processing oriented managers. "PLOT***" is used in conjunction with GE's Management Analysis and Projection (MAP) Service which is available in 300 metropolitan areas throughout the world, with the following features:

1. MAPCAST--a multi-part subscription service which provides access to GE's view of the present and future

prospects for the U.S. economy. MAPCAST provides valuable browsing for upper-level managers.

2. MAP data banks--a portfolio of economic, industrial, marketing, and financial data banks which, along with the user's own data files, assists the business manager in evaluating the economic environment, in analyzing his business, in making reasonable assumptions about its future, and in forming sound business strategies. The manager can, for example, compare the GNP with his company's growth rate, compare industry production with that of his own plant's, or current consumer spending patterns with his own marketing data. (14:n.p.)

Boeing Computer Services, Inc. offers "EIS" (Executive Information Service) via its national time-sharing service utilizing IBM System 370 equipment. "EIS" is a financial and program management system which allows the user to interactively access specific data base information to depict status, estimate changes, and forcast results. The Executive Information Services package is designed to solve problems in all areas of financial analysis, budgeting and planning, program management, performance tracking, financial estimating, "what if" gaming, etc. "EIS" resources include a full range of mathematical capabilities, graphics and report writing services, and a number of other special features. Graphics, like all of the other capabilities within "EIS", was developed for use by persons in business and management, not computing.

For that reason, nearly all "EIS" graphs can be created by a single, one line instruction. A large number of options are available with which special graphic effects can be obtained. These include the selection of graphic form, line control, shading, placement on the page, multiple images on a page, control of scaling and labeling, optional grid lines, and stack charts. The following types of graphical output are available: time spread, semi-log, log-log, vertical bar, horizontal bar, pie, and three-dimensional. "EIS" graphics are available on-line through Tektronics terminal equipment. (1:n.p.)

PART IV: IMPLICATIONS FOR THE FUTURE

The results of research conducted for the purposes of this report indicate that, while the use of interactive computer graphics is fairly well established in such areas as computer aided design, medical research, structural analysis, and text editing, managerial applications are still in an embrionic stage of development. Two reasons for this have become apparent. First, there has been a general reluctance on the part of managers, themselves, to become involved in the design of application software. It is imperative that management take the lead in this effort if the real benefits of interactive graphics technology are to be achieved. The lack of time in the manager's schedule and the failure of previous efforts on the part of the computer experts to meet

the needs of real-time decision making work against success in overcoming this stumbling block. Second, the cost of most computer systems has been too high, in the past, to allow for the acquisition of unproven computer capabilities in the budgets of all but the largest companies. The solution to this problem appears to be more readily at hand than the first with the recent precipitous drop in the cost of computing hardware.

Results of the author's research also indicate that the computer industry is placing its emphasis on improvements in hardware technology rather than on software design. Marketing brochures collected during the research effort underscore the widespread availability of equipment and a disheartening lack of commercially available business application software. This is undoubtedly due to the fact that most of the software for interactive graphics applications has been written by the user rather than the equipment manufacturers and the user has been found largely in the scientific community. Until management becomes convinced that interactive computer graphics capabilities can be a practical and economical aid to decision making and becomes involved in the development of software packages, we will not see rapid and widespread growth in this area.

Trends in the computer industry which may ultimately overcome the resistance to managerial involvement include the development of minicomputer based turnkey systems and TV compatable graphics. Turnkey interactive graphics systems of

the future will undoubtedly become smaller, in terms of stand alone capabilities, and less expensive than present systems. New systems will be designed for use with a host computer and will provide general local processing capabilities such as data base creation, graphic editing and interrogation, file formating and the like. (13:53)

While the graphics community has not yet reached a consensus regarding the direction of future technological developments in visual output media, many research and development efforts seem to point to the primacy of raster scan (TV compatable) techniques, which structure data left-to-right and top-to-bottom, as a replacement for the current storage and refresh type CRT's. There are many factors which facilitate movement in this direction: television sets provide a low cost terminal (there are approximately 120 million TV sets in the U.S. of which almost half are color), raster scan video memories are lowering in cost and have low power requirements, and gray tones and color outputs are readily achieved on raster scan displays. Finally, raster scan technology has the potential of merging computer graphics with picture processing technology, thereby making possible the mixing and manipulating of photographic images with computer generated displays. Turnkey interactive graphics systems, when combined with television compatable graphics and when available for under $50,000, will lead to the appearance of entirely new classes of users and applications.(2:87)(13:53)

Given the previously discussed developments in system design and utilization of interactive computer graphics capabilities in industry, what might we expect to see in the development of planning and control application packages to support DOD major weapons systems acquisition program management?

The most obvious and pressing need for development of interactive computer graphics application packages lies in the management information systems employed by program management offices. This need has been recognized and application programs to support cost and schedule performance tracking efforts are in the early stages of development.(15) Other possible application areas abound. A few examples are given below.

Availability of an interactive graphics text editing capability in conjunction with a computerized library of key program management documents would be extremely useful during the early stages in the growth of the program management office when extraordinary demands are placed upon available manpower. Such a system would be an aid in speeding the development of such documents as the systems specification, the program management plan, requests for proposal, source selection plans, contracts, etc. While word processing equipment is currently available from the office machine industry, it is envisioned that an interactive graphics application package would combine the features of on-line

text editing with random access to and display of selected segments of pertinant regulations and previously approved key program management documents stored in a centralized DOD computer facility. The user, working at a terminal in the program office, would be able to call up available samples to take advantage of the "corporate memory". The text editing feature would then allow him to integrate original work with previously used verbage into a document tailored to his particular requirement.

Another possible application might be in the evaluation and structuring of incentive arrangements for multiple incentive cost plus contracts. An interactive graphics application package would be a natural outgrowth of the work performed by the DOD Program Office for Evaluating and Structuring Multiple Incentive Contracts (POESMIC). Program management personnel would then be able to generate instant displays of the impact caused by changing such parameters as target cost, target fee, maximum fee, minimum fee, share ratio, and fee pool allocation. Such an application program would be invaluable prior to and during negotiations with the contractor when going-in and counter-offer combinations could be prepared rapidly for analysis and discussion by the government negotiating team.(6:1-5)

The program manager must often deal with querries as to the impact of changes in the level of program funding, early or late delivery of subsystems or components, and changes in

requirements on his program. Utilizing the capabilities of interactive computer graphics to play "what if" games, he could prepare contingency plans for such potential questions or respond more quickly to "Unk-Unk's". He could, for example, develop a series of curves displaying the probability of certain consequences given one or another set of performance, schedule, and cost objectives. Comparison of these graphic outputs would vividly portray levels of risk inherent in a given set of circumstances.

There are many planning and control applications in which the capabilities of interactive computer graphics could be brought to bear to assist in the management of major weapons systems acquisition programs. Some have direct corollaries in industry, others are unique to the Department of Defense. All require the active interest and participation of program managers and their staffs if meaningful benefits are to be achieved. The efforts of the Defense Systems Management College in this area to date is an indication that the potential for success is present. It is hoped that this report will contribute, in some measure, to that success.

It is strongly recommended that the Defense Systems Management College continue to pursue its research efforts concerning the use of interactive computer graphics in program management planning and control. Particular emphasis should be placed on obtaining information pertaining to business applications currently in use or under development through telephone and/or personal interviews with key management

personnel in industry. Such an effort, conducted perhaps by a student in a future Program Management Course, would add significantly to the storehouse of information being developed on this timely subject.

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