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Interactive Computer Graphics - An Advanced Computer Technology

George V. Yuscavage

Research Engineer, The Boeing Company, Southeast Division

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INTERACTIVE COMPUTER GRAPHICS
AN ADVANCED COMPUTER TECHNOLOGY

George V.J. Yuscavage
Research Engineer
The Boeing Company
Southeast Division
P. O. Box 1680
Huntsville, Alabama 35807

ABSTRACT

Computers have been an invaluable aid as man has grappled with advancing technology. As the computer tool has become more sophisticated, man's ability to master new technologies and applications has been proportionately accelerated. One of the very promising sophistications today is graphics. A research project to:

1. Determine capability and
2. Promote utilization

has been underway at Boeing Huntsville and is the subject of this paper. Reference 1 is devoted to some of the "mechanics" of the program and its operation. This complimentary paper will document the graphics program as an entity, its relationship to the parent organization's function, and some of the details of selected applications.

BACKGROUND

It is of some importance to orient and relate the graphics project. Figure 1 shows the computer work load that was processed by Boeing's central computer facility over the past few years from five locations spread from Houston, Texas to Washington, D.C. The primary mission in all locations was support of NASA's Apollo Program (flight dates are indicated). The tenure of various IBM System 360 units is indicated by the bar chart. In addition to the Model 67 and 65's, that processed the digital workload, the Model 44 supported a hybrid (i.e. with analog) and the 1130 supported the small digital graphics. Another very successful big digital graphics program utilizing a cathode ray tube (2250-III on the 360/65D) is primarily concerned

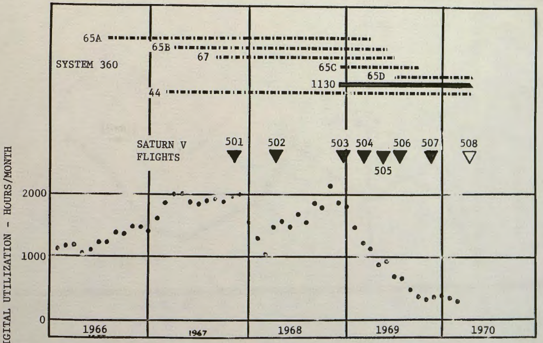

FIGURE 1. BOEING HUNTSVILLE WORKLOAD

with processing flight data and is not included in this paper.

PROGRAM SUMMARY

Figure 2 shows the key milestones and the lengths of time that were required to:

1. Get the system to perform
2. Get potential users introduced to the new capability, educated in its use, and convinced of its merits and finally
3. The duration of its self-sustaining life.

The lower portion of the figure shows the utilization that has accrued as particular applications come and go subject to the demands of the technical community.

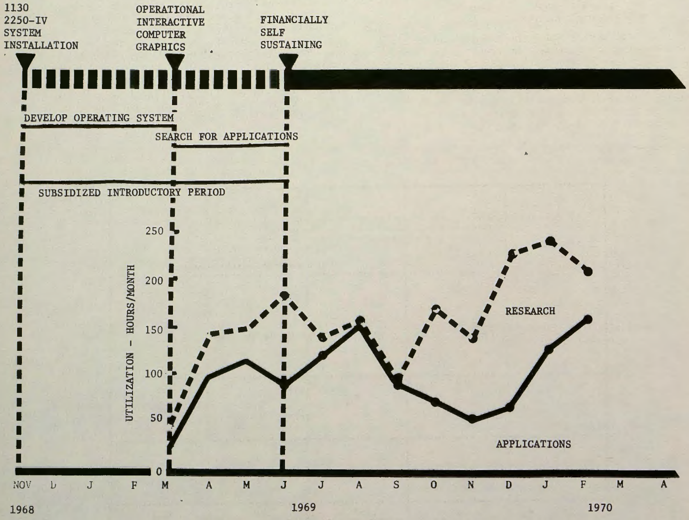

FIGURE 2 GRAPHICS PROGRAM SUMMARY

Because of the wide variety of the computer services available to the user, and because of the wide variety of tasks in which the 4700 or so personnel in Boeing Huntsville were engaged, the search for applications was an arduous undertaking. However, the applications that were successfully garnered, were technically justified and were not "captive" applications without other alternatives. This situation then, produced the experience which led to the belief that small computer graphics was most effective in an environment characterized by:

1. Continuous stream of new problems, involving differing technical disciplines,
2. A pressing need for quantitative data based on perhaps only a partial understanding of the dependent parameters, and
3. A prompt response for initial data, measured in terms of days, rather than weeks or months, (but in most cases refined data is acceptable at later dates).

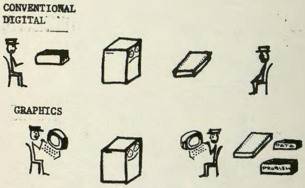

FIGURE 3 GRAPHICS CONCEPT

Of the many different types of activities that were solicited for potential applications, the best response came from the technical staff side of new business activities. Most users who were enthusiastic with the tool, but in the final analysis abandoned the small computer graphics, did so because as knowledge of the problem increased, the size of the problem outgrew the capability of the tool. This sort of difficulty was the subject of additional concurrent research (shown in Figure 2 and identified as research utilization). Some other requirements that were identified during the project:

1. Automatic plotting of documentation quality was required with overnight service
2. Arrange for data filtering of the graphic results (e.g. band pass filter of specified frequencies)
3. Many minor program innovations to aid flexibility or remove constraints.

CONCEPT

To the user, the fundamental differences between conventional digital and graphics are as caricatured in Figure 3. In the former, the user defines his problem and communicates with the computer through the card deck, usually prepared with the assistance of programmers. After processing, the results are returned in the form of a tabulation or listing. When a reprocessing is necessary, the complete cycle is repeated. Depending on workload and equipment, this recycle may be hours or days in duration.

In the case of graphics, a cathode ray tube (CRT) is the means of communicating with the computer. It can accept the problem statement and report back results as soon as processing has been completed. The user prepares the problem statement with the assistance of a conventional typewriter keyboard and a lightpen to call attention to portions of the screen. The cycle time in this case may be measured in minutes, and when satisfactory results are obtained, the calculated data may be prepared as a conventional listing or a deck. The problem statement may also be obtained as a deck for use in a subsequent session.

SOFTWARE

The hardware manufacturer provided with the computer about 54 general purpose software packages that spanned a wide variety of technical disciplines. Only one, the CSMP shown in Figure 4, was originally written with graphics capability. At various times during the project, other parts of the other programs were modified to add graphics, but this was only experimental.

For customized programs, the manufacturer provided a graphics language (Graphics Subroutine Package). The use of GSP and the experimental graphics programming activities mentioned above, are also beyond the scope of this paper. The utilization data on Figure 2 includes only a very minor impact from customized graphics programming, therefore, this paper is similarly

	UNDER EVALUATION	GRAPHIC
1. CONTINUOUS SYSTEM MODELING PROGRAM	X	X
2. SCIENTIFIC SUBROUTINE PACKAGE	X	EXPERIMENTAL DEVEL.
3. STATISTICAL SYSTEMS	X	EXPERIMENTAL DEVEL.
4. PROJECT CONTROL SYSTEM	X	
5. LINEAR PROGRAMMING SYSTEM	X	
6. STRUCTURAL ENGINEERING SYSTEM SOLVER	X	
7. MECHANICAL DESIGN SYSTEM		
8. PROGRAM FOR OPTICAL SYSTEM DESIGN		
9. WORK MEASUREMENT AID		
10. DECLINE CURVE ANALYSIS		
.		
.		
.		
.		
54.		

FIGURE 4 SOFTWARE, GENERAL PURPOSE

restricted to just what was done with CSMP, a general purpose interactive (i.e. graphic) program.

The CSMP was built to offer the following features:

1. Interactive, to minimize the need for programmers
2. Analog format, to allow combinations of predefined blocks to describe the problem
3. Repeatability characteristics typical of digital, and unlike analog
4. Minimum setup time
5. Minimum turnaround (or cycle time), and
6. Inexpensive (compared to a CRT attached to system 360).

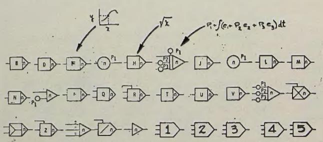

FIGURE 5 CONTINUOUS SYSTEM MODELING PROGRAM BUILDING BLOCKS FOR PROBLEM STATEMENT

Figure 5 shows the assortment of blocks with predefined routines (the lettered blocks) and the special user-defined routines (the numbered blocks). Three typical mathematical operations are shown which are performed by the indicated blocks. The user then, is only required to state his problem in terms of these blocks, properly assemble them, specify constants and conform to some very general limits. No limits exist relative to technology, so all sorts of applications may be accommodated.

APPLICATIONS

A summary of some of the more diverse technical problems (Reference 2) that a modern-day aerospace company must pursue in their search for new business is shown in Figure 6. Graphic CSMP made a contribution, in some degree, to each one. Some examples:

1. Six Degree of Freedom Performance and Control Model is a general purpose tool frequently used for first approximations. It requires the simultaneous solution of 12 differential equations. In most cases, it is a hybrid problem (i.e. analog and digital equipment), but investigators have discovered and cherish the flexibility and quick set up time offered by graphic CSMP. From the block diagram of a typical version shown on Figure 7, it is clear that most problems of this sort press the limit of 75 blocks. While a problem undergoes preliminary investigation, the amount of detail available is often sparse,

VEHICLE CONTROL	FLIGHT MECHANICS	STRUCTURES	PROPULSION	ELECTRICAL ELECTRONIC	MISCELLANEOUS
. 6^D PERFORMANCE & CONTROL (WITH 3 DERIVATIVES)	. ORBITAL ELEMENTS	. DROP TEST	. POGO	. PHASE LOCK LOOP	. AREA COVERAGE CALCULATIONS (WAR GAME)
. 2^D GUIDED MISSILE	. THREE BODY PROBLEM	. FLAT PLATE LOADING		. HIGH FREQ. AMPLIFIER	. ECONOMETRIC (COST OPTIMIZED DESIGN)
. 2^D INTERCEPT		. NON-LINEAR BEAM			. TIMELINE PREPARATION & ANALYSIS
. MARS CONTROL SENSITIVITY		. LUNAR ROVER DEPLOYMENT (WITH 3 DERIVATIVES)			
. RATE FILTER DESIGN SAT V		. SPRING MASS PENDULUM			
. LRV NAVIGATION SYSTEM DESIGN (5 MODELS)		. BOMBLET MOTION ANALYSIS			
		. TRANSPORTATION SHOCK ENVIRONMENT OF SMALL MISSILE			

FIGURE 6 SUMMARY OF SOME OF THE PROBLEMS INVESTIGATORS BROUGHT TO THE SMALL STAND ALONE GRAPHICS SYSTEM

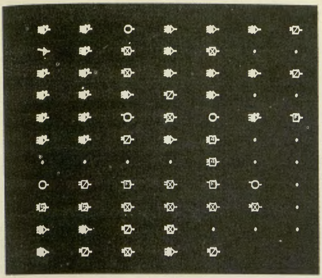

FIGURE 7 CSMP DIAGRAM FOR SIX DEGREE OF FREEDOM PERFORMANCE AND CONTROL MODEL

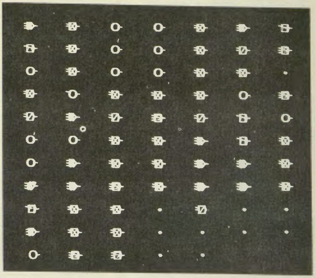

FIGURE 8 CSMP DIAGRAM FOR ORBTIAL ELEMENTS (OE 2)

and this 75-block limit is quite adequate. Many problems never get beyond this preliminary stage. For those that do, elaborate hybrid versions may later be built, but with a prior knowledge of the rudiments of that particular problem obtained from the graphic CSMP work.

2. Lunar Roving Vehicle Navigation System

Very recently a program was initiated to develop a vehicle to assist astronauts on the lunar surface. One of the great technical uncertainties was the sophistication of the navigation system. Cost and development time were at a premium. In very short periods of times, quantitative measures of system effectiveness had to be obtained and evaluated. The investigators chose CSMP graphics for the tool, based on its flexibility to readily accept major changes in the problem statement, and the assurance of quantitative data within minutes. These advantages permitted trial and error approaches to system design; techniques not otherwise acceptable with conventional computer systems.

3. Orbital Elements calculations are for the most part quite standard and laboriously routine. What was required, was a quick, easy, relatively accurate "sliderule". Figure 8 illustrates the most frequently used approach to go from insertion conditions to calculate position, ephemeris and time-dependent parameters. With the predefined routines offered by the lettered blocks of CSMP, most of the available 75 blocks for the problem were filled. This allowed very little additional programming space for the user. Therefore, special Fortran (IV Basic) routines were written and preloaded into the numbered special blocks. The drastically reduced block count

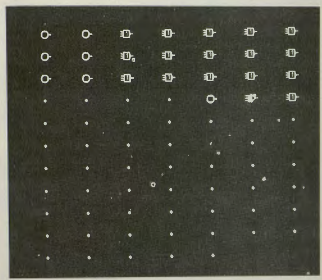

FIGURE 9 CSMP DIAGRAM FOR ORBITAL ELEMENTS USING SPECIAL BLOCKS (OE 4)

in Figure 9 resulted and, accomplishing all the computions done by the Figure 8 block diagram, freed large numbers of spaces for additional user programming involving the orbital parameters.

4. Drop Test Simulation was an investigation to save substantial funds by substitution testing. A massive system (more than half a million pounds) had been scheduled to undergo a very expensive shaker test. To build the facility capable of accelerating and decelerating this mass, in an attempt to simulate a nuclear shock enviornment underground, was a momentous project. One proposal was to substitute a more economical drop test on a frangible mat very carefully designed to duplicate points on the specified shock spectra (i.e. frequency and acceleration curve). Figure 10 shows the model which simulated the relationships between all the primary parameters. This model was used to determine feasibility of the substitution.

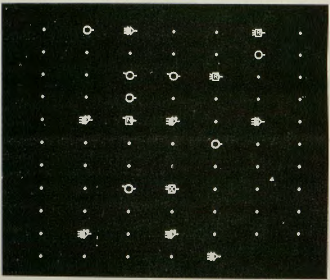

FIGURE 10 CSMP MODEL FOR DROP TEST SIMULATION

5. Lunar Rover Vehicle Deployment from the piggy-back position aboard the spacecraft is a task of great importance. The vehicle is heavily constrained by weight, volume and operational performance limits. Deployment is implemented by a single cable which unfolds the vehicle into its operational configuration. The mathematical model development to verify deployment was subject to the same rigorous cost and schedule constraints. The model's object was to produce the data for design. By selecting graphic CSMP, the model (Figure 11) was ready within several days and offered the necessary flexibility as the primary analytic tool. It proved to be an extremely efficient means of determining design data.

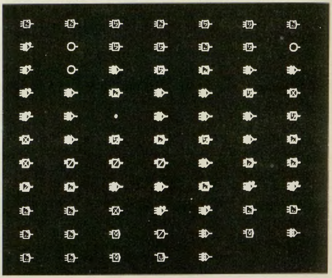

FIGURE 11 CSMP MODEL FOR LUNAR ROVER VEHICLE DEPLOYMENT

6. Timeline Preparation and Analysis is ordinarily a very involved process involving great masses of data. However, to study techniques of scheduling, an objective which requires very limited data, rapid turnaroud and flexibility are much more desirable to the investigator. In this case, a graphic CSMP system was selected for the initial models. These models facilitated: quantitative comparisons of alternative scheduling principles, the acquisition of preliminary input data, and the resolution of basic output problems. One such model involving the random scheduling of experiments to determine the effect on resource requirements is shown on Figure 12. (The blocks are shown tied together with lines to indicate the sequence. The other diagrams omitted the sequence information for the sake of clarity.)

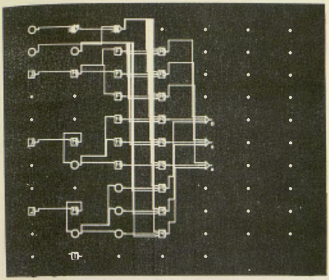

FIGURE 12 CSMP MODEL FOR TIMELINE PREPARATION AND ANALYSIS

These are just a few of the examples of how the apparently limited capability of a small stand alone computer when combined with an interactive device and a truly flexible program such as CSMP has become a potent tool. The matured research project has provided some interesting insights into the requirements of a technical community charged with handling a wide variety of continuously changing involved problems in a quantitative manner. This experience would tend to indicate there is a place for small digital "Interactive Computer Graphics," even in a central computer facility with many other sophisticated computer systems that have already been proved.

CONCLUSION

Startup, turnaround and flexibility, these are the virtues of interactive graphics, but the greatest of these is probably flexibility.

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1. B. Schroer, Interactive Computer Graphics Applied to Continuous Systems Simulation, Seventh Space Congress, Cocoa Beach, Florida, April 22 - 24, 1970.

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