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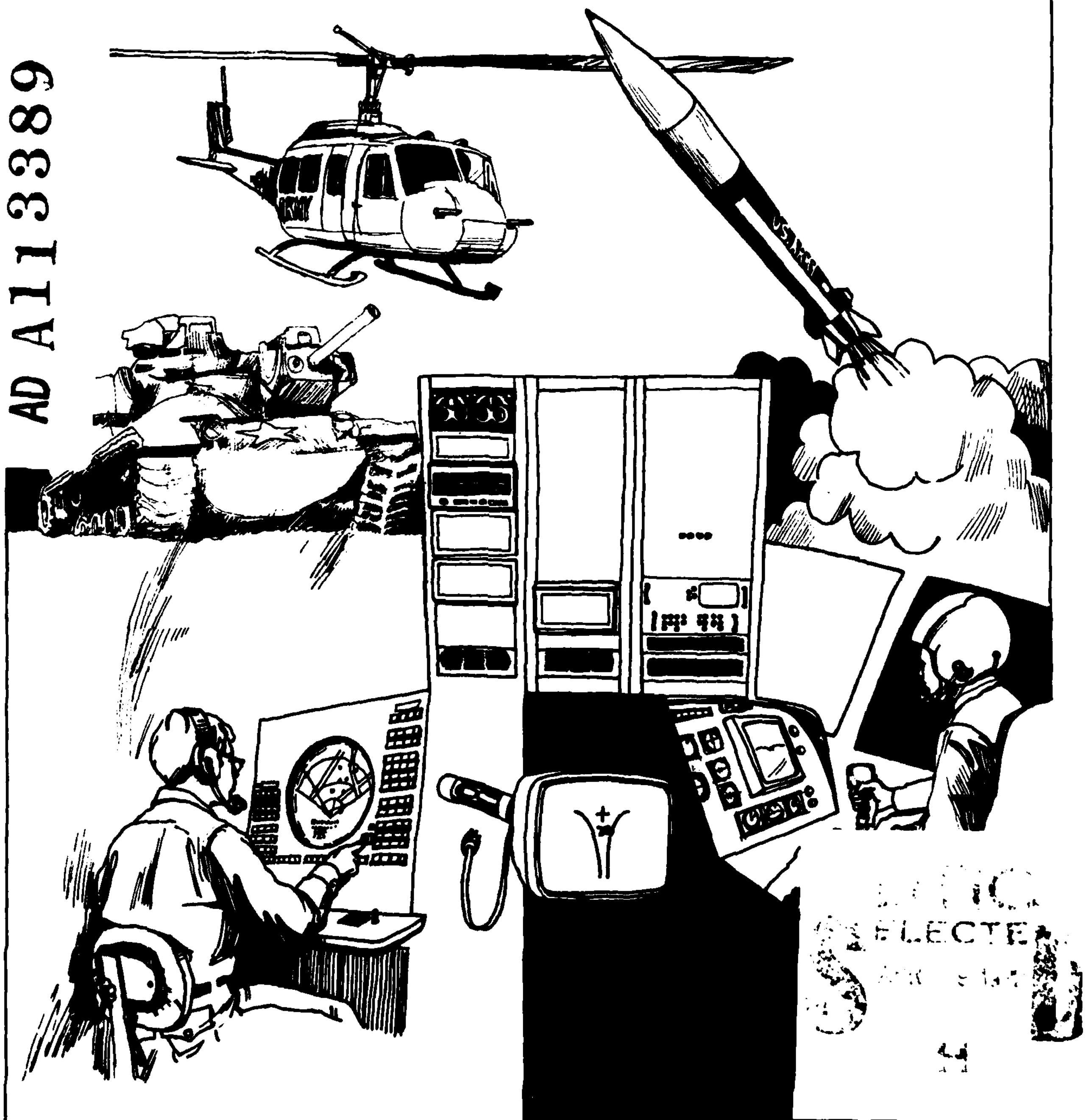
INTERACTIVE GRAPHICS

A TOOL FOR APPLIED HUMAN FACTORS ENGINEERING



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INTERACTIVE GRAPHICS - A TOOL FOR APPLIED HUMAN FACTORS ENGINEERING

INTRODUCTION

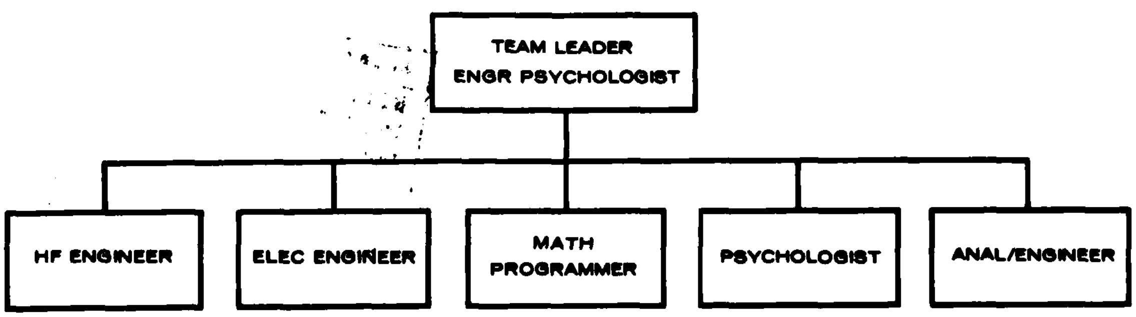
The Human Engineering Applications Directorate (HEAD) is one of three directorates in the US Army Human Engineering Laboratory (HEL). The HEAD is currently composed of four teams with specific expertise in aviation, missile, communication, armor, tactical data, weapons, automotive systems, and display and control. Additional expertise is provided in the areas of:

1. Computer graphics and programming
2. Electronic design and development
3. Experimental design and statistical analysis
4. Vision and illumination

The teams serve as human factors engineering consultants to various DARCOM Project Managers. A yearly support contract (scope of work) is agreed upon between the directorate and the project manager being supported with specific tasks delineated for completion during the year. Important results, including design recommendations, potential problem areas, trade-offs and test results are provided to the project manager.

The Applied Research Team has primary responsibility within HEAD for command/control display systems. The mission of the team is to conduct applied research studies in the area of advanced display technology for the purpose of defining human factors display criteria during conceptual and validation phases of the materiel development process. Additional functions include providing experimental design expertise and display research support to other HEAD teams.

The organization of the Applied Research Team is shown below:



In line with its mission, the Applied Research Team has assembled a versatile display system dedicated to the study of human factors engineering problems involving dynamic real-time display presentations found in military equipment. Our experience ranges from hand-held digital message panels to anti-ballistic air-defense radar display consoles and encompasses low light level or infrared sensor terrain images for Army aircraft.

Human factors tests are supported by the Applied Research Team to develop equipment design recommendations, determine potential problem areas and identify basic problems related to visual information transfer.

COMMAND/CONTROL SIMULATOR HARDWARE

The hardware facilities of the HEL Command/Control Simulator have been evolving since the basic calligraphic display system was installed in 1969. A Varian 620f-100 computer and associated CDS 114 disk drive provide the digital control and storage for the simulator system. The digital system is interfaced to an IDIIOM calligraphic display system, an ISI raster scan imaging system, an Owens-Illinois plasma panel and a Singer Helicopter Operational Trainer (HOT). Emphasis has been placed on flexible real-time interactive display and control capability in the selection of equipment. Incremental hardware additions are made with a view of maintaining software compatibility, thus allowing maximum versatility with a minimum of staff.

DIGITAL SYSTEMS

A general purpose Varian 620f-100 digital computer serves as host computer for the simulator system. The computer processes 16-bit words and has a memory cycle time of 750 nanoseconds. A maximum of 32k words of core is available. Fixed-point hardware addition/subtraction requires 1.5 microseconds. There is no floating-point hardware. The following optional features have been provided.

a. Real-time clock

b. Priority interrupt module (PIM)

c. Priority memory access (PMA)

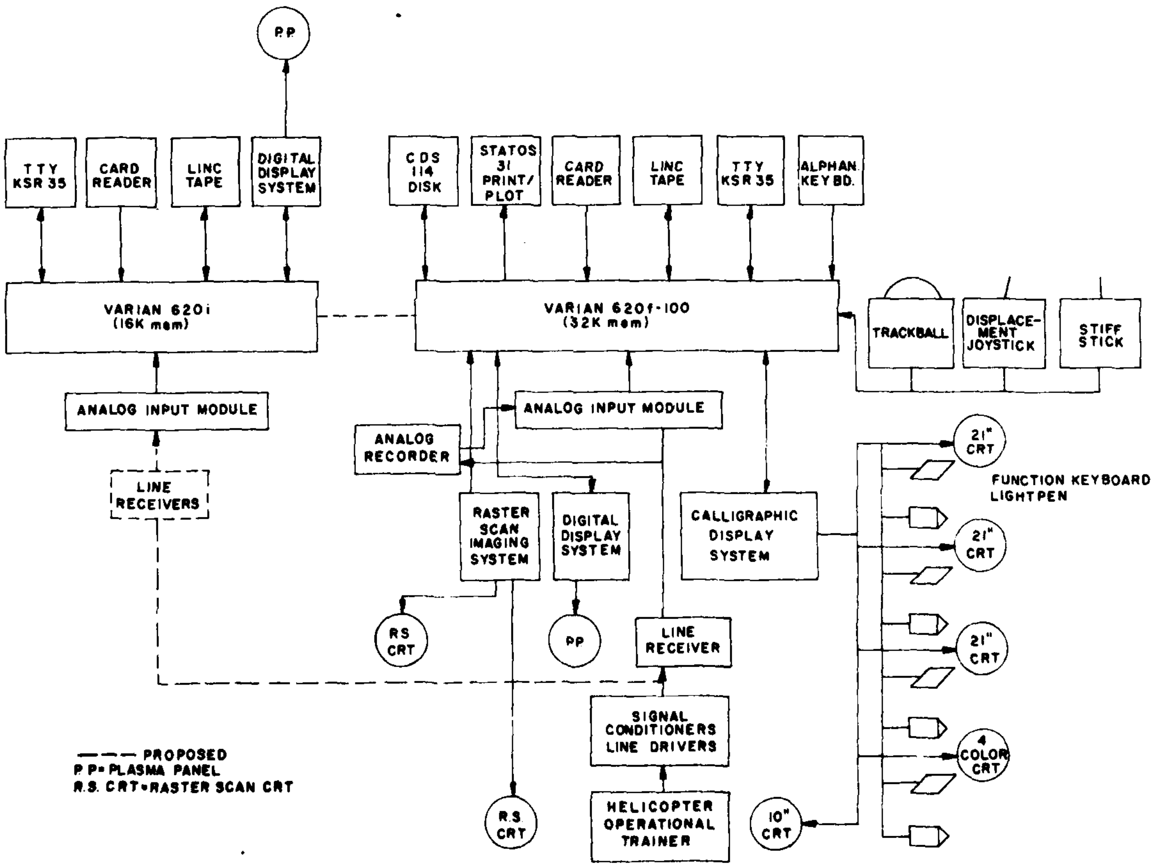
d. Analog input module

e. Direct memory access (DMA)

Computer peripherals consist of a card reader, COI LINC tapes, Varian Statos 31 printer/plotter, electronic alphanumeric keyboard, KSR-35 teletype, and a 29 million byte CDS114 disk system.

The disk drive uses a removable eleven-high disk pack as a storage medium to provide 20 usable recording surfaces. Average rotational latency is 12.5 milliseconds. Cylinder to cylinder seek time is 12 milliseconds. Interfacing to the Varian 620f-100 is through the priority memory access option. Data transfer occurs at 150 thousand words per second.

A data conversion station, built about a Varian 620i computer with 16k words of core, has peripherals consisting of a card reader, KSR-35 teletype, COI LINC tape and high-speed paper tape reader and punch. It is planned that this system will eventually provide a data conversion function for the Helicopter Operational Trainer and will be connected to the Varian 620f-100 via a DMA interface for the high-speed data transfer. A block diagram of the total system is shown below.



DISPLAY SYSTEMS

CALLIGRAPHIC DISPLAY SYSTEM

The IDIIOM 1.2 display processing unit bidirectionally interfaces with the Varian 620f-100 digital system to interpret and convert the digital graphic commands to the analog form required for the CRT displays. The display processing unit also provides the means by which the function keyboards and light pens send interrupts to the digital systems.

The system has four monochrome CRT's with P31 phosphor. Three of the monochrome consoles are 21-inch diagonal tubes and the fourth is a 10-inch diagonal tube with a remote display head mounted in the helicopter trainer. Color capabilities are provided by a large screen four-color beam penetration phosphor CRT which uses a multilayer screen comprised of a green phosphor layer, a barrier layer and a red phosphor layer. By switching the accelerating voltage, red, green, orange and yellow colors can be displayed. Full length vectors, 1024 raster units long, can be written in 50 microseconds. CRT display specifications are given in Appendix A.

RASTER SCAN DISPLAY SYSTEM

Solid surface image capability is provided by a raster scan imaging system developed by Interpretation Systems Inc. Images are presented on television monitors in black and white or color. This system is bidirectionally interfaced with the Varian 620f-100 digital system.

Graphic generators permit the automatic drawing of vectors, conics, plots, and characters. Composite displays are permitted by combining computer-generated images with TV camera input. Raster scan display specifications are given in Appendix B.

PLASMA PANEL DISPLAY SYSTEM

A display medium which is neither calligraphic nor raster scan is available on both the simulator system and the data conversion station. This display is an Owens-Illinois 8.5-inch x 8.5-inch flat panel plasma display unit (DIGIVUE) featuring 262,144 addressable points. The panel has some of the advantages of both the refresh cathode ray tube and storage tube devices. Once elements are displayed on the screen, they need not be refreshed from any computer or other external source. Unlike storage tubes, individual display elements can be erased without the need to erase the entire screen. Flicker-free operation results at any data density. Dynamic graphics can be displayed, however, not to the degree that can be attained with refresh graphics systems.

Several other highly desirable features of this unit should be noted. There is no distortion present at the edges of the viewing screen, the location of each illuminated point is fixed by wire intersection, thus providing a jitter-free display with excellent registration. The device is capable of providing composite pictures by utilizing its rear projection screen along with computer-generated graphics.

Reference 7 provides additional information on this display system. Plasma panel display and controller specifications are given in Appendix C.

INTERACTIVE DEVICES

A 32-key function keyboard and light pen are available at each of the large screen calligraphic consoles. Other interactive devices are available which may be used at any display position. They are:

1. Electronic alphanumeric keyboard

2. Trackball cursor control

3. Displacement joystick cursor control

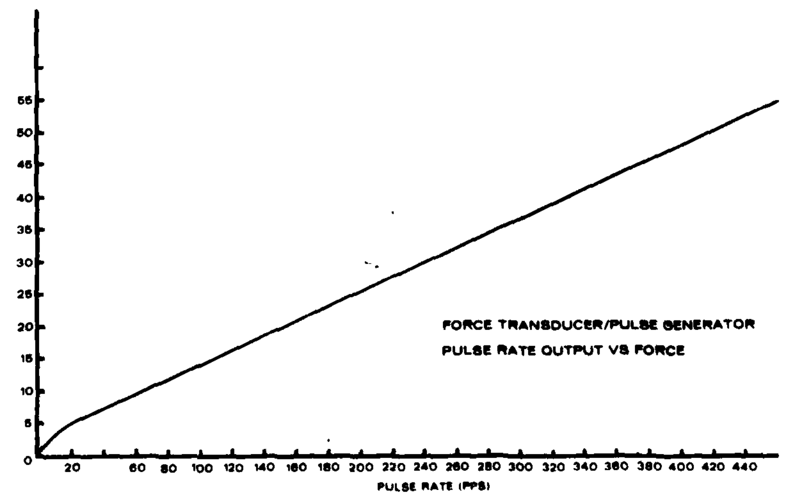
4. Stiff stick (isometric stick) cursor control

The electronic alphanumeric keyboard is a send-only unit which provides a full 128-character code output. Unshifted characters are lower case. It may also be used in the teletype mode to act as an alternate system teletype.

The trackball cursor control consists of a 3-inch ball mechanically coupled to two bidirectionally optical shaft encoders, one encoder for the x-axis and one for the y-axis. Each encoder output provides 1000 cycles per revolution of the ball.

The displacement joystick utilizes two pin-contact type shaft position encoders which are mechanically coupled to a stick extending 3¼ inches above the table surface. One encoder is provided for the x-axis and one for the y-axis. One revolution of the shaft provides 2048 counts. However, since the stick displacement is mechanically limited, about 1024 counts are provided for maximum stick displacement.

A third cursor control device is available at the CRT console positions. This unit is a dual-axis force transducer, sometimes referred to as a stiff stick, an isometric stick or force stick. A short 1.3-inch control shaft extends above the table top. Forces applied by the operator generate analog voltages which are converted to pulse rates and directional gating signals. The pulse and gating signals are fed to 12-bit up-down counters. The figure below provides a plot of the pulse rate versus force for this cursor device.



POWER SYSTEM

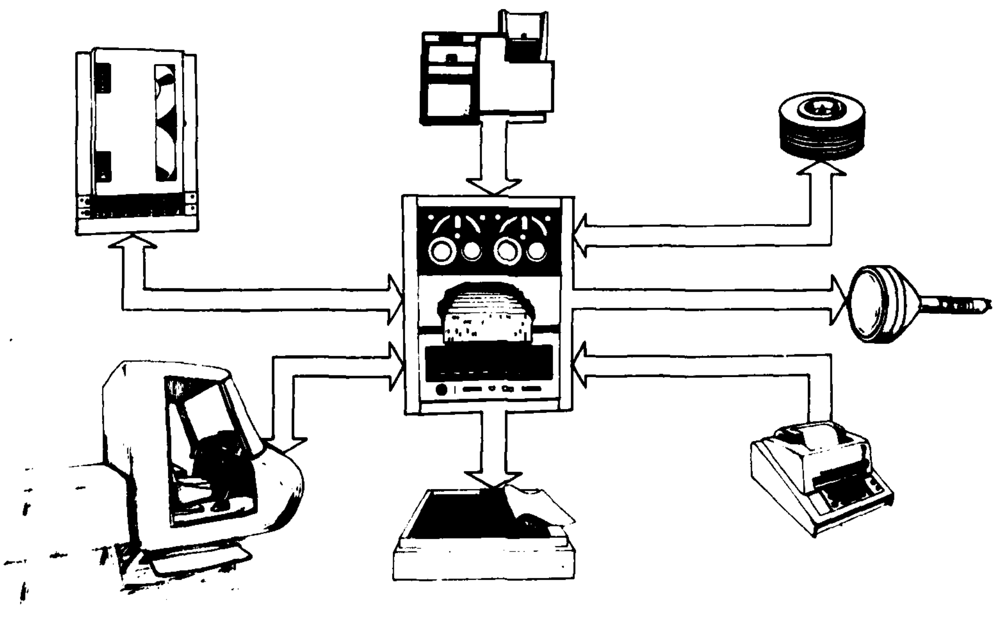
Interruptions to testing procedures caused by local AC power line disturbances have been minimized by the installation of a 12.5 KVA motor-generator set. This unit isolates the command/control simulator from the effects of line transients, momentary power drop-outs, lightning strikes and voltage fluctuations. A transfer switch permits operation of the system directly from the utility "clean line" whenever the motor-generator set is shut down for maintenance.

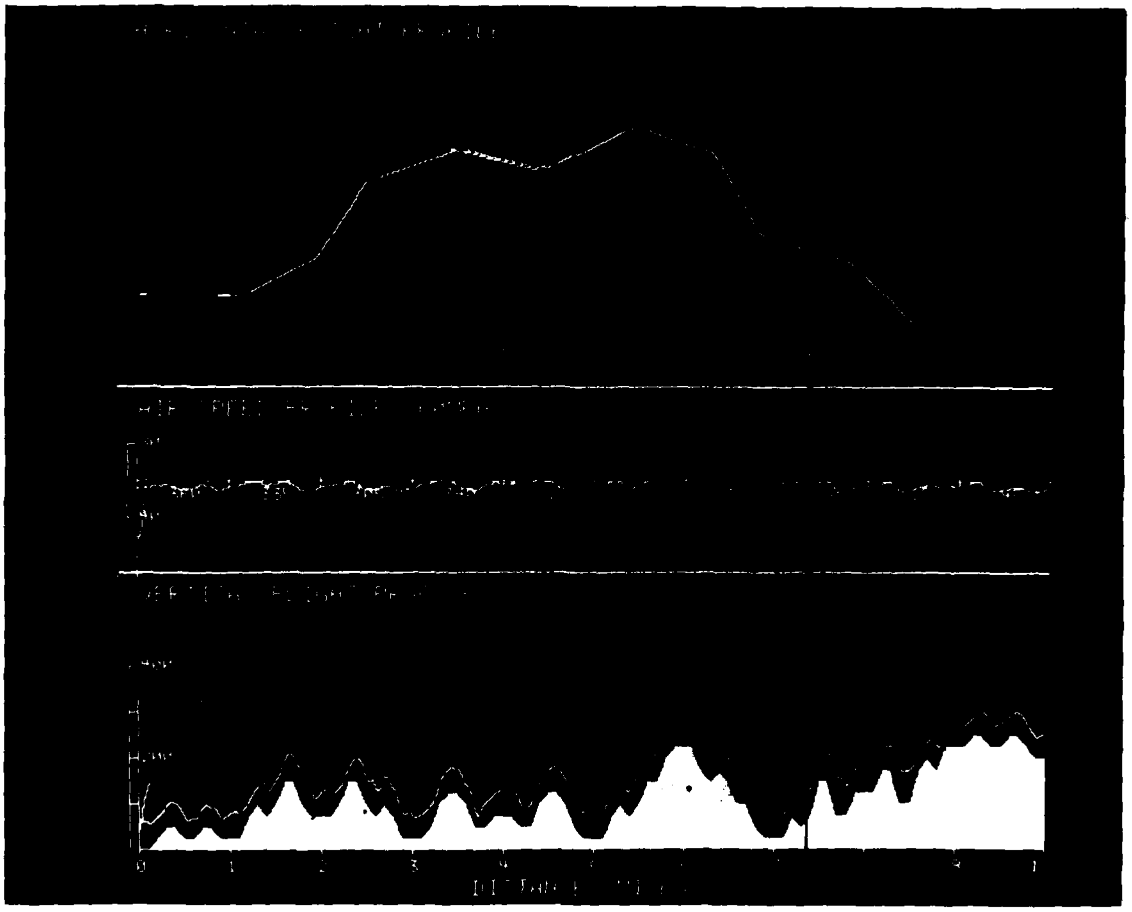
SYSTEM SOFTWARE

The HEL graphic display system operates under a disc-based operating system called HIGHER, developed by Information Displays, Inc. HIGHER is written in a high level language (FORTRAN) and supports itself by providing for maintenance and modification using the HIGHER FORTRAN compiler. In addition, HIGHER contains a DAS assembler. Compilation converts FORTRAN source statements to assembly language, then to machine language. This technique allows imbedded assembly language code to perform operations outside the syntax of FORTRAN.

HIGHER employs a dynamic memory management and automatic overlay technique which allows programs larger than 32k to be run. A resident monitor loads subroutines into memory as they are called. If not enough memory is available, the least active subroutines are deleted until enough space is available. Each time a subroutine is deleted, the remaining subroutines are relocated so that all free space is in one block. Provisions are made for subroutines which must remain permanently in memory at a particular location.

A full library of floating point, double precision, and complex arithmetic routines are provided.





GRAPHIC SOFTWARE

A series of IDIIOM FORTRAN graphic subroutines provide a means of constructing IDIIOM display files using the FORTRAN programming language. Interface with the IDIIOM is through a set of subroutines called the IDIIOM Handler. The IDIIOM Handler performs all machine level input/output and interrupt handling required to drive the IDIIOM. The IDIIOM Handler provides the capability of interrogating the actions of an operator using a light pen or keyboard. On the basis of these interrogations or from outside sources, the contents of the IDIIOM display file can be modified using calls to other FORTRAN graphic subroutines, thus extending the full facility of interactive graphics to FORTRAN.

Graphics capability for the DIGIVUE plasma panel is also provided through a set of FORTRAN callable subroutines. Primitive geometric figures can be displayed and combined to build complex graphic pictures. These subroutines cause the geometric figures to be written or erased directly on the panel. No display file is maintained for the plasma panel as it is a memory device by design.

A plasma panel input/output driver has been added to the system software to provide system output capability to the DIGIVUE. All output through this driver utilizes the hardware character generator. A software special-character generator with character rotation capability is also provided for displaying user defined special symbols or characters.

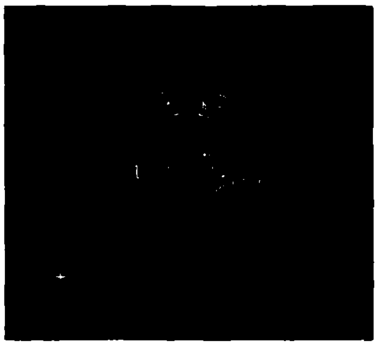
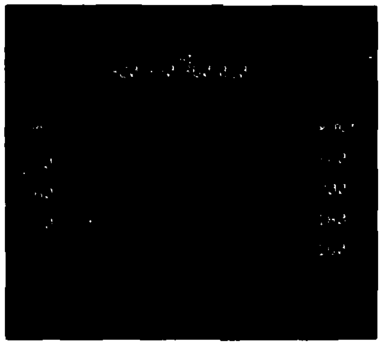
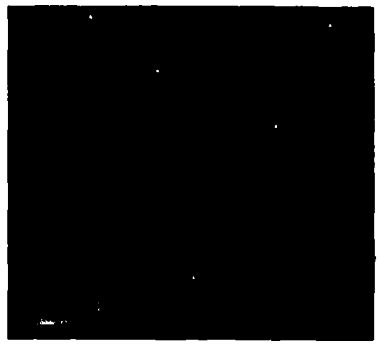
APPLICATIONS

Described below are examples of human engineering studies conducted or supported by the Applied Research Team using the Command/Control Simulator.

FLIGHT INFORMATION SCALE TEST

A study was designed to assess airspeed, heading, and altitude flight status scale design for an Army helicopter heads-up display (HUD) and/or panel-mounted display.

Scales providing altitude, airspeed and heading information were combined into six flight display formats which were displayed on a 21-inch monochrome CRT to a subject. The subject interacted with the display by using a 4-inch displacement control stick which simulated the cyclic control of a helicopter.

The subjects (qualified rotary-wing pilots) were instructed to maintain a predetermined heading, altitude, and airspeed. Under program control, the scale readings displaced and the subject would respond by providing the cyclic control response using the control stick. Response time and incorrect control motion were the dependent variables.

Results indicated that considerable leeway in scale design is permissible without causing a significant difference in pilot performance as measured by the dependent variables. Details of this study are found in reference 6.

DATA ENTRY METHODS FOR THE SB-3614/TT SWITCHBOARD

The automatic SB-3614/TT is a stored program, processor controlled, tactical switchboard. Operation of the switchboard is dependent on information stored in the memory which is manually loaded and modified by an operator using a data entry device.

Evaluation of the contractor's method of data entry found that method was prone to common human errors, which, if committed, could significantly degrade the system performance.

Alternative methods of data entry were devised and a study was conducted to comparatively evaluate the contractor's method and the alternative methods.

A data entry device was built and interfaced with the Varian computer and the DIGIVUE memory display unit. A program was written to simulate the SB-3614 processor and to accept three methods of data entry. Subjects were tested on each of three methods of data entry:

a. Double entry (contractor's method)

b. Single entry without visual feedback

c. Single entry with visual feedback

As a result of this study, it was found that both of the single entry methods were faster and produced less errors. Both single entry methods were preferred by the subjects, although the visual feedback had no significant effect on the subject's performance. Details of this study can be found in reference 9.

EVALUATION OF TOUCH SENSITIVE KEYSET

In conjunction with the Project Manager. US Army Tactical Data Systems, a study was undertaken to investigate the effect of two center-to-center keyspacings for 'touch sensitive' type keysets.

Two modified keysets were fabricated having center-to-center spacing of .5 inch and .75 inch. Each keyset had 12 keys, each key designated by an engraved number symbol. No audible or tactile feedback was given when a key was pressed.

The keyset was interfaced with the Varian computer and the DIGIVUE display memory unit and a program was written that would present a stimulus and collect and record the data. A four-digit number was presented to the subject who would enter that number via the 'touch sensitive' keyboard. Two seconds after the subject entered the number, the next number would appear. The operators were tested with bare hands, wearing mittens with trigger finger, and wearing arctic mittens.



Data analysis concluded that when either mitten was used, operator performance was degraded considerably with the .5 inch spacing. Details of this study can be found in reference 10.

STUDIES LEADING TO STANDARDIZATION OF RADAR SYMBOLOGY III. DISCRIMINATION IN MIXED DISPLAYS CATHODE RAY TUBE PRESENTATION

The radar scope is a major source of information in air defense. Early radar displays are similar to oscilloscope diagnostic traces with a polar coordinate representation of the covered area and a time-based sweepline rotating about the antenna location. Any object struck by the transmitted beam is seen as a 'pip' on the screen.

It later became possible to replace the raw input with synthetic video by generating a geometric form around a particular 'pip'. With geometric form, it is possible to code the object associated with each return.

The HEL has been attempting to design an idealized standard code for use on radar displays. Studies were conducted using pencil and paper drawings. After the HEL acquired the IDIIOM display system, the previously described test was replicated using the CRT to display the symbols.

The subject sees a 25-symbol page on the CRT with various coded targets scattered throughout the viewing area. The subject selects a target by pointing the light pen and pressing the light-pen switch. This action draws a line through the selected symbol. When all the appropriate symbols have been selected, he calls for the next page. Errors of omission/commission and total time are recorded for each series of symbols. The program allows for experimenter selection of console and geometric symbols and for random selection of symbol locations so that the tests cannot be memorized.

The test results and conclusions are lengthy and detailed and can be found in reference 4.

PATRIOT CONSOLE DISPLAY

As a natural followthrough of earlier investigations into radar symbology, the Applied Research Team, in conjunction with the Project Manager, PATRIOT, has been extensively involved in human engineering evaluation of the operator console for the PATRIOT (formerly SAM-D) air-defense system. The operation of this system, which is still under development, requires complex man/machine/display interactions. To properly evaluate a soldier's ability to operate this system, a realistic simulation of the operation of the console was necessary. For this purpose, the Applied Research Team has developed a real-time operator interactive simulation of the PATRIOT operator console and related activities.

Using contractor specifications, two of the IDIIOM CRT consoles were reconfigured to simulate the physical appearance of the PATRIOT operator console. Software to emulate the operator console activities was developed (reference 3) which had the following characteristics:

a. Modular structure for easy software changes.

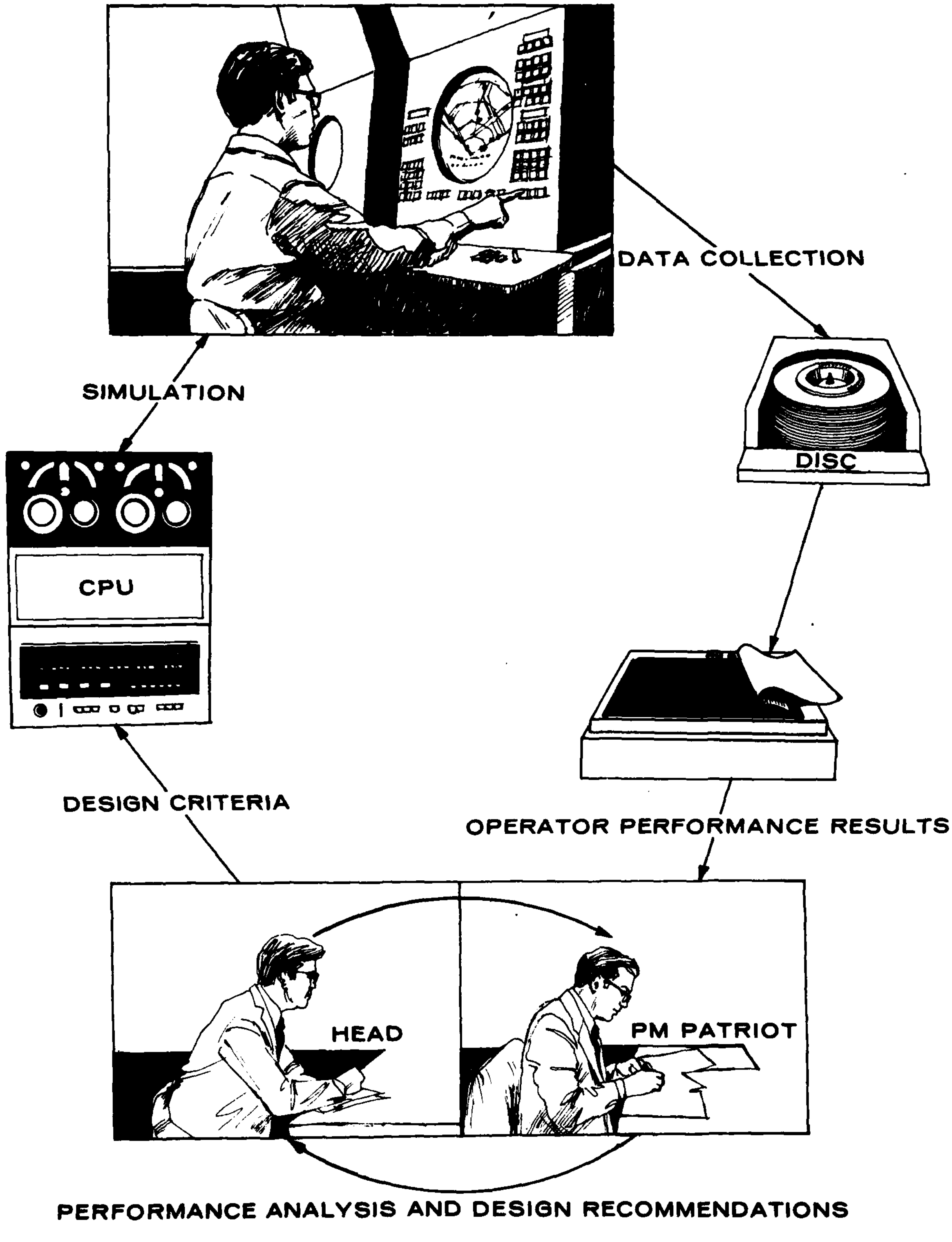
b. Real-time execution.

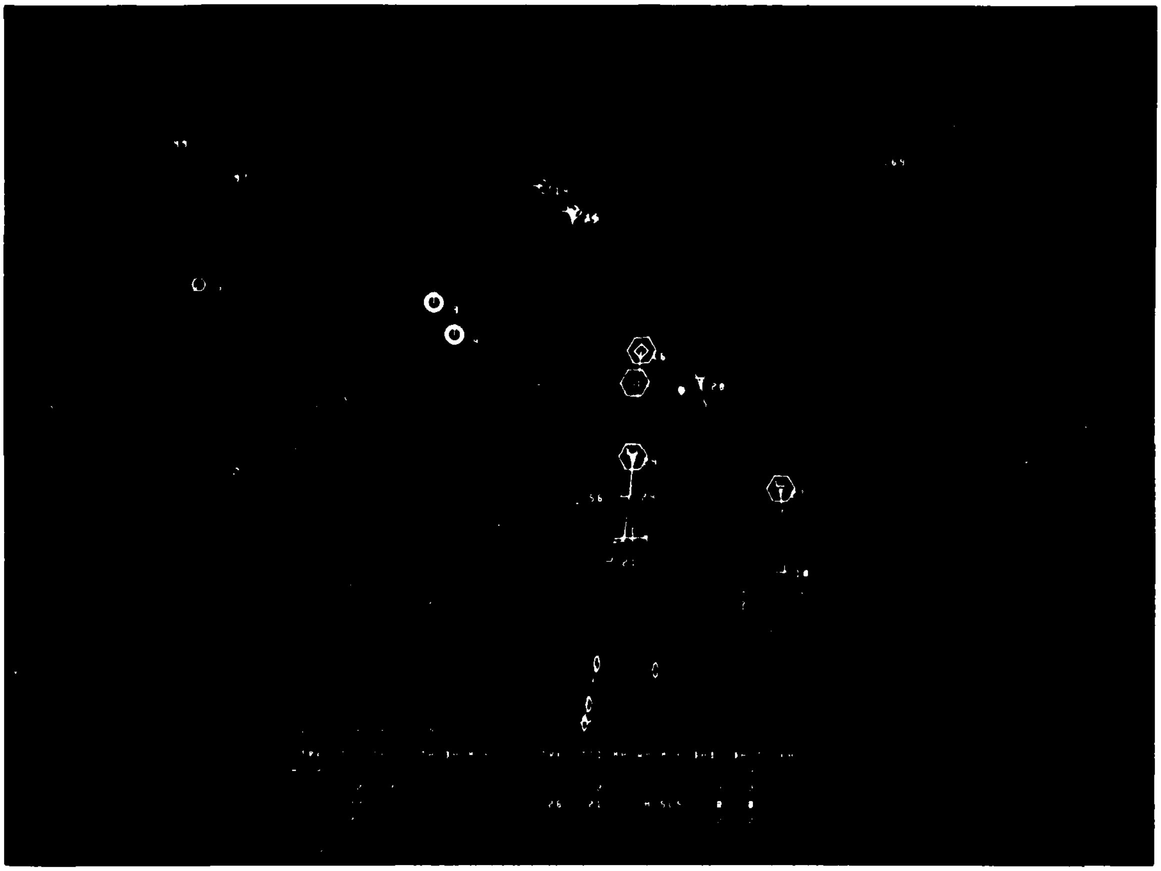
c. Faithful simulation of PATRIOT display and control processes.

d. Operator interaction via keys/stiff stick.

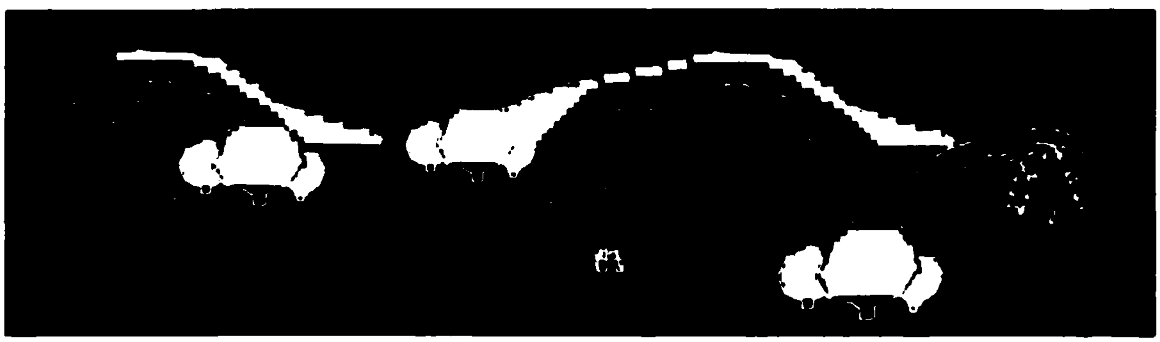
e. Collection and storage of performance measures.

f. Ability to present unlimited number of tactical scenarios.


DATA COLLECTION
DISC
SIMULATION
CPU
DESIGN CRITERIA
OPERATOR PERFORMANCE RESULTS
HEAD
PM PATRIOT
PERFORMANCE ANALYSIS AND DESIGN RECOMMENDATIONS



The simulator is currently being used to assess operator performance over a variety of conditions. Extensive data analysis programs have been written to assist in the evaluation of operator performance. The structure of the software has allowed HEL to test and evaluate alternate methods of information display and to locate potential human factors problems which might interfere with an operator's ability to perform his mission. Testing and evaluation of this system is expected to continue.



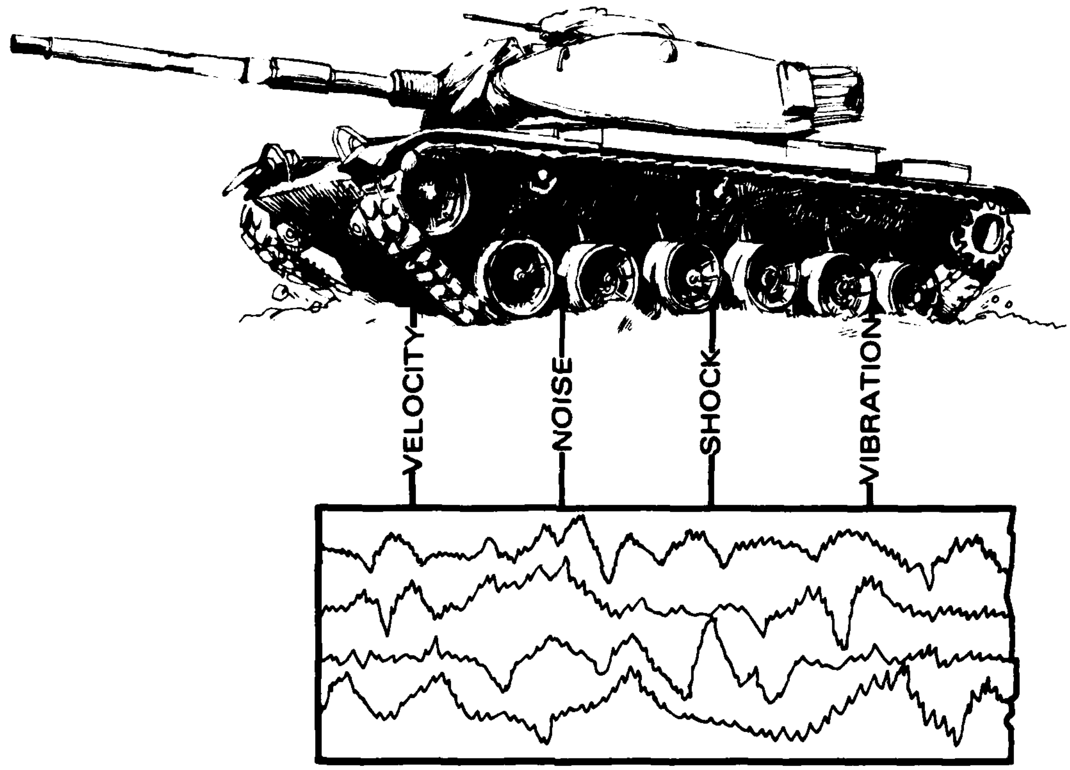
TANK-FIRE CONTROL

Recently HEL has generated a technique for studying tracking performance by tank gunners.

INTERACTIVE DATA GRAPHICS PREVIEW

Many testing programs at HEL result in the collection of vast quantities of analog data which may range from DC to 10 kHz. This data is often recorded on a 14-channel analog instrumentation recorder to provide a permanent record for data analysis.

Frequently essential data, consisting of short intervals, is imbedded in many hours of continuous recording. A means has been developed to obtain a quick visual analysis of large quantities of recorded analog data using the CRT. Interactive programming techniques permit the interrogating and manipulation of the data.



The technique provides for the virtually unlimited storage of 12 channels of digitized data. Any 4 of the 12 channels can be selected for simultaneous display on the CRT. Some of the features available to the user to aid in reviewing the data are:

a. Plotting the displayed data on STATOS 31 plotter/printer.

b. Scrolling data left or right (fast/slow).

c. Selecting new region for display.

d. Selecting the X/Y scaling factors.

This software has been modularized to easily accept future changes and to meet new requirements. One of the possibilities appears to be near real-time display of multiple channel physiological responses. Details on the use of this program are found in reference 8.

HELICOPTER TRAINER GRAPHICS INTERFACE

Software and hardware components are being assembled to provide for the real-time generation of various types of visual displays for use in the GAT helicopter trainer. Types of displays include computer-generated terrain images, dynamic visual flight displays, and integrated flight instrumentation displays. Already demonstrated is the ability to generate flight instrumentation displays, navigation displays, and radar detection warning displays using the real-time GAT input. A versatile computer-generated dynamic flight display capability (reference 1) has been successfully adapted to run on the Varian computer. This program is particularly useful in providing visual presentation for approach and landing procedures.

A development contract is in progress which will provide the capability to generate a real-time terrain image that would simulate the view from a sensor located on a helicopter in low-altitude flight. When completed, this program will generate a real-time visual presentation of terrain images for display on the raster scan monitor with overlaid flight instrumentation displays. The terrain model data base will cover a large terrain area and a variety of distinct terrain features. This program, when interfaced with the GAT helicopter trainer, will provide the ability to evaluate pilot performance during nap-of-the-earth flight.

THE INFLUENCE OF SIMULTANEOUS AND SEQUENTIAL DISPLAY MODES ON HUMAN INFORMATION TRANSFER BEHAVIOR

In spite of wide ranging automation, there are many situations where automation cannot replace man as a link in data processing. One such task is manually feeding data into a computer system. Usually, these data are not generated by the operator himself; he must acquire them from elsewhere, either from displays, from lists, or from other information sources.

This research experiment studied the transfer tasks, input strategies and transfer behavior involved in reading data that are presented, and then, without processing them, immediately keying the data into the computer. This transfer process usually demands both speed and accuracy, so the criteria for evaluating performance was entry time and errors.

The IDIIOM display system with a specially interfaced subject-response keyboard was used for this study. Subjects read test numbers from a cathode-ray tube and entered them into the keyboard. The numbers appeared either one digit after another (sequentially) or all digits at once (simultaneously). There were three number-lengths (four, six, and eight digits) and three exposure times (100, 500, and 1000 msec.).

The study concluded that simultaneous displays transferred digits more effectively than sequential ones. Performance was better with shorter numbers or longer exposure times. Subjects could transfer only four to five digits accurately and only when the exposure time was 500 msec. or longer. Additional details can be found in reference 2.

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APPENDIX A

CRT DISPLAY SPECIFICATIONS

Display Specifications:	
Monochrome CRT's	Phosphor-P31
Beam Penetration CRT	Phosphor-P22 red-P22 green
Deflection	Magnetic (electrostatic for characters on 21 inch monochrome CRT's)
Resolution	.015 inch spot size
Character Writing Time	10 μs
Vector Writing Time	50 μs full screen and proportionally less for shorter vectors
Circle Writing Time	100 μs any diameter
Position Generator Resolution	1024X by 1024Y
Functions	Blink control Line structure-dot, dash, dot-dash, solid Character rotate 90^{o} ccw 4 levels intensity

APPENDIX B

RASTER SCAN SPECIFICATIONS

1. 512 x 640 horizontal raster scan 2:1 interlace
2. 16 levels grey scale, 1 level alphanumeric overlay
3. 4096 colors
4. Image manipulation functions
   a. windowing
   b. translation
   c. scaling
   d. zooming
   e. scrolling
   f. reversal rotation
5. Graphic functions
   a. vectors
   b. conics
   c. plots
6. Characters - 7x9 font

APPENDIX C

DIGIVUE SPECIFICATIONS

Individually Addressable Light points	262,144
Character capacity	
with 5x7 matrix	4,335
with 7x9 matrix	2,223
Dot spacing	.0167"center to center
Vector address rate	7.5-8.5 mil.
Viewing angle	160^{o}
Brightness	50 ft./L approximately
Contrast ratio-small area	> 25:1 nominal
Light spectrum	neon orange (5852A^{o} predominant)
Bulk erase	20 microseconds
Operating temperature range	0^{o}C to +55^{o}C
Storage temperature range	-62^{o}C to +85^{o}C
Addressing rate	
Serial	1,400 characters/sec 5x7
Parallel	10,000 characters/sec 5x7
Logic level	TTL
Clock	Synchronous or asynchronous
Overall unit size	16.5" x 15.5" with hollow rear projection port
Panel size	12.25" x 12.25"
Active display area	8.55" x 8.55"

Character size	
5x7	80 x 120 mils
7x9	120 x 150 mils
Power supply input requirements	105-125 VAC 60 Hz 1.8 amps max

DIGIVUE CONTROLLER SPECIFICATIONS

Character size	5x7, 7x9

Modes–Point, Character 5x7 Normal,
Character 7x9 Normal, Character 5x7 Rotated
Character 7x9 Rotated

Logic – TTL

Operation – Asynchronous

Power – 5 Volt (for logic)