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MTR-945

AFICCS DISPLAY SOFTWARE RECOMMENDATIONS

Otto W. Beebe

NOVEMBER 1969

Prepared for

DIRECTORATE OF PLANNING & TECHNOLOGY
ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
L. G. Hanscom Field, Bedford, Massachusetts

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Project 512A
Prepared by
THE MITRE CORPORATION
Bedford, Massachusetts
Contract AF19(628)-68-C-0365

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FOREWORD

This report of recommendations for improvement of the AFICCS display system is in partial fulfillment of Project 512A under Contract No. AF 19(628)-68-C-0365. It was prepared under the cognizance of Mr. Frank Cataldo of The MITRE Corporation, Bedford, Massachusetts. The USAF Project Monitor is Mr. Charles Bruce.

REVIEW AND APPROVAL

Publication of this technical report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

WILLIAM F. HEISLER, Colonel, USAF
Chief, Command Systems Division
Directorate of Planning and Technology

ABSTRACT

This document summarizes a study of the AFICCS display system. Currently available AFICCS display features are reviewed and deficiencies, or lack of existence, are noted. Recommendations for improvements are segregated into two categories; near-term and long-range.

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SECTION I

INTRODUCTION

This document summarizes a study of the AFICCS display system. Currently available AFICCS display features are reviewed and deficiencies, or lack of existence, are noted. Recommendations for improvements are segregated into two categories; near-term and long-range.

The approaching advent of system phaseover from IBM 1410 to third generation precludes any serious thought of redesigning the 1410/BR-90 peculiar display software. Near-term recommendations for AFICCS display software improvements center on eliminating deficiencies of the existing system and implementing additional features designed to increase operational and functional effectiveness.

Long-range recommendations are not influenced or biased by time restrictions and stress an orderly process of system design and definition.

The majority of techniques and methods recommended for implementation are based on the results of programming experiments conducted at the AFICCS Support Facility.

SECTION II

AFICCS DISPLAY SYSTEM

HISTORY

CRT console display devices evolved from early attempts to overcome restrictions associated with lineprinters on obtaining quick computer output and response. Initial forms of CRT display devices were laboratory oscilloscopes, used primarily as auxiliary output devices to display curves and graphs. The early 'CRT-console' increased in sophistication with the introduction of data input components. The initial type of input device attached to CRT consoles was the light-gun; the resultant combination providing the first example of an interactive display station.

Interactive display devices (and techniques) distinguish themselves from conventional input/output devices by providing for rapid man/machine interaction; the highest level of this interaction being a continuous man/machine dialog. A further significant difference is provided by the ability of display devices to rapidly represent the same data in various formats (i.e., numeric data may be represented graphically).

A major deterrent to using displays was the amount of time wasted by the CPU waiting for operator responses. The only effective way of interactive processing is to share the CPU among a number of display consoles or among different tasks. The introduction of third generation equipment with operating systems directed to time sharing and multiprogramming has reduced this problem considerably.

A further approach to reduce 'system suspense time' caused by display utilization was the introduction of small display processors (computers) dedicated to the interactive display consoles and operating in parallel with the CPU. It is the function of this small processor to free the CPU from performing display specific operations such as frame formatting, CRT refreshing and function key interpretation. The advantage of this type of operation, called distributed processing, is the reduction of the number of display interrupts in the CPU and referrals between the CPU and the display console. Naturally, nothing is gained if the CPU does not operate in a multi-task environment.

The functional effectiveness of any display system is bounded by the versatility of its software. The usefulness of console displays can be greatly enhanced by compiler-type display languages permitting graphics manipulation through symbolic operands. The lack of such software is analogous to producing computer programs solely with machine language.

SYSTEM COMPONENTS

Hardware

The standard equipment components for each AFICCS facility are:

a) One to six AN/FYQ-45's, better known as BR-90's, functioning as the display consoles;

b) One AN/FYQ-38, better known as a CIB (Computer Interface Buffer), functioning as the communication link between the display consoles and the CPU (Central Processing Unit);

c) One IBM 1410 Data Processing System (40K of core memory, no priority alert feature), functioning as the CPU; and

d) Various auxiliary I/O and storage devices, including tape units and disk, attached to the CPU.

The AN/FYQ-45 (BR-90) is a highly sophisticated display station. Its features include graphic capabilities (lines, circles, points), two function keyboards, alphameric keybcard, cursor, lightpencil and a background slide projection system. The BR-90 is driven by its own dedicated processor with a memory capacity of 8192 12-bit words. The processor has a repertoire of 16 instructions, which permit the control of all console features including interrupt processing and CRT frame refreshing.

The CIB provides the communication link between the CPU and up to six BR-90 display consoles. The CPU treats the CIB as a tape unit and communicates with the display consoles through tape read and write commands. While the CPU may interrupt a BR-90 console processor at any time, the reverse is not true. The CPU must test an attention request bit to determine if a display unit requires service.

Software

The AFICCS display software is comprised of three sets of program packages. The Bunker-Ramo supplied N-mode program controls the operation of the dedicated display processor, and as such, exercises control over all features of a display station. The BR-90 resident N-mode program permits the operation of a display console either in an off-line fashion or on-line in conjunction with the CPU.

The IBM supplied Computer Interface Program (CIP) package, in conjunction with the N-mode program, constitutes an applications programming system. These 1410 resident programs essentially provide for buffer management and CPU/display console interface. They may be regarded as utility programs to be utilized by user generated display programs to exercise operational control over the display system.

User-capability programs constitute the third set of display programs. These are functional programs, written with the aid of the above programming system, to solve particular problems or form a broader set of applications programs which may be used by persons not familiar with the peculiarities of the display system. The QUEST II Overlay Capability is such an applications program.

GENERAL PROBLEMS

The limited utilization of the display consoles has been the immediate observation of any study of the AFICCS system. While this situation results from lack of a wide range of display oriented user-capability programs, the fundamental problem source lies at the core of the AFICCS system and its basic display software. These problems fall into two categories:

a) The standard AFICCS system does not provide an environment suitable for the support of interactive displays; and

b) The display software (CIP/N-mode), while satisfying some of the requirements for interactive display operations, is seriously deficient in terms of graphic utilities and exploiting the available features of the BR-90.

An inherent trait of display systems, interactive or otherwise, is their unique form of CPU utilization. Since the next CPU action generally is in response to an operator reaction to the previous display output, considerable CPU idle time can be incurred while the display console operator decides on his next move. In facilities

performing large volumes of serial and batched processing, this manner of display operation can be prohibitive. Precisely this problem is incurred by AFICCS when operating in the display mode; the CPU is dedicated to the displays even at periods of console inactivity. Further, the distributed processing potential of the BR-90 resident display processor is not used, for there is nothing to process in parallel.

Any effective display software must provide methods and techniques for the efficient construction, modification and maintenance of display frames and strings. AFICCS provides for frame construction in disk buffers; however, the available methods for textual frame construction can be classified as marginal, while in the case of graphic strings the programmer is completely on his own without any aids.

The following sections of this document present recommendations for more efficient use of the available display components of the AFICCS system. Included for consideration are various categories of user-capability programs intended to extend the interplay with operational requirements of the system. Near-term recommendations employ available software whenever possible and provide methods and techniques through which the impact of previously mentioned problems may be reduced or overcome.

SECTION III

NEAR-TERM RECOMMENDATIONS

CAPABILITY PROGRAMS

The primary objective of an interactive display system is mission oriented toward the fulfillment of the system's operational requirements. In a command and control environment, such as AFICCS, a display system must interact with the data base to provide a variety of timely services. These may include the quick retrieval of data items, dynamic maintenance of data structures, representation of reports in various formats, pictorial representation of complex dynamic situations and many others.

While some AFICCS commands are currently undertaking serious efforts to supplement their operational capabilities with displays, the standard system makes very limited use of the BR-90. The following areas of display application are suggested for implementation. In most cases, prototypes or models of these capabilities have been implemented at the AFICCS Support Facility.

(The implementation of these suggested capabilities should be conducted in such a fashion to ensure their compatibility with a multiprogramming environment as described in later sections).

Data Base Management

The ability to interact online with a data base to perform functions such as retrieval, exception updating and browsing is desirable. While some display retrieval capabilities already exist (QUEST II Overlay and Query Language), their modification and refinement is necessary for efficient and meaningful operation.

Information Retrieval

The QUEST II Overlay capability furnishes extensive retrieval and computational features for AFICCS serial tape files. Utilization of this feature is minimal because of its great CPU time requirement. For more efficient operations, the following changes are mandatory:

a) Construction of cues must be performed in a distributed processing mode. This means that the CPU will not be dedicated while the operator constructs the multitude of lengthy job control cues, but continues with the processing of an independent task.

b) When actual retrieval processing begins (following completion of cues), communication with the CIB should be reduced or eliminated. Currently, the retrieval programs continuously request the BR-90 status, apparently to test for CANCEL/DEACTIVATE requests. While this operation is not only time consuming, it also forces the dedication of the display station in instances where this is no longer required. (Example: QUEST II Overlay is used for tape sorting; no output appears on the display console.)

File Maintenance

On-line file maintenance is exceptionally well suited for the relatively infrequent updating of static entries as appear with AFICCS parallel files. Capability programs of this category currently exist at the AFICCS Support Facility[1,2]. They permit on-line file generation, modification and deletion.

The ability to browse a data set, file or table should be considered. This would allow the leisurely examination of file entries selected by parameter specifications; thus, providing tools to ensure the overall data quality and reliability. Operating in a multi-task environment is mandatory for a capability of this nature. A serial file 'browsing' capability exists at the AFICCS Support Facility[3].

---

[1] MTR-573, Dynamic Data Integration: Design Specifications for AFICCS File Manipulative Functions.

[2] MTR-757, The AFICCS Serial File Maintenance Capability.

[3] WP-2576, A BR-90 Display Experiment in Distributed Processing.

Report Generation

The extensive textual and graphic features of the BR-90 display console are particularly suitable for the generation of a wide variety of reports. These may range from textual console query responses to more sophisticated graphic representations of numeric data.

Graphic Data Representation

Complex numeric data relationships are understood most rapidly if they are described in pictorial form. Consequently, capability programs which permit the graphic representation of numeric data are required. Capabilities of this category should be able to construct. on selective qualification of input data, comparative graphs, plots, scattergrams, histograms and other representations which compare data items against their environment. Graphing programs should produce their output against any (predefined) scale and should provide some statistical analysis features.

A display program for graphic data representation has been produced at the AFICCS Support Facility and is fully operational. A more detailed summary of this capability is presented in Appendix A.

Briefing Aid

Use of the BR-90 as a briefing presentation aid should be considered. To ensure the continuity of such a briefing, all of its display frames should be prepared in advance and prestored on the disk. This approach is essential if it is desired to include displays generated by relatively slow retrieval programs.

The following types of displays render themselves applicable for inclusion in stored briefings:

a) Manually prepared displays;

b) Display responses to Query programs, such as QUEST II or Query Language;

c) Graphic representations of numeric data; and

d) Geographic display with background map and superimposed CRT data.

Essentially, two items are required for the implementation of these briefing aids:

a) Utility routines callable by retrieval programs to save CRT images and associate projector control information on disk; and

b) A briefing control program to retrieve saved displays via a directory.

Dynamic Situation Displays

One of the prime operational functions of AFICCS is the monitoring of constantly changing resources. Capability programs exist for status of force evaluation, mission and exercise planning, and a variety of other dynamic, mission-oriented tasks. The application of the BR-90, as a truly interactive display device, should be considered for some of these tasks for the following reasons:

a) Geographic displays, generated with background maps and superimposed CRT information, provide quick understanding of tactical environments and problems;

b) The display console provides the tools to call for additional data pertaining to a given situation; and

c) The course of an exercise or simulation can be affected dynamically by timely command interaction with the system.

For implementation of 'background'[4] map capabilities, techniques are required which correlate map coordinates with CRT coordinates. Appendix B presents mathematical methods to achieve this conversion for the projections of the standard AFICCS map slides (Mercator Conformal Cylindrical and Polar Stereographic).

A model of a dynamic situation display, involving the allocation and monitoring of mobile resources (tanks, helicopters and troops) is presented in MTR-754. While this model pertains to a limited tactical environment, it is representative of this type of display utilization.

[4] Utilizing the background projector.

Summary

Each of the above areas in display application was presented to stimulate interest in enlarging the set of display associated capabilities within AFICCS. While they appear under the classification of 'near-term' improvements, it is not to be implied that they all should be implemented within the remaining life of the 1410 AFICCS system, for obviously, neither the time nor the resources exist.

SOFTWARE TECHNIQUES

Section II of this document outlined serious deficiencies of the AFICCS display software. Software techniques designed to overcome these deficiencies and improve the overall efficiency of the AFICCS/1410/BR-90 display system are now presented. The recommendations stress the retention and application of existing software whenever possible.

Distributed Processing Techniques

Extensive display usage in AFICCS is only feasible if the forced dedication of the CPU during display operations is eliminated. CPU dedication requirements resulted from the absence of an automatic interrupt feature in the 1410, whereby the BR-90 processor could interrupt the 1410 whenever it required attention. As it stands, the 1410 may interrupt the BR-90, but the converse is not true. Consequently, the 1410 must either continuously or periodically perform a programmed status test of an attention request indicator in the CIB. As the display software is implemented, this test is performed continuously whenever the CPU is anticipating a BR-90 request, thus dedicating the CPU and inhibiting the potential processing of any secondary tasks.

The software approach presented to eliminate dedication of the CPU involves the following principles:

a) The CIB attention request indicator is tested only periodically;

b) The freed CPU time is used for secondary or background processing; hence, some type of time-sharing control is required; and

c) Distributed processing techniques are applied to reduce CPU/display interaction and free additional CPU time.

While initially this appears to be a formidable undertaking, sufficient system structure and components already exist within AFICCS to allow circumvention of prohibitive redesign and reprogramming.

Programmed Interrupt Test

The periodic testing of the CIB request indicator can be included in one of the heavily used utility and control routines, such as DSKACC or COPS. In this fashion, the programmed interrupt feature is available every time the disk is addressed or COPS is called. During standard AFICCS operations, these routines are called sufficiently often to provide a satisfactory frequency of interrupt tests.

Time Sharing Techniques

The above programmed interrupt test, by itself, provides no advantages over the existing system. A feature must be made available which permits useful employment of the freed processor time.

AFICCS already provides for the overlaying of program levels in core; the COPS routine saves existing core images in disk buffers, loads higher level routines to be executed and consequently restores the old program from the disk buffer. This feature can serve as the basis for a time-sharing environment within AFICCS. MITRE WP-2241, A Way to Time Share Within AFICCS, describes three techniques of employing COPS for program buffer management in a multi-task environment. All three of these techniques conform to the following fundamental principles:

a) A periodic, programmed status test determines if the display console requires service;

b) If a service request is encountered and the background (non-display) job is currently in CPU core, the core image is saved on a disk buffer and the display program is loaded;

c) After the display program completes its service, the background job is restored from disk and resumes control; and

d) If no display request is detected in consequent tests, the background job retains control; otherwise, the program swapping cycle repeats.

A disadvantage of this technique is the high processing

overhead[3] incurred by repeated buffer exchanges. An alternate solution would allow for the partitioning of core for two programs, the foreground and background programs. In this fashion, no buffer exchange is required; only a jump in program control.

Distributed Processing

Time-sharing methods, as discussed in the preceeding paragraphs, provide for meaningful usage of CPU time which otherwise would be lost while waiting for operator responses from the display station. Additional savings in CPU processing time may be obtained by employing the display resident processor more efficiently through distributed processing techniques. The objective of distributive processing (within AFICCS) is to decrease the number of data and attention request referrals between the CPU and the display processor, and consequently to increase the amount of CPU time available for 'background' processing. This objective can be obtained in AFICCS by full utilization of the programmable BR-90 resident computer.

Certain categories of display oriented processing, which are performed by the CPU in the current AFICCS system can easily be designated to the display processor. Coupled with more ambitious buffer management techniques, it is conceivable to operate the BR-90 in a semi-off line fashion, referring back to the CPU only if a (large) data buffer has been exhausted. In the interim, the CPU is free to do something else. Distributed processing techniques discussed in the succeeding paragraphs center on the following principles:

a) The modular design of the N-mode program provides a basis for the inclusion of specific user display programs within N-mode. Assembly programs exist to facilitate the coding and assembly of such subprograms;

b) The usage of the CIP programs is optional; the 1410 capability programs may contain the necessary code to achieve display interface; and

c) CPU/display referrals are further reduced through application of buffer management techniques.

Display Prccessor Programming. The BR-90 display processor has a repertoire of 16 instructions, including arithmetical, logical (shifting and merging), control (branching) and I/O operations. Its core memory capacity is 8192, 12 bit words; a 4096 word region of the core may contain executable programs, the

(3) WP-2576, A BR-90 Display Experiment in Distributed Processing.

other 4096 words can be used as a storage or display buffer area. As such, it provides the potential to perform a wide variety of display computation.

In the AFICCS display system, N-mode is the sole program to operate from the display processor. N-mode consists of a set of standard non-functional utility routines and exercises control over all components of the display console, including the interrupt, input/output and refresh features. A review of the program has shown that it is organized modularly permitting the replacement of program sections (not pertaining to some applications) with any desired routines. It is therefore suggested that N-mode be used as a basis for the implementation of additional BR-90 routines. The selective retention of any desired control features of the N-mode program is a major advantage of this approach.

MITRE WP-2535, The AFICCS BR-90 Display Software, provides a rather detailed description of the N-mode program and presents specific programming techniques for its modification and extension.

Currently, two assembly programs[5,6] exist which permit the writing of any desired display programs.

CPU/BR-90 Software Interface. CPU core requirements for display interface may be relaxed by incorporating the necessary code directly in the capability program, instead of calling the CIP programs. An additional advantage gained in this case is a reduction in the number of COPS calls. A disadvantage, however, is the cumbersome bit construction of the control codes required for communication with the N-mode programs. (The implementation of small control subroutines would decrease this disadvantage).

Buffer Management

Buffer management is of extreme importance in the design and implementation of interactive display systems. Efficient buffering techniques are necessary to utilize the BR-90 display processor to its fullest extent.

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[5] MTR-597, BR-90 Assembly Program — BRASS.

[6] The Program EZY, produced by Bunker-Ramo.

The following buffer management techniques, designed to enhance the distributed processing potential of the AFICCS display software, are recommended for near-term implementation:

a) Compression of display frames through dense polystrings; and

b) Utilization of projector slides as a static storage medium.

Display Frame Compression

The existing software provides for the displaying of textual and graphic frames from disk buffers. Individual frames are associated with distinct relative records of a Symbolic Disk Address (SDA) and a separate CPU referral is required for each frame to be displayed. Each textual frame is generated from a single message string[7] which requires one cell of BR-90 core memory for every character position on the display screen. Consequently, each text message requires 2820 words of core. Since it is not conceivable that all available screen character positions will be used for any single textual display, there is no requirement for a fixed length display message string. A better approach, for the sake of less storage requirements, would be the deletion of sequences of successive blanks from the display message. The correct character position of the next non-blank segment is specified by separate x,y coordinates.

Essentially, this process involves the conversion of a single text string into a (graphic) polystring message composed of a number of short text strings. The resultant saving in display core storage may be used for additional display polystrings to permit the displaying of successive frames without further reference to the CPU.

Experimental observations with textual polystrings[8] have verified average core savings of 80 percent. A discussion of text format analysis and coordinate conversion techniques for text strings is presented in MITRE MTR-754, Display Software Techniques for AFICCS.

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[7] A text message string consists of a pair of x,y screen coordinates, the actual message text and an end of message symbol. Detailed explanation of display message strings is found in Programming Reference Manual for Message Console AN/FYQ-45, Bunker-Ramo Corporation.

[8] The experiments showed that greatest savings was obtained with the deletion of 'blank' sequences of length greater or equal to 3 (blank characters).

Software components required for implementation and usage of this frame compression feature include:

a) CPU routines to convert (textual) monostrings into graphic polystrings. More than one frame should be stored on one referral buffer to decrease CPU/display communications (this requires frame directories); and

b) Display processor routines to provide for the orderly sequential displaying of frames obtained in batched transmission.

While the preceding discussion centers primarily on textual displays, it is recommended that the same multi-frame buffering techniques are applied to graphic display frames.

Slide Data

Slides of the BR-90 background projector may be employed as a secondary storage medium for static text data. The objective is again to minimize the number of CPU/display referrals.

Data elements on slides become recognizable for internal machine-processing by associating them with a CRT superimposed raster of points. In this fashion, a one-to-one correspondence is established between distinct slide data items and light pencil sensitive points, so that a unique data item is identified if a particular raster point is selected by light pencil. A data item recorded on a slide can be uniquely identified as a consequence of a light pencil activation by the following criteria:

a) Current magazine number;

b) Current slide number; and

c) Core location of 'light-penciled' element (permits identification of x,y coordinates of 'hit' raster point).

These items are made available to the CPU, which in turn, performs any necessary decoding, via tables and directories, to obtain the required data item. Naturally, this process can also be performed in reverse, so that the CPU can identify a unique slide data item for the viewer by blinking the associated raster point.

The advantage gain by this approach is the ability to transmit textual information in a very compactly coded form, freeing additional core memory for other processing.

Graphic Facilities

The lack of suitable graphic utility programs to aid in the construction and maintenance of graphic displays was discussed in Section II. The futile construction of graphic display strings through bit manipulation in the 1410 can deter the most ambitious undertaking.

The BR-90 assembly language offers more readily usable bit manipulation commands including macro operations to generate display items such as circles, vectors, and alphameric strings. It is therefore recommended that, whenever possible, any generation and formatting of display strings be performed in the BR-90 processor. This approach does not substitute for a well designed compiler-type display language; however, the implementation of such a feature can not be considered seriously as a near-term item in the current environment.

Summary

The central theme of this section has centered on the concept of distributed processing. Without some form of CPU waiting time utilization, extensive display operations are not feasible in the AFICCS system. To aid in the implementation of such a feature, the following concepts have been introduced:

a) Periodic programmed interrupt-tests via DSKACC or COPS;

b) Time-sharing techniques using the COPS program;

c) Distributed processing techniques to make full utilization of the power of the display processor; and

d) Buffer management techniques to further enhance distributed processing operations.

The recommendations fit within the structure of the existing AFICCS display system and do not constitute a major redesign.

SECTION IV

LONG-RANGE RECOMMENDATIONS

SYSTEM COMPONENTS

An orderly definition of system functions and requirements is of paramount importance in the acquisition and implementation stage of any display system. Current and anticipated functional requirements should be the prime motivation in the acquisition of any display hardware. The wide range of display equipment now available permits intelligent selection of display stations and consoles according to intended functional requirements.

Selection criteria to be considered include the following:

a) Complexity of desired graphics capabilities;

b) Degree of required man/machine interactivity;

c) Availability of manufacturers supplied software; and

d) Operational requirements.

CRT display devices range from simple alphameric to complex, multicolor graphic display consoles. Whereas alphameric displays permit only the viewing of preformatted symbolic data, similar to a typewriter, graphic displays provide for both symbolic data and line (vector, curve) data. The associate cost scale may range from the $1,000 category for simple alphameric devices to $500,000 for sophisticated graphic display stations. Consequently, the need for an analysis of the functional requirements becomes apparent.

Man/machine interaction with displays may range from simple monitoring (no or little interaction) to a continuous dialog, where man and machine interchange information and the path of follow-on action is determined dynamically. The anticipated degree of this interaction should be a leading factor in the selection of displays.

In the past, displays were considered and purchased simply as hardware items; little or no supporting software was provided by the manufacturer. The same condition existed for computers in their earlier stages of evolution; however, at this time, little or no consideration would be given toward purchase of a data processing system without supporting software. Similarly, displays require programming and consequently, the programming facilities and aids provided <u>with</u> the displays should provide a role in their selection.

Rarely have displays been an integral part in the initial design of a data processing system. As in AFICCS, they usually were added after the system became operational, resulting in their partial incompatibility and inefficient utilization. It is therefore recommended that if displays are to be utilized, they should play an integral part in the initial system definition.

SOFTWARE CONSIDERATIONS

Fundamental design criteria for display software consists of the attainment of the following objectives:

a) Utility programs must provide control over <u>all</u> features of the display;

b) The basic software must be programmer oriented to permit the relatively easy implementation of higher level application programs; and

c) Functional application programs must be user (non-programmer) oriented and interact significantly with the primary functional requirements.

To achieve these objectives most easily, a hierarchical or multi-level structure in display program design is desirable. In this fashion, the lowest level software would comprise the basic building blocks upon which higher level programs are built. The software levels required for an interactive display environment may include the following:

a) Basic Hardware Service Routines;

b) Buffer Management Utilities;

c) Application programming facilities; and

d) Functional user programs.

The hardware service routines provide the basic elements to the operation of the displays and higher level programs. Their functions include CRT refreshing, interrupt processing, data transmission and in general, all detail control associated with the features of the display console. (In the existing AFICCS display system, the N-mode program generally performs this type of operation).

Efficient buffer management techniques are of extreme importance in display operation, since it is desired to use the features of the display to their fullest potential. In general, buffer management includes the following operations:

a) Allocation of CPU core memory for display buffer construction;

b) Retrieving display strings or blocks from secondary storage;

c) Allocation, maintenance and modification of multistring display frames;

d) Allocation of display processor core and transfer of frames from the CPU to the display processor; and

e) Allocation and loading of display programs.

This category of display software may be considered one level above the elementary routines with their combination forming the basis to the construction of application programming aids.

A compiler-type display language should be the core of the programming facilities for modern interactive displays. It should serve as the basic programming tool to the generation of user programs. As such, it must provide for the easy construction of symbolic display messages and permit the addressing and modification of detail components (subpictures) of a display frame.

SUMMARY

In view of long-range planning, such as conversion to third generation equipment, AFICCS has the opportunity to avoid (existing) problems that prohibit efficient use of displays. Hence, the following recommendations are presented:

a) Plan the display system as an integral component of the data processing system;

b) Utilize the inherent characteristics of the display devices to their maximum; and

c) Provide comprehensive programming tools which lead to efficient utilization of the available display components.

APPENDIX A

GRAPH GENERATION CAPABILITY

A general capability for the graphic representation of numeric data has been produced at the AFICCS Support Facility. The capability was designed to produce comparative line graphs or scattergrams of numeric attributes of any AFICCS serial tape file. The program is controlled completely by user interaction on the BR-90 console; the only 1410 console operator action required is the initial loading of the display system[9] and the mounting of the input tape.

FUNCTIONAL DESCRIPTION

Input Selection

Selection of the desired fields to be graphed and the specification of other record qualification criteria is entered on-line on the BR-90 console. The user specifies the following:

Record selection parameters (maximum of four) which conjunctively determine if a given record qualifies for retrieval.

Each parameter is identified by:

a) Relative location in logical record;

b) Field length;

c) Value.

Coordinate selection parameters (two) which determine the numeric fields to be plotted as the (x,y) coordinates.

Each coordinate parameter is identified by:

a) Relative location in logical record;

b) Field length.

---

[9] MTR-857, A BR-90 Operating System.

Scale Selection

Two methods are available:

a) Scale limits computed from qualified input; and

b) Scale limits (minimum, maximum) determined by user.

If the user does not specify minimum or maximum scale values for either coordinate axes, they will be determined automatically by scanning for the maximal values of the coordinates. (In this case, the minimum value; e.g., left end point of both axes, is zero.)

By selectively determining the extremal values of either axes, the user can further subset his displayed data and produce a magnification effect.

Extremal scale values can be specified by up to ten (10) digit numbers.

Any combination of scale selection is allowable. (Example: Maximum ordinate value is user specified at 10,000 while others are left to be computed.)

Plotting Options

At most, two distinct graphs or plots may be displayed concurrently. The following combinations are available:

Single Graphs

a) Vector Graph (narrow lines);

b) Point plot;

c) Average[10];

d) Sum[10].

---

[10] Sums or averages may be computed if more than one data value is associated with a distinct x-coordinate.

Overlay Graphs

a) First graph is always narrow vector;

b) Second graph may be:

i) Wide flashing vector (same scale);

ii) Points (same scale);

iii) Special character: delta (same scale);

iv) Wide flashing vector (different scale).

Display Limits

A single graph may consist of up to 248 vectors or 249 points or special characters (deltas). If more data were qualified, an averaging algorithm is used to reduce the data to less than 250 average values. (If averaging is not desired, sufficient restraints should be established to qualify less than 250 records.)

Unsorted Input Data

The capability contains a sort routine to produce simple (not overlapping) vector graphs for unsorted input data.

PROGRAM DESCRIPTION

The capability essentially consists of two distinct programs: a 1410 retrieval program and a BR-90 resident display control and formatting routine. The capability was implemented under the MITRE generated BR-90 Operating System[11] and as such, does not employ the CIP/N-mode configuration.

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[11] MTR-857, A BR-90 Operating System.

The 1410 program component performs the following functions:

a) Retrieval of qualified tape records and attribute values;

b) Interim disk storage of qualified data;

c) Automatic scale selection and scale conversion for CRT screen compatibility;

d) Sorting (if required); and

e) Statistical operation (sums and averages).

CPU/Display communication is conducted in unformatted stream mode under control of the Display Operating System. Display frames are not transmitted from the CPU to the BR-90; only the data pertinent to the construction of a frame is sent. The BR-90 resident display application routine performs the actual frame construction in addition to controlling the operator interaction.

(Examples of a control cue and the resultant graph are shown in the following figures.)

```
PARAMETER SELECTION CUE FOR GRAPH GENERATION CAPABILITY

                RECORD SELECTION PARAMETERS:

                 REL LOC.    LENGTH VALUE

        PAR1      (0002 )      (05 )     (SUU                    )
        PAR2      (0005 )      (05 )     (SGN                    )
        PAR3      (_    )      (_  )     (_                      )
        PAR4      (_    )      (_  )     (_                      )


               COORDINATE SELECTION PARAMETERS:

            LOC    LENGTH          SCALE RANGE                LABEL
                                MIN              MAX
ABSCISSA   (0008 )   (05)   (_            )   (_            )   (JULIAN DAY  )
ORDINATE   (0106 )   (10)   (_            )   (_            )   (CARGO WGHT  )


                    TAPE CONTROL:

                LOG REC LENGTH    (0107 )
                BLOCK FACTOR      (025 )
                TAPE MODE         (0)

                TITLE OF GRAPH:   (SUU/SGN TOTAL CARGO     )
                                  (                        )
                SORT OPTION       (N)
```

Figure 1. Graph Generation Cue

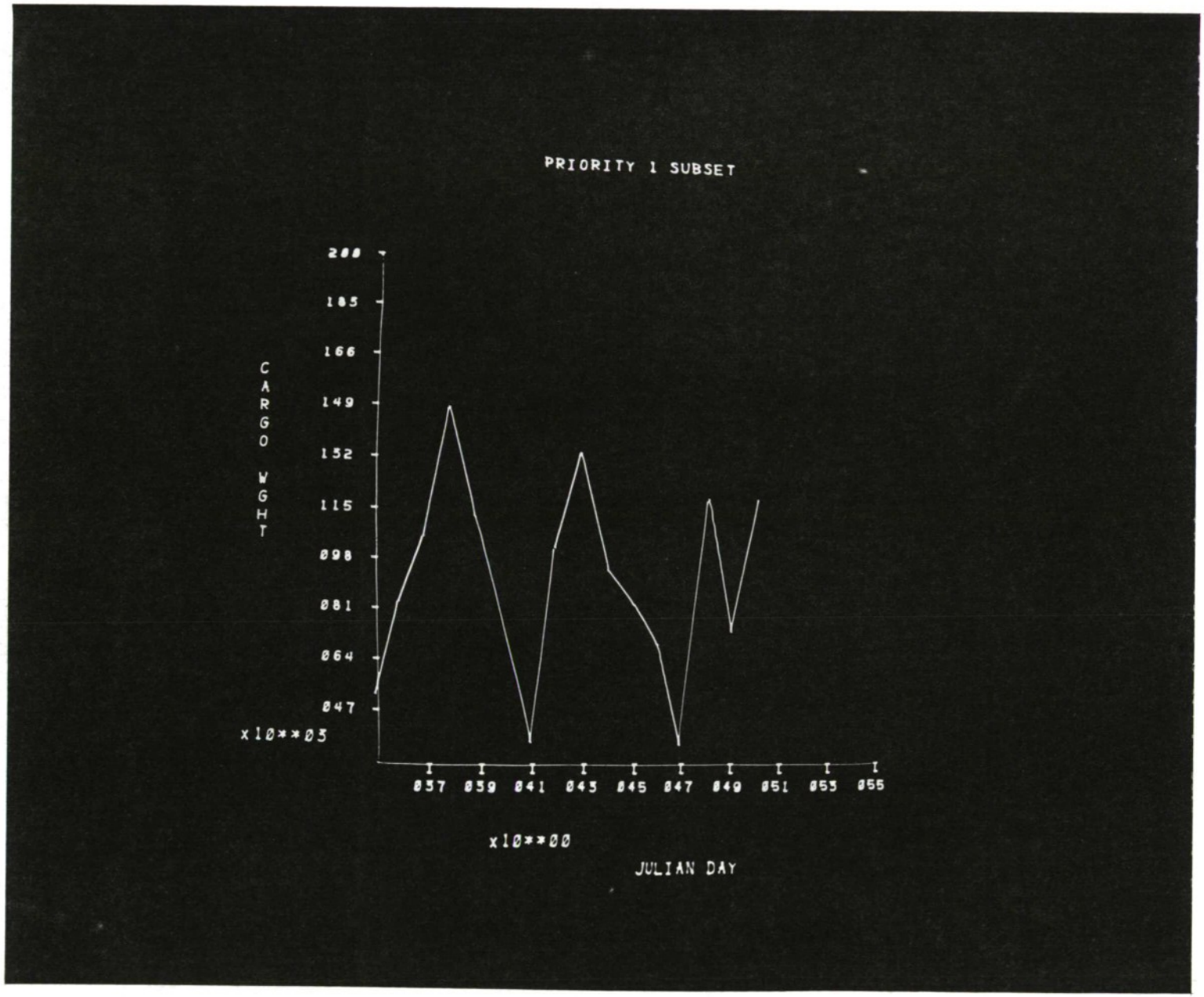


Figure 2. Graph Generation Output

APPENDIX B

MAP COORDINATE CONVERSION

Coordinate conversion techniques are required to correlate superimposed CRT data with maps projected from background slides. Essentially, two projection types are employed by the standard geographic reference slides in magazine zero[12] of the BR-90:

a) Mercator's Conformal Cylindrical - Slides 1 to 81;

b) Polar Stereographic - Slides 82 to 99.

This appendix provides mathematical conversion formulas for the above projections.

MERCATOR CONFORMAL CYLINDRICAL

Transformation from map coordinates (latitude, longitude) to rectangular (x,y) screen coordinates is rendered by:

$$\begin{cases} X = k(\lambda - \lambda_o) + X_p \\ Y = k \log_e \tan\left(\frac{\pi}{4} + \frac{\phi}{2}\right) + c \end{cases} \qquad (1)$$

where λ = longitude of point whose conversion is desired;

ϕ = latitude of point whose conversion is desired;

k = scaling factor (must be computed for each slide);

λ_o = longitude of fixed reference point;

X_p = screen x-coordinate associated with fixed reference point;

c = slide constant (must be computed for each slide).

---

[12] Magazine zero is a standard AFICCS feature.

Example

For each map (slide) for which conversion is desired, the following constants and reference points should be computed and stored in a table. (The computations show below are for Slide 79, The World, 105 W to 124 E):

Scaling Factor (k)

Determine the screen distance between two parallels of longitude (via cursor and cursor coordinate feature). If the distance between two parallels is 205_8 units and their separation is 30° (.52 radians) then:

$$k = \frac{205_8}{.52} = \frac{133}{.52} = 256 \frac{\text{unit}}{\text{radians}}$$

Slide Constant (c)

This constant represents the distance from the bottom of the screen (y = 0) to the equator. If the equator is shown on the map, then the distance can be measured directly via the cursor; otherwise, it must be computed from (1) by solving for k. For Slide 79 the distance was measured and found to be:

$$c = 553_8.$$

Fixed Reference Points (λ_o,X_p)

The fixed reference point is usually chosen in the center region of the map to reduce distortion by optical irregularities. In this case, the reference point was selected as (30^oN, 30^oE) with the corresponding (via cursor) screen coordinates of $(1110,777)_8$. Hence:

$$\lambda_o = 30^o$$

$$X_p = 1110_8$$

Conversion Example

Assume coordinates 45°N, 90°W are to be converted:

Then $\begin{cases} \lambda = -90^{\circ} = -1.57 \text{ radians} \\ \phi = 45^{\circ} \end{cases}$

$$x = 256(-1.57 - .524) + 1110_8 = 61_8$$

$$y = 256 \ln \tan(1.177) + 553_8$$

$$= 256(.884) + 553_8 = 1115_8.$$

Consequently, the desired screen coordinates are $(61,1115)_8$.

POLAR STEREOGRAPHIC (Northern Hemisphere)

The transformation is given by:

$$\begin{cases} x = k \tan\left(\frac{\pi}{4} - \frac{\phi}{2}\right) \cos(\lambda+\alpha) + c_1 \\ y = k \tan\left(\frac{\pi}{4} - \frac{\phi}{2}\right) \sin(\lambda+\alpha) + c_2 \end{cases} \tag{2}$$

where λ = longitude of point whose conversion is desired;

ϕ = latitude of point whose conversion is desired;

k = scaling factor (to be computed);

c_1, c_2, α = constants (to be computed or measured).

Example

The computations shown below were performed for Slide 88, Entire Northern Hemisphere.

Scaling Factor (k)

This factor must be computed by solving either component equation of (2) for k. A fixed point must be selected to provide corresponding values of (λ, ϕ) and (x,y). For this slide, k was found to be 553_8.

Constants

The pair (c_1, c_2) represents the screen coordinates corresponding to the North Pole; in this case $(754,761)_8$ as measured by cursor.

The constant α represents the angular displacement of the central meridian from the screen x-axis, measured in a counter-clockwise direction. (This constant was found to be 15° for all polar stereographic slides in magazine zero).

Conversion Example

Assume coordinates 30N, 30E to be converted:

$$x = 553_8 \tan\left(\frac{\pi}{4} - 15^o\right) \cos\left(30^o + 15^o\right) + 754_8 = 1200_8$$

$$y = 553_8 \tan\left(\frac{\pi}{4} - 15^o\right) \sin\left(30^o + 15^o\right) + 761_8 = 1205_8$$

REMARK

While the set of constants needs to be computed only once for each slide, differences in optics and slide mounting between BR-90 consoles necessitate the computation of separate constants for distinct display consoles.

APPENDIX C

GRAPHIC MANIPULATION

In modern applications of interactive graphic displays, it is common to perform various operations on individual components (subpictures) of an existing display string (frame). The general objective of such operations is the construction of a new picture from an existing frame with a minimum of effort and high degree of versatility. Typical examples of such procedures include:

a) Construction of complex pictures from simple components (i.e., construction of electrical network diagrams from basic subpictures showing resistors, capacitors, etc.);

b) Changing sections of an existing display frame to indicate occurrence of a dynamic process (i.e., change in disposition of forces with respect to a background map);

c) Enlarging a display or selected components (zooming or scissoring).

In addition to sophisticated buffer management, various mathematical display string manipulation techniques are required to perform operations of this category. All of these mathematical functions result in transformation of the CRT screen coordinates associated with the vectors or points constituting a frame or subframe. Two categories of elementary transformation are presented with the objective of stimulating interest for application to a command and control environment[13].

RIGID TRANSFORMATIONS

Preliminary Assumptions

a) The three dimensional Cartesian coordinate system will be chosen as follows. The CRT screen will be the xy plane, as is the usual fashion, and the z axis will be normal to the screen toward the observer. It should be noted that this coordinate system is right handed.

---

[13] These techniques have been employed for BR-90 demonstrations at the AFICCS Support Facility.

b) The object to be displayed will be assumed to exist in 3-dimensional space with some predefined configuration (i.e., we are given a set of points (x,y,z) which define the object). For our purposes, the z coordinates will be less than zero, since the object to be displayed will be considered to be 'behind' the screen.

c) Once we have chosen some point (x_o, y_o, z_o) as a basis of projection (here z_o is also less than zero), we can project a point (x,y,z) from the base point (x_o, y_o, z_o) onto the screen yielding some (x',y',0). The ordered pair (x',y') will be the desired CRT screen coordinate.

Rigid Motions

The following formulas govern rigid motion (translation, rotation) in space:

I) Translation of a point (x,y,z) by a displacement (δx, δy, δz):

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} + \begin{bmatrix} \delta X \\ \delta Y \\ \delta Z \end{bmatrix} \qquad (1)$$

II) Rotation of a point about a coordinate axis (all rotations are assumed to be clockwise):

a) Rotation of a point (x,y,z) by an angle α about the x axis:

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\alpha & \sin\alpha \\ 0 & -\sin\alpha & \cos\alpha \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \qquad (2)$$

b) Rotation of a point (x,y,z) by an angle β about the y axis:

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} \cos\beta & 0 & \sin\beta \\ 0 & 1 & 0 \\ -\sin\beta & 0 & \cos\beta \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \qquad (3)$$

c) Rotation of a point (x,y,z) by an angle α about the z axis

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} \cos\alpha & \sin\alpha & 0 \\ -\sin\alpha & \cos\alpha & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \qquad (4)$$

Observations

For display purposes, in light of assumption (1), the equation of the plane of projection will simply by z = 0. The above ideas were implemented in a BR-90 program which displays a projection of a 3-dimensional cube which can be translated or rotated. A table of sines was stored in the BR-90 core for use in equations (2) - (4). The cosine was computed by the fact that $\cos\theta = \sin(90 - \theta)$. Translation was considered along the x and y axes only. Also, the point of projection was taken to be at an infinite distance away on the z axis.

DATA SCALING

This process is the mapping of one rectangular area onto another rectangular area. Data scaling is required for the conversion of any numerically oriented input for particular CRT displays. Immediate applications are:

a) Superimposition of background map data with CRT data; and

b) Zooming (expansion of selected portions of CRT screen to the full screen).

The following notation will be used for the data scaling function:

a) Let A be the rectangle to be projected, while B is the rectangle onto which images of rectangle A are projected;

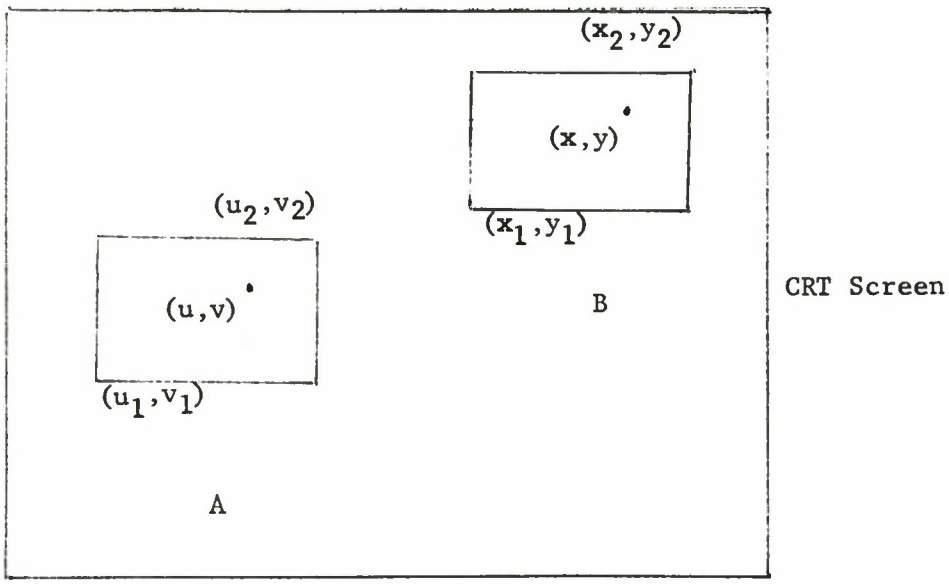
b) Let (x_1,y_1) be the coordinates of lower left corner of B;

c) Let (x_2,y_2) be the coordinates of upper right corner of B;

d) Let (u_1,v_1) be the coordinates of lower left corner of A;

e) Let (u_2,v_2) be the coordinates of upper right corner of A; and

f) Let (u,v) be the point of A which is to be projected onto B at point (x,y).



The following linear functions can be used for data scaling:

$$x = \frac{(u - u_1)\ (x_2 - x_1)}{(u_2 - u_1)} + x_1; \text{ and}$$

$$y = \frac{(v - v_1) \cdot (y_2 - y_1)}{(v_2 - v_1)} + y_1$$

Zooming

Zooming provides for the expansion of selected portions of the CRT screen to the full screen size in such a manner as to preserve angles (conformal) and relative distances. The above equations are applicable and for the BR-90 reduce to:

$$x = \frac{1777_8\ |u - u_1|}{d}$$

$$y = \frac{1777_8\ |v - v_1|}{d}$$

where $d = \max\ (\ |u_2 - u_1|,\ |v_2 - v_1|\ )$.

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Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)*

The MITRE Corporation
Bedford, Massachusetts

2a. REPORT SECURITY CLASSIFICATION

Unclassified

2b. GROUP

3. REPORT TITLE

AFICCS Display Software Recommendations

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

N/A

5. AUTHOR(S) *(First name, middle initial, last name)*

Otto W. Beebe

6. REPORT DATE

28 August 1969

7a. TOTAL NO. OF PAGES

43

7b. NO. OF REFS

--

8a. CONTRACT OR GRANT NO.

AF19(628)-68-C-0365

b. PROJECT NO.

512A

c.

d.

9a. ORIGINATOR'S REPORT NUMBER(S)

MTR-945

9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*

10. DISTRIBUTION STATEMENT

This document has been approved for public release and sale; its distribution is unlimited.

11. SUPPLEMENTARY NOTES

N/A

12. SPONSORING MILITARY ACTIVITY

Director of Planning and Technology, Electronic Systems Division, AF Systems Command, USAF, L. G. Hanscom Field, Bedford, Massachusetts

13. ABSTRACT

This document summarizes a study of the AFICCS display system. Currently available AFICCS display features are reviewed and deficiencies, or lack of existence, are noted. Recommendations for improvements are segregated into two categories; near-term and long-range.

DD FORM 1 NOV 65 1473

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Computer Graphics						
Display Software						
AFICCS						
Time Sharing						
Buffer Management						
Graphics Applications						