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CR-102841

M&S Report No.: 70-0020

Contract No.: NAS8-25621

BANNING DESIGN AUTOMATION
SOFTWARE IMPLEMENTATION
INTERIM REPORT

Prepared for:

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Technology Division
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June 30, 1970

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REFERENCES

1. "Banning User's Manual for Artwork;" RCA, Contract No. DA-18-119-AMC-03460(X); July 1967.
2. "Banning Artwork Program User's Manual;" M&S Computing Inc., Report No. 70-0012; April 24, 1970.
3. "Programmer's Manual for the Banning Artwork Program;" M&S Computing Inc., March 17, 1970.
4. "Graphic Display Software Design Document;" M&S Computing Inc., March 17, 1970.

SECTION I

INTRODUCTION

Under the direction of NASA Contract NAS8-25621, M&S Computing, Inc. has been implementing the Artwork Program, the Placement-Route-Fold Program (PRF), the Banning Library portions of the Banning Design Automation System and a "quick look" capability on the Astrionics Laboratory Technology Division's XDS Sigma 5 facility.

The complete Banning Design Automation System is composed of a comprehensive set of component programs which allow the circuit design engineer to design, simulate, verify design concepts, and produce the development artwork needed to manufacture MOS-FET circuits.

Figure 1.1 delineates the complete Banning Design Automation sequence which consists of seven basic software components. The Network Simulator, the Convert Program, the Signal Trace Program, the PRF Program, the Artwork Program, the Transient Analysis Program and the Artcheck Program. As can be seen from Figure 1.1, the Artwork and PRF Programs currently being implemented by M&S Computing are essential Banning building blocks and provide the designer with the ability to easily create complex MOS-FET Artwork. However, they do not provide the engineer with those Banning capabilities explicitly created to support the design phase of circuit development.

The quick look feature is being implemented by means of a Sanders ADDS/930 Graphics Display Terminal which is interfaced with the Technology Division's Sigma 5 facility through an XDS Sigma 2 used as a display driver and interface.

M&S Computing is developing not only the specific "quick look" feature which will allow simplified artwork initialization but also the general graphics software required to support the ADDS/930 Terminal during normal facility operation.

This report reviews each of the software components being developed or implemented under this contract, discusses the project effort to date, and summarizes the major problems and difficulties encountered during the past five months.

Figure 1.2 delineates the implementation schedule, phasing and time durations for the individual efforts directed by this contract.

Table 1.1 details the Technology Division's XDS Sigma 5/Sigma 2 Facility Hardware Components.

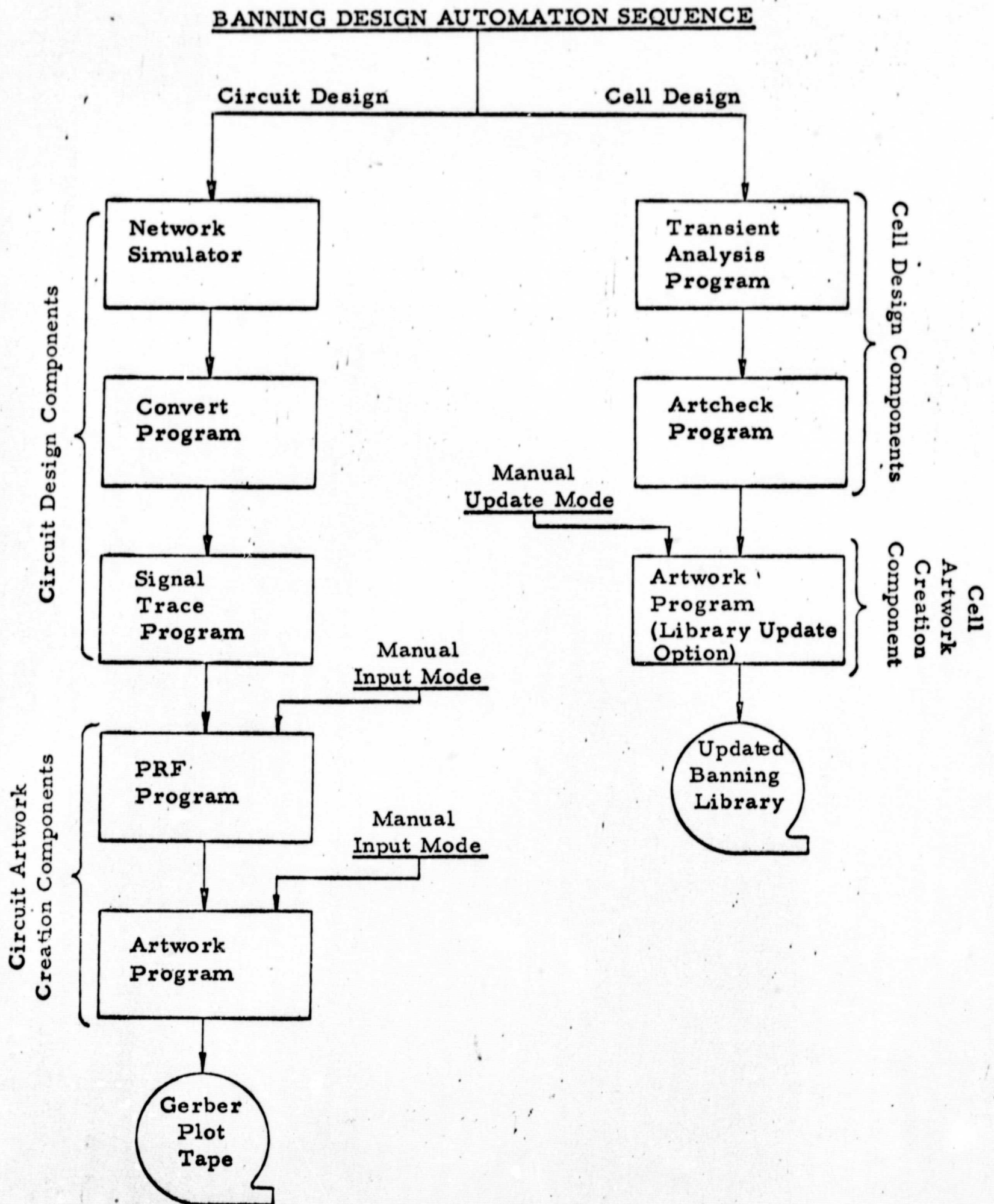


Figure 1.1

BANNING IMPLEMENTATION

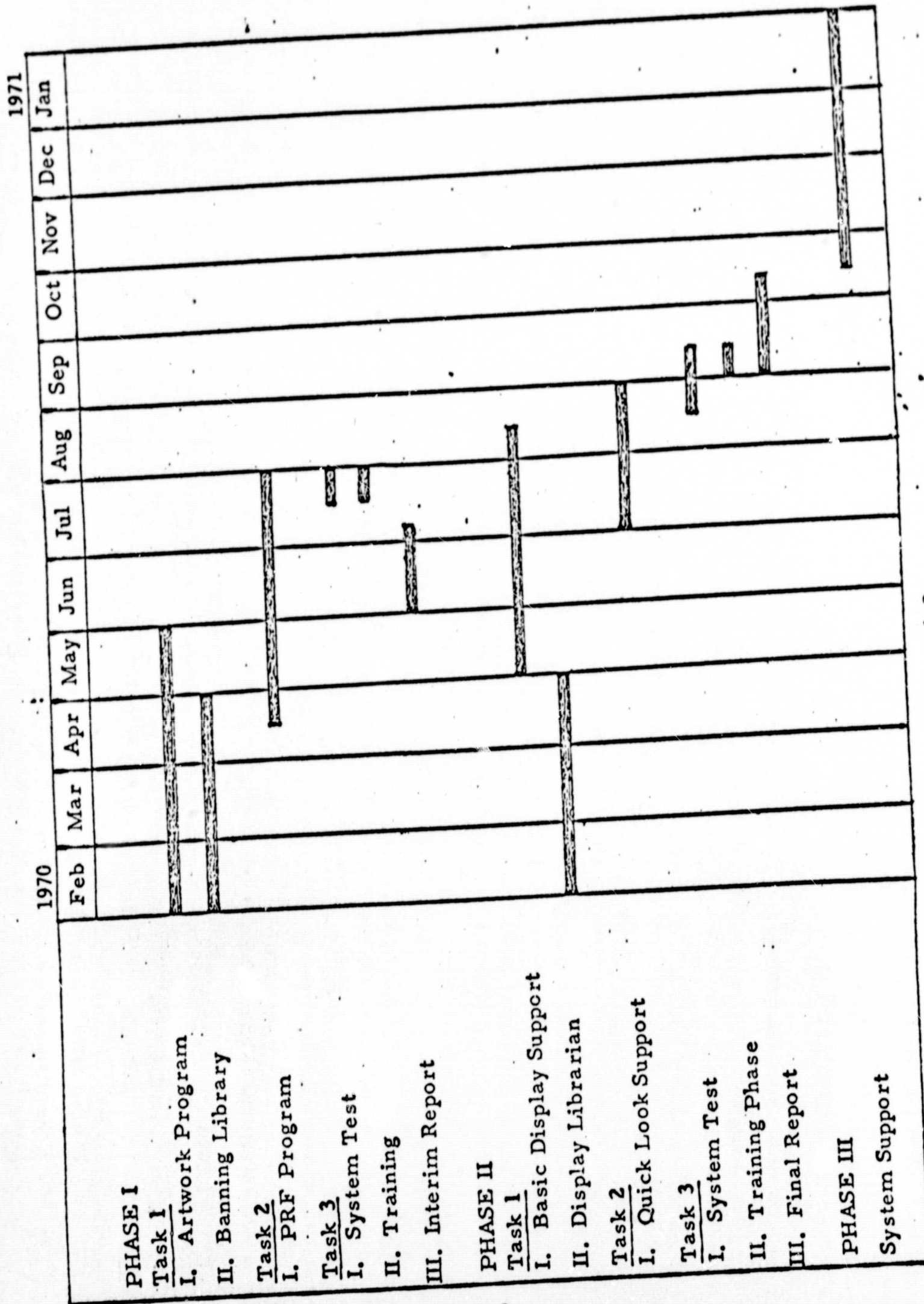


Figure 1.2

FACILITY HARDWARE COMPONENTS

- 1) An XDS SIGMA 5 computer with 64K, 32-bit words of main storage.
- 2) Standard peripheral devices including:
 - o Four magnetic tape units
 - o ASR-35 Teletype keyboard printer
 - o Paper tape reader/punch (part of ASR-35)
 - o Three million byte RAD (Random Access Device)
 - o Card reader/punch
 - o Line printer
- 3) An XDS SIGMA 2 computer with 8K, 16 bit words of main storage.
- 4) A Sanders ADDS/930 Display System consisting of:
 - o Interface adaptor
 - o ADDS/900 Display Generator
 - o Model 930 21-inch CRT display indicator
 - o Character Generator
 - o Photopen Unit
 - o Alphanumeric Keyboard
 - o Vector/Position Generator
 - o Console Control Module

Table 1.1

Figure 1.3 details the financial status through June 26, 1970. Expenditures and task implementation schedules (Figure 1.2) have closely followed the original plan. As indicated in Figure 1.3, the current estimated cost is equal to the negotiated cost.

In addition to this interim report M&S Computing has released, to the Technology Division, Programmer and User's Manuals for the Artwork Program and a Graphic Display Software Design Document. The reader should refer to these documents for additional information on these program components.

FINANCIAL MANAGEMENT REPORT

COMPUTING, INC.
 Suite #80, Holiday Office Center
 3322 Memorial Parkway, SW
 Huntsville, Alabama 35801

Contract: NAS8-25621 BANNING

Type: CPFF

CATEGORY	THIS MONTH			INCEPTION TO DATE			ESTIMATE TO COMPLETE	CURRENT ESTIMATE COST
	Budget	Actual	% A/B	Budget	Actual	Over/ (Under)	% A/B	
Direct Labor Hours								
Engineering	540.0	521.0	96.6%	2,560.0	2,728.0	168.0	106%	5,390.0
Other	48.0	34.0	71.0%	96.0	131.5	35.5	137%	232.0
Direct Labor Dollars								
Engineering	3,897.00	3,273.25	84.0%	18,512.00	17,072.45	(1,439.55)	92.4%	38,515.50
Other	240.00	119.42	49.8%	480.00	500.13	20.13	104%	1,119.92
Total Direct Labor Dollars	4,137.00	3,392.67	82.0%	18,992.00	17,572.58	(1,419.42)	92.6%	39,635.42
Overhead	1,034.88	976.80	94.6%	4,674.56	5,062.64	388.08	108%	9,894.72
G&A	2,379.06	2,009.96	84.5%	10,886.61	10,412.20	(474.41)	96%	22,783.36
Travel	-0-	-0-		610.50	292.24	(318.26)	48%	610.50
Other Direct Costs	76.00	39.00	51.3%	76.00	301.30	225.30	396%	666.00
Sub-Total	7,626.94	6,418.43	84.2%	35,239.67	33,640.96	(1,598.71)	95.5%	73,590.00
Fee	533.89	449.29	84.2%	2,466.78	2,354.88	(111.90)	95.5%	5,151.00
TOTALS	8,160.83	6,867.72	84.2%	37,706.45	35,995.84	(1,710.61)	95.5%	78,741.00

Total Negotiated Cost: \$78,741.00

Total Amount Billed: \$35,995.84

Current Estimated Cost - Over/(Under): -0- Figure 1.3

Total Amount Received: \$22,505.19

SECTION II

PROJECT COMPONENTS

The software components which comprise this contractual effort can be separated into four distinct areas:

- 1) Artwork Implementation
- 2) PRF Implementation
- 3) Display Support Development and Implementation
- 4) Quick Look Development and Implementation

The remainder of this report discusses each area in detail. This section (Section II) provides background information on each component and Section III discusses the implementation efforts conducted by M&S Computing to date.

2.1 ARTWORK

This program is used to generate the commands for the Gerber Plotter to draw the required artwork for the MOS-FET arrays. The program output tape contains light aperture and motion commands which control the Gerber Plotter. The topology describing the individual cells is stored on the library tape for the Artwork Program. From the input specifications furnished by the PRF program, the list of apertures available at the plotter and the scale desired for the output artwork, the Artwork Program calculates the Gerber instructions to draw artwork for each level of the MOS-FET chip. There are several options available for drawing the polygons that compose the individual cells. The option providing the highest degree of precision consists of first outlining the polygons using the smallest available light aperture and then filling in the remaining, less critical areas by using larger light apertures, all under program control. Accurate test plots for verification of artwork can be made by outlining only (omitting the "fill" step), thus conserving plotter time. The Artwork Program also provides a number of "housekeeping" functions such as updating the standard cell library tape and formulating Gerber instructions for drawing standard cell composites from the digitized cell data.

2.2 PRF (PLACEMENT, ROUTING AND FOLDING)

Once the Logic Designer is assured by various simulations that his logic is correct and after he has partitioned the logic into individual arrays the PRF Program is used to accurately place the individual circuit cells on a chip area. The PRF Program will optimize the logic routing and folding in order to minimize the interconnection lengths.

The final placement of cells on a chip is decided upon by a computation to establish a suitable minimum total wire-length for intraconnecting the array. Cells are first interchanged until a satisfactory placement is accomplished. Then the interconnections are routed utilizing aluminum metalization and P-diffusion tunnels.

This program provides the following computer printouts to aid the engineer in the total array design:

- a) Two basic categories of capacitance loading information:
 - (1) Loading before interconnections are routed.
 - (2) Loading after interconnections are routed.
- b) Folded-array printout showing chip size. Cell locations, cell orientations and type, and paths of all interconnections.
- c) A listing of the PRF Program output specifying cell locations and orientations, signal interconnections, and power bus and bonding pad locations. This particular output is available in printed form, on magnetic tape, or on punched cards. All outputs are fully compatible with the Artwork Program.

The major PRF output is a tape containing the accurate cell and interconnection placement data required by the Artwork Program to generate the mask generation commands.

2.3 DISPLAY SUPPORT

The Display Support Software Package being developed by M&S Computing for the Technology Division's facility provides both the specialized display services required to support the specific application areas now being considered by the Technology Division as well as the general display servicing capability needed to support yet-to-be defined applications. The software is at present designed to support the execution of only one application at a time yet has the flexibility to be easily expanded to operate in a more complex multi-job environment with only minor modifications.

Since the primary user of this facility will be an engineer rather than a computer specialist, the ADDS/930 Display provides an ideal method for efficient user oriented, two-way communication between the engineer and the system. This communication is achieved through the use of the graphic display software which provides the interface between the application programs operating in the Sigma 5 computer and the ADDS/930 display unit through which the user communicates with the system. Figure 2.1 presents the general flow of communication between the application program and the user at the display and the two graphic display software components, the Display Controller and the Display Processor, which provide the interface.

COMMUNICATION FLOW

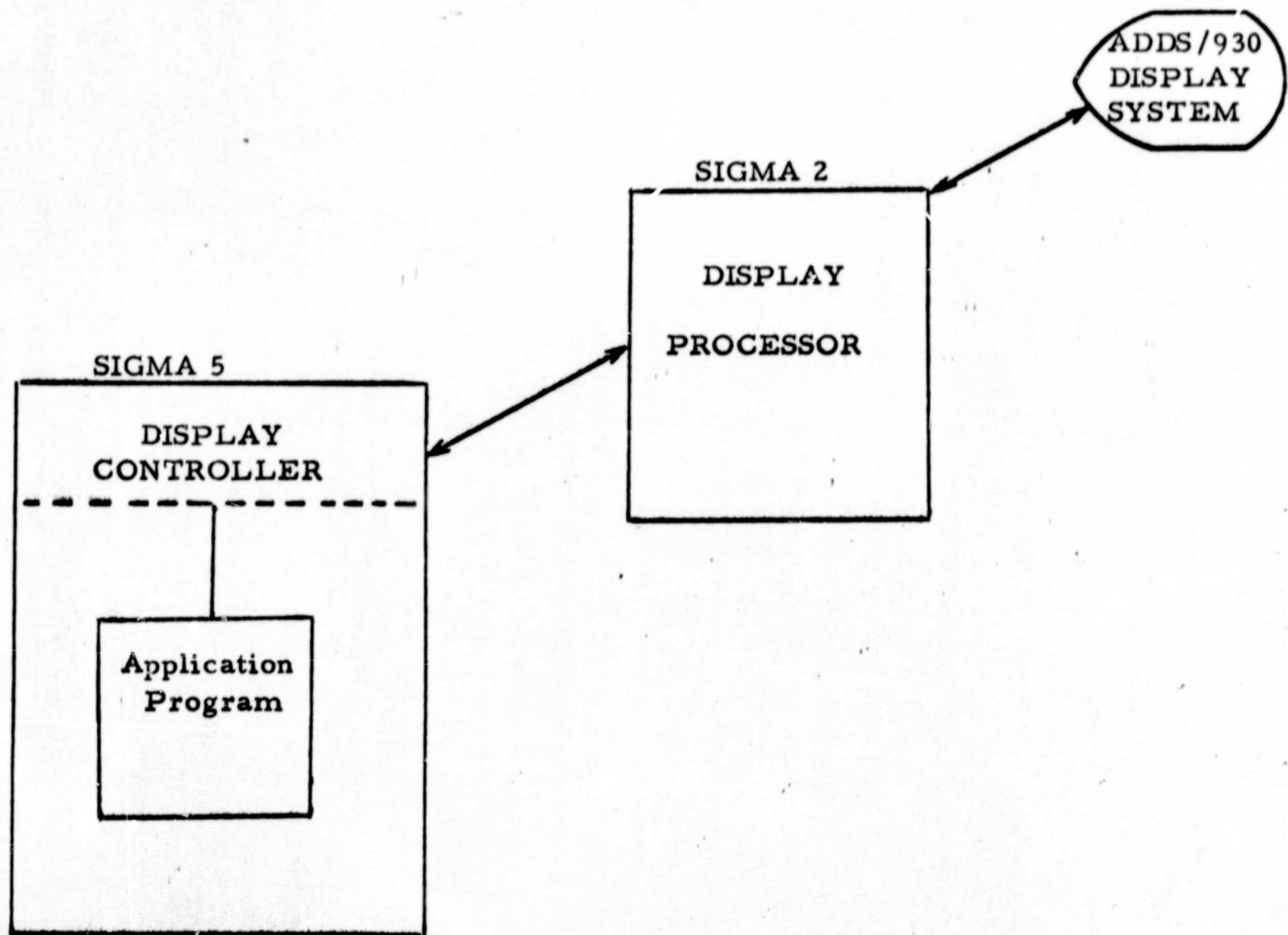


Figure 2.1

The Display Support Software is made up of three subcomponents interacting to form a highly flexible graphics capability:

- o The Display Librarian, an off-line Sigma 5 program which preformats the application oriented displays and from them creates a Display Library to be accessed by the Display Controller during real time operation.
- o The Display Processor, residing in the Sigma 2 computer, which provides the interface between the ADDS/930 Display and the Sigma 5 by validating keyboard inputs, displaying application program output, and passing control information to the Display Control Program resident in the Sigma 5.
- o The Display Controller, residing in the Sigma 5 computer, which provides the interface between the application program in the Sigma 5 and the Display Processor in the Sigma 2 by identifying and/or initiating response software programs, accessing the display library on "New Display" requests, and transmitting application program requests and data to the Display Processor.

Each of these components is discussed in more detail in the following sections.

2.3.1 Display Librarian

To minimize the on-line core and time requirements necessary to create each individual application program oriented display and to provide a completely general graphics capability, all displays are preformatted by an off-line display librarian. The librarian accepts card images of the text and control information defining each display and creates a "book" of displays. The display book resides on disk and is divided into one index and as many chapters as there are displays. For each display created by the off-line graphics program, there is an entry in the index containing the name and disk address of the corresponding chapter.

Each display chapter is further subdivided into three "pages":

- 1) Text Page
- 2) Photopen Page
- 3) Keyboard Page

The text page of each display chapter contains display text information in an "expanded" format containing embedded graphic control commands.

The text page exists in a format which is ready for immediate generation on the display screen and requires no editing, scanning, or unpacking in real time. The keyboard and Photopen pages of each chapter provide the control information needed by the real time display processor to respond to operator keyboard and Photopen inputs.

Figure 2.2 presents the process by which the display book is generated and the organization of its index and chapter data sets on disk.

In addition to creating the display book on disk, the Display Librarian creates a printed listing of the text page of each display in the display book. The listing will be effectively the same picture as seen on the display screen.

2.3.2 Display Controller

All communication between the Sigma 2 Display Processor and the programs resident within the Sigma 5 computer is directed through the Display Controller (Figure 2.3), which will serve primarily as a transmitter/receiver.

The means of communication between the Sigma 2 and Sigma 5 is through system level interrupts with a parameter or transmission list set up in the Sigma 5 shared memory prior to issuing the interrupt. The term "parameter" list is used to denote requests passing from the Sigma 5 to the Sigma 2. These requests are initiated by either the Display Controller or an application program. The term "transmission" list is used to denote requests passing from the Sigma 2 to the Sigma 5. These requests are initiated from the display as a result of a Photopen or keyboard action.

Each time the display operator initiates a Photopen or keyboard action, the Sigma 2 Display Processor determines if the Display Controller is in a position to be interrupted. If the Controller is still processing a previous request from the display and cannot be interrupted, the Display Processor will notify the display operator with a one-line message that his request cannot be honored at this time.

2.3.3 Display Processor

The Display Processor Software provides the interface between the user at the ADDS/930 and the Application Software executed in the Sigma 5 Computer. The Display Processor not only handles keyboard, and photopen inputs from the user but also processes requests from the Sigma 5 to Display Data to the user.

Figure 2.3 illustrates the Display Processor interface with the display unit and the Sigma 5 Display Controller. The control information pages for a display chapter will remain in memory as long as that display's text is being presented to the operator. When the operator uses

DISPLAY BOOK GENERATION

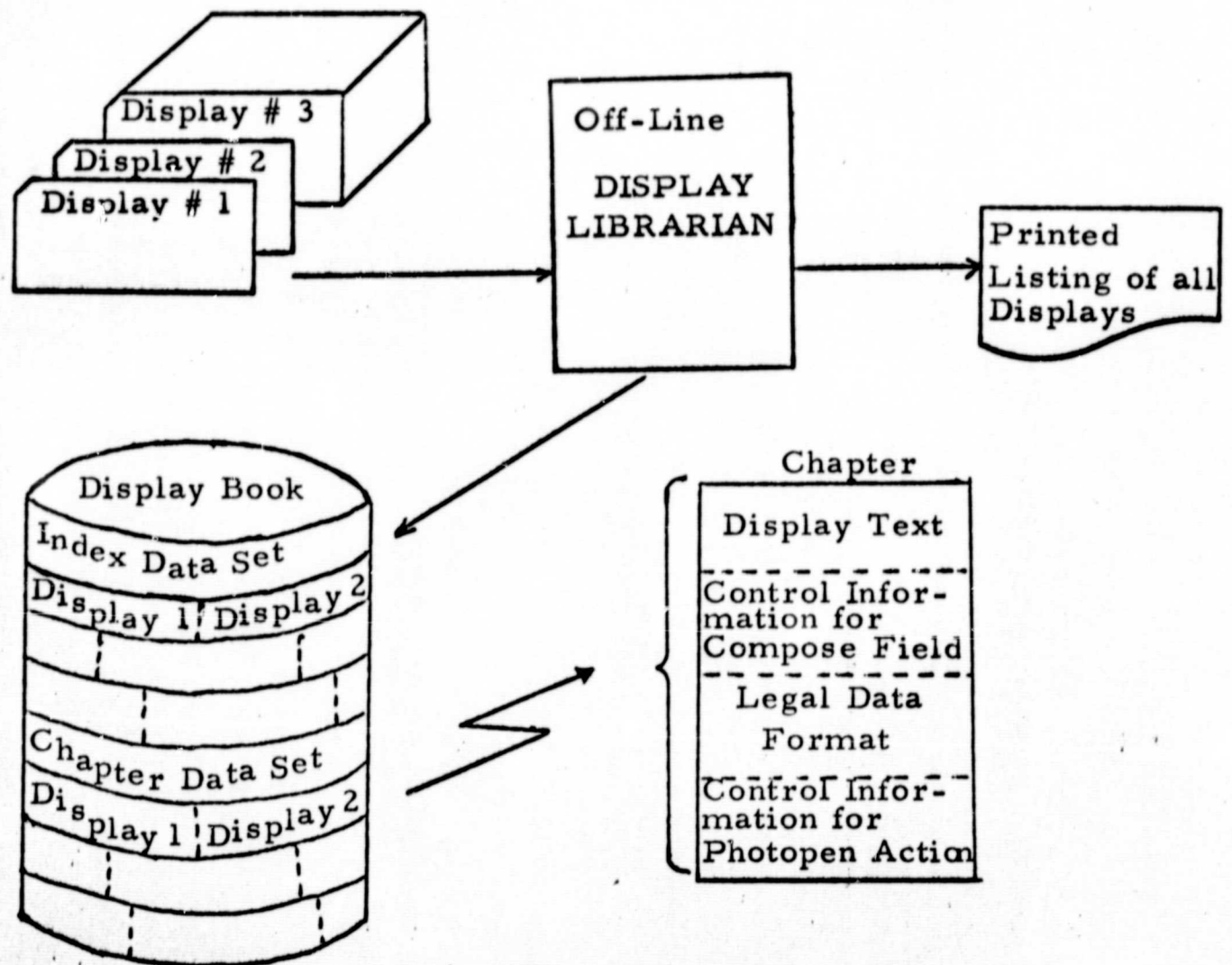


Figure 2.2

FUNCTIONAL OPERATION

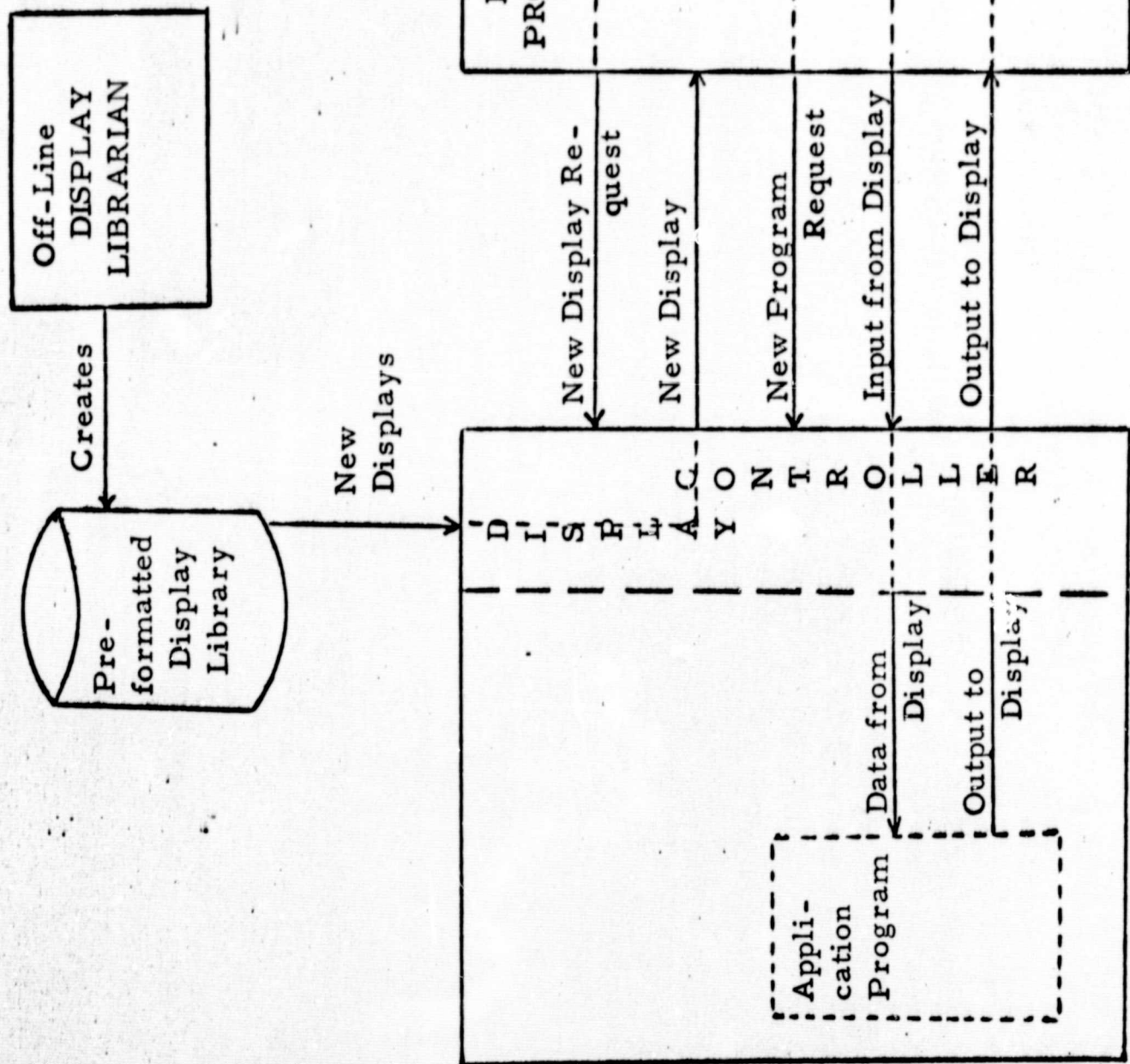


Figure 2.3

the Photopen or keyboard, the Display Processor will use these pages to determine the NEXT PROGRAM and the NEXT DISPLAY and will pass the information to the Display Controller in the Sigma 5 through a Sigma 2 Transmission List.

2.4 QUICK LOOK

The Quick Look feature being implemented as part of this contract effort will utilize the Display Support Software by interfacing the Display Terminal with the Banning Artwork Program in a manner which permits the user to perform artwork job set-up and control card deck generation from the Graphics Terminal.

This feature will provide an application program test bed for demonstrating the basic capabilities of the Display Support Software while at the same time simplifying the Artwork Program user training requirements and user operation.

SECTION III

PROJECT IMPLEMENTATION

During the first month of this contract our efforts were primarily concerned with getting on-board both the Banning system of programs and the Sigma 5 computer. In particular, the following in-house goals were set for our first month's work:

- a) Study all available documentation on the Banning system of programs in order to become as familiar as possible with the Banning MOS design cycle and the internal structure and operation of the individual programs comprising the Banning system. It was necessary to complete this effort before the scheduled trip to NSA in order to be able to use the meeting with the NSA personnel to its full potential.
- b) Create usable source programs and a usable pattern library from the original Banning source tape. The original source tape was created on an octal machine using a 6-bit character code. In order to be compatible with the required input to the XDS Fortran Processor, this original source tape had to be converted to an equivalent tape containing an 8-bit character code (EBCDIC) suitable to the hexidecimally oriented Sigma 5 computer.
- c) Study the available documentation on the XDS Sigma 5 computer, Sigma 5 operating systems, assembler, and Fortran Processor.

Each of these internal goals was satisfactorily met during February.

A trip to NSA was made February 29, 1970, to discuss the Banning PRF and Artwork Program with their technical personnel. The trip was highly successful and productive, and Mr. D. Durr of NSA was able to satisfactorily answer all our questions and provided us with a number of examples of Banning Program output which provide considerable insight into program operation. Appendix A to this report documents the discussions held with Don Durr.

A major Banning progress review was held with the cognizant NASA personnel on March 26, 1970. At this design review, four major subjects were discussed in detail.

- o Current Artwork Progress and Status
- o The Display Support Software

- o Quick Look
- o Additional Banning Considerations

3.1 ARTWORK

3.1.1 February

Since our major effort through April was directed toward the Artwork Program, our major study effort in February was concentrated on the Artwork manuals and program listing. The Artwork User's Guide and Artwork Programmer's Manual were sufficient to determine the general flow of the program and the formats of the input control information to Artwork. The program listing provided information necessary to determine the formats of the large data arrays and to understand how the pattern library was used by the Artwork Program.

3.1.2 March

The first step necessary to provide a usable Artwork program required the development of the "binary pattern library." The information required to create the Banning binary pattern library was supplied on magnetic tape by NSA in the form of approximately 50,000 card images. The reformatting that was necessary to produce the binary library required an extensive use of the available Sigma 5 tape drives. The tape drives were poorly aligned requiring a larger amount of time to be spent with maintenance personnel in solving the tape hardware problems before the binary library could be created.

The compilation of an error-free version of Artwork on the 32K Sigma 5 was the next step in the implementation of the Artwork Program. Modifications to the Fortran coding were necessary to compile successfully under the constraints of the available Sigma 5 Fortran IV-H compiler. To force the program to fit into the available 32K memory, the circle drawing capabilities of Artwork were deleted. The major difficulties in producing the error-free Artwork Program, however, were not within the program itself, but were in the area of Sigma 5 machine time availability.

The Banning PRF Program normally drives the Artwork Program, however, since the PRF Program was not operational, the manual mode of operation was used to debug the Artwork Program. The cell design capabilities of the Artwork Program were verified by actually designing a cell, creating a composit artwork of the cell, and adding the cell to the Banning Cell Library.

The major Artwork verification effort consisted of producing the Artwork necessary to create the masks of the test chip illustrated in the Banning User's Manual. This test chip uses 59 Banning cells and is considered to be an extensive test of the Artwork Program's capabilities. The masks produced as a result of running this test case were made available to NASA at the March 26, 1970, Banning Progress

Review.

Since the Gerber Plotter accepts only paper tape input and the Artwork Program produces only magnetic tape output, two special Magnetic-tape-to-paper-tape conversion programs were written. One program runs on the SEL 840 and has a punch output rate of 300 characters per second. The other program executes on the Sigma 5 and has a punch output rate of 10 characters per second. Since the Sigma 5 has such a slow rate, it is to be used only when the SEL 840 is not available and will not be available for some time. Thus this program is termed "emergency."

The Banning Artwork Program is designed to optimize the use of the Gerber plotter by using slit apertures to decrease the number of plotter movements required to fill a polygon. Slit apertures are not presently available on the NASA Gerber plotter, but the work order was given to begin manufacturing them. Examples that we have indicated that the slit apertures could produce a 50% savings in plotter time, and paper tape.

3.1.3 April

Once a value for a particular field within the Gerber Artwork Generator command has been specified, it remains in effect until replaced by a new value. However, the Artwork Program created a complete command for each generated Gerber operation. In order to reduce the amount of paper tape produced when transferring the data from magnetic tape to paper tape, logic was included in the conversion program to eliminate the repetitious plotter command fields. This modification to the punch program reduced the amount of paper tape required to represent the Gerber commands produced by the Artwork Program by approximately 60 percent.

The major Artwork verification effort was conducted during March by producing the artwork necessary to create the masks of the test chip illustrated in the Banning User's Manual. However, during April numerous additional smaller tests were conducted in order to determine how different apertures and filling techniques effect Gerber plotting time and efficiency.

The results of these tests were documented and presented to a group of cognizant NASA personnel on April 16, 1970. The purpose of these tests and the resulting meeting was to determine the most efficient way to use the Artwork Program in terms of plotter efficiency, program efficiency, and impact on the present Gerber plotter operational procedures.

The final documentation of the Artwork Program was developed in two parts:

- 1) User's Manual
- 2) Programmer's Manual.

These two manuals correspond to the original documentation supplied by NSA for the Artwork Program. However, the original documentation was several years old and had not been updated to reflect the current status of the program. The original manuals were programming oriented, even in the definition of user control options, and were difficult to interpret without a working knowledge of the Artwork Program.

In rewriting these manuals, M&S Computing hoped to be able to produce documentation that could be easily read and interpreted by the engineer/designer user of the program. The User's Guide to the Artwork Program was completed and circulated to the Technology Division personnel during April.

As soon as a usable version of the Artwork Program was developed, an effort was begun to prepare material for a user-oriented class describing the capabilities of the Artwork Program. The class was designed to describe the functions performed by the Artwork Program in relation to the overall functions performed by the Banning system of programs. The class discussions and material given out within the class provided the user with sufficient information to use the Artwork Program for creating circuit mask. The class was held April 27-30.

3.1.4 May to Present

During May NSA released a new version of the Banning Cell Library in order to correct problems with numerous Banning Cells that had been reported by Banning users. M&S Computing felt that it would be better to convert to the new library immediately so that the NASA designers would have the benefit of the most up-to-date Banning Cell Library. The information required to create the Binary Pattern Library was supplied on magnetic tape by NSA in the form of approximately 50,000 card images. The reformatting that was necessary to produce the binary library required approximately 40 hours of work on the available 32K Sigma 5 computer. The new library was completed and is presently being used by the NASA designers.

An error-free version of the new Artwork Program containing the Aperture Sort capability was compiled. Since the Artwork Program requires from 2 to 4 magnetic tapes to operate, the final verification efforts had to be postponed until additional tape drives are installed on the new 64K Sigma 5 computer.

The "Programmer's Manual" was completed and distributed to NASA personnel.

The Programmer's Manual contains a detailed description of the internal logic and flow of the Artwork Program. The document is primarily a rewrite and update of information contained in the original documentation for the Artwork Program produced during the contract for the initial definition and implementation of the Banning System of Programs. The Programmer's Manual and the User's Reference

Manual serve as the final documentation of the Banning Artwork Program as implemented for the Technology Division's Sigma 5 computer.

Roy Avani and Bob Forston have designed a circuit composed of 50 standard Banning cells. M&S Computing is working closely with these people in order to introduce them to the capabilities provided by the manual design mode of the Banning Artwork Program.

3.2 PRF (PLACEMENT, ROUTING, AND FOLDING)

3.2.1 February

Although our major PRF effort did not begin until mid April, it was important to review the available documentation in order to determine the general flow of the PRF Program, the accuracy of the available documentation, and the type of additional information that would be required to support our future work with PRF. Since the documentation and program listing indicated that major modifications had been made to the type and number of inputs to the PRF Program, particular emphasis was placed on reviewing these inputs and preparing questions needed to clarify the discrepancies. These questions and their answers have been included in the Appendix A attached to this report.

3.2.2 March

During March M&S Computing conducted a PRF study effort at a much reduced manpower level. This effort was directed toward reviewing the available program documentation and studying the program listing in order to determine the general flow of the program. The major output of this effort during March was the identification of possible program break points. These program logic break points are important in designing an overlay scheme for PRF. Since the program is currently configured for a 96K memory size, it was realized that it would be necessary to segment the program into several smaller programs and overlay them during execution.

3.2.3 April

The PRF documentation study begun in March continued during the month of April as a parallel low-key effort to the Artwork Program efforts. The major output of this effort during April was the functional flowcharts of the major subroutines within the program. These functional flowcharts were a necessary step toward understanding the program listing and determining the general flow of the program. It was necessary for M&S Computing to produce these flowcharts since only minimal documentation on PRF was available from NSA.

3.2.4 May to Present

In addition to the Artwork effort conducted during May, M&S Computing started a major PRF study effort. This effort was directed toward the program listing in order to produce flowcharts of each

of each subroutine within the PRF Program. M&S Computing intends to produce a programmer's manual for the PRF Program containing flowcharts and descriptions of each subroutine within the PRF Program.

Implementation requirements for the PRF Program include:

- 1) Design an overlay scheme to force the PRF Program originally developed for a computer with 96K memory storage, to fit in the memory available on the Sigma 5;
- 2) Rescale the arrays to fit the constraints of the available Sigma 5 memory;
- 3) Implement the PRF Program;
- 4) Verify the PRF Program;
- 5) Document the PRF Program;
- 6) Provide PRF user training.

3.3 DISPLAY SUPPORT

3.3.1 February

Our initial efforts were primarily concerned with getting on-board with the Sigma 5 and Sigma 2 computers and the ADDS/930 Display System. The following goals outline the concentration of our first month's effort.

- a) Study the available documentation on the Sigma 5, Sigma 2, and ADDS/930 in order to become familiar with the system components. This effort was necessary to detect possible hardware restrictions or capabilities to be taken into consideration in designing and developing the display support software.
- b) From the information gained from Step a, design a graphics software package which will optimize the use of system components and operate efficiently in the Sigma 5/Sigma 2 system environment.

3.3.2 March

The detailed design effort on the graphics software package was completed and resulted in the preparation of a graphics display software design document. This document was submitted to NASA for approval on March 17, 1970.

On receiving approval of the designed software package, the display support effort shifted to the implementation of the off-line display librarian. The concentration of effort in this area was primarily concerned

with the detailed flow charting of the display librarian.

3.3.3 April

During April, the major effort was directed toward coding and debugging the off-line display librarian. Every section of this program, except the section that builds the book of displays on the disk, became operational. The lack of documentation on the display hardware, Sigma 2/display interface hardware, and the Sigma 2/Sigma 5 interface hardware prohibited the building of the actual display refresh program required to construct the book of displays on the disk.

We asked for help in obtaining the required documentation, but all indications were that the documentation would not be available until after the Sigma 2 and display hardware were delivered. This was a late date for receiving programming information, but was tolerable if the delivery schedules were not slipped appreciably. In the meantime we had been able to locate a contact at the Sanders facility in New Hampshire that we could contact directly for information on the Sigma 2 and display.

3.3.4 May to Present

In the display support area, work on the Display Processor flowcharts was restricted by the lack of definition of the communication between the Sigma 2 Display Processor, the Sigma 5 Display Controller, and the application programs. The major concentration of effort, therefore, shifted from the development of the flowcharts to the final detailed definition of the communication. This definition was completed and the Graphic Display Software Design Document was being updated to include, in detail, the communication requirements.

We received the ADDS/930 display hardware documentation about the middle of May. Work on the off-line Display Librarian was, therefore, resumed and is nearing completion.

The portions of the Librarian software, which have been completed and are operational under CASAM, are presently being converted to operate under the newly SYSGENed BPM system.

3.4 QUICK LOOK

As can be seen from the schedule of Figure 1.2 it is not planned to initiate the major Quick Look effort until July 1, 1970. As a result little has been done in the Quick Look area to date other than to define the basic philosophy and general intent of the package. In order to gain operational experience with the Display Librarian the displays necessary to permit the user to perform artwork program job setup and control card deck generation from the graphic terminal were designed. The displays were verified and formatted by the Display Librarian Program. A complete set of displays was completed and ready for NASA review on the 27th of May. NASA has reviewed and approved the Quick Look

package of displays and it is this package which will be used as the implementation baseline for the Quick Look effort.

SECTION IV

MAJOR PROBLEMS

4.1 CREATING USABLE BANNING SOURCE PROGRAMS

It initially seemed like a minor programming effort to write a program to convert the octal character codes on our original Banning source tape to the 8-bit EBCDIC codes suitable for input to the XDS Sigma 5 Fortran processor; however, several problems developed that complicated the conversion. The following problems extended the development time and increased the programming effort required to produce the conversion program.

- a) Our first complication appeared when the Sigma 5 was unable to read our original source tape at 800 BPI density. The quickest way around this problem was to copy the original Banning source tape from 800 BPI to 556 BPI density on another computer. This required writing special software for another Astronics computer to perform the tape copy. The copy was done using the Ratheon 520 computer and the Sigma 5 was able to read the 556 BPI tape with no further hardware problems.
- b) As soon as we began printing the tape, a format problem was encountered. The program that had been used to store the original source program cards onto the tape had written 84 characters of data for every 80 character card image. The four extra characters were carriage control information that should have been suppressed when the card image was written onto the tape. Since the XDS Fortran processor cannot handle anything other than 80-character card images, the conversion program had to be expanded to reformat the source input and eliminate the extraneous four characters of data.
- c) The definition of the conversion program had to again be expanded when we learned that the available XDS control system (CHASM) does not support blocked input and output. The original Banning source tape was blocked 15-card images per tape record; therefore, an additional capability had to be added to the conversion routine to deblock the source tape and create tape records containing one card image.

These additional capabilities that had to be incorporated into the conversion program extended the development effort approximately three weeks. The resulting program, however, is a useful general purpose utility program that will be used extensively in the future. The program will be documented in detail and made available as a regular utility program.

4.2 SIGMA 5 ORIENTATION EFFORT

The Sigma 5 orientation effort was straight forward in that the standard XDS documentation provided sufficient information to allow us to begin immediate work on the system. This study effort, however, uncovered one problem concerning the various XDS operating systems and their support of various versions of Fortran. The Astrionics Flight Systems Simulation Branch's Sigma 5 uses a basic operating system called CHASM, which is designed to support Fortran IV H.

Fortran IV H is a subset of the Fortran IV which is supported by the Basic XDS Batch Processing Operating System (BPM). As such, it is a one-pass compiler that emphasizes compilation speed at the expense of core optimization and the loss of certain extended capabilities.

The Technology Division chose to implement BPM and Fortran IV on its Sigma 5 facility to provide the greatest possible flexibility, however, considerable difficulty in generating a usable BPM system was experienced.

The Fortran IV H vs. Fortran IV problem does not affect us until we begin to implement the PRF Program. Artwork could be implemented using any of the available operating systems and Fortran compilers. As a result we proceeded to implement the initial Artwork Program on the 32K Sigma 5 under CHASM and Fortran IV H. The final version is to be implemented on the 64K Sigma 5 under BPM and Fortran IV.

4.3 MACHINE TIME ON THE 32K SIGMA 5

Only very limited machine time during second and third shift was made available to us for implementing the initial version of the Artwork Program and it was only by using extensive weekend time on the computer that artwork was implemented on schedule.

4.4 PAPER TAPE VS MAGNETIC TAPE INPUT FOR THE GERBER PLOTTER

The normal Banning Artwork Program output as developed by NSA is magnetic tape. The Gerber Plotter available to NASA only supports paper tape input. This is an extremely inefficient method for supplying the mask generation input and is extremely wasteful of paper tape (the test chip masks required seventeen reels of paper tape). The only long term solution is to find a way to use magnetic tape input, however M&S Computing has incorporated an interim solution by writing a "Magnetic to Paper Tape Conversion" Program to write the Gerber commands in a compacted shorthand form. This has resulted in reducing the required paper tape by approximately 60%.

Another major problem in this area was the limited amount of paper tape which was available in the Astrionics Laboratory. While this did not severely hamper the Artwork Program debug phase it did limit the ability of the program to be used in a fully operational mode by the Technology Division.

4.5 SLIT APERTURES

The Artwork Program is designed to successfully use any apertures defined for its use, however, it is considerably more efficient when it can use a selection of slit apertures. No slit apertures exist for the NASA facility at this time. The lack of slit apertures has not seriously hampered program debug but could be a problem during operational runs.

4.6 BPM

It was decided by NASA to use BPM as the primary operating system on the 64K Sigma 5. The SYSGEN'ing of BPM was primarily the responsibility of XDS and NASA, however, M&S Computing, as the primary system user, had to devote considerable time to supporting the generation of the system. This effort has placed considerable strain on our personnel who have had to provide this support while minimizing the impact on the primary work efforts.

4.7 LACK OF ADEQUATE PERIPHERALS

The 64K Sigma currently has only one 9-track tape drive and no card punch. Three more tape drives, one 9-track and two 7-track, are to be delivered shortly. However, until they are available the Artwork Program cannot be implemented on the larger machine and the checkout of PRF is being severely restricted.

4.3 SIGMA 2/SIGMA 5 INTERFACE

To date this is only a potential problem in that this interface has not yet been needed to support program checkout. However, it will be of such critical importance in the very near future that it is worthy of mention in this report as a serious concern.

The shared memory hardware and the cross processor interrupts are necessary for checking out the display support software and quick look.

APPENDIX A

ARTWORK QUESTIONS/ANSWERS

1. Q The Artwork's Programmer's Manual defines a "binary mode" library tape which is different from the pattern library tape that we currently have.
 - a. Q Distinguish between the two pattern library tapes and determine the process to follow to create a "binary mode" library tape from our existing pattern library tape.
A The pattern library supplied by NSA contains the card images that define the numerous patterns that combine to form the standard cells described in the Banning Engineering Notebook. The Utility subroutine of Artwork accepts these card images as input and reformats the data on the cards to a format acceptable for use by the drawing routine of Artwork. The card image pattern library is currently on the first 19 files of the Banning source tape, blocked 15-card images per physical record. Before this data can be used as input to the Utility routine, the 19 files of data must be merged into one file and the card image must be deblocked to single card records. Control cards must also be inserted within the card image library to control the creation of the "binary" library.
 - b. Q Is the "binary mode" pattern library the one actually used by the Artwork Program?
A Yes.
 - c. Q Is the format of this pattern library the same as defined in the Programmer's Manual?
A Yes.
 - d. Q Is the "binary library" actually in binary or in BCD card images? Can this library be printed? Is a sample listing available?
A The "binary library" is written in the binary mode on magnetic tape, and cannot be printed in a readable format without specially designed conversion software.
 - e. Q Does the "binary mode" pattern library consist of only one file?
A Yes.

- f. Q Can the Artwork Utility Routine handle our 19-file pattern library tape?
- A No, the current 19-file card image library must be merged into one file before it can be used as input to the Utility routine.
2. Q Since the on-line printed output of Artwork has changed from the output described in our documentation, we need a current sample of an Artwork run.
- A There are now two versions of the Artwork Program: 1) the old version - Artwork and 2) the new version Artwork with Aperture Sort. We have a sample of the input and output of each version using the same input data for each.
3. Q Pattern Sets are not used by PRF input to Artwork. Does this mean that pattern sets are merely a convenience designed to facilitate manually driving Artwork?
- A Yes, the only requirement is that each cell within a pattern set must be on the pattern library.
- a. Q What are the major uses of pattern sets?
- A Pattern sets are primarily used to reduce the amount of repetitious input required by Artwork.
- b. Q Why are they defined absolutely when they are obviously used in a relative manner? (Digitizer?)
- A Digitizer output is in absolute format.
- c. Q Is the Gerber plotter information on each pattern set definition card ignored by the Artwork Program?
- A The Gerber plotter information is automatically created by the digitizer, but is ignored by Artwork.
4. Q The Artwork output, titled "Patterns in Order of Output from Library," does not list patterns in a perfectly sequential manner. Does this imply that the patterns do not have to appear on the library tape in a sequential manner?
- A Patterns are stored on the library tape in the order in which they were fed into the Utility subroutine. However, levels appear on the library tape in a sequential manner.

5. Q What are the 5 and 6 level masks? Where do they appear on the pattern library? Can you draw level 6 without using level 5?

A Levels 2 and 5 are interchangeable. Level 5 was originally used by AMI. Level 2 is used by Philco. Level 5 is more widely accepted now. Level 6 is merely a protective covering that covers the entire chip except the pad and test transistors.

Any number of levels (1 to 6) may be drawn on a particular Artwork run; however, levels are drawn sequentially making it impossible to skip levels. The only control inputs are the first level to draw and the number of levels to draw. Therefore, if you need to draw levels 1, 3, 4, 5 you must also draw level 2 because you start with level 1 and must continue in a sequential manner. However, an end-of-file is written after each level is completed so that any unnecessary levels can be deleted before plotting.

6. Q Review the circle patterns. In particular;

a. Q There are no circle patterns on the existing pattern library.

A Correct.

b. Q Under what circumstances will they be required?

A Future designing requirements such as a bull's eye for an alienment mark.

c. Q Must all patterns be full circles rather than arcs?

A No, an arc may be drawn if the two end points on a radius are specified.

7. Q Review in detail the purposes of the options of the FILL subroutine options card.

A For best results use the standard options defined and illustrated in the Banning User's Manual.

8. Q What is the function of the LEVEL card, especially the BR1 and BR2 fields? What are the presently defined BR1 and BR2 values? Are these values fixed or variable?

A The LEVEL card allows the user to specify which levels to draw and to define the values for BR1 and BR2. The values for BR1 and BR2 are essentially fixed, but may differ from facility to facility.

All patterns with numbers less than BR1 are family patterns and

must contain a pattern for all levels (1-6). All patterns numbered between BR1 and BR2 are single-level patterns. All patterns numbered above BR2 are unique patterns that are to be drawn on every level.

9. Q Is a triangular polygon (to be filled with circular aperture) any polygon of more or less than 4 sides? Are all pattern library cells defined by rectangles? When are non-rectangle polygons necessary?

A The Banning Artwork Program defines any polygon that is not a rectangular polygon as a triangular polygon. All of the standard Banning cells are defined by rectangle polygons and all PRF output results in rectangular polygons. Manual operations may produce triangular polygons.

10. Q Why is the BLKOUT subroutine called at the beginning of each level with an N number of 998?

A This feature is used as an end-of-file mark on the output Gerber command tape. This command will be the first Gerber command on each level and will stop the Gerber plotter so that the operator can prepare the plotter for the next level of output.

11. Q Review the impact of blocked input and output on the Artwork Program.

A Since the binary mode pattern library is unblocked, a user written blocked I/O routine will probably not be required.

12. Q What are the 9 levels of a pattern referenced on page 15 of the User's Guide? Discuss the multiple use of the word "level" in referencing pattern sets and circuit masks.

A There are currently 6 mask levels defined by the Banning pattern library; however, the program has been structured to support a maximum of 9 levels. The currently defined levels are:

Level 1 = P-REGION
Level 2 = CONTACT & GATE
Level 3 = CONTACT
Level 4 = METAL
Level 5 = SAME AS 2 (DEEP DIFFUSION)
Level 6 = PROTECTIVE COVERING

13. Q Is line set information normally needed for only the metalization and P-levels?

A Yes, be careful, however, in reading the Artwork Manual (because it contains an example using a thin oxide process which orders the levels differently).

14. Q Review the printed output of Artwork.

A We have current examples.

PRF QUESTIONS

1. Q Parameter cards permit the following debug printout options: 1) PLACE, 2) INPUT, 3) ROUTE, 4) FOLD, 5) DIDDLE, 6) READ, 7) ASSIGN, 8) ARTWRK, 9) POWER. What are these options? Try to get an example of the output printout of each option.
A These debug options consist mostly of dumping the data in the internal arrays of the program. These debug printouts are extremely program dependent and would be meaningless without a working knowledge of the PRF coding. We have an example of some of this output, but will be unable to access its worth for the next couple of months. Other Banning users rely on NSA for interpretation of this output.
2. Q The parameter card formats appears to be different than those defined in the PRF User's Guide. What is the current format for the parameter card inputs? For example: The PRF User's Guide identifies only 5 pattern cards, but the PRF listing shows 7.
A The last two cards contain information required by the Signal Trace and Speed Analysis subroutines of PRF. Current information on these cards will be available from NSA within the next 2 weeks.
3. Q Are the parameters of the circuit type file cards correctly defined by the Banning Engineering Notebook?
A Basically the fields defined are correct, but additional parameters have been added for Signal Trace and Speed Analysis. The Pattern Library and Circuit Type File are related and it is important to use the Circuit Type File that goes with our version of the pattern library.
 - a. Q Why does the new definition of the left and right edge spacing on a circuit type file card contain so much less information than the original PRF documentation?
A Many of the parameters have been absorbed into the program code as constants. Many of the variables were useful in the thin oxide process, but are not used in the thick oxide process.
 - b. Q The Engineering Notebook indicates that field C of the circuit type file pattern card is a cell identifier for the LOG BLOSIM V and CONVERT routines. The current circuit type file does not appear to use this field, and in fact field B appears to overlap into this area on occasions.

- A This is an error in the Engineering Notebook. The field is not used by LOG BLOSIM V or CONVERT programs and the PRF program uses it only as part of the name field.
- c. Q The Engineering Notebook defines the maximum distance in edge cell spacing to be 0.9 mils, but the current circuit type file never appears to use a value greater than 0.6 mils. Is this actually the maximum spacing?
- A The 0.9 mils was originally used simply because it is the largest maximum one digit number. However, 0.6 mils is the process limit and we will never see anything larger.
- d. Q In the current circuit type file, column 2 of the pattern card is always blank. The Engineering Notebook indicates that the circuit name can start in column 2. Is this true?
- A Column 2 is the beginning of the name field and in fact column 1 could be used as the beginning of the name field.
- e. Q We wish to review completely the use of the field reassignment flag of the circuit type file pin card (Field B). Should the summing values for the phase one node with an internal killer start with the number 17 rather than the number 15? (See Engineering Notebook, pp. 4-23).
- A The reassignment flag is used to equate pin assignments so that the PRF program can have move flexibility in routing interconnections. The summing value 15 is an error in the Engineering Notebook and should be omitted. This will result in the number 17 being the first weighting value assignable to a cell consisting of a phase one node with an internal killer. The multiple weighting numbers are provided to allow the designer flexibility in assigning different values to pins that are similar, but are not logically equivalent.
4. Q We need to go through the PRF input formats in detail.
- A Follow-up documentation will be available from NSA in approximately 2 weeks that describe the changes that have been made in the PRF input deck since the original PRF documentation.
5. Q What is the card prior to the end card in the PRF input deck?
- A We were given documentation that covered the uses of the 18 parameters on this card. One of the more useful parameters is the "Fix and Fold" parameter which allows the designer to control the PRF Folding operation. This and the other parameters

5. A (Continued)

are explained sufficiently in the supplemental documentation provided by NSA.

6. Q We need an example of the current input to PRF and the corresponding output listing produced during a normal run.

A We have a listing of the compilation of PRF and a printout of a PRF sample run.

7. Q If the circuit type file is maintained on magnetic tape, can it be used directly as part of the PRF input? If yes, what control cards are necessary?

A The Circuit Type File can be maintained on magnetic tape and accessed by PRF by the use of the control card ALTR.

8. Q Columns 48 and 72 are zeros in the circuit type file library. What is the definition of these numbers?

A This is a spacing parameter that seems to always remain constant, but NSA was unable to give the specific purpose of the parameter without addition research.

9. Q What is an "ALTR" control card for PRF?

A This is not a system control card, but it is a control card to the PRF program that specifies an alternate data file. This control card is described in greater detail in the follow-up documentation that will be supplied by NSA within the next couple of weeks.

10. Q Review in detail the printed output of PRF.

A We have a sample PRF run.

MOS DESIGN CYCLE FLOW QUESTIONS/ANSWERS

1. Q What are the TRANSLATE routines that allow you to go from the coding sheets to the PRF input deck?
A We have a listing of the program, but it is referred to as CONVERT rather than TRANSLATE. The program actually converts the input to the LOG BLOSIM V into the PRF input format.
2. Q What is the Circuit Simulation Routine executed during the definition of new cells?
A This is a Fortran stand-alone program that is used to confirm the cell design.
3. Q What is the Aperture Sort Routine? We do not have a copy of this routine.
A This was previously a stand-alone program that sorted the Artwork Gerber plotter commands according to apertures. The new version of the Artwork program has the Aperture Sort Routine built into it.
4. Q Review in detail the MOS design cycle flow.
A This was done and comments and notes were written directly on the flow diagram.
5. Q The design cycle flow indicates that the input to the LOG BLOSIM V program is translated directly to PRF input format. Are the input cards to the simulator the same as the input to PRF? If yes, where is the cell logic information defined?
A The LOG BLOSIM V input contains the same information as the PRF program input, but in a different format. The cell logic information is built into the simulator.
6. Q How does the stand-alone PLACEMENT program differ from the PLACEMENT subroutine of PRF? What is the input to this program?
A They are the same programs available as a stand-alone version or as a routine to PRF.
7. Q What is the purpose of the 0 to 3 cycle PRF loop?
A This is the average number of cycles experienced by NSA required to verify manual cell substitution and placement modification.

8. Q What is the purpose of the ARTCHECK routine? Size? Language?

A This is a stand-alone Fortran program that checks the digitizer output for errors.