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# ADVANCED SIMULATION IN UNDERGRADUATE PILOT TRAINING: AUTOMATIC INSTRUCTIONAL SYSTEM

Victor Faconti, et al

Singer Company

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# ADVANCED SIMULATION IN UNDERGRADUATE PILOT TRAINING: AUTOMATIC INSTRUCTIONAL SYSTEM


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# NOTICE



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This technical report has been reviewed and is approved.

GORDON A. ECKSTRAND, Director
Advanced Systems Division

Approved for publication.

HAROLD E. FISCHER, Colonel, USAF
Commander

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20 ABSTRACT (Continue on reverse side if necessary and identify by block number)

The report describes the automated instructional system designed for the ASUPT simulator. Each hardware and software element is described with emphasis given in areas which presented significant design problems such as manual page preparation, data recording, preprogramming, etc. The system is the implementation of concepts investigated in the report, Automated Instruction and Performance Monitoring In Flight Simulation (AFHRL-TR-69-29).

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20. ABSTRACT (Cont)

The ASUPT system included requirements for capabilities related to performing research in training technology. In order to accomplish this, AFHRL established the need for the most sophisticated repertoire of instructional features ever included in a flight training system. The features covered in this category are designed to enhance the training effectiveness of the device, or more precisely, provide research capability in this area. The systems are designed to implement the concepts of learning theory. These include such concepts as performance feedback, knowledge of results, positive reinforcement, etc. This report describes the resulting system in an overall manner and discusses certain areas in more detail due to the unique design problem presented.

# SUMMARY

## PROBLEM

The advanced simulator for undergraduate pilot training (ASUPT) is a research device designed for investigating the role of simulation in the future undergraduate pilot training (UPT) program. For ASUPT to be effective in training research, the latest state-of-the-art instructional features implemented with flexibility for research must be available. This report describes the Automated Instructional System designed for the ASUPT simulator.

The development of the Automated Instructional System for ASUPT was based upon the research requirements for: (1) malfunction insertion, (2) variation of task difficulty, (3) performance feedback, (4) demonstration and replay, (5) data recording, (6) instructor feedback, and (7) maneuver sequencing.

These requirements are manifested in the hardware and software developed for this advanced training system.

## APPROACH

The approach to providing the above requirements was one of developing the most sophisticated repertoire of instructional features ever included in a flight training simulator. The systems are designed to enhance the training effectiveness of the ASUPT and to provide research capability in the advanced training area.

The major components are an alphanumeric CRT system, a calligraphic CRT system, an addressable reel-to-reel audio tape recorder, a random access audio memory drum, and an interactive software package which permits the user to develop preprogrammed exercises.

## RESULTS

An automated instructional system was successfully developed for ASUPT. The system provides the instructor with the information necessary to exert simulator control and a variety of hardware and software instructional capability; as such, the system represents one of the most important elements of ASUPT.

## CONCLUSIONS

The ASUPT automated instructional system is perhaps the most advanced training system ever developed for a flight simulator. The system is aptly suited for its role in UPT research.

## PREFACE

This report is the 4th of seven volumes describing the Advanced Simulation in Undergraduate Pilot Training (ASUPT) system development program. The seven volumes of AFHRL-TR-75-59 are as follows:

Volume I: Advanced Simulation in Undergraduate Pilot Training: An Overview

Volume II: Advanced Simulation in Undergraduate Pilot Training: Motion System Development

Volume III: Advanced Simulation in Undergraduate Pilot Training: G-Seat Development

Volume IV: Advanced Simulation in Undergraduate Pilot Training: Automatic Instructional System

Volume V: Advanced Simulation in Undergraduate Pilot Training: Computer Image Generation

Volume VI: Advanced Simulation in Undergraduate Pilot Training: Visual Display Development

Volume VII: Advanced Simulation in Undergraduate Pilot Training: Systems Integration

This project derived from a DOD Directive to the three Services requesting programs of advanced development in the area of training and education. The purpose was to insure that military training and education make the fullest use of recent innovations and technological advances. In October 1967, a joint Air Training Command/Air Force Human Resources Laboratory effort culminated in a recommendation to establish an advanced simulation system at an undergraduate pilot training base. Hardware development of the ASUPT began in 1971 and the system was released for research in Jan 75.

All members of the ASUPT Program Office and participating organizations who worked on the program contributed to the final system. In addition to the listed contract monitors, they include Don Gum, ASUPT Program Manager, James Basinger, CIG Project Engineer, Israel Guterman, Basic Simulators Project Engineer, William Albery, Systems Integration Project Engineer, Patricia Knoop, Advanced Training Systems Project Engineer, Kenneth Block, Program Controller, and Virginia Lewis, Secretary, all of the Advanced Systems Division, Air Force Human Resources Laboratory, Wright-Patterson AFB OH; Warren Richeson, Capt Frank Bell III, Maj Ray Fuller, Capt John Fuller, Capt Dennis Way, Capt Steve Rust, Capt Mike Cyrus, and Mr. Glenn York, all from the Flying Training Division, Air Force Human Resources Laboratory, Williams AFB AZ.

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## AIP RESEARCH/EXPERIMENTATION CAPABILITIES

The AIP provides research and experiment capability in the following areas:

(1) Malfunction Insertion: System failures may be inserted automatically as a function of simulator state variables. The capability is also incorporated to apply stochastic variables to the conditions for insertion.

(2) Variation of Task Difficulty: Task difficulty can be varied by controlling flight simulation fidelity, motion system response, environmental conditions, and the frequency and number of malfunctions.

(3) Performance Feedback: Student feedback is provided via two of the human sensory channels, auditory and visual. A speech retrieval system, manufactured by Cognitronics, Inc., allows computer-controlled audio messages to be output to students via the head-set. The in-cockpit CRT (Cathode Ray Tube) provides feedback messages generated automatically or by the instructor.

(4) Demonstration and Replay: The demonstration capability permits student exposure to standarized, prerecorded demonstrations of flight maneuvers. In addition, student performance can be recorded and replayed automatically.

(5) Data Recording: This feature is designed to provide large amounts of performance data for detailed analysis. Data accumulation and output can be up to the maximum iteration rate of the flight equations (as a function of selected output device). Any one of several devices may be selected as the output medium for this feature. Included as output devices are the CRT, line printer, TTY (Teletypewriter), magnetic tape unit, and CALCOMP plotter.

(6) Instructor Feedback: This capability is provided at the various instructor/operator stations. The display types and associated software were designed to provide a comprehensive display and control package. This package combines both digital and graphic representations of performance data which can be used by experimenters to analyze problems. A hardcopy capability is associated with this system to permit retention of certain types of data for debriefing and analysis.

(7) Maneuver Sequencing: Both manual and automatic maneuver sequencing are provided as part of the structure of the ASUPT preprogramming system. One automatic mode operates in the absence of manual intervention and is called auto-explicit sequencing. During this mode, the system software, upon detecting maneuver end conditions, prepares for execution of the next maneuver in the sequence as defined during preprogrammed exercise generation. The other automatic mode of sequencing, auto-computed, determines which maneuver should be practiced next as a result of past performance and predefined input data. This concept is described in more detail in the SOFTWARE section.

By using the preprogramming system during operation, most of the features listed above can be implemented automatically. Other features may be implemented manually by the user at the Advanced Instructor's Operation Station (AIOS). (Figure 1 illustrates the AIOS CRT controls panel.) The preprogramming system allows the user to design, monitor, and control conditions during a training exercise which may consist of up to twelve maneuvers (exercise segments). Each maneuver may utilize any subset or all of the AIP features available in the preprogramming system.

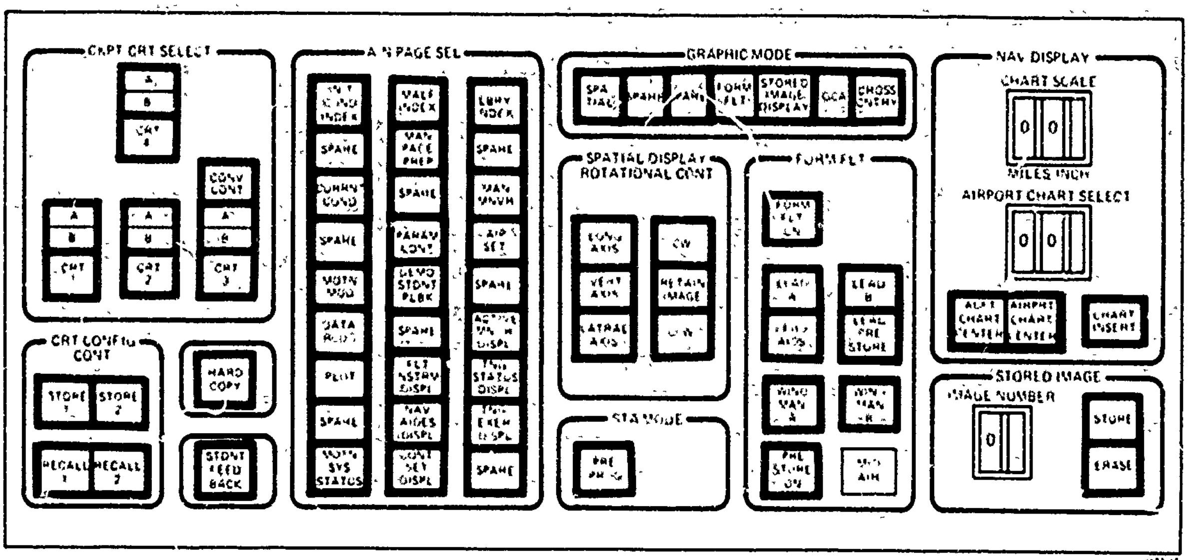



Figure 1. AIOS CRT CONTROLS PANEL

SYSTEM DESCRIPTION

The ASUPT training system consists of various hardware devices and related software designed to implement the training technology discussed earlier. The major components are an alphanumeric CRT system, a calligraphic CRT system, an Addressable reel-to-reel audio tape recorder, a random access audio memory drum, and an interactive software package which permits the user to develop preprogrammed exercises. Figure 2 illustrates overall software/hardware interface.

The alphanumeric CRT provides five separate display channels and is used to display digital information. Two of the channels provide a seven-color display at the AIOS. Two other channels drive monochrome displays, one located at each Instructor Pilot (IP) position in each T-37 cockpit. The fifth channel is not displayable in real time. This channel is connected to the hard-copy device which provides display after complete images are generated.

The calligraphic system drives two displays located at the AIOS, and is mainly used to present graphical information to users. Several different display types are possible (e. g. cross country maps showing location of navigation aids, airways, and aircraft location). It is further possible to display any alphanumeric page displayable on the alphanumeric CRT system.

The addressable audio tape unit is used in conjunction with the maneuver demonstration capability. During replay of the recorded flight, the audio system provides a narrative to the student position, with instructions to the trainee as to what should be monitored and observed during the maneuver.

The random access audic system operates in conjunction with a computer program that constructs verbal messages and transmits these to the student position through the head set.

Many of the capabilities associated with the hardware system described above are implemented by the user through the preprogramming system. This system allows generation of preprogrammed exercises which are used during experimentation to effect control over various aspects of training problems. Thirty different exercises may be stored at one time. During generation, the user interacts with this software, executing a background mode through the CRT/keyboard. FORTRAN code is generated and stored in various files which are combined to develop each exercise. The system is designed in a hierarchal manner. The highest level in this system is the exercise, which is comprised of a series of exercise segments, which, in turn, are comprised of one or more cases. A case contains the FORTRAN statements required to implement each AIP feature for that case. Certain unique cases may be assigned to more than one segment.

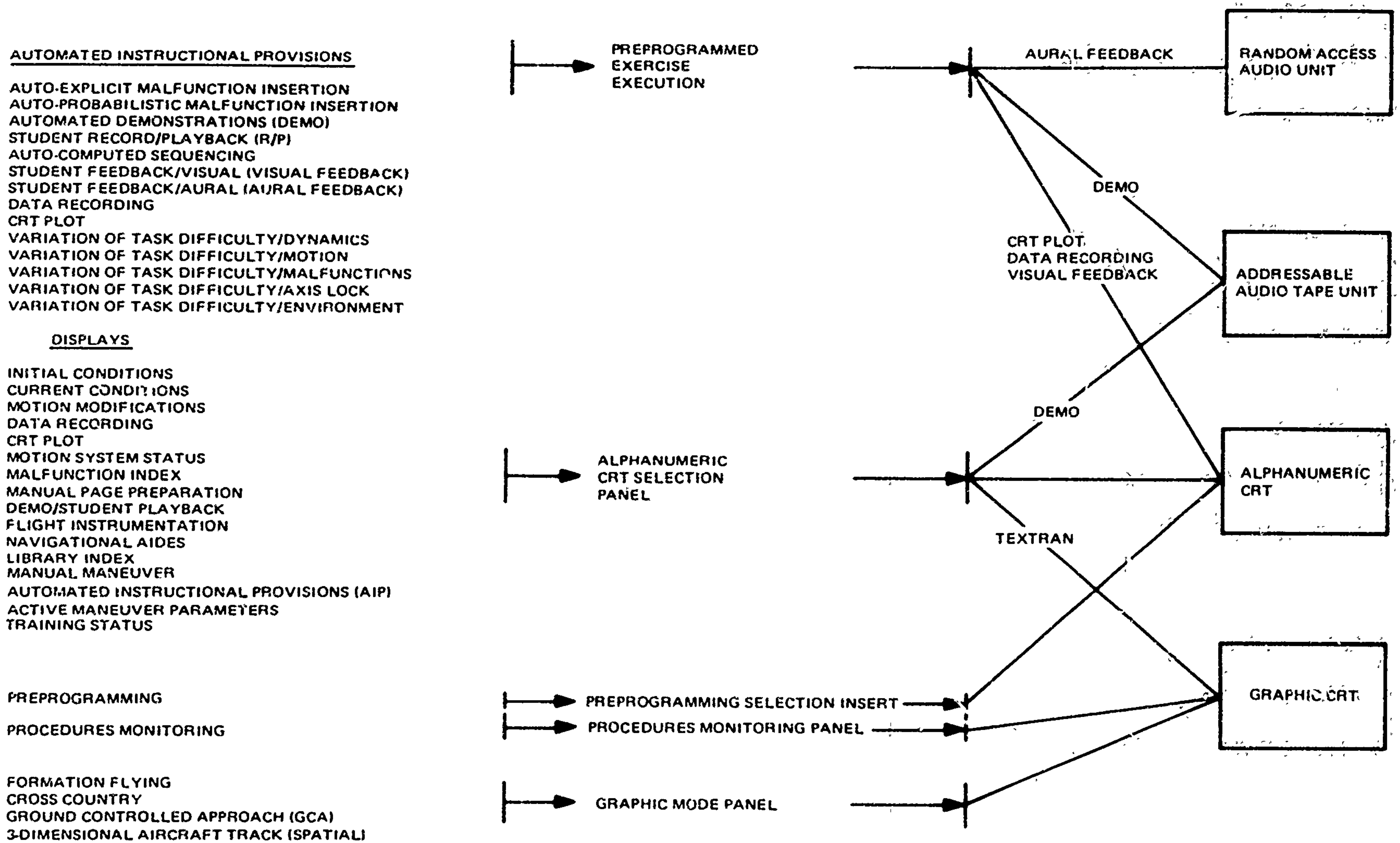



Figure 2. SOFTWARE/HARDWARE INTERFACE

All of these features combine to provide experiment capability in the areas discussed under AIP Research/Experimentation Capabilities. Flexibility is a key word associated with this system, as very little predefined structure is required.

## HARDWARE

The following paragraphs provide an overview of the hardware systems associated with the ASUPT automated instruction system.

### Alphanumeric (A/N) CRT Display System

The A/N CRT display is a raster type display capable of simultaneously displaying 3456 characters in one of seven colors. It is also possible, through the use of special graphic characters, to construct a "graphic" image with this system. This is a multi-channel system consisting of five totally-independent channels; one channel for each of the two cockpit CRT displays, two channels for the two-color displays at the external AIOS, and one channel for the hardcopy device.

The A/N CRT display system is built by Aydin Controls, Inc., and is configured with two display generators; one driving three monitors, and the other driving two monitors. The display generators are interfaced to a single SEL 86 data terminal through a multiplex/interface unit. Each display generator has refresh memory for each monitor. A Tektronix 4620 video hardcopy unit is driven through video switching circuits by display generators. Figure 3 illustrates the alphanumeric CRT display system.

### Graphic Display System

The graphic display system used for the AIOS was manufactured by Vector General, Inc. This system has two display tubes driven by a single display generator. The system is interfaced to the SEL 86 via a dual data terminal approach. On one channel, the data channel, serial data for display instructions is transmitted at the required refresh rate. The rate is derived through a clock-interrupt system within the display generator with the interrupts being transmitted to the SEL 86 over the Input/Output (I/O) channel at the rate of 120 per second. The refresh rate is controlled by software which counts down for the appropriate rate. Figure 4 illustrates the graphic display system.

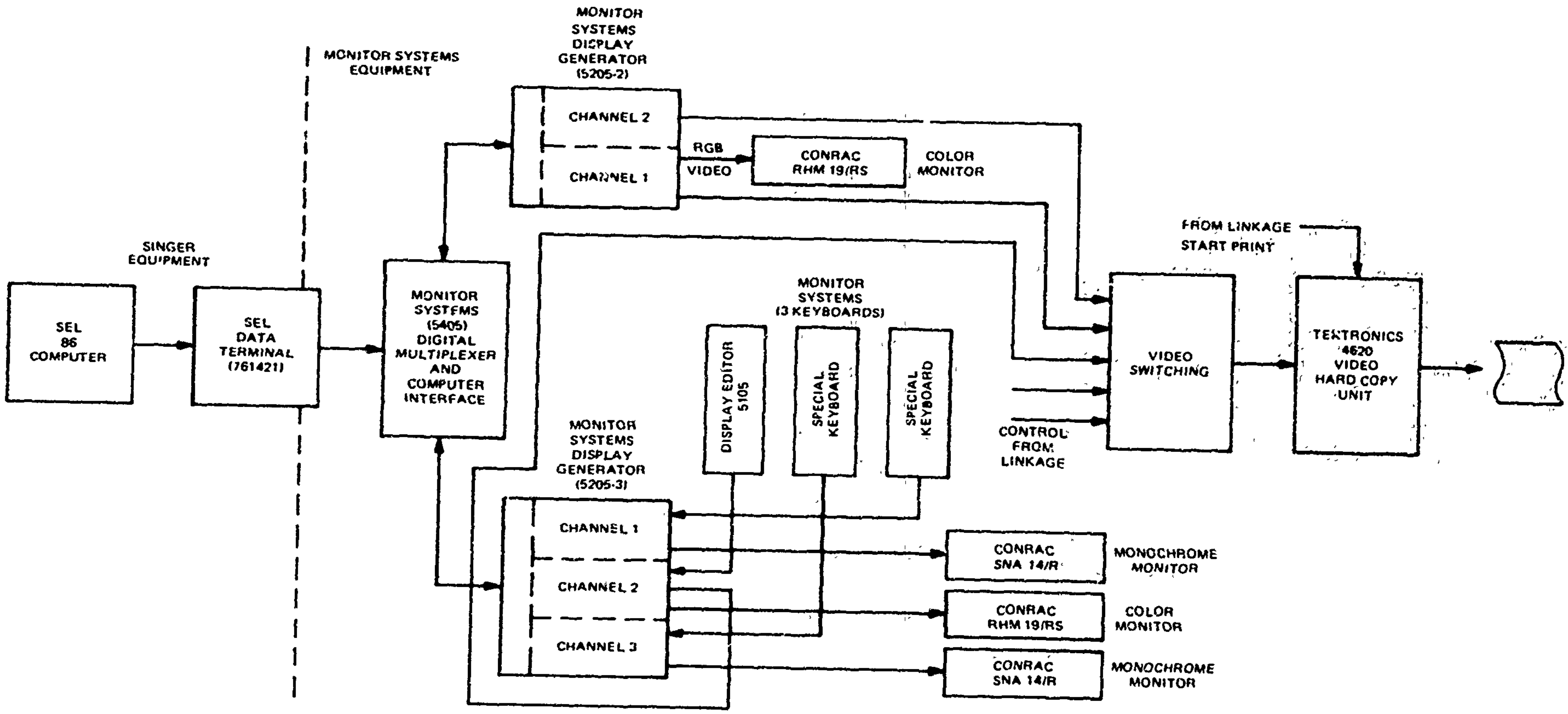



Figure 3. ALPHANUMERIC CRT SYSTEM CONFIGURATION

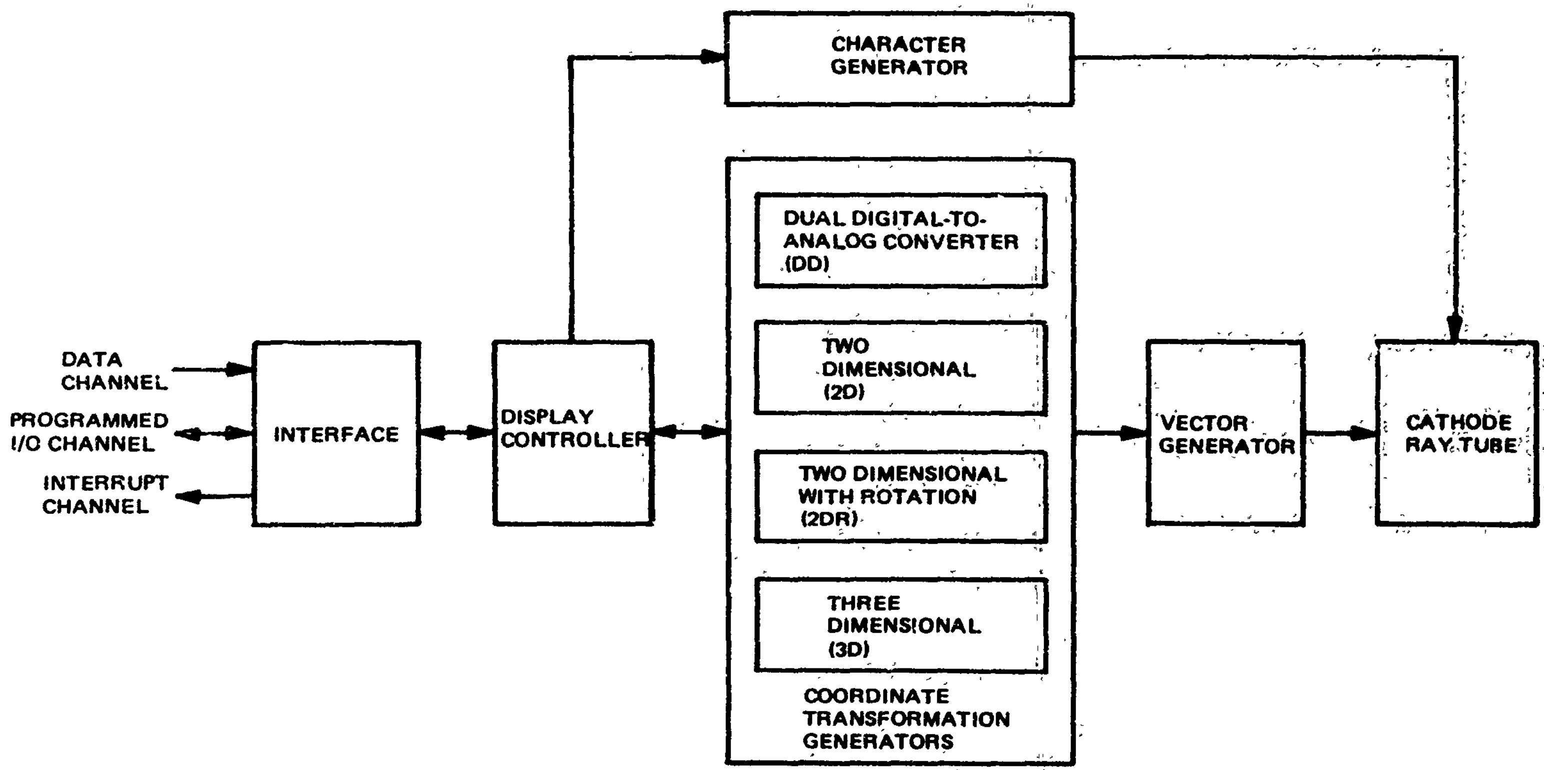



Figure 4. GRAPHIC DISPLAY SYSTEM BLOCK DIAGRAM

## Audio Feedback System

An audio feedback unit manufactured by Cognitronics, Inc. is provided to generate audio messages. The messages are generated from 189 individually-stored words which are randomly addressable. The system can output on two audio channels, one per cockpit, simultaneously. Since only one memory source is available, multiplexing is used to derive the desired word during each word time. Although all the stored words are output at the same time, the switching logic operation insures that only the audio amplifiers associated with the desired word for each channel are turned on. Therefore, there is only one word output per channel to each cockpit during each word cycle. Figure 5 illustrates the audio feedback system.

## Computer Controlled Audio Tape System

This system consists of a time code reader/generator, a tape search unit, and a reel-to-reel multi-channel audio-tape recorder. The system was manufactured by Eldorado Electrodata System, Inc. It is used to provide descriptive audio dialogue in conjunction with and synchronized with performance demonstrations. During the record operation, high-frequency time codes are written on one channel of the tape, while audio is being recorded on another channel. A single tape will then have several audio briefs associated with specific demonstrations. Each has a specific time address, and when required for replay, the tape search portion of this system is given the address by the demo software, and automatically searches and positions the tape to the correct address. Figure 6 illustrates the computer-controlled tape system.

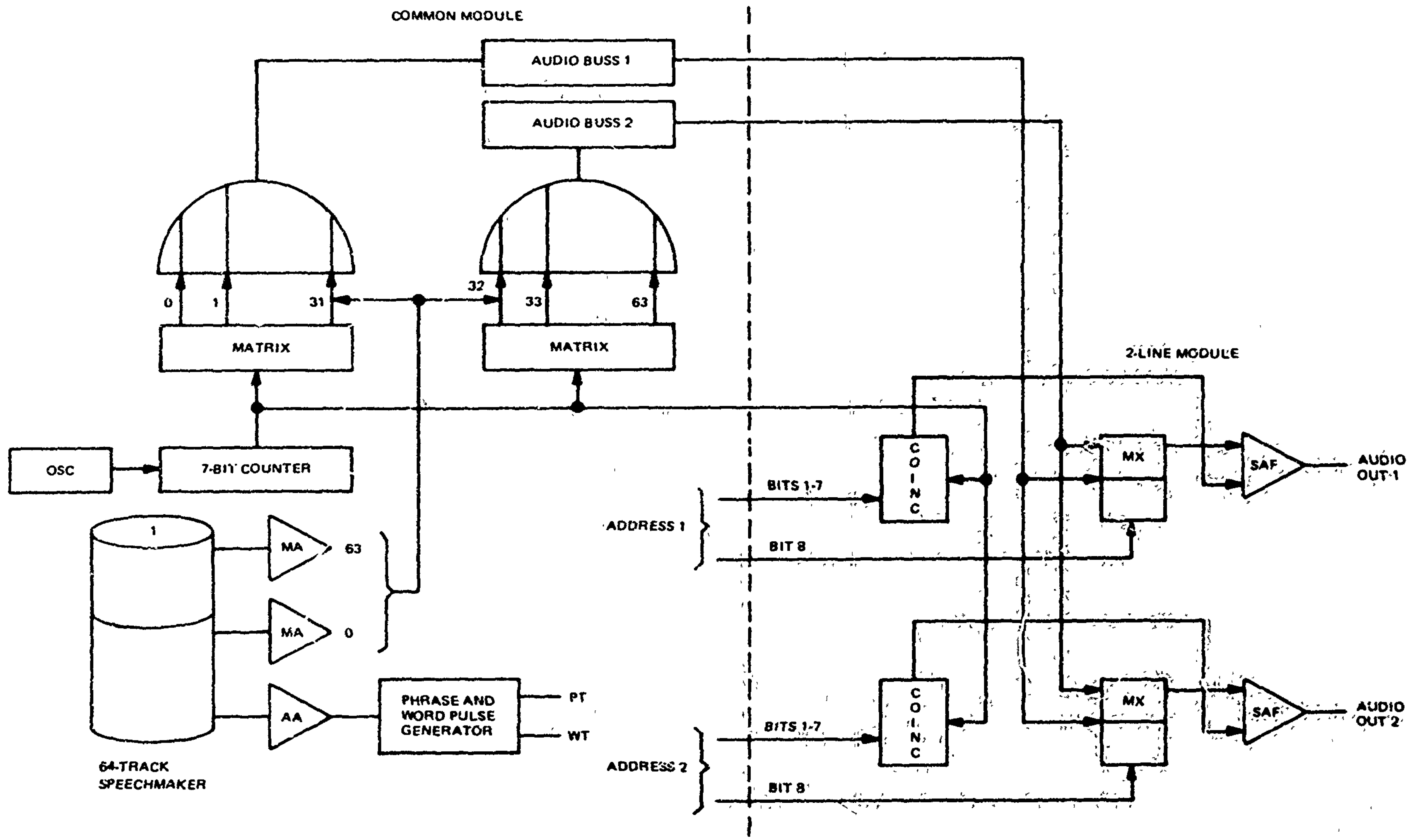



Figure 5. AUDIO FEEDBACK UNIT

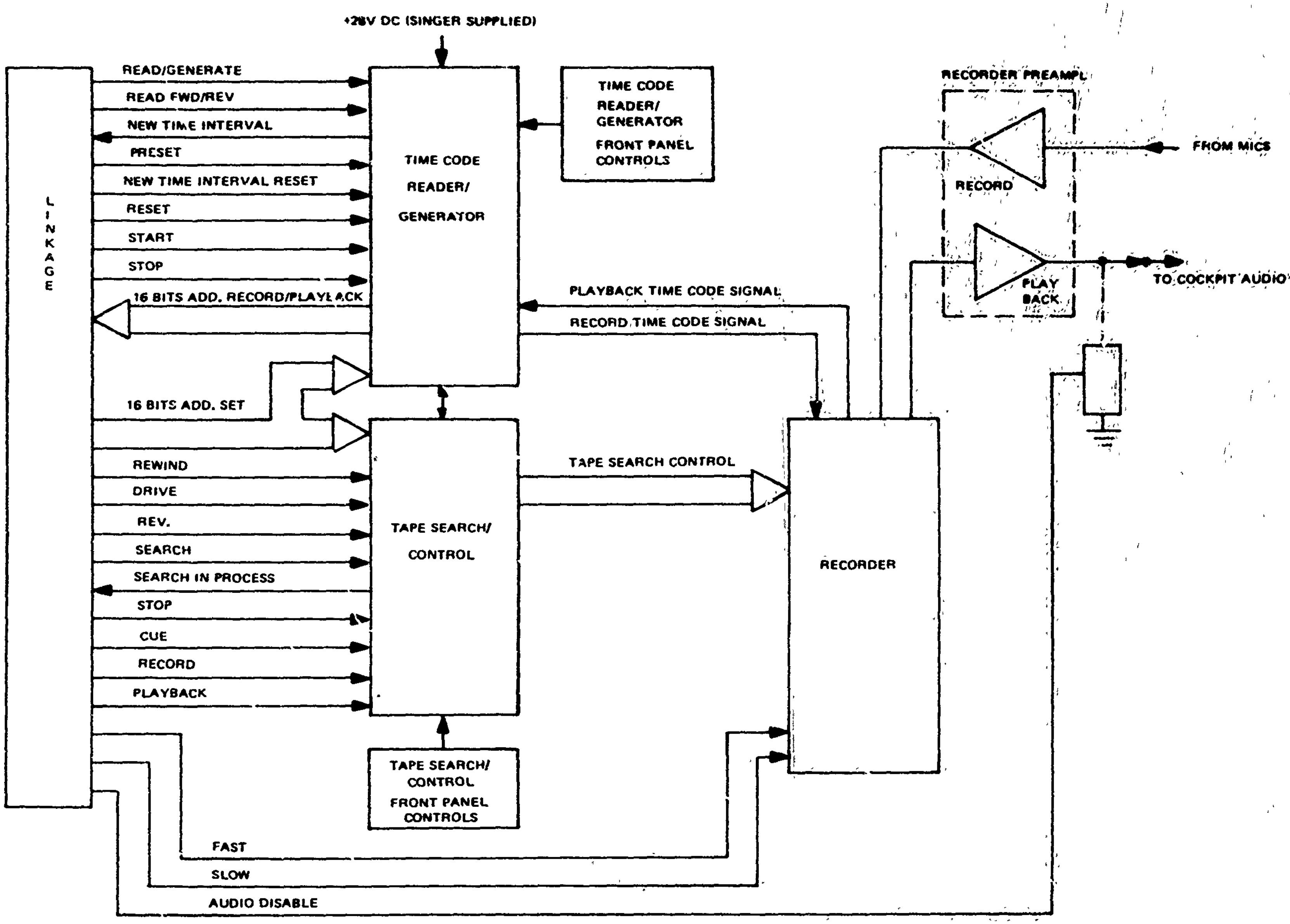



Figure 6. COMPUTER-CONTROLLED TAPE SYSTEM

## SOFTWARE

The AIP features, discussed earlier in this report, and the associated hardware are coordinated through a complex software package. This package takes advantage of many of the design features of the SEL 86 system; such as background processing, parallel I/O control, etc. The following paragraphs discuss the design approaches used for the automated instructional system. In particular, those areas requiring unique solutions are highlighted more than those for which coding was straightforward. Figure 7 illustrates the panels used to activate these software elements.

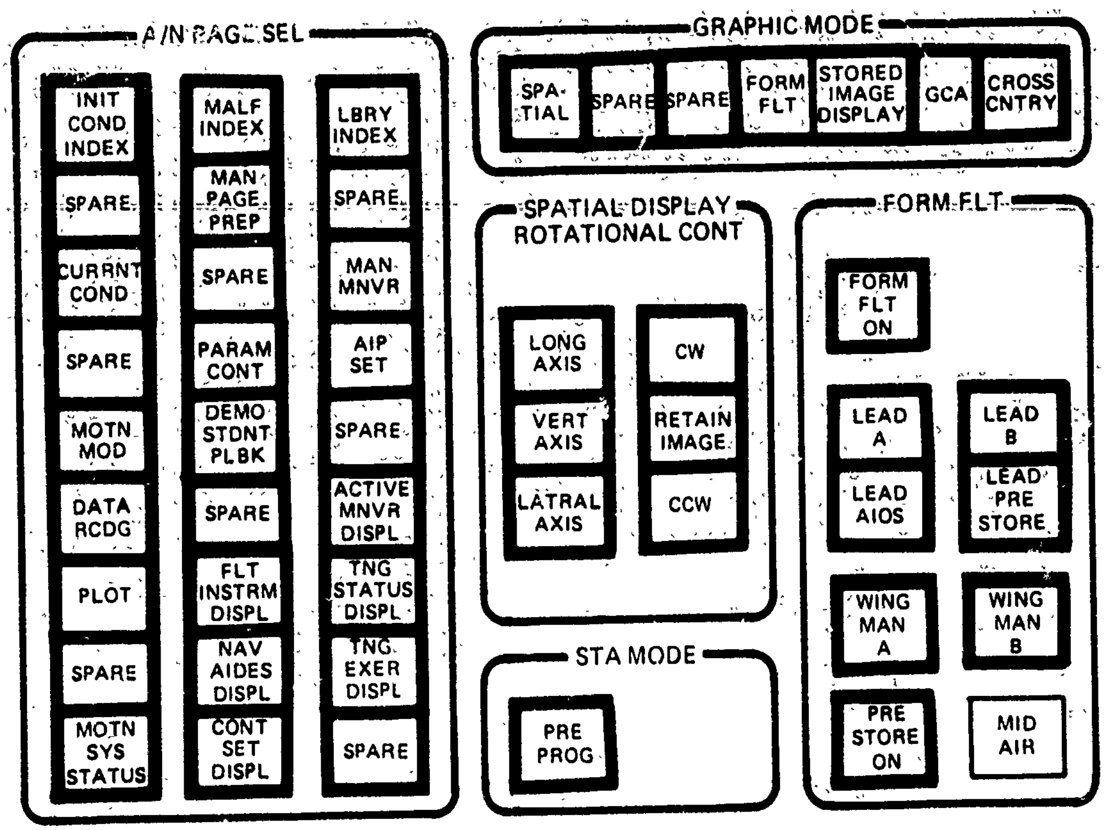



Figure 7. AIP CONTROL PANELS

Alphanumeric Display System

The major innovations of the alphanumeric display system are programs to generate alphanumeric pages on-line in the non-real time foreground environment (manual page preparation), programs to plot simulator/student variables (CRT plot), programs to provide real time data sampling and display of ASUPT data pool variables (data recording system), and programs to provide record/playback of training exercise (record/playback system).

Manual Page Preparation - Typical systems require off-line programs to generate new CRT pages. However, one of the ASUPT proposal requirements was to allow users at the AIOS to selectively tailor the content of up to four CRT pages to allow for combinations of variables not normally contained on one of the standard, selectable CRT pages. The original scheme was to identify a list of variables and allow users to identify from the list those variables which they desired to have displayed on one of the four constructible pages.

Each of these variables would need a recognizable symbolic name, a relative address, and conversion information so that the displayed information would be meaningful. Realizing that such a list existed, (i.e. the ASUPT symbol dictionary), and that further service software to retrieve the needed data also existed (i.e. SYMLOOK), the decision was made to provide user interface software to generate all alphanumeric CRT pages in this manner, including those required at delivery. The resulting package allows the user to generate new alphanumeric CRT pages or modify any existing page with little effort. The procedure to select a page which may be modified or used for a new set of parameters is as follows:

(1) At CKPT/CRT SELECT panel, depress CRT 2 or CRT 4 switchlight. The selected switchlight will illuminate.

(2) At CKPT/CRT SELECT panel, depress associated A/B switchlight one, two, or three times (depending on whether control is desired for cockpit A, B, or both). The selected section of the switchlight will illuminate.

(3) At A/N PAGES SEL panel, depress MAN PAGE PREP switchlight. The selected switchlight will illuminate, and the index page will appear on CRT with line identifiers representing each manual page. The MAN PAGE PREP group of CRT pages has two separate and distinct functions which should not be confused. One function is to create all permanent pages for display on the CRT's. The second function is to display groups of parameters of a particular operator's choosing (i.e., flight K-factors, motion K-factors, etc.). There are 48 pages following an index and instruction page which can be used to display up to 80 parameters each.

(4) At keyboard, type the line identifier of desired page, and then depress shift key and XMIT P. PAGE switch (above keyboard). The selected page will appear on CRT.

When calling a display page from the index, the manual page software changes the nature of the CRT page so that parameters may be displayed and changed. This modificiation of the control word precludes the use of a paging option, available on other types of pages, when going from the manual page index to a display page. That option is one transmitting of a plus sign to advance one CRT page or a minus sign to back up one page. This option may be used only between display pages.

The value of a particular parameter on a selected page may be changed by entering the following control sequence on the keyboard:

A:B 'XMIT P.PAGE'

Where A is a two-digit parameter line number and B is the desired value.

To change the value for both cockpit A and cockpit B at the same time, enter the following sequences on the keyboard:

A1:A2:B 'XMIT P.PAGE'

Where A1 is the line number of the cockpit A variable, A2 is the line number of the cockpit B variable, and B is the desired value.

A boolean value may be changed in the above sequences by typing INS or DEL in place of :b.

The manual page preparation programs provide the operator with a means of generating or changing any CRT page provided with the ASUPT simulator. The page is generated on the CRT which displays inputs from the keyboard.

The CRT page may be made up of any combination of fixed words and phrases, and computer-supplied responses. The page format has the following limitations:

(1) The first line and last three lines must be blank.

(2) Space must be allowed for ten digits of computer-supplied values.

(3) No more than 80 computer responses can be placed on a CRT page.

Upon selection of the MAN PAGE PREP switch, as previously described, an index of all manual pages (figure 8) will appear on the selected CRT. Select page 01 PAGE GENERATOR by typing the following on the keyboard:

01 'XMIT P.PAGE'

The manual page index page will be replaced by a set of instructions shown in figure 9.

Select the desired page to be generated by typing a control sequence of the following form:

A:B:1

A is a one or two digit numeral designating the desired A/N PAGE SEL switch number. The switches are assumed to be numbered from 1 to 27 (top to bottom, left to right). There are two exceptions to this rule. Procedures sequence monitor is assumed to be switch 35 and the cockpit CRT index is assumed to be switch 36.

B is a one, two, or three digit numeral designating ~~the~~ particular page number of the above group. Page numbers begin at one and continue through a three digit number unspecified as far as this program is concerned. The number, however, may not be greater than 125.

Insert the control sequence by keying 'XMIT P.PAGE'.

Example:

It is desired to change a malfunction on the third page of the malfunction group of CRT pages.

Type in 10:3:1 'XMIT P.PAGE'

Where 10 is the number of the MALF INDEX switch
and 3 is the third page of the group

Once a page has been selected for change or generation, the program will enter a generation mode. While in this mode, the instruction page will be displayed on CRT 4 (the second A/N CRT at the AIOS which displays pages) and the page being changed or generated will be displayed on CRT 2 (the A/N CRT which displays keyboard entries at the AIOS). Keyboard control will automatically transfer to CRT 2. Any keyboard entry from the AIOS while in the generation mode will be processed as an entry to CRT 2 and will be accepted as a CRT page change.

MANUAL PAGE INDEX (11-01)

| PAGE NUMBER | TITLE |
|---|---|
| 01 | PAGE GENERATOR INSTRUCTIONS |
| 02 | FLIGHT ACCELERATIONS |
| 03 | PRATT'S PAGE OF PERTINENT PARAMETER'S |
| 04 | ANTON'S AGONY |
| 05 | TOMMY'S TRIALS AND TRIBULATIONS |
| 06 | EXEC PARAMETER AND TIMING DISPLAY |
| 07 | FLIGHT'S FABULOUS FLOCK OF FUDGE FACTORS CPT A |
| 08 | K-FACTOR TEST PAGE |
| 09 | RECORD PLAYBACK PARAMETERS |
| 10 | PREPROGRAMMING PARAMETERS |
| 11 | AUTO COMPUTED SEQUENCING DATA PAGE |
| 12 | AUTO COMPUTED SEQUENCING TEST PAGE |
| 13 | FORMATION FLYING PARAMETERS |
| 14 | FORMATION FLYING - EMULATOR |
| 15 | |
| 16 | TEMPORARY CHECKS |
| 17 | AUTO COMPUTE TASK SEQ CPT B |
| 18 | AUTO COMPUTE TASK SEQ CPT A |
| 19 | MESSAGE PAGE |
| 20 | MANUAL PAGE TEST PAGE |
| 21 | SIMULATOR/CIG INTEGRATION |
| 22 | SIMULATOR/CIG INTEGRATION LOGIC FLOW |
| 23 | |
| 24 | MESSAGE PAGE |
| 25 | R. BLACK TEST PAGE |

TO SELECT PAGE, ENTER PAGE NUMBER AND 'XMIT P.PAGE'

Figure 8. MANUAL PAGE INDEX PAGE

MANUAL PAGE PREPARATION INSTRUCTIONS (11-01)

KEYBOARD ENTRIES TO THIS PAGE ARE OF THE FORM:

A:B:1 'XMIT P.PAGE'

A IS A ONE OR TWO DIGIT NUMERAL DESIGNATING THE DESIRED A/N PAGE SEL SWITCH NUMBER. SWITCHES ARE ASSUMED TO BE NUMBERED 1 TO 27, TOP TO BOTTOM.

B IS A ONE, TWO, OR THREE DIGIT NUMERAL DESIGNATING THE PARTICULAR PAGE OF THE ABOVE GROUP.

* * * * * * * * * * * * * *

ALL INPUTS AFTER TRANSMITTING THE ABOVE CONTROL STRING WILL BE DECODED AS CHANGES TO THE PAGE DISPLAYED ON CRT 2.

MOVE THE CURSOR TO THE DESIRED LOCATION.

EXCEPT WHERE COMPUTER RESPONSES ARE DESIRED, TYPE IN WORDS AND PHRASES EXACTLY AS YOU WISH THEM TO APPEAR ON THE COMPLETED PAGE.

WHERE COMPUTER RESPONSES ARE DESIRED, ENTER THE PROGRAM SYMBOL (WITH OR WITHOUT A LINE NUMBER) PRECEDED BY A 'START XMIT' AND FOLLOWED BY AN 'END XMIT'. LEAVE NO BLANK SPACES BETWEEN 'START XMIT' AND 'END XMIT'. LEAVE A BLANK SPACE AFTER 'END XMIT'.

NO MORE THAN EIGHTY COMPUTER RESPONSES MAY APPEAR ON ANY ONE PAGE.

'XMIT P.PAGE' TO TRANSMIT YOUR COMPLETED PAGE TO THE COMPUTER.

AFTER TRANSMITTING THE PAGE, CHECK THE RESULTS FOR ACCURACY. IF THE WORD "ERROR" APPEARS IN A COMPUTER RESPONSE AREA, AN INCORRECT PROGRAM SYMBOL HAS BEEN ENTERED. RETURN TO THE GENERATION MODE FOR CORRECTION BY TRANSFERRING CONTROL TO CRT 4 AND REPEATING THE CONTROL SEQUENCE.

---

Figure 9. MANUAL PAGE PREPARATION INSTRUCTION PAGE

There are two ways to return to normal operation from the generation mode. One is to permit the generation process to run to completion. (The process must be allowed to run to completion once XMIT P.PAGE switch has been depressed to process the formatted page.) The second is to depress another switch in the A/N PAGE SEL matrix anytime during CRT page change except when blinking message PAGE PROCESSING IN PROGRESS appears on CRT.

Computer-supplied responses are obtained by depressing START XMIT switch, typing in the computer program symbol, and then depressing the END XMIT switch. These requests for computer-supplied responses may take one of two forms: numbered or unnumbered. Numbered requests will be filed in a table in a specified order, so that they may be operated upon later by other routines. The number must have two digits and be enclosed in the same START XMIT and END XMIT sequence as the program symbol. No spaces are permitted between the number and the symbol, in fact no spaces are allowed anywhere between START XMIT and END XMIT. A space must be provided after the END XMIT, before the next word. A space will be supplied between the number and the computed value by the manual page program. Some parameters do not have program symbols defined in the symbol dictionary for both cockpits 1 and 2. In any case, the symbol for cockpit 1 preceded by a / will define the parameter for cockpit 2.

Figure 10 illustrates creation of a page, and figure 11 illustrates how the page created in figure 10 displays values.

When the manual page program has completed processing the information transmitted to it by XMIT P.PAGE, it will display the generated page with all computer response areas blank (the processing may take more than one minute). If an undefined program symbol has been detected, the word ERROR will appear instead of the blank area. ERROR will become a permanent word and remain on the page until the operator takes appropriate action to correct it.

| | | |
|---|---|---|
| <01AERPM1> | PERCENT | ENGINE RPM |
| <02AFHP> | FEET | PRESSURE ALTITUDE |
| <03AGQTYTOT> | POUNDS | TOTAL FUEL QUANTITY COCKPIT A |
| <04/AGQTYTOT> | POUNDS | TOTAL FUEL QUANTITY COCKPIT B |
| <05AASECOND> | SECONDS | MISSION ELAPSED TIME |
| <AEPOILL> | PSI | OIL PRESSURE COCKPIT A |
| <HEPOILL> | PSI | OIL PRESSURE COCKPIT B |

Figure 10. CREATION OF MANUAL PAGE

| | | | |
|---|---|---|---|
| 01 | 36.03 | PERCENT | ENGINE RPM |
| 02 | 11.41 | FEET | PRESSURE ALTITUDE |
| 03 | 2007. | POUNDS | TOTAL FUEL QUANTITY COCKPIT A |
| 04 | 2008. | POUNDS | TOTAL FUEL QUANTITY COCKPIT B |
| 05 | 5640. | SECONDS | MISSION ELAPSED TIME |
| | 9.883 | PSI | OIL PRESSURE COCKPIT A |
| | 44.93 | PSI | OIL PRESSURE COCKPIT B |

Figure 11. DISPLAY OF CREATED PAGE

In general terms, the program processes the information by looking up the symbol in the symbol dictionary to find its address, type, precision, scale factor, etc., as appropriate. It files this information in an eighty double-word table assigned to that particular page. This implies two things. First, the information in the symbol dictionary must be complete, accurate, and as specified by ASUPT-74. Second, no more than 80 computer responses may be requested for any page.

The computer response information is placed into the table by separate schemes for numbered and unnumbered entries. Numbered entries are placed in the table from the top down in their numbered spot. The unnumbered entries are placed in the table from the bottom up according to the time order in which they are processed. It is therefore important that when both numbered and unnumbered computer responses appear on a page together, the numbered items start around 01 and advance through the low numbers.

CRT Plot - The graphic plotting capability is innovative in that the user can completely define up to two separate plots at one time from the keyboard. The user simply enters the plot mode and enters a series of symbols identifying the following:

(1) Symbolic name of the ordinate variable;

(2) Range to be plotted for this variable;

(3) Symbolic name of the absissa variable;

(4) Its range.

The software then constructs the axes, labels each, and displays the range along the appropriate axis. The user then, through the use of the keyboard, starts and stops the plotting as desired. (See figures 12 and 13.)

CRT PLOT

PLOT MAY BE OPERATED ON CRT 2 OR CRT 4 ONLY.

ANY DATAPOOL VARIABLE MAY BE PLOTTED AGAINST ANY OTHER DATAPOOL VARIABLE. ONE OR TWO PLOTS MAY BE OPERATED SIMULTANEOUSLY.

PLOT DEFINITION IS OF THE FOLLOWING FORM:

A:X:XMIN:XMAX:Y:YMIN:YMAX:B

WHERE

| | |
|---|---|
| A | IS THE PLOT NUMBER (1 OR 2) |
| X | IS THE PROGRAM SYMBOL OF THE X-AXIS VARIABLE |
| XMIN | IS THE LEFT LIMIT OF THE X-AXIS |
| XMAX | IS THE RIGHT LIMIT OF THE X-AXIS |
| Y | IS THE PROGRAM SYMBOL OF THE Y-AXIS VARIABLE |
| YMIN | IS THE LOWER LIMIT OF THE Y-AXIS |
| YMAX | IS THE UPPER LIMIT OF THE Y-AXIS |
| B | IS AN OPTIONAL PRERECORDED DEMO STANDARD NUMBER (3 DIGIT) |

COMMON PROGRAM SYMBOLS MAY BE FOUND IN TABLE 2-1, PAGE 2-14, OF THE AIOS POSITIONAL HANDBOOK. USE THE SYMBOL NAMES AS GIVEN FOR COCKPIT A; PRECEDE THEM WITH A "/" FOR COCKPIT B.

AXIS LIMITS MAY HAVE UP TO EIGHT CHARACTERS INCLUDING SIGN AND DECIMAL POINT. BUT ONLY THE FOUR MOST SIGNIFICANT ONES WILL APPEAR ON THE PLOT. "MAX" NEED NOT BE GREATER THAN "MIN".

ENTER "XMIT P.PAGE" AFTER DEFINING EACH PLOT.

ENTER "INS" AND "XMIT P.PAGE" AFTER TRANSMITTING THE LAST DEFINITION.

IF AN ILLEGAL PROGRAM SYMBOL IS FOUND IN EITHER, BOTH PLOT DEFINITIONS MUST BE RE-ENTERED.

Figure 12. CRT PLOT INSTRUCTIONS

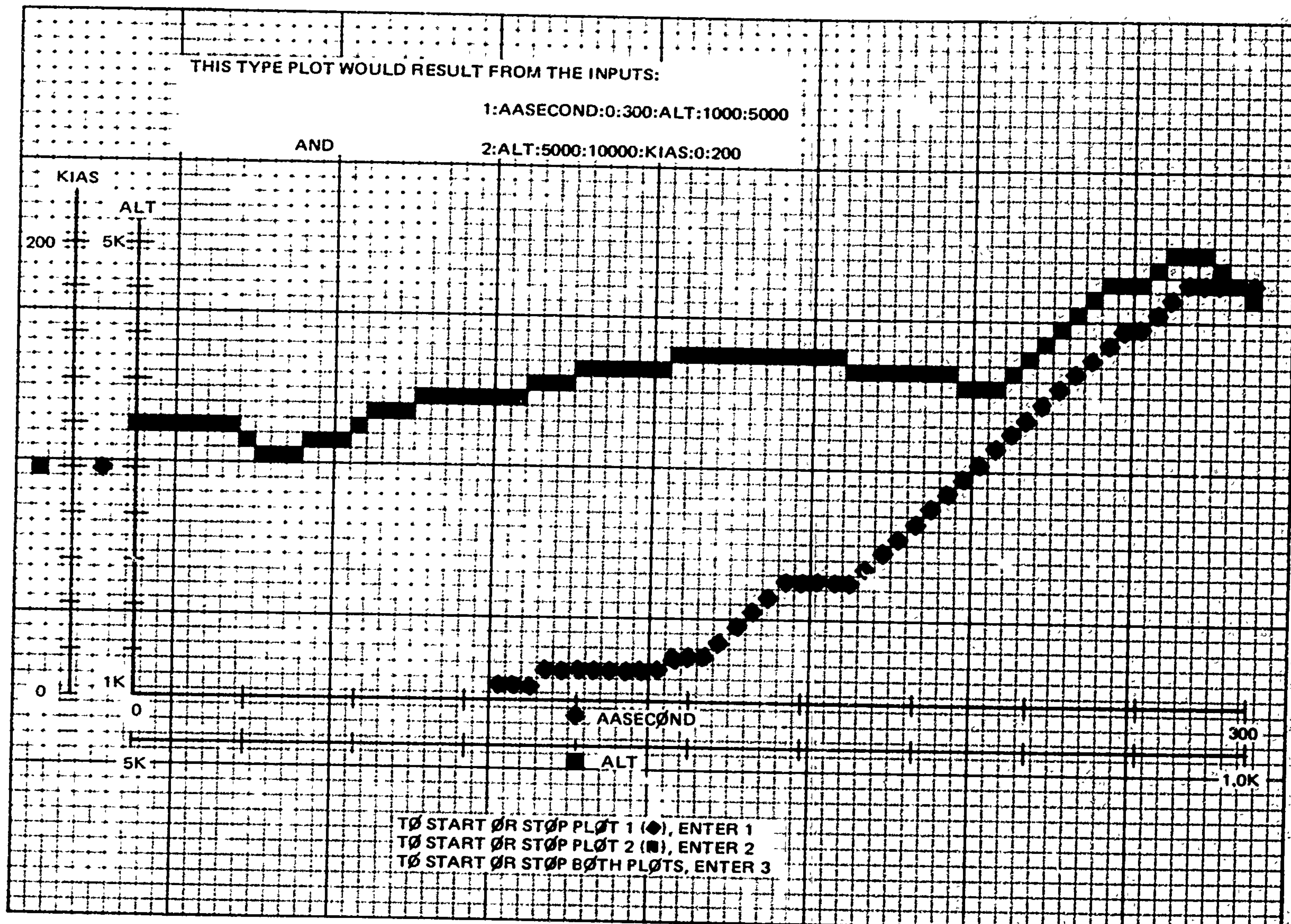



Figure 13. CRT PLOT DISPLAY

This capability is also available automatically via preprogrammed exercises, as described in the ASUPT preprogrammers guide. Operation is exactly the same, but instead of the plot appearing on one of the display tubes, it is generated on the fifth display system channel. When the plot is completed, a hard copy is automatically provided.

The hard-copy unit has proven invaluable for data collection. A copy may be made of any operating display from either of the two alphanumeric CRT's at the AIOS.

Data Recording System - The Data Recording System consists of two elements; an overlay program which performs the real-time sampling of specified variables and stores data to disc file, and a non-real-time, low-priority foreground task which fetches data from the disc file and displays it on the specified output device. The system may be invoked either manually or automatically. (See figures 14 and 15.)

The manual operation of the system may be performed for teletypewriter (TTY), CRT or card reader. The TTY and CRT communication is interactive. First, the user is requested over the CRT to input the type of output device. After the type of output device has been entered, the CRT will request variables to be sampled, then rate of sampling, and finally duration of sampling. The program constructs a data management block which contains all of the input information, plus additional information about the variables, such as the absolute address, type (integer, logical, etc.), precision (byte, halfword, etc.), and if applicable the scale factor. Once the data management block is constructed, it is stored in the first block of disk file.

The automatic operation of the system is available through the preprogramming system. When a preprogrammed data recording subroutine is defined, the user must insert into the FORTRAN subroutine identical input data as described for manual operation. (This is illustrated in the paragraph which discusses preformatted pages). When the subroutine is executed, a non-real time program is invoked which performs the building of the data management block, and then activates the overlay program to perform the sampling. The manual, card reader mode of operation parallels the automated mode. The user duplicates the data recording subroutine onto cards and activates the intermediate program described above. From that point, the process is identical to automated mode.

The non-real-time program performing the display function of the system is activated automatically by the overlay program after sufficient data has been collected. The user has control of non-real-time program with sense switches. The program reads the data management block from the disc file and proceeds to convert and output data to the specified device. Output devices available are the line printer, TTY, CRT, or plotter. Figure 16 illustrates the output from a line printer.

## DATA RECORDING

| PROGRAM MESSAGE | USER REPLY |
| --- | --- |
| (1) OUTPUT DEVICE TY,LP,PL,MT OR CT? | ❮XX❯ (XMIT P.PAGE)<br>WHERE IF XX IS :<br>TY-TELETYPE OUTPUT<br>LP-LINEPRINTER OUTPUT<br>PL-CALCOMP PLOTTER OUTPUT<br>MT-MAG TAPE OUTPUT<br>CT-CRT OUTPUT |
| (2) * | ❮(LIST OF SYMBOLS)❯ (XMIT P.PAGE)<br>THE SYMBOLS MUST BE SEPARATED BY COMMAS.LIST WILL BE TERMINATED BY "*".<br>EXAMPLE: (AASECOND,FRAME,CYCLE*❯ |
| (3) @ | ❮YY❯ (XMIT P.PAGE)<br>WHERE IF YY IS :<br>AA-RATE OF 15 TIMES PER SECOND<br>BB-RATE OF 7.5 TIMES PER SECOND<br>CC-RATE OF 3.75 TIMES PER SECOND<br>SLOWER RATES MAY BE SPECIFIED BY ENTERING A TWO DIGIT DECIMAL NUMBER - EXAMPLE:<br>01-RATE OF ONCE PER SECOND<br>02-RATE OF ONCE PER TWO SECONDS |
| (4) ) | ❮ZZZZ❯ (XMIT P.PAGE)<br>WHERE ZZZZ IS AN INTEGER IN UNITS OF SECONDS TO GIVE THE LAPSE TIME FOR SAMPLING<br>EXAMPLE:❮0009❯ 9 SEC. SAMPLE |

Figure 14. DATA RECORDING INSTRUCTIONAL AND INTERACTIVE DISPLAY

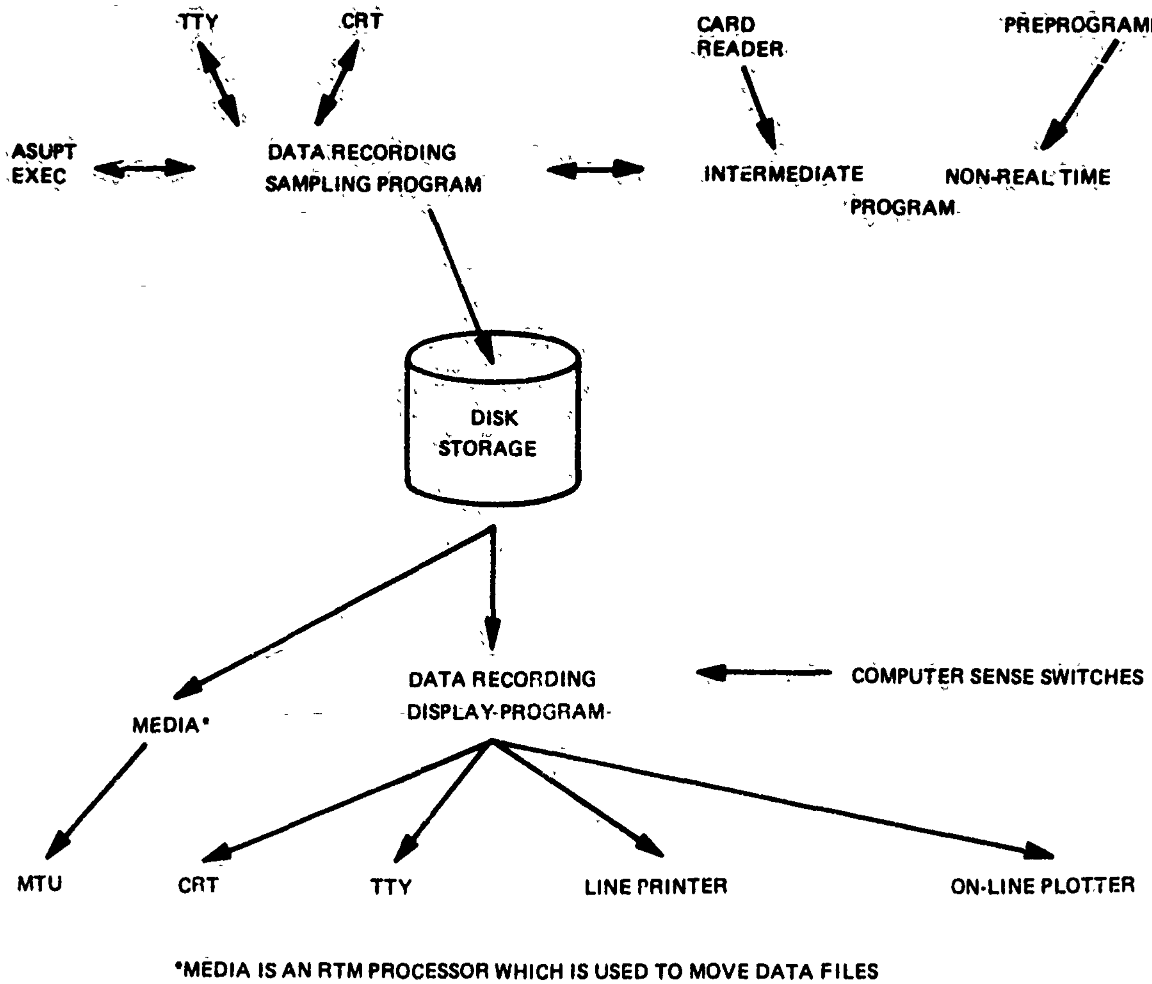



Figure 15. DATA RECORDING HARDWARE/SOFTWARE INTERFACE

Record/Playback System - The Record/Playback System provides the capability of recording and playing back a portion, or all, of any training exercise. The data is recorded at a fixed rate. However, the playback is available at the normal rate, fast (twice normal) rate or slow (half of normal) rate. The system utilizes the magnetic tape unit (MTU) and the audio tape unit (ATU) to perform its task. The data which is recorded allows the playback of aircraft position, environment flight characteristics, and positions of controls (see figure 17).

The system provides the capability of establishing a library of automated demonstrations which are created by instructor pilots and used to demonstrate to the student proper procedures for performing particular maneuvers or exercises. The students performance may also be recorded and played back as an additional provision.

FIRST SELECTIONS

| TIME | HFFZGLP | HFFZGRP | HFFZGNP | HFFXGLP | HFFXGRP | HFFXGNP | HFVCAL |
|---|---|---|---|---|---|---|---|
| 00:03:26.49 | - 4809.8 | 761.81 | - 697.75 | 131.339 | -150.583 | 26.800 | 0.000000 |
| 00:03:26.73 | 741.43 | - 4808.3 | - 691.33 | -156.844 | 131.325 | 26.899 | 0.000000 |
| 00:03:26.94 | - 4805.7 | 763.84 | - 683.64 | 131.248 | -155.325 | 26.402 | 0.000000 |
| 00:03:27.18 | 756.60 | - 4809.4 | - 683.22 | -157.946 | 131.357 | 26.778 | 0.000000 |
| 00:03:27.39 | - 4807.9 | 767.27 | - 683.00 | 131.311 | -157.512 | 26.478 | 0.000000 |
| 00:03:27.63 | 765.13 | - 4811.4 | - 687.02 | -158.146 | 131.406 | 27.039 | 0.000000 |
| 00:03:27.84 | - 4809.9 | 769.74 | - 691.17 | 131.363 | -157.929 | 26.908 | 0.000000 |
| 00:03:28.08 | 771.15 | - 4812.0 | - 696.91 | -157.817 | 131.420 | 27.532 | 0.000000 |
| 00:03:28.29 | - 4810.6 | 774.39 | - 701.94 | 131.386 | -157.708 | 27.455 | 0.000000 |
| 00:03:28.53 | 778.24 | - 4811.9 | - 706.75 | -157.550 | 131.422 | 28.025 | 0.000000 |

Figure 16. LINE PRINTER DISPLAY OF COLLECTED DATA

```
                    DEMO STUDENT PLAYBACK

       A                     -DEMO LOG-                  B
 #SEG      TITLE                               #SEG      TITLE


TIME REMAINING     75                   TIME REMAINING      75
STATUS                  OFF             STATUS                   OFF

TO PLAY BACK THE STUDENT, ENTER 1:A:B
TO PLAY BACK A DEMO,      ENTER 2:A:B:C:D
TO TURN OFF,              ENTER 3
TO RECORD A DEMO,         ENTER 4:D
TO LOG A DEMO,            ENTER 5:C:E

WHERE A IS THE SEGMENT NUMBER (0 TO 9)
      B IS THE SPEED, 1/2/3 = SLOW/NORMAL/FAST
      C IS THE THREE CHARACTER DEMO NUMBER
      D IS THE AURAL REQUEST, 1 = ON, 0 = OFF
      E IS THE TITLE, (MAXIMUM OF 28 CHARACTERS)

WAIT TO UNFREEZE AND START DEMO UNTIL STATUS IS "READY".

WAIT TO LOG THE DEMO UNTIL STATUS REUTRNS TO "OFF".

CAUTION: DO NOT TRANSFER IOS CONTROL DURING RECORD OR PLAY-
BACK.
```

Figure 17. DEMO RECORD/PLAYBACK DISPLAY

The primary difficulty encountered with implementing this system was the development of a recovery scheme when specific MTU errors occurred on playback. The procedure established consisted of saving the data blocks (initiation buffer, discrete input (DI) variables and analog-to-digital (A/D) input variables) in a core buffer before each tape read request. If the MTU handler detected any of a particular set of device or data control channel (DCC) errors, the saved buffer was restored to the data blocks.

The record playback system may be implemented either manually, via CRT, or automatically through the preprogramming system. Figure 18 illustrates the system's hardware/software interface.

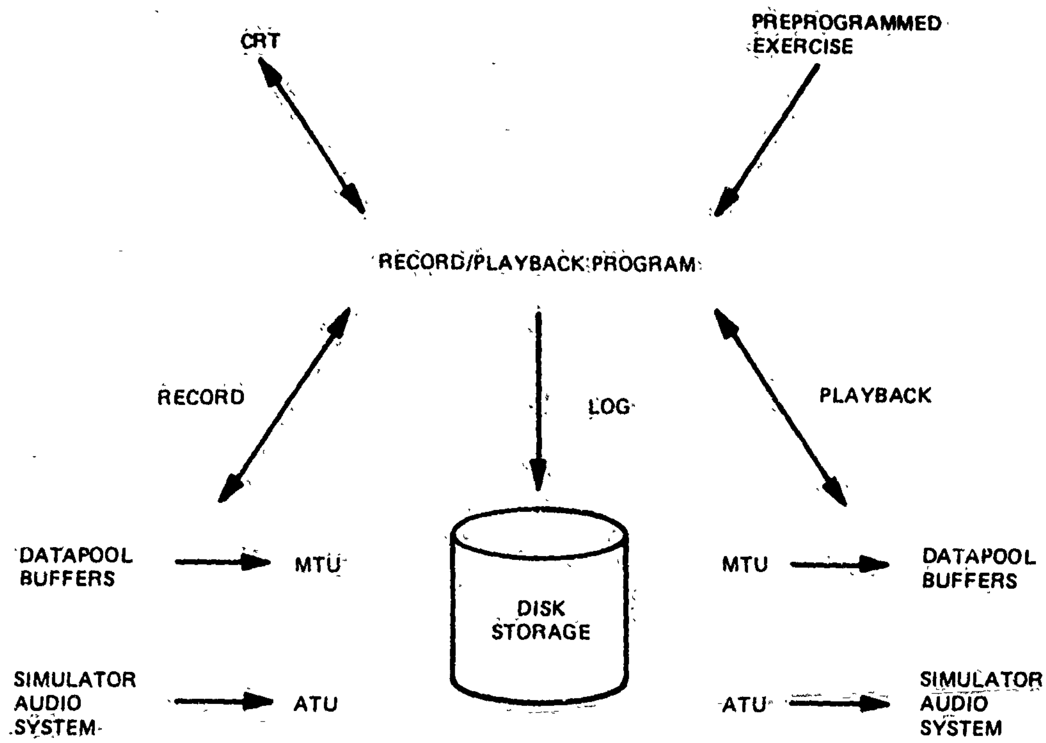



Figure 18. RECORD/PLAYBACK SYSTEM HARDWARE/SOFTWARE INTERFACE

Graphic CRT Display System

The graphic display system incorporated at the AIOS provides five types of displays; cross-country, ground-controlled approach (GCA), formation flying, spatial, and text translation (TEXTRAN). These displays are used primarily to portray performance patterns. The following paragraphs describe these displays.

Cross-Country Display - This display provides two modes of operation: one, an airfield-centered mode, and two, an aircraft-centered mode. In the former, airport and navigation facilities remain fixed on the screen, and the aircraft (A/C) symbol moves, leaving a ground track. In the latter mode, the A/C symbol remains at the center screen while the navigation facilities move. Construction of the basic image and frequent, periodic reconstruction in the A/C-centered mode, required innovative approaches to picture construction or display list generation. The first problem encountered was related to the wrap-around phenomenon. Some airways terminated outside the image area of the display system. The XY CRT coordinate of the end of these airways has to be within this area, or spurious lines would appear on the CRT screen as a result of wrap-around.

A simple procedure is used to determine the intercept for line segments extending beyond the CRT display area. The octant in which the out of bounds endpoint lies is determined (see figure 19). If the endpoint lies in octant 2 or 6, the Y-coordinate Y' is set to Y-axis upper bound (YUB) or Y-axis lower bound (YLB), respectively, and the X-coordinate X' is computed as:

$$X' = X_o + \frac{\Delta X}{\Delta Y} (Y' - Y_o)$$

Where: $X'Y'$ = coordinates of intercept;
$X_o$, $Y_o$ = coordinates of in-bounds point;

$\Delta X$ = X-coordinate of out of bounds endpoint minus $X_o$;

and, $\Delta Y$ = Y-coordinate of out of bounds endpoint minus $Y_o$.

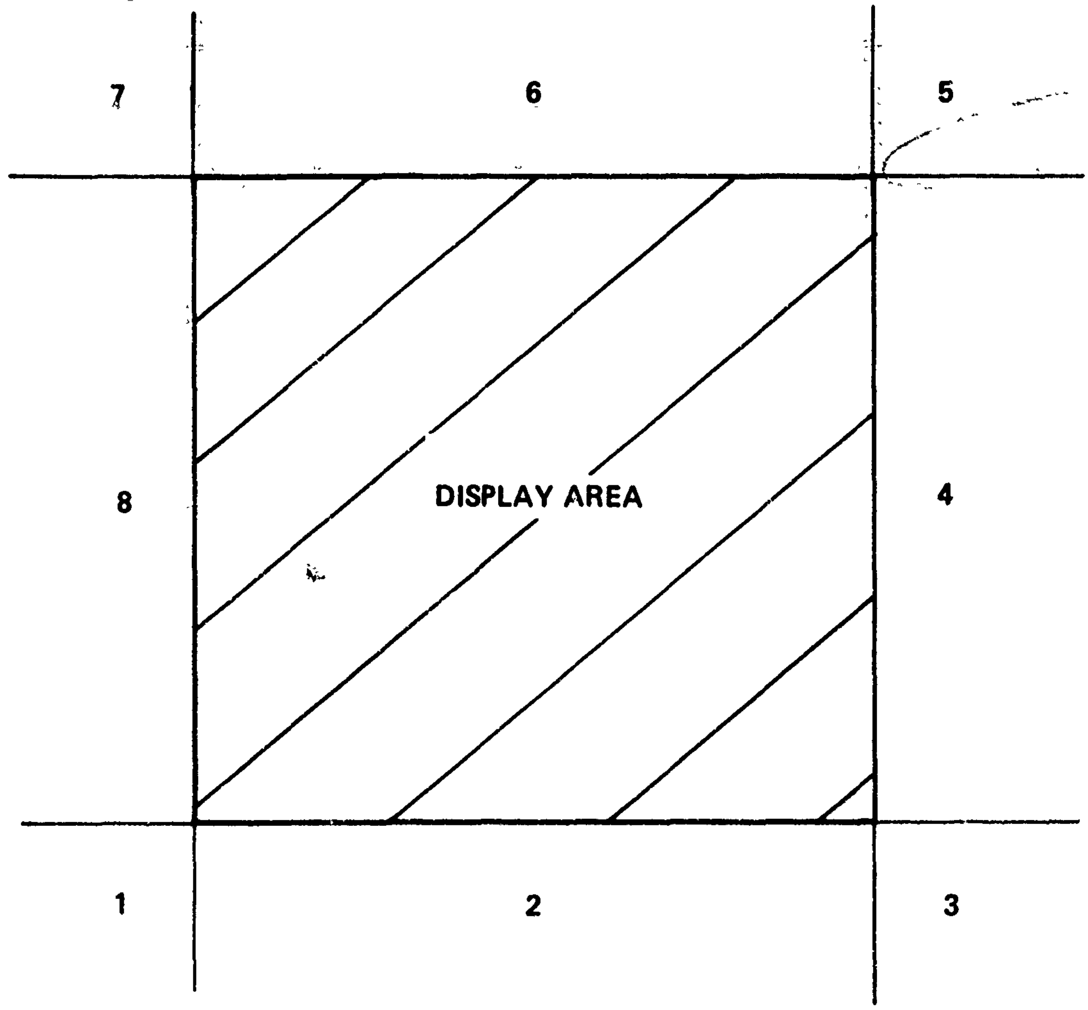
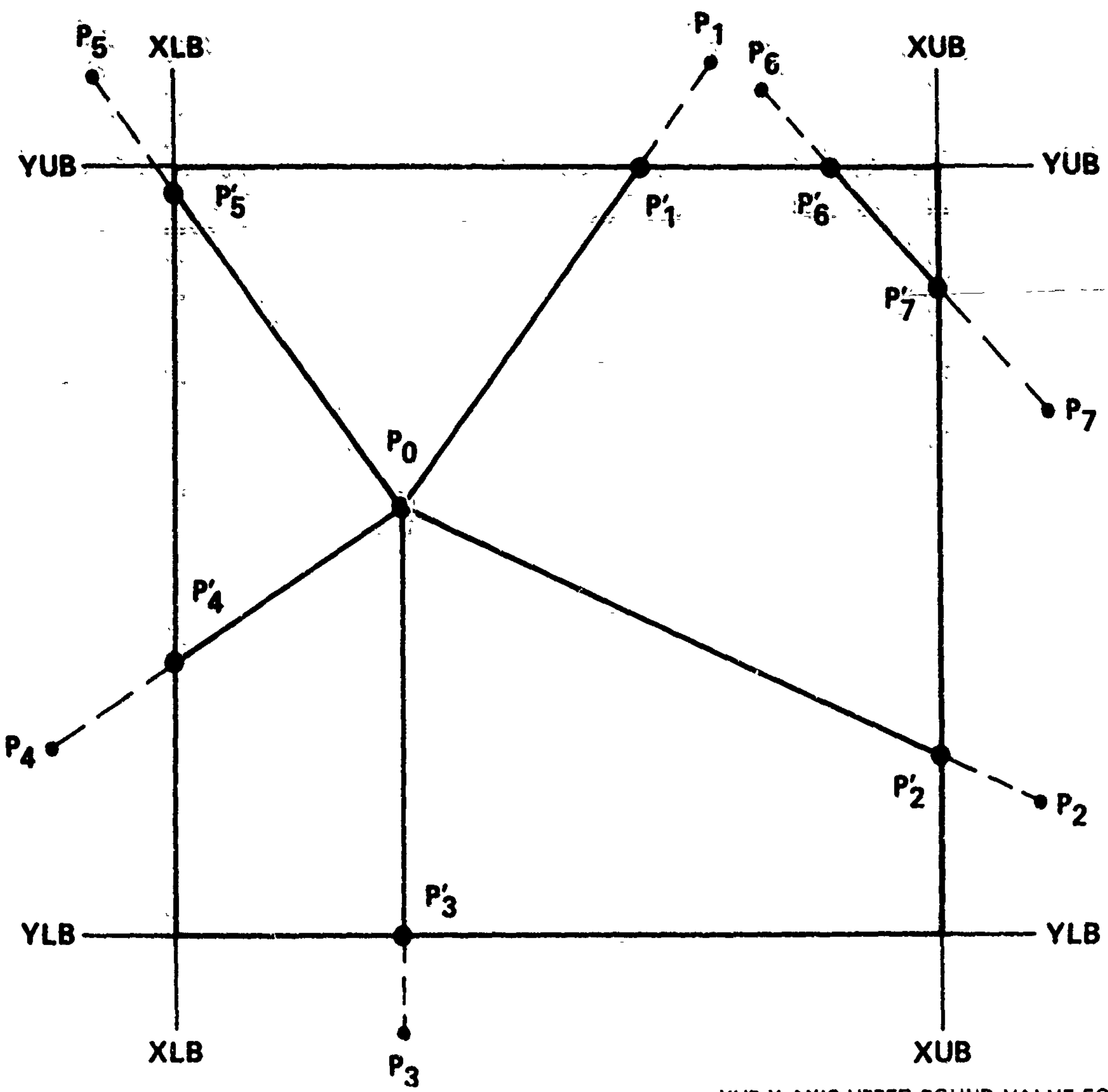



Figure 19. DISPLAY AREA AND OUT-OF-BOUNDS OCTANTS

If the endpoint is in octant 4 or 8, the X-coordinate X' is set to X-axis upper bound (XUB) or X-axis lower bound (XLB), respectively, and the Y-coordinate Y' is computed as:

$$Y' = Y_o + \frac{\Delta Y}{\Delta X} (X' - X_o)$$

If the endpoint is in octant 1, 3, 5, or 7, an additional computation of the same nature is required to insure that the intercept has been properly determined. If both endpoints are out of bounds and line segment passes through display area, as illustrated by line segment $\overline{P_6P_7}$ in figure 20, the appropriate intercepts are computed and the segment $\overline{P'_6P'_7}$ is displayed.




$\overline{P_oP_1}$, $\overline{P_oP_2}$, $\overline{P_oP_3}$, $\overline{P_oP_4}$, $\overline{P_oP_5}$, $\overline{P_6P_7}$: REQUESTED LINE SEGMENTS

$\overline{P_oP'_1}$, $\overline{P_oP'_2}$, $\overline{P_oP'_3}$, $\overline{P_oP'_4}$, $\overline{P_oP'_5}$, $\overline{P'_6P'_7}$: ALLOWABLE LINE SEGMENTS

XUB-X AXIS UPPER BOUND VALUE FOR CRT
XLB-X AXIS LOWER BOUND VALUE FOR CRT

YUB-Y AXIS UPPER BOUND VALUE FOR CRT
YLB-Y AXIS LOWER BOUND VALUE FOR CRT

Figure 20. GRAPHIC DISPLAY LINE SEGMENT CLIPPING

Another problem occurs in the A/C-centered mode. The entire map image (NAV facility, airport, airway vectors, A/C symbols, and track) must be reconstructed every few seconds as a function of A/C position change. If the image were constructed in real time, simulation modules would not be able to maintain the required execution rate.

The execution of the cross-country program takes more than a frame (66.67 milliseconds) to complete when constructing the map. In order to reconstruct a map without affecting simulation module rates, the cross-country program was incorporated in a special module (ZMOSAOAC) that was made a separate task under RTM, lower in priority and unlinked to the interval timer or real time clock driving the main simulation task (modules). Under this scheme, ZMOSAOAC can be executed until complete with the main task, interrupting at its required rates and allowing spare time to ZMOSAOAC for map construction.

Figures 21 and 22 illustrate two types of maps which are available under cross-country mode. Figure 21 represents facilities and airways, and figure 22 represents parallel runways. Figure 23 illustrates the panel which is used to vary map scale and select an airport. The feature of requesting aircraft-centered mode is also incorporated into this panel.

Since cross country required this special task, it was decided to incorporate other graphic CRT application programs which share variables and subroutines in ZMOSAOAC; which are spatial, Form Fly, GCA, and TEXTRAN.

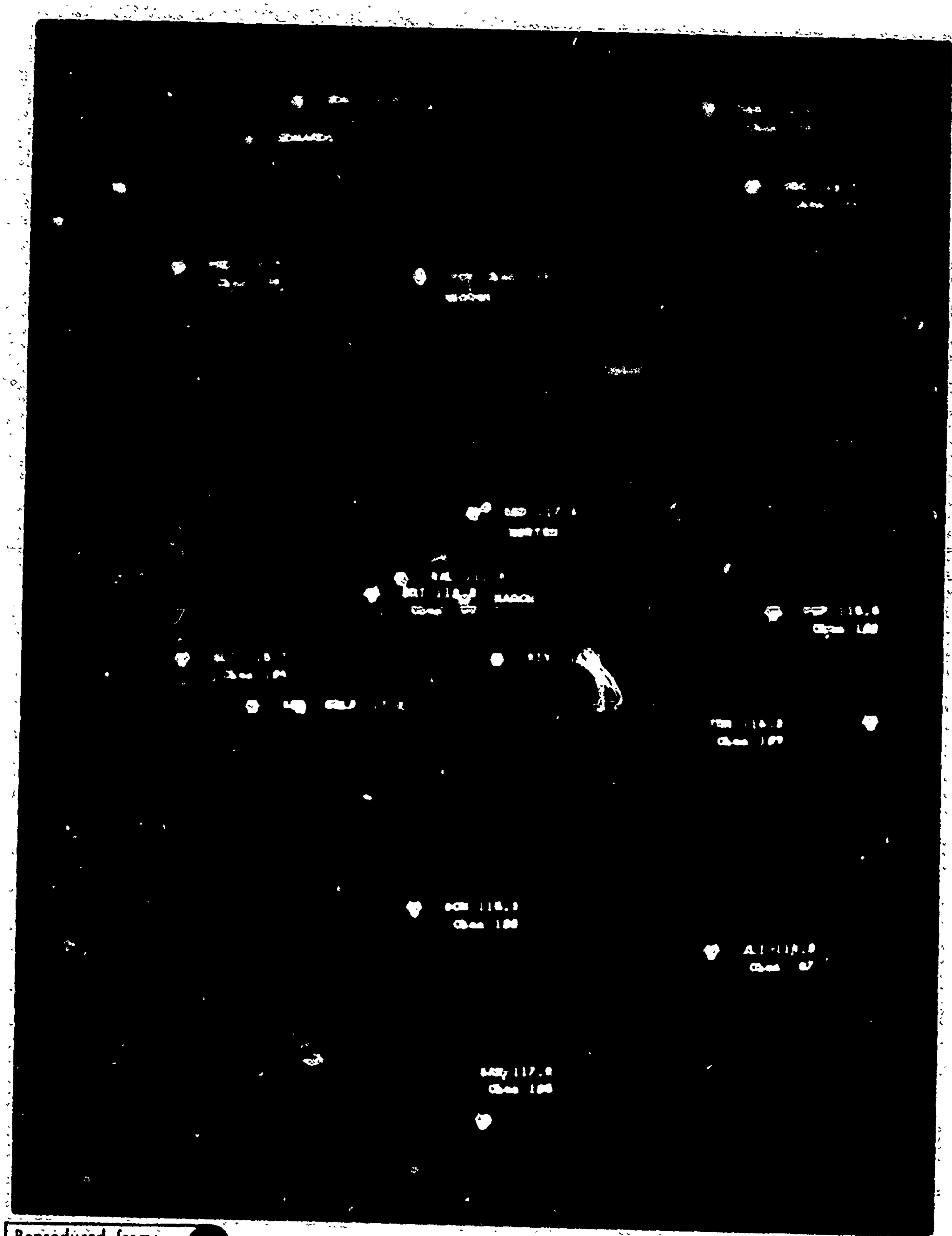
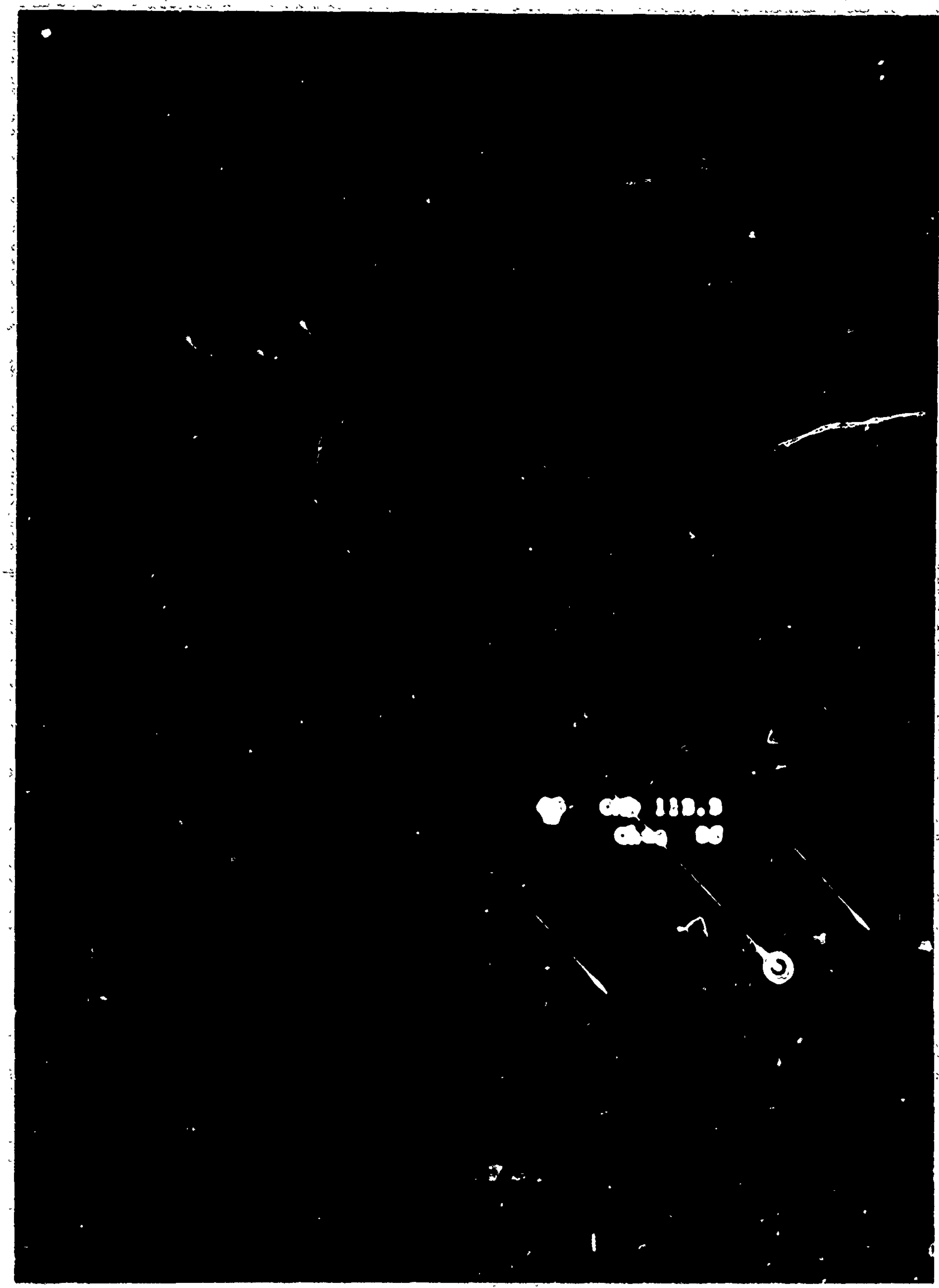




Figure 21. FACILITIES AND AIRWAYS DISPLAY, CROSS-COUNTRY MODE



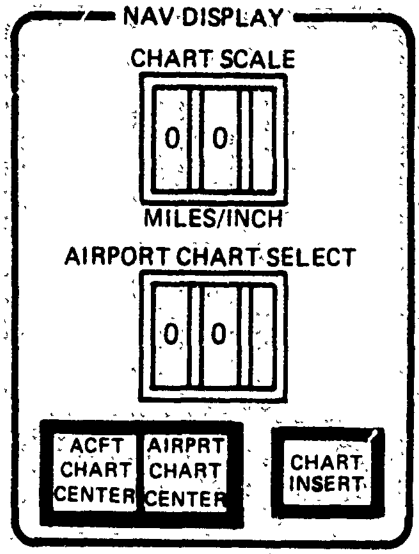



Figure 23. CROSS-COUNTRY SCALE/MODE SELECTION PANEL

GCA Display - This provides the user with a presentation similar to the conventional radar display. Implementation was straightforward with no unique problems. Figure 24 illustrates a GCA display.

Formation Flying Display - This display has two images of the lead and wing A/C in a formation flight maneuver. The top image is a plan view and the bottom image is a rear view. The images have three separate range scales which change automatically as a function of slant range. The display is designed to serve two purposes. The first purpose is to provide relative position and attitude data for instructor monitoring. The second purpose is to assist the user in acting as lead A/C through the hand controller at the AIOS. The major innovation here is in the content of the display. The image of the aircraft is constructed in three dimensions (not a statement of work (SOW) requirement) in order to provide angular and depth information, in addition to what could be provided by stick images. The only cost is in buffer size (which was large enough due to other display requirements) and additional engineering effort to define a scale model of the T-37.

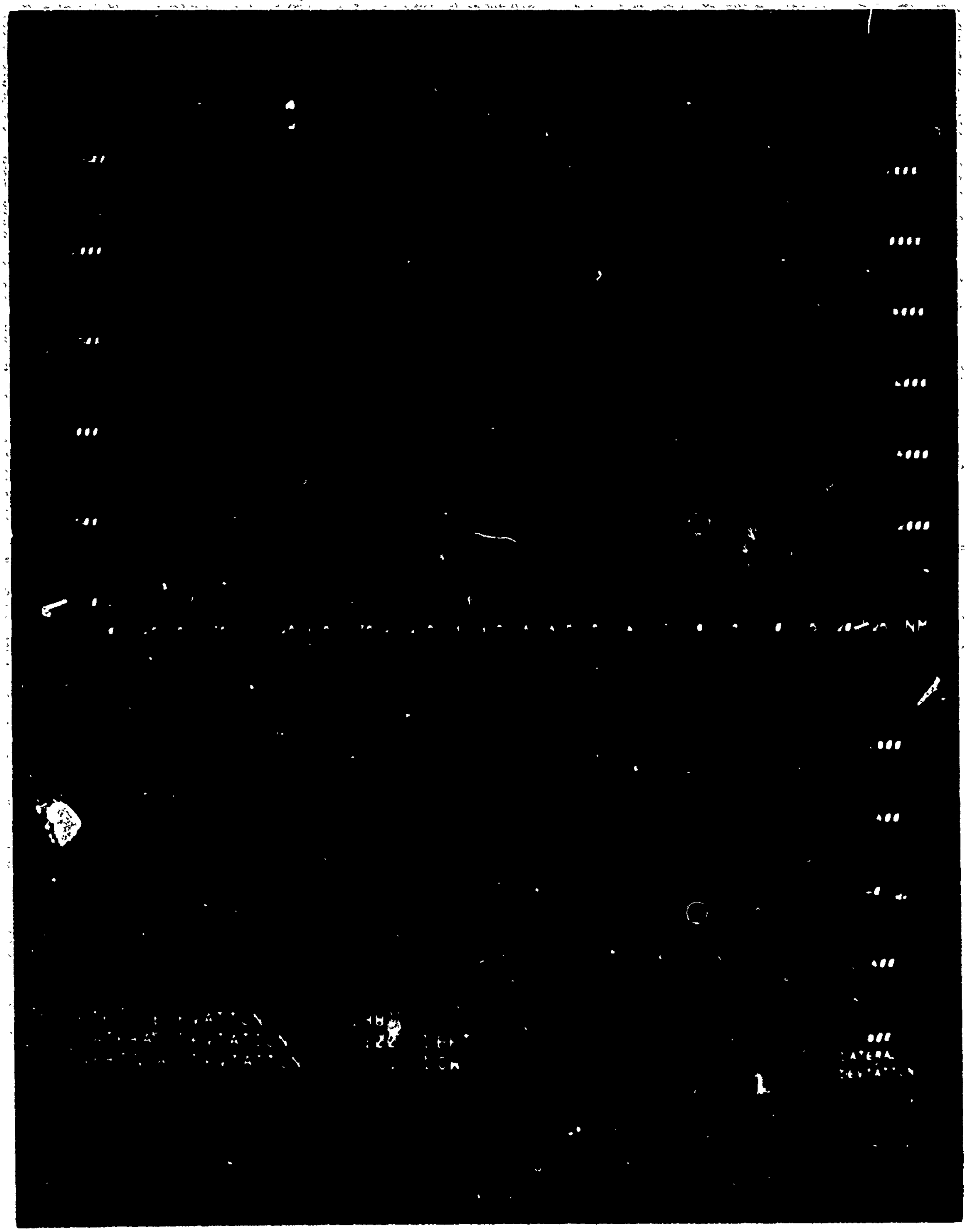



Figure 24. GCA DISPLAY

Another display content design innovation concerned image movement. Since any translational motion in the lead A/C image tends to confuse the presentation, the position of the lead A/C is fixed in both display halves. Similarly, rotational motion in the lead A/C would cause the horizon to change constantly; furthermore, the wing A/C, in order to maintain position, would trespass into the top display, causing confusion. Therefore, it was decided to fix the angular motion (i.e., all rotational and translational motion is displayed as relative motion of the wing A/C). A not quite serendipitous benefit of the resulting design is that when the AIOS is used as lead A/C, the bottom rear end display can be used as a synthetic attitude indicator. The horizon and pitch bars and the display exhibit the actual lead A/C motion. Figure 25 illustrates the formation flying display, and figure 26 illustrates the formation flying control panel.

Spatial Display - This provides a three dimensional view of aircraft track, utilizing the three-dimensional incremental mode of vector generation. Longitude is assigned to CRT X-axis, altitude is assigned to CRT Y-axis, and latitude is assigned to CRT Z-axis. The track data is generated by using the latitude, longitude, altitude, and cosine of latitude.

When the maximum number of allowable track points are reached, the instruction generated frum the data is wrapped around the plot buffer. The result is, as the new track points are generated, the points at the start of the track are eliminated giving the appearance of a sliding track.

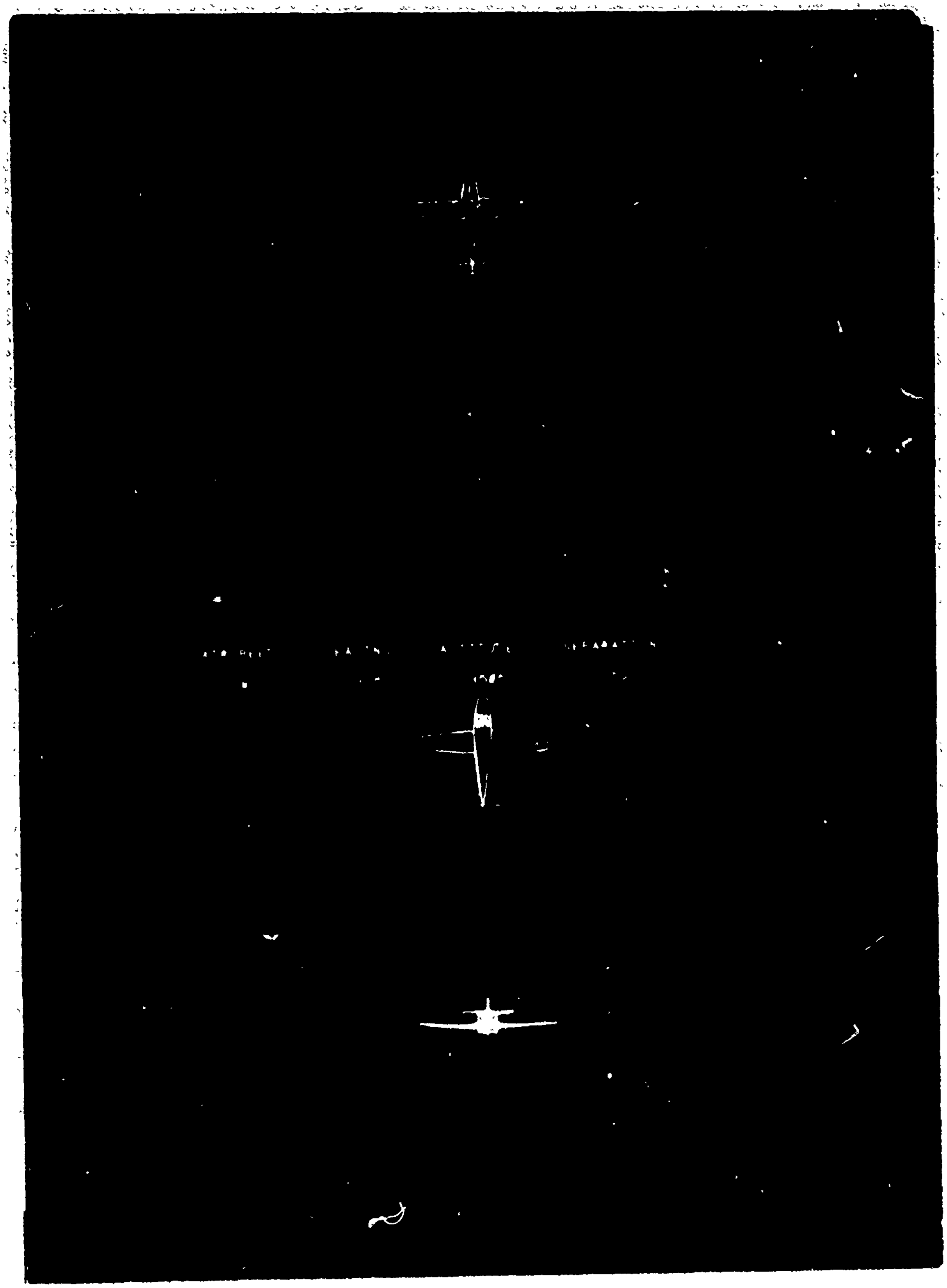


Figure 25. FORMATION FLYING DISPLAY

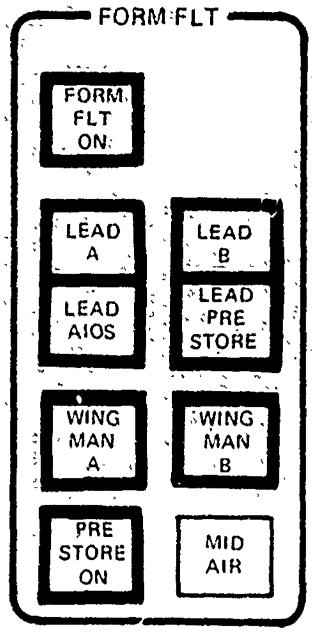



Figure 26. FORMATION FLYING CONTROL PANEL

The spatial display allows for rotation about any of the three CRT axes with control from the AIOS. The rotation is performed dynamically in ten-degree increments. Figure 27 illustrates the spatial display.

TEXTRAN Display - This display provides text translation from alphanumeric displays to graphic display. The process consists of editing the alphanumeric display data and translating it to valid graphic display data.

ASUPT AIP Features

The ASUPT system incorporates the most comprehensive package of instructional features incorporated in any flight training or research system built to date. Most of these features are implemented utilizing the capabilities of the preprogramming system. Prior to discussing the preprogramming system, a brief description of each ASUPT AIP feature is provided. (See figure 28 for an example of AIP control set page). The following paragraphs provide, in most cases, a brief description of each of the instructor-control features, with additional information provided for those features posing unique design problems.

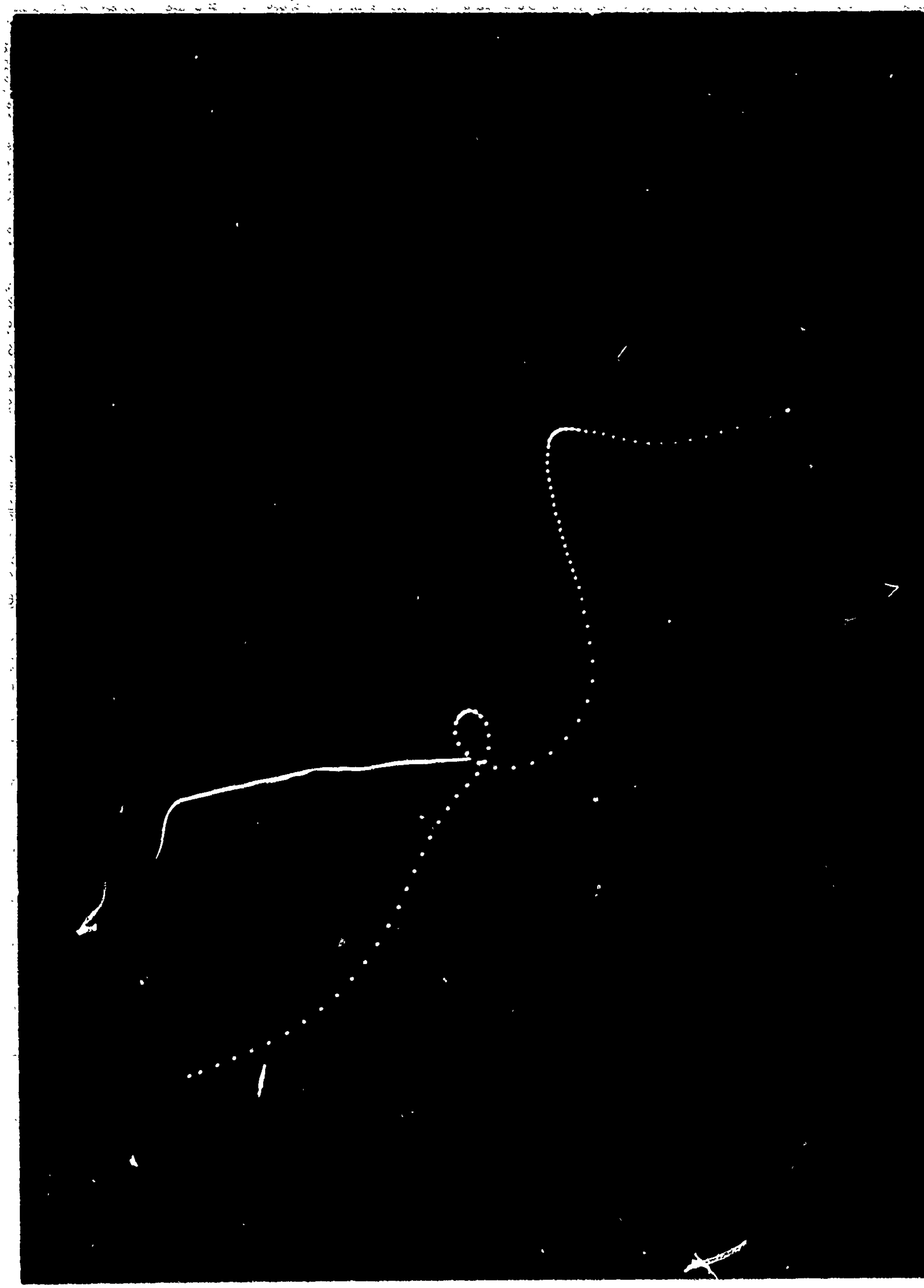


Figure 27. SPATIAL DISPLAY

AIP CONTROL SETTINGS

| | | | | |
|---|---|---|---|---|
| 01 | FALSE | AUTO EXPLICIT MALF INSERTION | 41 | FALSE |
| 02 | FALSE | AUTO PROBABILISTIC MALF INSERTION | 42 | FALSE |
| 03 | FALSE | VTD-DYNAMICS | 43 | FALSE |
| 04 | FALSE | VTD-AXIS LOCK | 44 | FALSE |
| 05 | FALSE | VTD-ENVIRONMENT | 45 | FALSE |
| 06 | FALSE | VTD-MOTION | 46 | FALSE |
| 07 | FALSE | VTD-MALFUNCTIONS | 47 | FALSE |
| 08 | FALSE | VISUAL FEEDBACK-ALPHANUMERIC | 48 | FALSE |
| 09 | FALSE | AURAL FEEDBACK | 49 | FALSE |
| 10 | FALSE | DEMONSTRATION | 50 | FALSE |
| 11 | FALSE | DATA RECORDING | 51 | FALSE |
| 12 | FALSE | CRT PLOT | 52 | FALSE |
| 13 | FALSE | PERFORMANCE RECORDING | 53 | FALSE |
| 14 | FALSE | AUTO COMPUTED SEQUENCING | 54 | FALSE |
| 15 | FALSE | AUTO EXPLICIT SEQUENCING | 55 | FALSE |
| 16 | FALSE | EXERCISE MANUALLY TERMINATED | 56 | FALSE |
| 17 | FALSE | MANUALLY TERMINATE ES | 57 | FALSE |

Figure 28. AIP CONTROL SET PAGE

Malfunction Insertion Features - Two types of ASUPT AIP malfunction insertion features are available using preprogramming auto-explicit and auto-probabilistic insertion. In the auto-explicit malfunction insertion, the user defines the simulator conditions under which the malfunction will be activated. In the auto-probabilistic malfunction insertion, the user has a choice of fifteen randomly-generated numbers against which to establish a test. These numbers are generated after any initialization. The number range is between zero and one. The test may be established as follows:

(1) IF (Random Number < 0.8) Activate malfunction. This example is interpreted as the malfunction has an eighty-percent probability of occurring. The following is another example.

(2) IF (Random Number > 0.8) Activate malfunction. This may be interpreted as the malfunction has a twenty-percent probability of occurring. With fifteen random numbers available, the user has great flexibility to establish expectation values for malfunctions.

Variation of Task Dificulty - Five types of variation of task difficulty provisions are available using the preprogramming system; dynamics, motion, malfunctions, axis lock, and environment.

(1) Dynamics: This feature allows user to vary flight K-factors to modify the fidelity of the flight equations. Modification of angles affecting moment and rate equations is also possible.

(2) Axis Lock: This feature permits the user to selectively freeze any of the aircraft axes (roll, pitch and/or yaw) and/or set new values of roll, pitch, and/or yaw.

(3) Environment: This feature permits the user to modify environmental condition, such as icing, turbulence, etc.

(4) Motion: This feature allows user to vary motion K-factors to modify motion system performance.

(5) Malfunctions: This feature allows time-controlled insertions of malfunctions into specific aircraft systems (i.e. electrical, hydraulic, fuel, flight, etc.)

Performance Feedback - Two types of performance feedback are available; aural and visual.

(1) Aural Feedback: This feature allows user to generate aural messages from a repertoire of 189 words, which are transmitted to the cockpit headset.

(2) Visual: This feature allows user to specify a 50-character message to be displayed on the in-cockpit CRT's.

Demonstration and Replay - Automated demonstrations and student record/playback are the two features available in this class.

(1) Automated Demonstrations (Demo): This feature simply does a playback of a recorded demonstration. When this feature is executed, all other cases of the exercise segment (ES) are not executed until the playback is concluded. Aural feedback may also be requested in this feature. The aural message will come from prerecorded audio tape which corresponds with demonstration. Three playback speeds are also available.

(2) Student Record/Playback: This feature allows user to record and playback the performance of the student. The user may not request aural feedback in this feature. However, the playback speed is variable as in DEMO feature.

Data Recording - This feature allows user to sample up to seven simulator variables at a specified rate and at a specified length of sampling. The user also has the choice of output device to display the sampled data.

Maneuver Sequencing - The user is allowed three modes of maneuver sequencing; manual, auto-explicit, and auto-computed.

(1) Manual: This feature allows the user to manually override the next maneuver (exercise segment) selection. This is available by using the manual maneuver CRT page, or in-cockpit maneuver selection thumbwheels.

(2) Auto-explicit: This feature uses the order of the exercises segments as specified in the exercise table to dictate the order of execution of the exercise segments.

(3) Auto-computed: This feature allows the user to define a scoring alogrithm which computes a raw score for an exercise segment for the student. A sequencing subroutine then determines the next exercise segment to be executed. The decision is based on a user-generated matrix which the sequencing subroutine utilizes in making its decision.

Preprogramming System

Most of the features described in the preceding paragraphs can be implemented automatically, during operation, using the preprogramming capability. The design objectives for this system were to provide the appropriate capabilities in such a way as to allow sophisticated research capabilities in training technology utilizing a library of automated exercises, and to allow ease of operation for users not proficient in computer programming.

To do this, two design problems had to be addressed. The first design problem was to provide a flexible system that could easily perform the required functions during real time operation, and allow new problems to be generated or modifications made to existing problems through the instructor's CRT. (This capability operates in the non-real time foreground environment during simulator operation.). The second design problem was to provide an interface language that is useable by personnel who are completely inexperienced in computer programming and yet does not limit highly-experienced personnel, because of its simplicity.

The resulting design, taking advantage of the computer complex and associated software, provided satisfactory solutions to both these problems.

The preprogramming system allows the user to develop a library of exercises (maximum of thirty). Each exercise consists of a table which defines a minimum of one and a maximum of twelve exercise segments (maneuvers). Each exercise segment has associated with it a table which defines a maximum of fifteen cases. A case consists of FORTRAN statements which make it possible to implement any or all of the AIP features within an exercise segment. The system stores exercise tables, task tables, and cases on a disk file, once they are created. This makes it very easy to modify any element within the exercise structure. When any of these elements are created, an index page associated with the element is updated, so the user has the capability of looking at an index of the exercise tables, task (exercise segment) tables, or cases. When defining an exercise, the exercise table should be the last element created. After creation or modification of an exercise table, the complete exercise is compiled and catalogued (at exercise segment level). Each exercise segment of the exercise will be resident on the disk as an object module, which is ready for overlaying into core and executing.

The preprogramming system consists of a group of low-priority, non-real-time foreground programs. The primary program is interactive with A/N CRT. This program allows development of exercises and setting up specific core tables when a request is made for execution of a particular exercise. Another program updates manual page and training exercise A/N CRT pages when an exercise is executed. Another program has the task of performing the loading of the absolute overlays (exercise segment object code) when an exercise execution is requested.

The selection of FORTRAN allowed us to solve much of the user interface problems. First many of the interested users and technically-oriented instructor pilots (IP) are probably familiar with FORTRAN. The simplicity of much of the coding requires virtually no learning for those who might be unfamiliar with the language. The SPD design overcame most of this by the incorporation of preformated pages. Each input page encountered by the user contains all syntax-required data as well as structured statements requiring only data that is specific to desired results.

Figures 29, 30, and 31 illustrate preformatted pages for exercise table, task (exercise segment) table, and case, respectively. Figures 32, 33, and 34, respectively, give examples of how complete exercise tables, task tables, and cases may appear.

One of the requirements noted earlier was that the system should be interactive. The system is designed to lead the user through the steps and processes required for each phase of input. During exercise generation or modification, both alphanumeric CRT's and the associated keyboard are employed. Instructions appear on one CRT, while computer requests for user inputs and user responses appear on the other CRT. All user inputs are made via the keyboard once the mode is activated. Figure 35 illustrates the interactive system.

```
     *----(DESCRIPTION OF EXERCISE TABLE)--------------------
*

     EXERTBLE,###
01   TASK,###
02   TASK,###
03   TASK,###
04   TASK,###
05   TASK,###
06   TASK,###
07   TASK,###
08   TASK,###
09   TASK,###
10   TASK,###
11   TASK,###
12   TASK,###
*EOS

NOTE:    START ENGLISH TEXT DESCRIPTIONS AT THE '*' SYMBOLS
NOTE: INSERT EXERCISE NUMBER OVER THE '###' SYMBOLS
NOTE: INSERT TASK NUMBER OVER THE '###' SYMBOLS
NOTE: DELETE ALL EXTRANEOUS TASKS
```

Figure 29. PREFORMATTED EXERCISE TABLE DISPLAY

```
*----(DESCRIPTION OF EXERCISE SEGMENT (TASK) TABLE)------
*
        TASK,###
        INIT,###
        CASE,###
        CASE,###
        CASE,###
        CASE,###
        CASE,###
        CASE,###
        CASE,###
        CASE,###
        CASE,###
        CASE,###
        CASE,###
        CASE,###
        CASE,###
        CASE,###
        CASE,###
*EOS

    NOTE:    START ENGLISH TEXT DESCRIPTIONS AT THE '*' SYMBOLS
    NOTE: INSERT TASK NUMBER OVER THE '###' SYMBOLS
    NOTE: INSERT CASE NUMBER OVER THE '###' SYMBOLS
    NOTE: DELETE ALL EXTRANEOUS CASES
```

Figure 30. PREFORMATTED EXERCISE SEGMENT TABLE DISPLAY

```
                         DATA RECORDING

          IF(ASET.NE.1) EADATA07=.TRUE.
          IF(ASET.NE.1) GO TO 999
          IF(.NOT.EADATA07) GO TO 999
          EADATAON=.TRUE.
          IF(.NOT.EADATAON) GO TO 999
          IF(             ) GO TO 999
          GAOUTPUT='      '
          GARATE='@   >'
          GATIME='      '
          GADATA1='          '
          GADATA2='          '
          GADATA3='          '
          GADATA4='          '
          GADATA5='          '
          GADATA6='          '
          GADATA7='          '
          EADATA07=.FALSE.
      999 CONTINUE
          ASET=1

  *EOS
```

Figure 31. PREFORMATTED DATA RECORDING CASE DISPLAY

```
    THIS EXERCISE IS OF A SERIES OF TASKS INVOLVING
    INSTRUMENT TRAINING, DEMO AND AURAL TAPES 001 REQUIRED
    EXERTBLE,001
01  TASK,001  TAKEOFF FROM WAFB, CLIMB TO 7500 FEET, LEVEL OFF
02  TASK,005  AIRSPEED CHANGES, MAINTAIN LEVEL FLIGHT
03  TASK,003  CONSTANT AIRSPEED CLIMBS
04  TASK,008  CONSTANT AIRSPEED DESCENTS
05  TASK,002  TURNS, MEDIUM BANKS,MAINTAIN LEVEL FLIGHT
06  TASK,009  TURNS, STEEP BANKS, MAINTAIN LEVEL FLIGHT
07  TASK,007  RATE TURNS TO HEADING
*EOS
```

Figure 32. COMPLETED EXERCISE TABLE

```
    THIS SEGMENT CONSISTS OF A TAKEOFF FROM WAFB AND A CLIMB
    TO 7500 FEET.
  TASK,001
  INIT,009
  CASE,022 DEMO OF TASK
  CASE,002 AUTO PROB MALF-LEFT ENG OVERHEAT WHEN IAS 20 KNOTS
  CASE,003 ROUGH AIR WHEN ALT IS 3000 FEET
  CASE,075 STD PLOT VS. REAL TIME PLOT OF ALT AND IAS
  CASE,005 END POINT,ALT 7500 FEET AND R/C ZERO +,- 50 FPM

*EOS
```

Figure 33. COMPLETE EXERCISE SEGMENT TABLE

DATA RECORDING-AASECOND,ALT,KIAS,VERTVEL

```
      IF(ASET.NE.1) EADATAØ7=.TRUE.
      IF(ASET.NE.1) GO TO 999
      IF(.NOT.EADATAØ7) GO TO 999
      EADATAON=.TRUE.
      IF(.NOT.EADATAON) GO TO 999
      IF(ALT.LT.1ØØØØ.) GO TO 999
      GAOUTPUT='LP  '
      GARATE='@AA >'
      GATIME='ØØ6Ø'
      GADATA1='AASECOND'
      GADATA2='ALT     '
      GADATA3='KIAS    '
      GADATA4='VERTVEL '
      GADATA5='        '
      GADATA6='        '
      GADATA7='        '
      EADATAØ7=.FALSE.
  999 CONTINUE
      ASET=1
   .CS
```

Figure 34.   COMPLETE DATA RECORDING CASE

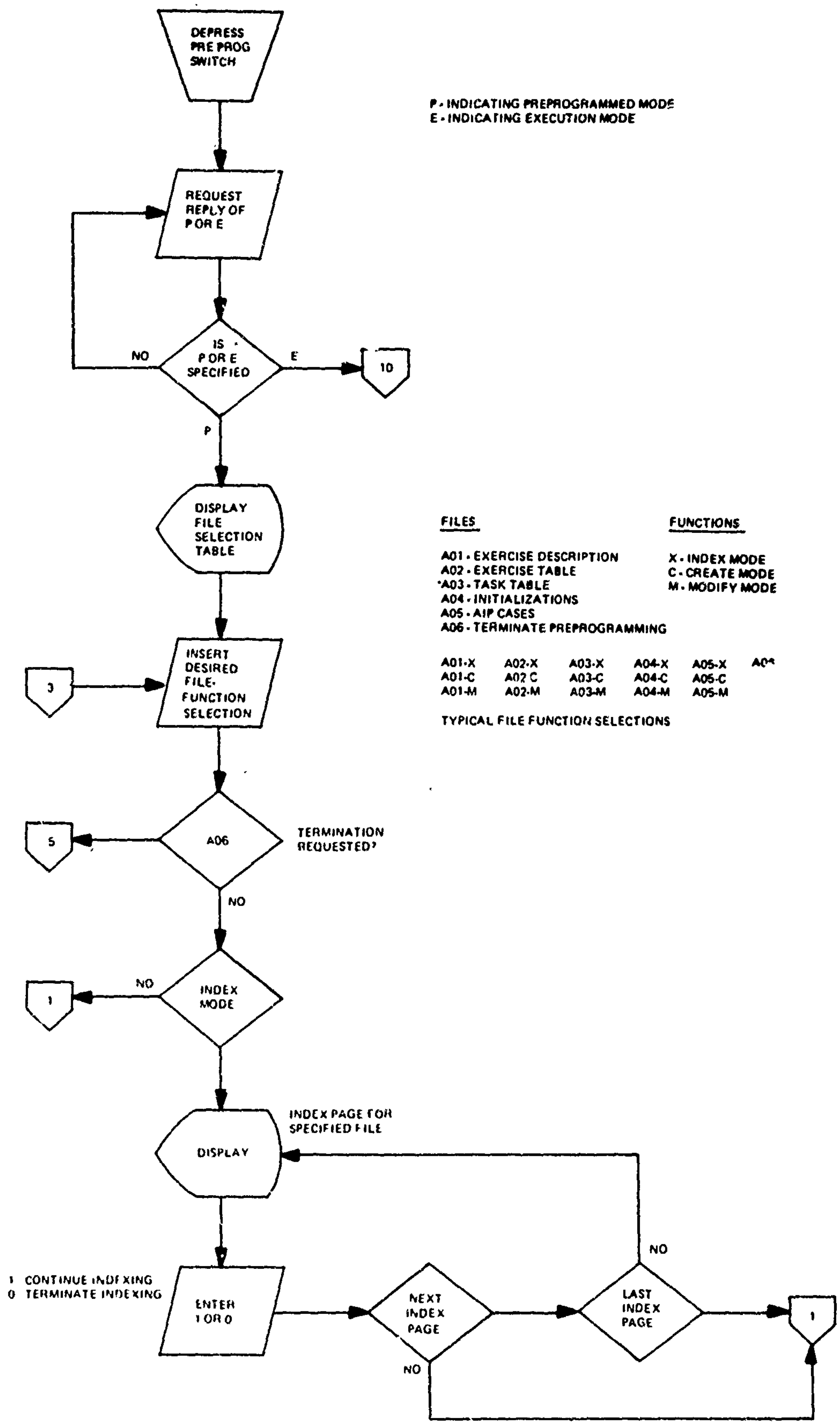



Figure 35. PREPROGRAMMING INTERACTIVE SYSTEM FLOWCHART (Sheet 1 of 6)

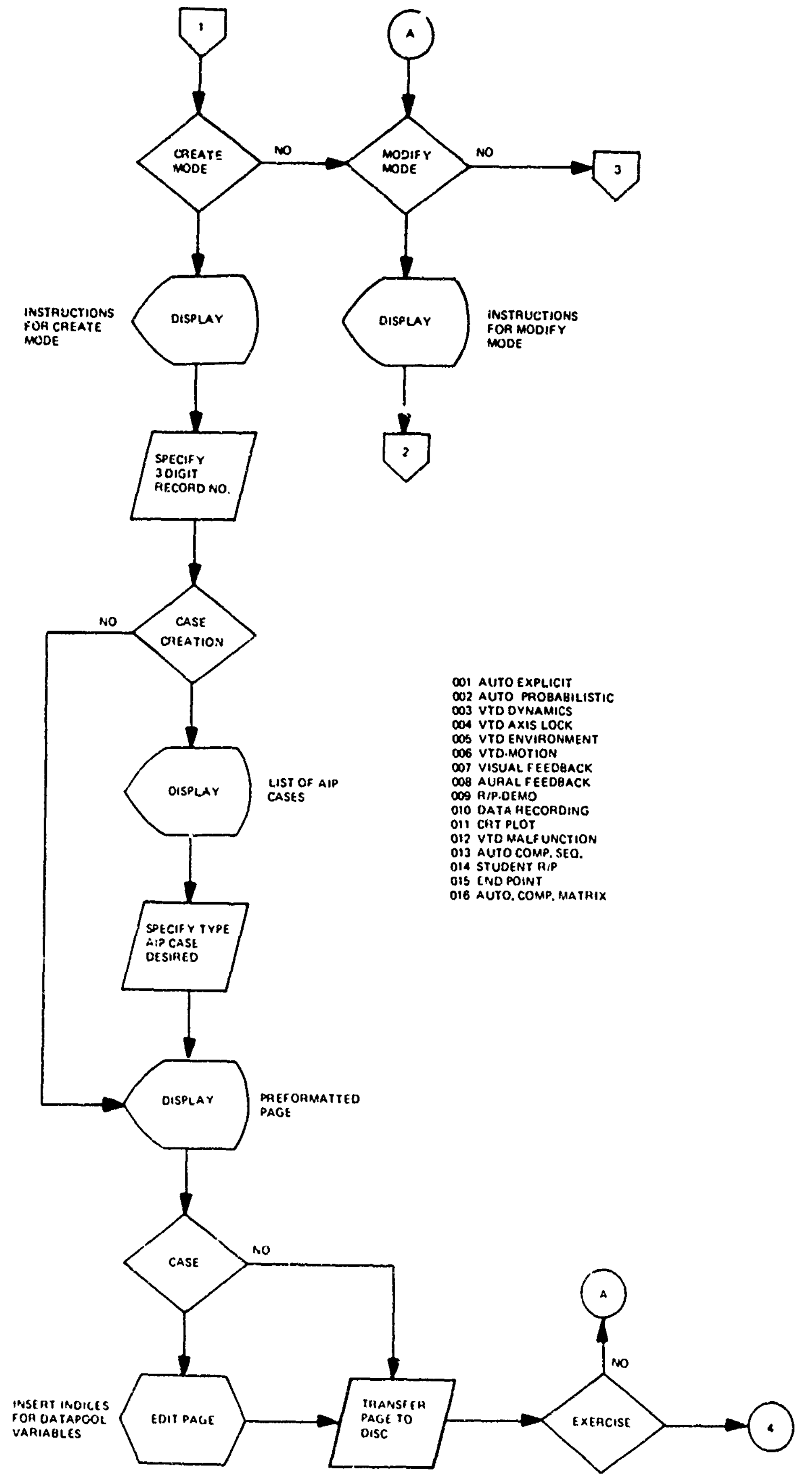



Figure 3?. REPROGRAMMING INTERACTIVE SYSTEM FLOWCHART (Sheet ? of 6)

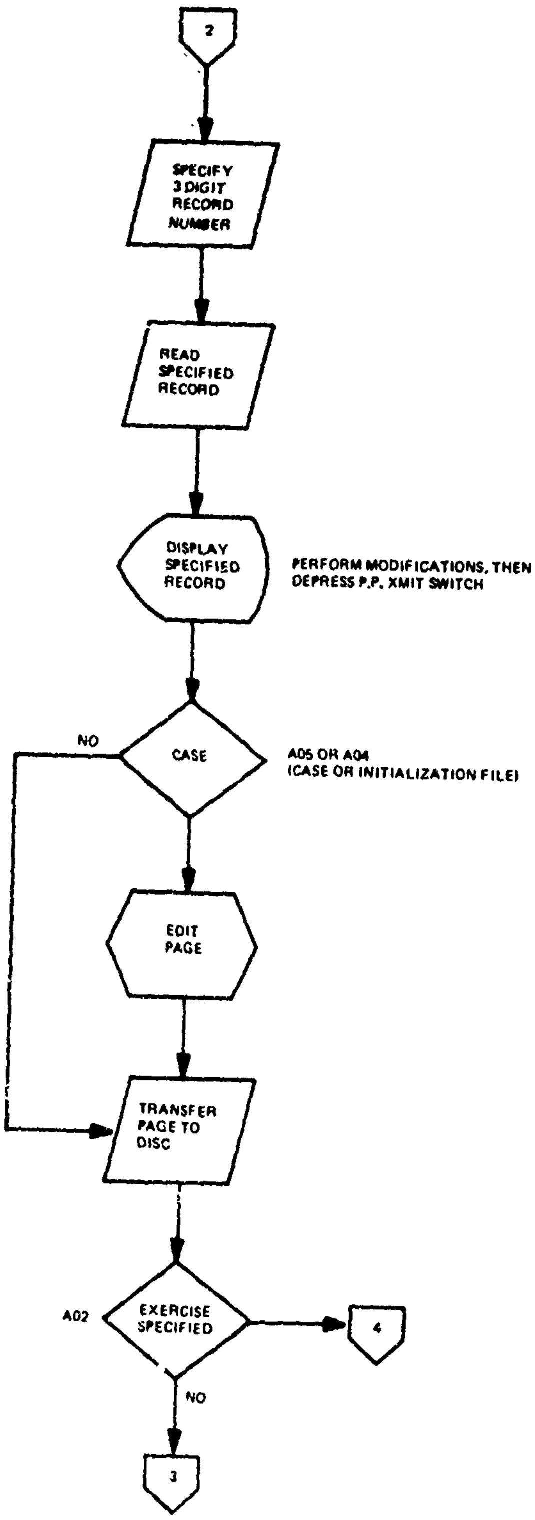



Figure 35. PREPROGRAMMING INTERACTIVE SYSTEM FLOWCHART (Sheet 3 of 6)

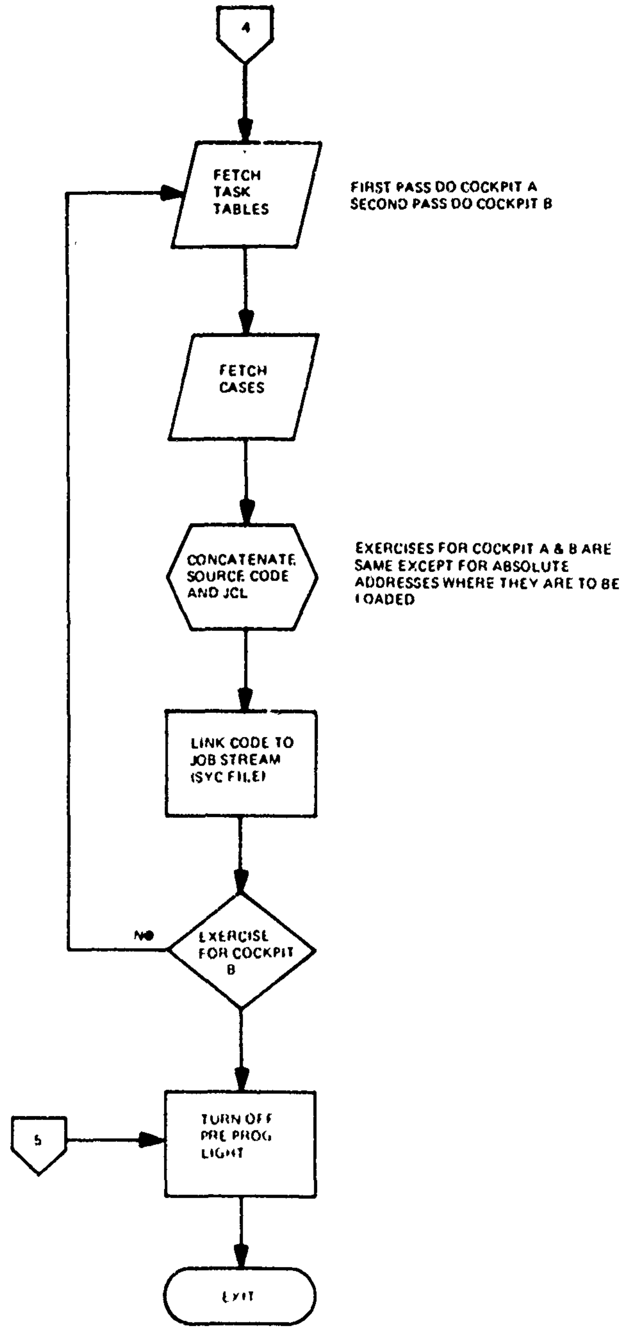



Figure 3[illegible]. PREPROGRAMMING INTERACTIVE SYSTEM FLOWCHART
(Sheet 4 of [illegible])

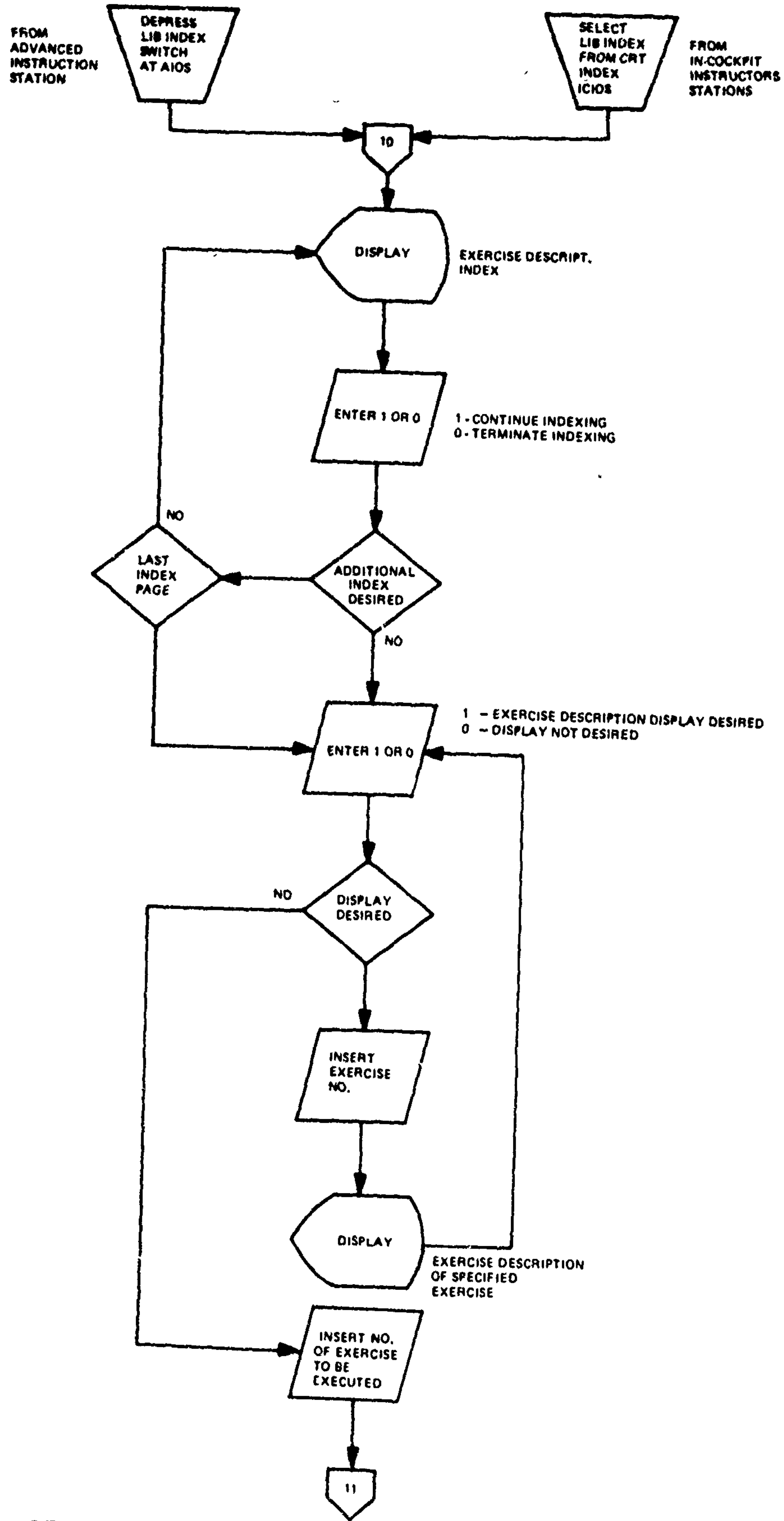



Figure 35. PREPROGRAMMING INTERACTIVE SYSTEM FLOWCHART
(Sheet 5 of 6)

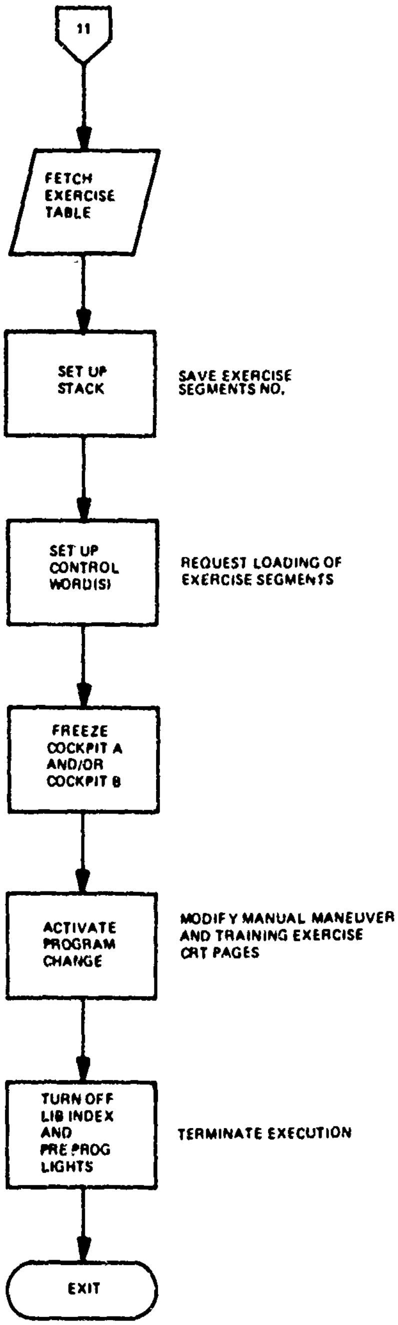



Figure 35. PREPROGRAMMING INTERACTIVE SYSTEM FLOWCHART (Sheet 6 of 6)

All software inputs needed to satisfy structural aspects of the exercises are preformatted with the user entering specific data such as:

(1) Record Titles: The system as mentioned is actually a series of files structured in the following hierarchy: exercise, exercise descriptions, exercise segments, and cases. Thus, each new record requires a title entered on the top two lines of the preformatted page. It should be noted that an index display is provided as part of the system. The generated titles, as mentioned above, are automatically added to the appropriate index.

(2) Record Numbers: The record numbers are the pointers used by the software in the concatenation process. As each source file is generated or modified, the user enters the number.

(3) File Assignments: The basic functioning syntax is usually at the case level. Files higher up in the hierarchy are constructed by assigning records of lower level files to them. An exercise segment consists of a series of up to 14 cases. Thus, to generate a segment, the coding contains only the text CASE XYZ (XYZ is the case record number). The syntax CASE references a file, and XYZ identifies the record number in that file.

(4) Conditions and Actions: At the case level, the user is generating conditional statements and action statements. For the most part, this is preformatted, but when it is not, the user's guide describes the steps required to perform the desired action. It should be obvious that the designers could not predict all possible combinations of condition statements and resulting actions. This much is left to the user.

Procedures Monitoring (PM)

Although not originally required by the ASUPT statement of work human engineering design analysis conducted during the first six months of the program established a need for a PM system. The analysis showed that when considering the nature of the UPT training requirements (basic training), a system should be available to the instructor providing an indication of the trainee's actions (steps) during important events (e.g., engine flameout).

The ASUPT PM system was designed to meet these requirements. The on-line program was written in FORTRAN. All possible data comparison modes are contained within the one program (branching is used to select the correct one based on checks associated with the selected procedure). A data table is provided, on disk, for each procedure. This table is loaded to the PM core data area upon selection by the user. Only one data table is core resident at a time.

The display portion of PM was implemented in a unique manner using the capability of the standard CRT display software in lieu of special-purpose PM display software. The PM program performs checks to determine the sequence in which each step is completed. When a step is completed, the PM program determines how many steps in the procedure have already been completed. This number is then stored in a data pool location specifically assigned to PM. The CRT pages displaying the text have as data the names of these variables associated with the appropriate step. These pages were generated using the manual page preparation program (see figures 36, 37, and 38).

Automatic Maneuver Sequencing

This system is provided to allow experimentation in two areas; lock-step versus adaptive task sequencing, and performance measurement.

The software is implemented as a subroutine which is called at the end of each segment of the current preprogrammed exercise.

The algorithm used is derived from previous research, namely AFHRL-RT-69-29.[1] The input data exists as a matrix within the file structure of the preprogrammed exercises. Current scores are generated within cases and are assigned to appropriate segments. No scoring algorithms are provided with the system. The responsibility for developing these rests with the user.

The sequencing algorithm is based on the weighted score concept. Using the input data which includes task importance, difficulty, and proportionality in terms of the effect of these parameters, a weight is computed for each maneuver. It should be noted that within the structure of the preprogramming system a task is equivalent to an exercise segment. The scores developed during each practice of the same maneuver are averaged and a dynamic-average weighted score is generated. The algorithm then selects tasks for subsequent practice, according to the lowest-weighted score (see figure 39).

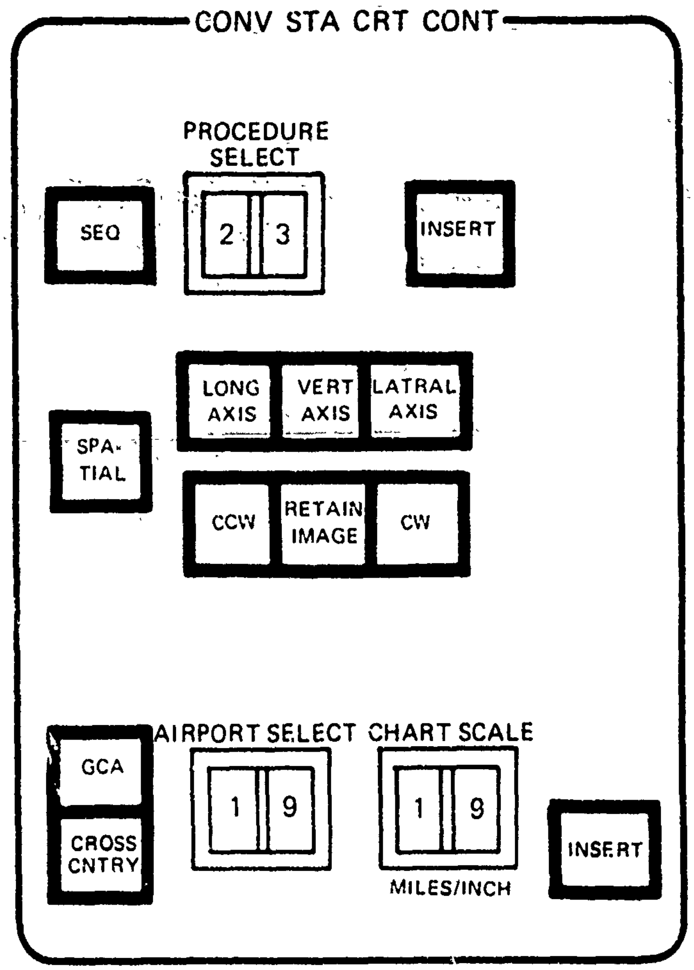



Figure 30. PROCEDURES MONITORING SELECTION PANEL

PROCEDURES MONITORING INDEX

01 BAT-ENGINE FIRE OR OVERHEAT DURING START
02 APU-
03 EMER GND EGRESS
04 ABORT TAKEOFF
05 EMER LDG GEAR RETRACT
06 R ENG FAIL TAKEOFF (AIRBORNE)
07 LEFT-ENG FAIL, TAKEOFF (AIRBORNE)
08 RIGHT-
09 LEFT-ENG FAIL, FLT
10 RIGHT-
11 R ENG FAIL, FLT
12 LEFT-ENG FAIL, FLT
13 RIGHT-
14 LEFT-ENG OVHT WARN, FLT
15 RIGHT-
16 AIR RESTART, LEFT
17 AIR RESTART, RIGHT
18 AIR RESTART, LEFT (LOW ALT)
19 AIR RESTART, RIGHT (LOW ALT)
20 FORCED LANDING
21 RUNWAY TRIM
22 GO AROUND, LEFT ENG INOP
23 GO AROUND, RIGHT AND INOP
24 ASYMMETRIC FLAPS
25 WHEEL BRAKE FAILURE
26 LDG GEAR EMER EXTENSION
27 LANDING WITH GEAR MALF
28 FUEL BOOST PUMP WARN LT (FLT)
29 DOUBLE GENERATOR FAILURE
30 MAIN INVERTER FAILURE
31 HIGH LOADMETER READING
32 LEFT LOADMETER READING ZERO
33 RIGHT LOADMETER READING ZERO
34 LEFT ENG OIL SYSTEM FAILURE
35 RIGHT ENG OIL SYSTEM FAILURE
36 O2 SYSTEM EMER OPERATION

TO SELECT PROCEDURE, SELECT NUMBER IN THE DIGI SWITCH AND DEPRESS THE INSERT SWITCH.

---

Figure 37. PROCEDURES MONITORING INDEX

2-ENGINE FIRE OR OVERHEAT DURING START (APU)

1. C THROTTLES-OUT OFF

000000000 C FUEL SHUTOFF'T'HANDLES-FULL OFF

N APU-DISCONNECT

(A) 2-ENGINE FIRE OR OVERHEAT DISPLAY

---

1-ENGINE FIRE OR OVERHEAT DURING START (BATTERY)

1. C THROTTLES-CUT OFF

000000000 C FUEL SHUTOFF'T'HANDLES-PULL OFF

000000000 C BATTERY-OFF

(B) 1-ENGINE FIRE OR OVERHEAT DISPLAY

---

Figure 38. EXAMPLES OF PROCEDURES MONITORING DISPLAY

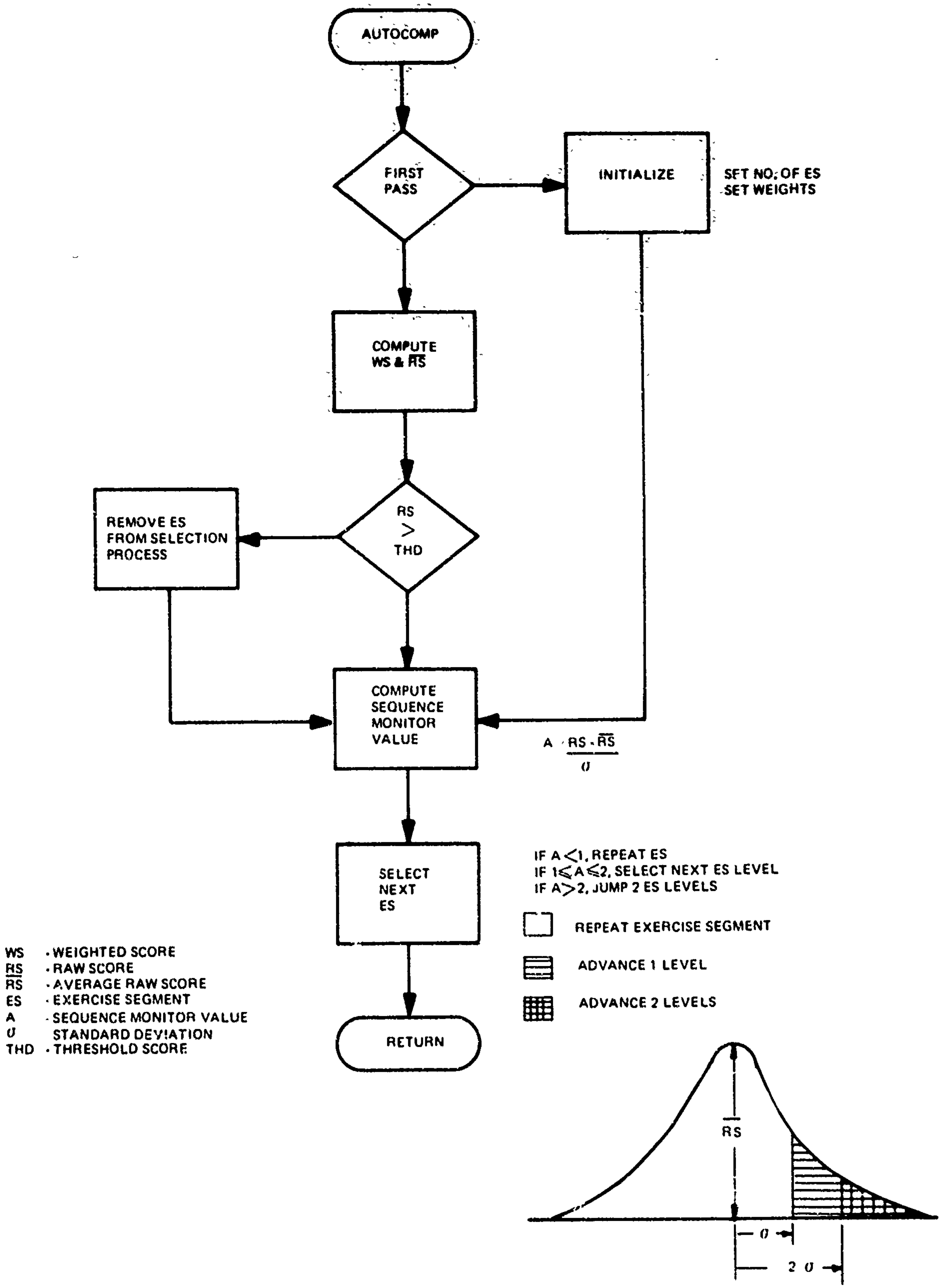



Figure 39. EXERCISE SEGMENT AUTO-SEQUENCING PROCESS

Intelligence exhibited on the 10 X 6 matrix consists of raw score, threshold, standard deviation, task importance, and task difficulty. There are twelve values (one for each possible exercise segment) for each area of interest. Intelligence elements are defined:

<u>Raw Score</u> - Student's accumulated score (range 0-100).

<u>Threshold</u> - Level of proficiency which students sccre must exceed in order to eliminate need to practice a particular exercise segment again (range 0-100).

<u>Standard Deviation</u> - Parameter indicating acceptance levels about the established, mean raw score.

<u>Task Importance</u> - Establish the relative importance of exercise segments within one exercise by assigning values 1 thru M to exercise segments ($1 \leq M \leq 12$).

<u>Task Difficulty</u> - Establish the relative difficulty in performance of a maneuver (exercise segments) within an exercise by assigning values 1 thru M to exercise segments ($1 \leq M \leq 12$).

Proportionality constants (PROPX and PROPY) are also defined and used in the weighted scores computation to introduce a means of specifying whether the importance or difficulty is more important in the weighted score calculation. (Range $0 <$ Value $\leq 1.0$). The formula for determining weight is shown below:

$$\text{WEIGHT} = \frac{1}{(\text{Difficulty})\ (\text{PROPX})} + (1\text{-PROPY})\ (\text{Importance}).$$

Figure 39 diagrams the sequencing program which selects next exercise segment to be executed. Once the weighted score (WEIGHTED SCORE = WEIGHT * RAW SCORE) and average of raw scores (RAW SCORE = ( $\Sigma$ raw scores) /N, N = # time exercise segment executed) are computed, the sequencing program checks the current raw score and compares it with threshold score for the exercise segment. If the raw score is greater than the threshold score, the particular exercise segment scored is removed from the selection process. The sequence monitor then evaluates the parameters and generates a value, A. If $A < 1$, the current exercise segment is repeated. If $1 \leq A \leq 2$, the sequence is advanced one level; and if $A > 2$, the sequence is advanced two levels. The selected exercise segment number is then passed to the program which requests exercise segments to be loaded into core. The value for the exercise segment is computed using the following formula:

$$A_j = \frac{(S_j - \bar{S}_j)}{\sigma_j};$$

Where: $\bar{S}$ = average score; S = current score; and $\sigma$ = Standard Deviation for the j exercise segment.

The algorithm which generates raw score values must be provided by the person who is generating the preprogrammed exercise, of which this is part.

RESEARCH AREA

Adaptive training reserach is a primary area for study. The research could address the following areas:

(1) Develop specifications for simulator task that can be varied in difficulty.

(2) Develop specifications for measurement of trainee performance upon which task difficulty will depend.

(3) Generate algorithms that will modify difficulty level as a function of trainer performance.

(4) Program these new algorithms.

(5) Test and Modify each algorithm based upon empirical training data.

Development in the specified areas would aid in diagnosing individual learning modes and processes, and in generating techniques for enhancing learning on an individual basis.

SYSTEM ENHANCEMENT AND EXPANSION CAPABILITIES

Enhancement of ASUPT's automated instructional system would include updating some of the hardware and software elements of the system.

Several advances in hardware design since the establishment of hardware configuration for ASUPT could add more capability to the total system. Several of the advances are stated below.

Pictorial Repeater Instruments On IOS CRT's

Currently, the conventional instructor station provides standard, repeater instruments, and the advanced instructor station provides tabular, alphanumeric displays of parameter values. It would be desirable to evaluate the effectiveness of having CRT, pictorial (graphic) representations of repeater instruments similar to those found on U. S. Navy T-2C Trainer (Device 2F101). These CRT displays represent aircraft instruments and other video forms, and are not bound by physical limitations of aircraft instruments.

VOTRAX Voice Synthesizer

The Cognitronics speech marker, currently on ASUPT, has a very limited vocabulary (189 words). VOTRAX, which assemblies speech from the basic phonemes or speech sounds, can provide a vocabulary limited only by disk storage.

Graphic CRT Hard Copy Device

The graphic display at the AIOS provides several displays which contain past history. In order to do debriefing other than at the AIOS, a hard copy device is needed.

CRT Plot Capability

Addition of CRT plot capability to the graphic CRT vector general is desirable. This capability would be similar to the monitor systems feature, except that a higher resolution system would be provided. This tool could be used effectively by those performing research in flight dynamics, motion, and other related areas.

Additional Software

Expansion capabilities for the software of the automated instructional system would require an additional disk storage device. With the addition of a disk drive to the hardware configuration, restrictions, such as the number of allowable preprogrammed exercises, could be tripled (as a minimum). It would also be conceivable to perform record/playback from disk, maintaining the current library structure of the system. This would allow the magnetic tape units to be available for use by background programs, data collection, etc. The number of available A/N CRT pages could also be increased.

The addition of a software package which performs output to a line printer and/or teletype, as directed from a preprogrammed case, would also add a new dimension to the preprogramming system.

## REFERENCES


1. AFHRL-TR-69-29, Automated Instruction and Performance Monitoring in Flight Simulation, Faconti, Mortimer, Simpson; Singer-SPD, Feb 70. AD-704 120.

2. ASUPT-74, Vol. V, Advanced Training, Black, Faconti, Epps; Singer-SPD, Feb 75.