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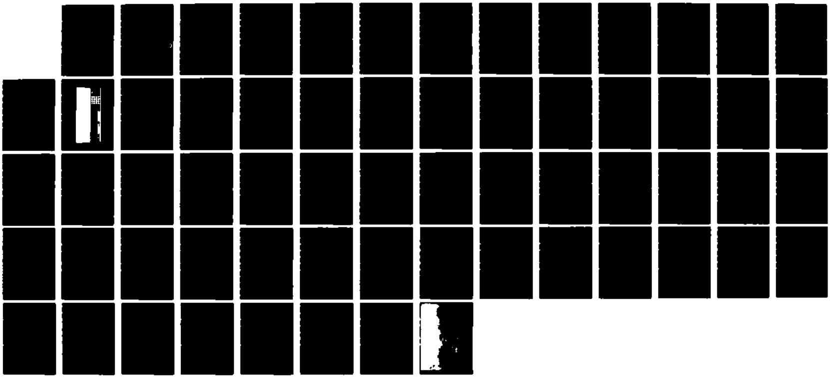

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Washington, D.C. 20591

System Description for Automated Radar Terminal Air Traffic Control System (ARTS II)—Enhancements

Burroughs Corporation
Federal and Special Systems Group
Paoli, Pennsylvania 19301

October 1982

System Description
Revision A

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16. Abstract

This document provides a system description of the ARTS IIA hardware and software. ARTS IIA is an expansion of the existing Automated Radar Terminal System (ARTS II). The expansion provides a safety package that includes beacon target tracking, minimum safe altitude warning and aircraft conflict alert. The warning and alert functions include the addition of an aural alarm and additional display data. An integrated target generator has been added to provide test and training modes of operation. Data extraction and reduction functions have been included to aid in the development testing.

To provide for increased performance and memory capacity, the computer has been upgraded and new software developed. Except for the processor, all ARTS II hardware has been retained. Brief descriptions of this hardware and the aural alarm unit are contained in Section 1. Section 2 contains a description of the existing, modified and new software functions. Section 3 contains the system performance requirements.

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INTRODUCTION

This document provides a system description of the ARTS IIA hardware and software, and fulfills the requirements of Section 3.1.2.2.1 of the Engineering Requirement (FAA-ER-D-120-012a, October 1, 1981). ARTS IIA is an expansion of the existing Automated Radar Terminal System (ARTS II). The expansion provides a safety package that includes beacon target tracking, minimum safe altitude warning and aircraft conflict alert. The warning and alert functions include the addition of an aural alarm and additional display data. An integrated target generator has been added to provide test and training modes of operation. Data extraction and reduction functions have been included to aid in the development testing.

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SECTION 1

SYSTEM AND EQUIPMENT DESCRIPTION

1.0 FOREWORD

The paragraphs in this section summarize the ARTS IIA system and equipment. The system, as it relates to the application software, is discussed in Section 2.

1.1 GENERAL SYSTEM DESCRIPTION

The basic ARTS IIA Beacon Tracking Level System includes three subsystems as shown functionally in Figure 1-1:

a. Decoding Data Acquisition Subsystem (DDAS)

b. Data Processing Subsystem (DPS)

c. Data Entry and Display Subsystem (DEDS).

The DDAS and DPS Computer, including peripheral device controllers, are contained in a single cabinet referred to as the acquisition and processing set (APS). The DDAS receives beacon video from beacon equipped aircraft within the terminal area via the beacon radar system, detects and isolates beacon reply code trains, and transmits the beacon replies in digital form to the DPS. The DDAS also supplies display video to the DEDS.

The DPS uses the DDAS data to detect beacon targets and associate them with flight plan information obtained from the ARTCC, traffic controller, or magnetic tape. Associated targets are processed by a beacon tracking function. By performing real-time position prediction calculations, these tracks are used to detect potential conflicts among aircraft and unsafe altitudes. The DPS furnishes this data and output signals to the DEDS for the air traffic controller.

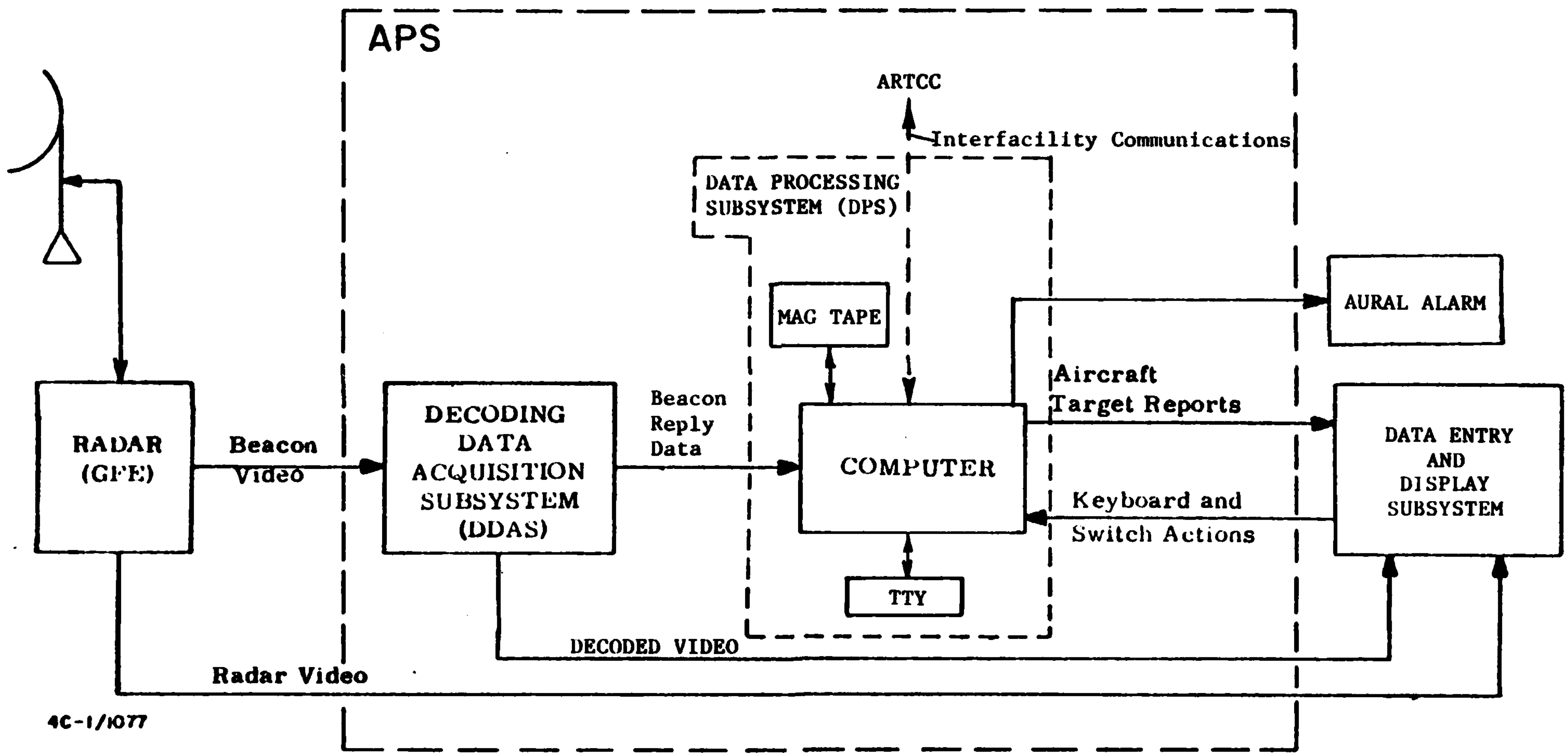


Figure 1-1. ARTS IIA System

Each DEDS accepts the data from the DPS and displays alphanumeric identity, altitude, ground speed and alert information in association with the broadband Plan Position Indicator (PPI) display of radar, beacon, and map video. The DEDS also provides the mechanism through which the Air Traffic Control (ATC) personnel can manually enter data into the system.

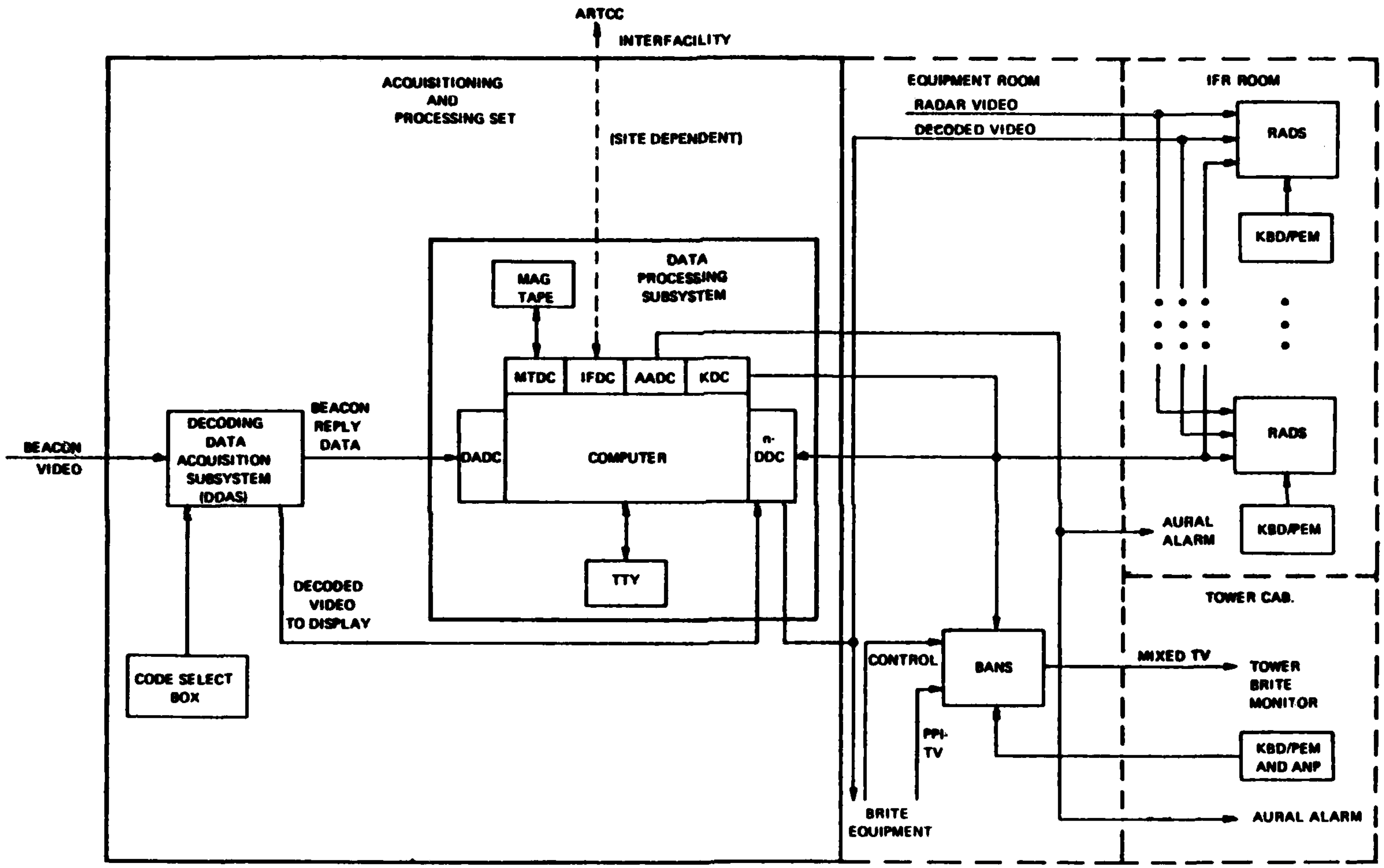
1.2 PHYSICAL CONFIGURATION OF EQUIPMENT

The ARTS IIA system is physically partitioned into the Acquisition and Processing Set (APS) and the Data Entry and Display Subsystem (DEDS). The location of the equipment is shown in Figure 1-2.

a. Acquisition and Processing Set (APS) - The APS contains both the DDAS and the DPS. The Decoding Data Acquisition Subsystem (DDAS) of the APS receives beacon video, identifies beacon replies, extracts beacon code data from the reply and converts the data to a form suitable for presentation to a computer. It processes both Mode-3/A, which provides aircraft identity information, and Mode-C, which reports aircraft altitude. In addition to providing reply data to the DPS, the DDAS interfaces with the DEDS to provide a real time decoded beacon display video signal as a backup in case of failure of the computer.

   The DPS uses statistical detection techniques to detect the presence of aircraft from the reply data received from the DDAS. The DPS provides processed data to the display subsystem for presentation to the controller for use in controlling traffic. Keyboard and Position Entry Module (KBD/PEM) inputs provided by the operator through the display subsystem are received by the DPS to modify the format of the data presented on the displays. The DPS has the capability of interfacility communication with the air traffic control center for the transmission of flight plan information and aircraft handoffs. Peripheral devices used with the DPS include a Teletype™ (with a tape punch and tape reader) and a magnetic tape unit. The APS also contains power supplies special purpose I/O, and the necessary battery backup system for the processor IC memory.

b. Data Entry and Display Subsystem (DEDS) - The display subsystem provides the man-machine interface for the ARTS IIA system by displaying synthetic alphanumeric data superimposed upon a real time PPI presentation and provides a means for entering data into the system by switch and keyboard action. The display subsystem function is provided in two forms.



MTDC - MAG TAPE DEVICE CONTROLLER
IFDC - INTERFACILITY DEVICE CONTROLLER
KDC - KEYBOARD DEVICE CONTROLLER
AADC - AURAL ALARM DEVICE CONTROLLER
DADC - DDAS DEVICE CONTROLLER

DDC - DISPLAY DEVICE CONTROLLER
RADS - RADAR ALPHANUMERIC DISPLAY SUBSYSTEM
KBD/PEM - KEYBOARD POSITIONAL ENTRY MODULE (PART OF BANS OR RADS)

ANP - ALPHANUMERIC CONTROL PANEL (PART OF BANS)
BANS - BRITE ALPHANUMERIC SUBSYSTEM

Figure 1-2. ARTS IIA Block Diagram

The Radar Alphanumeric Display Subsystem (RADS) is used in a TRACON environment and presents both broad band radar and beacon PPI data and the computer-generated alphanumeric information on a 22-inch CRT. For TRACON and tower operations, the BRITE Alphanumeric Subsystem (BANS) mixes the computergenerated alphanumeric information in TV format with the existing site BRITE equipment PPI information in TV format for TV monitor presentation.

1.2.1 Decoding and Data Acquisition Subsystem (DDAS) Functional Units

The DDAS contains a Range Azimuth Unit (RAZ) and a Beacon Reply Group (BRG). The DDAS also includes a Display Video Generator (DVG) with interfacing features that permit ARTS IIA to operate independently of other beacon decoder equipment.

1.2.1.1 Range Azimuth Unit (RAZ)

The RAZ generates all the basic timing pulses used by the DDAS. In addition, the RAZ generates various range and azimuth synchronous pulses and timing control for use within ARTS IIA. The RAZ accepts as input the beacon pretriggers, azimuth change pulses, and azimuth reference pulses from the airport surveillance radars, and synchronizes the DDAS to these inputs. Beacon interrogation pulse pairs are received and decoded to determine the mode of interrogation. If Mode-3/A or Mode-C is being interrogated, the BRG is activated.

1.2.1.2 Beacon Reply Group (BRG)

The BRG extracts beacon reply data from the beacon video signal by video conditioning and framing pulse detection. For each detected reply, the data code, including X and Special Position Indicator (SPI) bits, are sampled and garbling is sensed and flagged. In addition, the emergency codes (7700, 7600 and 7500) are detected. The code data is then transformed for Mode-C or Mode-3/A and made available with flags for further processing. Code data is discarded if it proves to result from a phantom reply, a second reply of a military identity (2 code trains reply), or because it is other than a first reply of a special military sequence (4 code trains) reply.

1.2.1.3 Display Video Generator (DVG)

The DVG provides a decoding capability (decoded video), independent of the computer, for 10 switch selectable Mode-3/A non-discrete codes, and three special discrete codes (7700 7600, and 7500). Upon comparing the reply with the switch-selected or special codes, the DVG produces unique video patterns on an analog video input channel to individually controlled displays. There is a single code select box whereby ten selected non-discrete (AB bits) beacon Mode-3A codes are specified. Each display position, by means of its display control panel, selects which of the ten codes are active at that display. Emergency code detections also enable an audible and visual alarm on the code select box.

1.2.1.4 Test Pattern Generator

A test generator is provided in the DDAS that is capable of testing the DDAS in an off-line mode of operation. It also provides a single predictable test target, Real Time Quality Control (RTQC), to support testing of the DDAS system during real time operation.

During off-line testing of the DDAS, the capability to operate independent of radar inputs as well as computer output interface is provided. For testing, the DDAS generates beacon pretriggers, mode triggers, azimuth change pulses, the azimuth reference pulse, and computer interface test signals. The DDAS is also capable of operating with test signals and communicating normally with the computer. The DDAS may also operate in the test mode in synchronism with the radar by enabling trigger and azimuth inputs while inhibiting the beacon video.

1.2.1.5 Azimuth Data Converter (ADC)

The DDAS contains an electronic Azimuth Data Converter (ADC) to convert antenna synchro information into digital azimuth information: 4096 Azimuth Count Pulses (ACP's) and an Azimuth Reference Pulse (ARP) for each antenna revolution. The ADC is physically housed in the DDAS backplane, and derives its power from the DDAS power supply. The ADC's digital azimuth output is internally selectable by wire strap jumper for the DDAS's azimuth unit, as well as being available for use by external devices.

1.2.1.6 Acquisition Signal Conditioner (ASC)

The Acquisition Signal Conditioner provides line compensation amplifiers for radar and beacon video inputs. This unit provides operation up to 12,000 feet (via cable) from the radar signal sources. An option, controlled by wire straps, allows separate or composite triggers for both beacon and video input. Azimuth control pulses (ARP and ACP) and triggers are buffered for distribution to the displays within this unit.

1.2.1.7 Back-Up Capability

In addition to the primary ADC and ASC, the DDAS contains a second ADC/ASC set. The second set is powered from a separate power suply.

The APS back-up power supply is controlled by a toggle switch located on the APS control panel. The back-up power supplies are independent of main power supplies. Therefore, the ADC and ASC that receive power from the back-up power supply can function when the main power is removed, providing for broadband operation of the displays.

1.2.1.8 Beacon Remote Control Box

A beacon remote control unit is provided near an operating position to interface by shielded cable with the DDAS logic and with the ATCBI-3B interrogator equipment via GFE demarcation junction box. The same size box is used for both the ATCBI-3B and ATCBI-4, 5.

1.2.2 Data Processing Subsystem (DPS) Functional Units

The ARTS IIA DPS performs the same Input/Output (I/O) control, data processing, and display refresh functions as the ARTS II. The DPS computer is the major equipment difference between an ARTS II and an ARTS IIA. The ARTS IIA DPS is based on a high-speed, Computer Automation LSI-2/40 computer that is upward compatible from the LSI 2/20. The 2/40 executes the same machine code and has the same hardware I/O interface as the 2/20. The computer operator's console shown in Figure 1-3 is identical to the ARTS II console. The following major assemblies comprise the new hardware:

a. Central Processing Unit (CPU)

b. Memory Management Unit (MMU) and Cache

c. Memory Modules consisting of Error Correcting Random Access Modules (ECRAM)

1.2.2.1 Central Processing Unit (CPU)

The ARTS IIA CPU is a high-speed digital processor that performs the logical and computational functions of the DPS and provides computer management and control of computer input/output activities.

The basic CPU word and processing length is 16 bits, but it also performs byte-mode (8 bit) processing. The memory addressing capability is 64K bytes directly, with extended capability using the memory management unit.

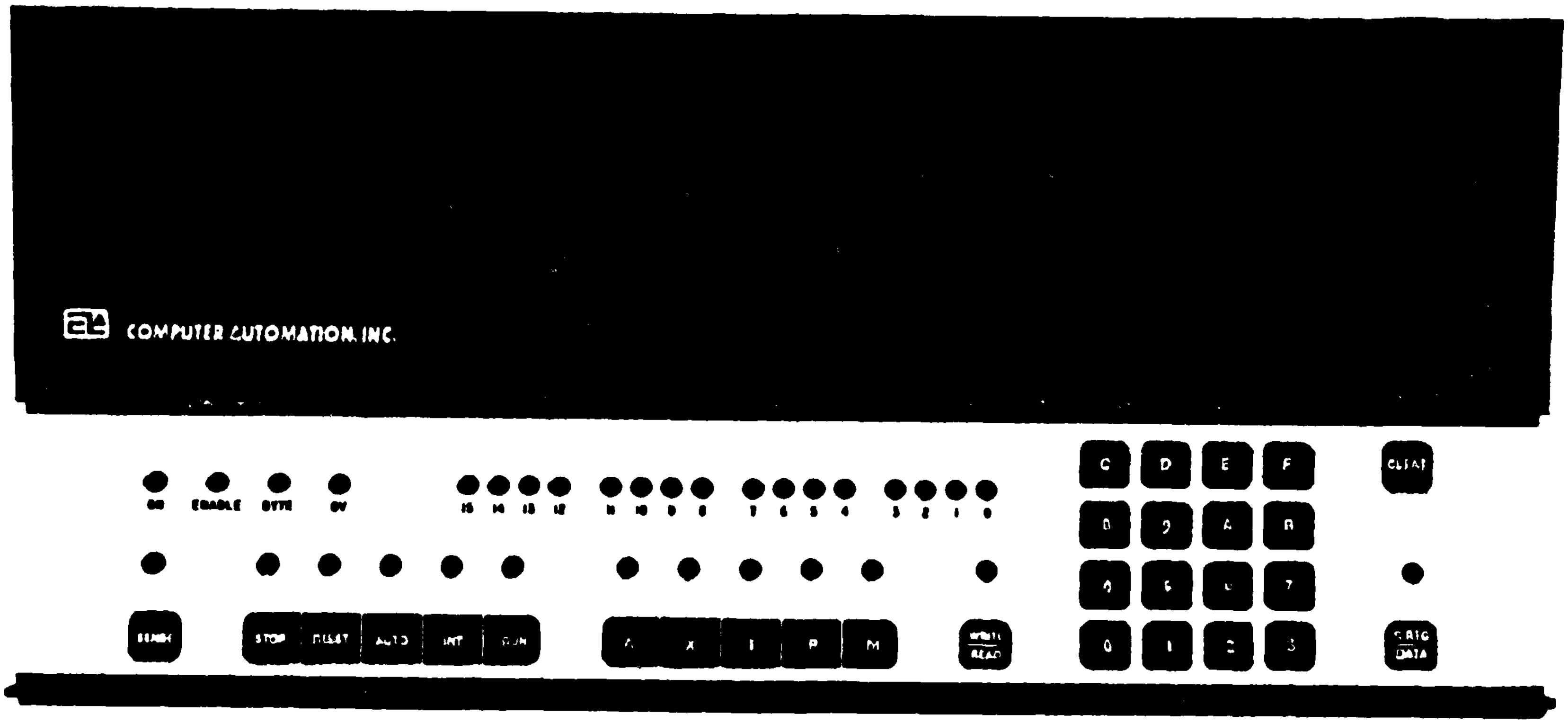


Figure 1-3. Computer Operator's Console

The entire processor logic - including power fail restart, real-time clock, autoload, Teletype™ interface and EIA RS232 interface are mounted on one full-card. The CPU has 188 instructions that include multiply/divide, single/double register shifts, memory scan, logical and stack instructions, and three-way branch, plus automatic I/O and programmed I/O. The interrupt system includes a vectored priority interrupt scheme.

The CPU also has the capability for Direct Memory Access (DMA) with typical transfer rates up to 1.72 million words per second.

There are five standard interrupt levels (two internal and three external). The third external level (with control lines) can accommodate a virtually unlimited number of vectored interrupts.

The CPU includes the hardware necessary to detect low input power conditions and bring the computer to an orderly halt until normal power is restored. When normal power is restored, the hardware will generate an orderly restart. The CPU interfaces with a modified ASR-4330 or ASR-37 Teletype™ and is fully buffered.

The real-time clock features a crystal-controlled internal clock that may be wired to produce clock rates of 100 us, 1 ms, 10 ms, or optionally for twice the input ac line frequency. The real-time clock will provide time-of-day information to the computer when properly set and may be used to time periodic events that must be controlled by the computer.

1.2.2.1.1 Memory Addressing

Instructions that access memory may operate in word or byte mode. The computer uses three control bits to specify several addressing modes. These addressing modes are scratchpad, relative, indexed, and indirect. These modes are described below.

a. Scratchpad addressing accesses the first 256 words in memory in word mode, or the first 512 bytes in byte mode.

b. Relative addressing can address an area of memory extending from the instruction address forward 256 words (+256) or backward 255 words (-255). In byte mode, the range is forward 512 bytes. Bytes cannot be directly addressed relative backward.

c. For indexed addressing, the Index (X) register can be added to the address field of memory reference instructions to form an effective memory word or byte address.

d. Indirect addressing uses scratchpad or relative addressing to access a word in memory that contains the address of a memory operand. The word that contains a memory address rather than an operand is called an address pointer.

Stack addressing is controlled by a stack pointer. Stacks may be accessed in the conventional "push" and "pop" fashion, utilizing automatic hardware predecrement and postincrement, respectively, of the stack pointer. Stack contents can also be accessed directly or with indexing through the stack pointer without altering the stack pointer value.

1.2.2.1.2 Hardware Registers

The following hardware registers form the basis of the CPU, (all except the I register are under program control):

a. A Register - A 16-bit register used for arithmetic, logical and input/output operations.

b. X Register - A 16-bit register that holds the index value for memory address modification. It is also used for input/output and certain arithmetic and logic operations.

c. OV (Overflow) - A one-bit register that is set when an overflow occurs.

d. BM (Byte Mode) - A one-bit register that specifies either word or byte mode.

e. EIN (Enable Interrupts) - A one-bit register that is set to enable interruption of processor operation.

f. I Register - A 16-bit register that holds the instruction currently being processed by the computer.

g. P Register - A 16-bit register that holds the program location counter.

1.2.2.1.3 CPU Instruction Set

The instruction set supports a single address architecture. Typical instruction time for basic instructions such as load, jump, etc. are under one microsecond. There are 188 instructions divided into eight classes:

1. Memory Reference - To access memory in word or byte mode and perform logical and arithmetic operations involving data in memory and in hardware registers.

2. Stack - Similar to the memory reference class, of instructions, except that stack instructions operate on words maintained in memory stacks.

3. Byte Immediate - Similar to the memory reference class, except that the data is contained within the instruction word so that it is immediately available for processing without requiring an operand cycle to fetch it.

4. Conditional Jump - Tests conditions within the processor and performs conditional branches depending on the results of the tests.

5. Shift - Performs single register logical, arithmetic, and rotate shifts; and double register logical and rotate shifts.

6. Register Change - Provides logical manipulation of data within hardware registers.

7. Control - Enables and disables interrupts; suppresses status, and performs other general control functions.

8. Input/Output - Provides communication between the computer and external devices. This includes conventional I/O instructions, block transfer and automatic input/output instructions.

1.2.2.1.4 <u>CPU Input/Output (I/O)</u>

Transfers are made to or from the CPU or memory. Word and byte data are handled directly, and byte data is packed automatically without the need for programmed routines.

Five distinct I/O modes are available:

1. Programmed Input/Output via Registers - Programmed I/O transfers the data directly to and from the operating registers of the processor.

2. Programmed Input/Output via Memory - This mode transfers data to or from memory without disturbing the working registers in the processor.

3. Automatic Input/Output under Interrupt Control - This mode permits an interface to transfer data to or from memory at its own data rate with minimal disturbance to the main program.

4. Block Input/Output - For high-speed transfer rates, block I/O transfers data blocks of any length (up to the size of the memory). Data is exchanged directly between memory and the peripheral interface with the index register providing the word count.

5. Direct Memory Access (DMA) - DMA transfers data directly to and from memory. This data transfer does not require the CPU. The CPU performs other operations, alternating with DMA on a cycle stealing basis. Multiple DMA controllers can use the DMA feature concurrently.

1.2.2.2 Memory Management Unit (MMU) and Cache

The MMU allows the user to expand beyond 64K bytes of memory. The MMU translates the logical address generated by the CPU and DMA controllers into a physical address for the memories.

The MMU provides a page table-oriented map. The page size is 2K bytes with 32 pages on-line. Sixteen page tables provide for address translation.

Included with the MMU is a 50nsec cache memory system that substantially improves CPU execution speed. It remembers recently used data and supplies this data at an increased speed if the data is needed again. The cache can hold up to 1024 words of data (byte accesses are not cached).

1.2.2.3 Memory Module

The memory module is an Error Correcting Random Access semiconductor Memory (ECRAM). The module provides 512K bytes of storage. It keeps soft errors from accumulating by performing error correction during the refresh cycles required by the dynamic semiconductor memory chips. The five-bit error code and associated logic correct all single bit errors and detect double bit errors. To provide safe store, the computer backplane has connectors for a battery backup power supply.

1.2.2.4 Memory Power System

The memory module and memory management unit is designed to prevent the loss of memory data during a power failure. The power system consists of an Uninterruptable Power Supply (UPS) which provides 120 VAC to a +5 VDC switching power supply. The UPS unit is external to the APC and the +5 supply is contained within the APC. The system is designed to provide approximately 1/2 hour of power when fully charged, for a 512 Kbyte module.

The UPS is a 60 Hz AC power source that contains batteries, a battery charger, and an inverter. The UPS connects to an AC power line and provides an uninterruptable power source for the AC input to the +5 VDC supply.

During normal operation when power is available, the battery charger keeps the batteries fully charged. If the power fails or drops below 15 percent of nominal, the inverter switches on to provide AC power to the +5 VDC power supply AC input. This Power System then provides memory power until the batteries discharge to 19v. When the normal power returns to a useable level, a monitor circuit shuts down the inverter and reconnects the normal power to the load. The battery charger then recharges the batteries.

1.2.3 Peripheral Device Controllers (Figure 1-4)

The computer contains an Input/Output (I/O) bus that is used by all peripheral devices connected to the computer. When the processor is using or requesting data from memory, no I/O device is permitted on the bus.

The common I/O bus contains three types of signals: data, address and control. The data signals (16 lines) are utilized to transmit data words to and from either the processor, a device, or memory. Device controllers also use the data lines to send vector addresses to the processor. The address lines (16 bits) are used by the processor or any device having a DMA capability to address specific memory words or other devices.

In general, device controllers are classified as having DMA or programmed I/O capability, depending upon the specific I/O bus signals processed by the device controller. It is also possible for a device controller to contain both DMA and programmed I/O capability.

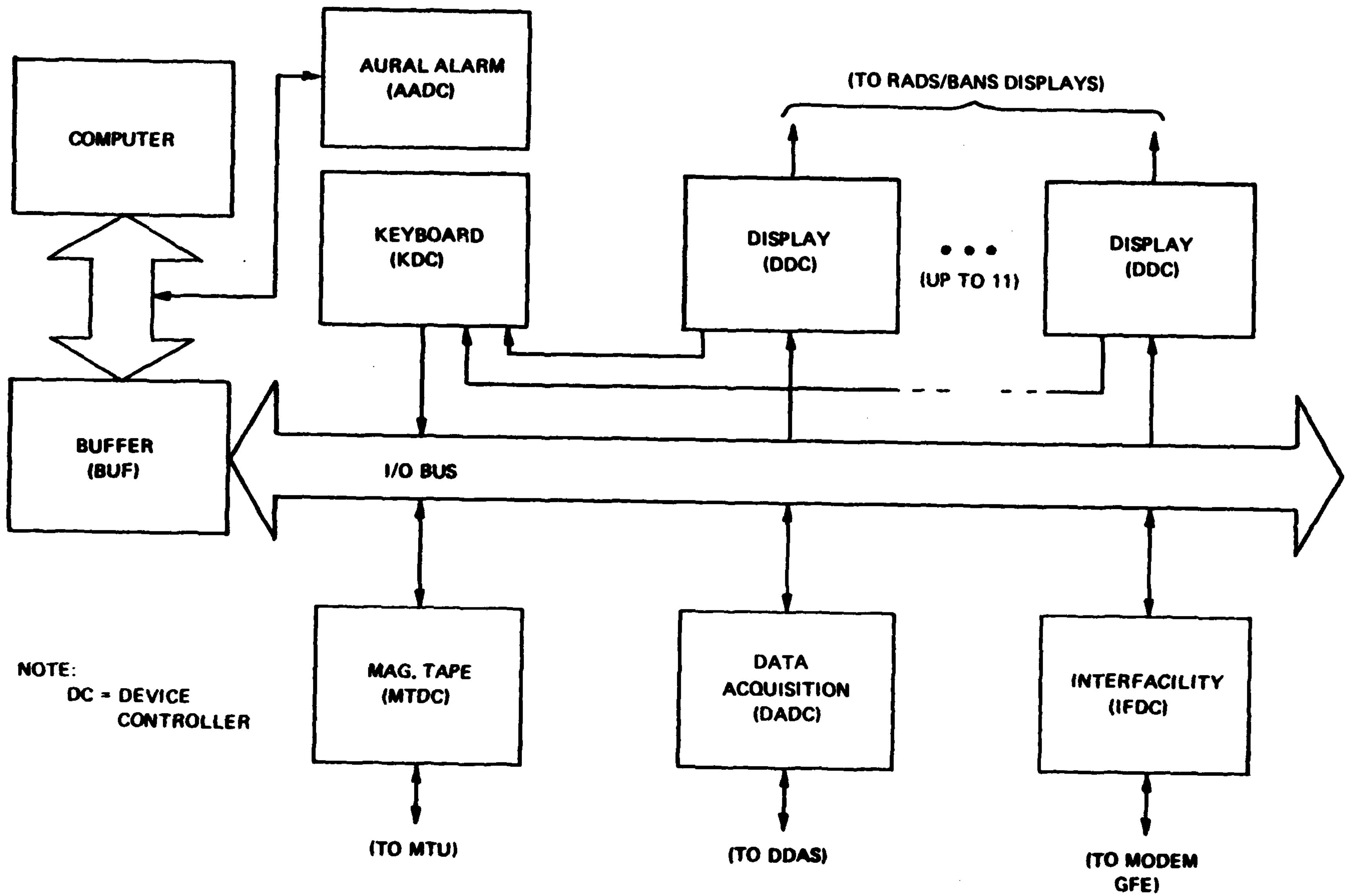


Figure 1-4. Device Controller Block Diagram

The devices that interface with the computer are standard and non-standard computer peripherals. The nonstandard devices are the DDAS, RADS and BANS displays, the aural alarm, and the interfacility modem. To interface these nonstandard devices with the computer, a number of special purpose device controllers are provided with the computer. These are:

Device Controller	Interfacing Device
DADC (Data Acquisition Device Controller)	DDAS
DDC (Display Device Controller)	RADS Display BANS Display
KDC (Keyboard Device Controller)	RADS and BANS Data Entry
IFDC (Interfacility Device Controller)	Modem
AADC (Aural Alarm Device Controller)	Aural Alarm Control Unit

1.2.3.1 Data Acquisition Device Controller (DADC)

The Data Acquisition Device Controller (DADC) interfaces the DDAS to the processor. The transfer of DDAS information is by DMA function. The DADC recognizes the sync message from the DDAS, and for each sync message, the DADC generates an interrupt. Response to this interrupt is the start address in memory for loading data to be received during the sweep. For each data transfer request from the DDAS, after sync message, the DADC transfers two 16-bit words from the DDAS into the DPS memory. The initial two words contain azimuth, interrogation-mode and alarm data. Each succeeding two word transfer contains reply data consisting of range, code, and status flags. The DADC contains check logic to insure that no more than 64 words of memory are transferred between sync messages. It also contains a check to insure that a new start address in memory was received before the first data request from the DDAS is serviced.

The DADC also provides the number of replies received during the previous sweep. The data is presented to the processor as part of the sync word generated during each sweep.

1.2.3.2 Display Device Controller (DDC)

The Display Device Controller (DDC) interfaces either the RADS or BANS display to the computer. A DDC is required for each display connected to the computer. The DDC is a direct memory-access controller. After completing the transmission of one refresh period (refresh file) to the display, the DDC generates an interrupt to the computer. This is utilized as a request for the memory starting address of display data. After a starting address is received by the DDC, it transmits the refresh file to its display.

To accommodate the efficient organization of the display output data in the refresh file, the DDC contains logic to recognize certain specific commands (instructions) embedded within the data stream. These instruction are CALL, JMP (Jump), RETN (Return) and INT (Interrupt).

In addition to the recognition and processing of special instructions, the DDC contains logic to control the refresh rate of the display and to synchronize the output data to the staggered period of the radar site.

If the DDCs were permitted to operate in a typical priority scheme, some displays would not get adequate service. To avoid this problem, the Direct Memory Sequence Resolver (DMSR) provides for a rotation of the DDC highest priority assignment each time a DDC receives a memory access. Within the instantaneous priority system established, the DDC that requests data and has the highest priority is granted the next DMA cycle. The DMSR is located on the Keyboard Device Controller (KDC).

1.2.3.3 Keyboard Device Controller (KDC)

A single Keyboard Device Controller (KDC) is provided as part of the special purpose I/O of the computer. The KDC, an interrupt based I/O, provides the interface between the data received from any keyboard and the computer. Only a single KDC is required because keyboard information is time-multiplexed by the KDC.

1.2.3.4 Interfacility Device Controller (IFDC)

The Interfacility Device Controller (IFDC) provides the interface between the computer and modem data set for transfer of data to or from an ARTCC. The IFDC is full duplex, (send and receive). The IFDC is an interrupt based programmed I/O design.

1.2.3.5 Aural Alarm Device Controller (AADC)

The ARTS IIA system provides a newly designed unit for audible alerts (MSAW/CA). This aural alarm subsystem includes an Aural Alarm Device Controller (AADC), which interfaces up to two Aural Alarm Control Unit(s) (AACU) with the computer. The AADC is a programmed I/O design. This unit provides the interface to allow the computer to turn on or off individual speakers via computer control.

1.2.4 Standard Peripheral Subsystems

The standard peripherals consist of a Magnetic Tape Subsystem and a Teletype™.

1.2.4.1 Magnetic Tape Subsystem (MTS)

The MTS provides a method for reading programs or flight plans or training target scenario data from magnetic tapes. It also may be used for recording data from the computer. Only one of these functions can be utilized at a given time since only one magnetic tape drive is available.

1.2.4.1.1 Magnetic Tape Device Controller (MTDC)

The Magnetic Tape Device Controller (MTDC) provides the interface between the magnetic tape unit and the computer. The MTDC transfers data to or from the magnetic tape unit by DMA or programmed I/O interface. To read data in DMA mode, the computer issues a read command with the number of characters to be read and the starting address of memory where the characters are to be stored. The MTDC then issues a read command to the magnetic tape unit. The read operation continues until a full record is read from the magnetic tape unit and is stored in the computer memory. To write information on the magnetic tape, the computer issues a write command and the number of words with the starting address of the computer memory that contains the first character to be written on the tape. The MTDC commands the magnetic tape unit to write and presents characters to it on demand and indicates when it is transmitting the last character to be written on the tape. In addition to the DMA mode of operation, the MTDC supports programmed I/O as well as tape record and file handling commands.

1.2.4.1.2 Magnetic Tape Unit

The magnetic tape unit consists of a magnetic tape transport and a formatter. The transport contains the mechanical mechanism for controlling tape motion and the read/write sense amplifier circuitry. All other control electronics are in the formatter. The characteristics are as follows:

Data Density	9-Track, 800 bpi
Tape Speed	25 ips (forward) 150 ips (rewind)
Recording Mode	NRZI
Read after Write	Available
Tape Format	IBM-compatible
Reel Size	10-1/2 inch

1.2.4.2 Teletype™

The supervisory I/O typewriter and paper tape system used with the computer is either the Model ASR 43 or Model ASR 37 manufactured by the Teletype Corporation. These units meet EIA RS-232 interface requirements and operate at up to 30 characters/second. The keyboard is a 4-row typewriter format and can generate all 128 ASCII characters and controls. The printer prints 94 ASCII characters at 80 characters per line. This model has an 8-hole tape reader/punch.

1.2.5 Aural Alarm Control Unit (AACU)

The Aural Alarm Control Unit is a newly designed unit for ARTS IIA and is used for MSAW and CA. It is a small panel-mountable device that contains all the necessary electronics to activate an alarm signal upon the command of the Aural Alarm Device Controller (AADC). It contains logic to provide individual speaker alarms for each display console. Up to two AACUs may be used with each system.

When activated, the AACU generates a 450 Hz ± 50 Hz tone that is interrupted at a 5 Hz ± 1 Hz rate. The interrupted tone is generated continuously until deactivated by the computer or the manual "off" control. The unit is designed for front access only, using a removable front panel. Enable/disable and volume controls are mounted on the front panel. The controls are located to provide easy access. Removing the front panel provides access to the internally mounted power supply, line filter, minimum volume controls, and other components. Natural convection provides cooling through the perforated top and bottom of the enclosure. Each of the two AACU's are connected to the computer with up to a 500-foot cable. Each AACU will drive up to six remote speakers up to 500 feet.

1.2.6 Data Entry and Display Subsystem (DEDS)

The DEDS provides the man/machine interface between the air traffic controller and the ARTS IIA equipment. Up to 11 DEDS consoles can be interfaced with an ARTS IIA display system. Two different types of DEDS are available: the Radar Alphanumeric Display Subsystem (RADS) and the BRITE Alphanumeric Display Subsystem (BANS).

The data entry devices provided with the RADS/BANS consists of a Keyboard (KBD), a Position Entry Module (PEM), and display control switches. The KBD is utilized to enter alphanumeric information into the system. The PEM is used to associate specific alphanumeric information with a particular aircraft or to reposition information on the display. The display control switches are used by the controller to format and select the most useful information.

1.2.6.1 Radar Alphanumeric Display Subsystem (RADS)

The RADS is a 22-inch CRT display which time-shares broad-band radar/beacon PPI (Plan Position Indicator) presentations with the computer-generated alphanumeric information. The display is synchronized to the facilities radar timing so that the broad-band mode is available during the radar live time, and the synthetic mode is activated during radar dead time.

Each console contains a KBD/PEM that may be attached to the console, but which are separate units connected via a plug-in cable to allow easy replacement. Two KBD/PEM's may be attached to each display console.

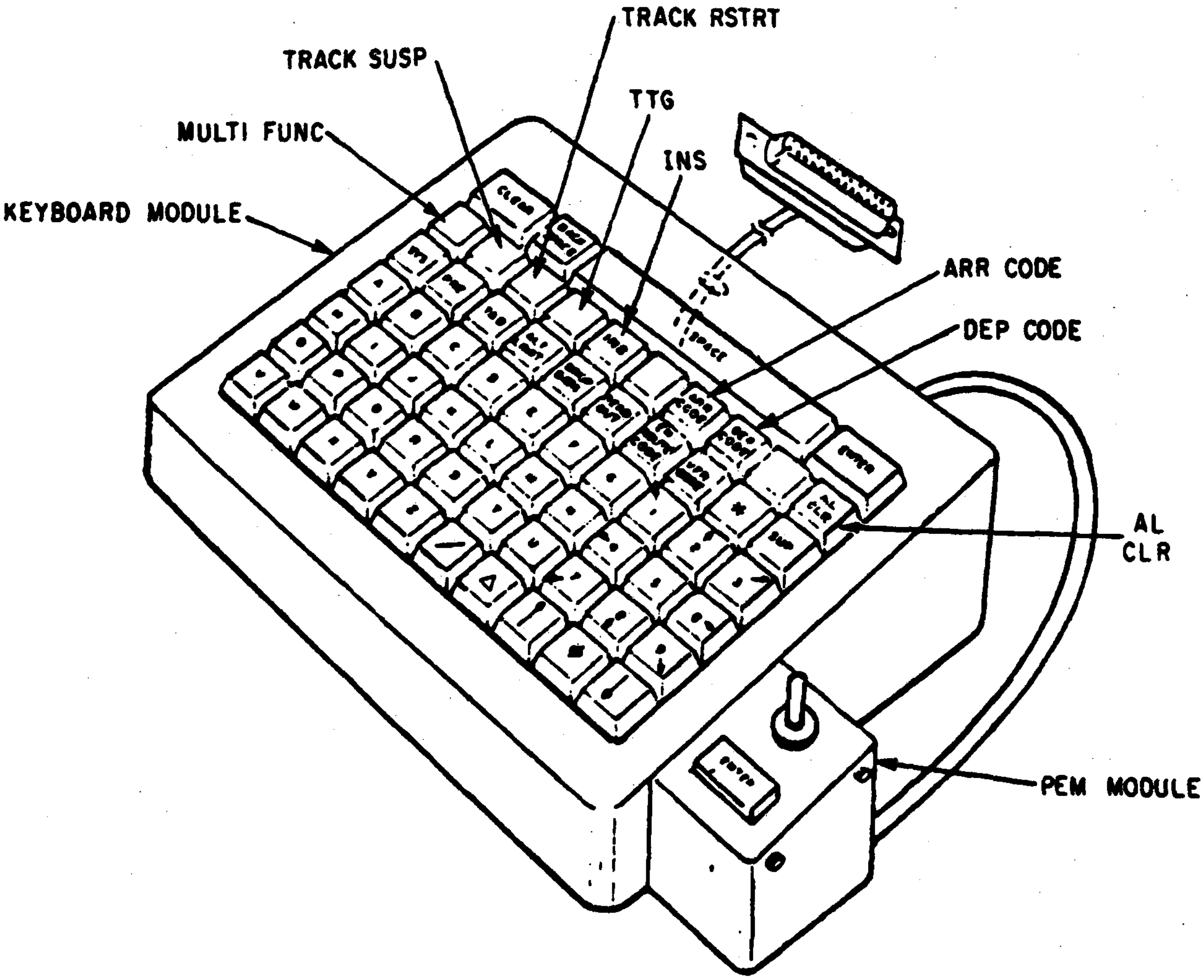


Figure 1-5. Keyboard and PEM Module

1.2.6.2 BRITE Alphanumeric Display Subsystem (BANS)

The interface of the BANS to the computer is done in an identical manner as the RADS display console. This manner of presenting data simplifies transmission of computer information to this display since the computer does not have to recognize any difference between a BANS and RADS display system.

The BANS provides for mixing of computer-generated synthetic alphanumeric information with the existing site's BRITE equipment. BANS converts the computer-generated synthetic data into TV format and mixes the data with existing TV-formatted PPI information. It accomplishes this function by taking a TV picture of a 5-inch, random-access CRT display that contains only synthetic alphanumeric information. The output of the TV camera is video-mixed with existing BRITE PPI information, and the composite TV signal is made available to BRITE displays at the site.

To permit the controller in the tower to interface with the ARTS IIA system, a KBD/PEM also is provided with each BRITE monitor. In addition to the KBD/PEM, an Alphanumeric Control Panel (ANP) is provided for control of the alphanumerics to the display. The ANP contains those switches used by a controller to modify and select the format of the synthetic displayed information. Controls on this panel are similar to alphanumeric controls provided on the front panel of the RADS display.

1.2.6.3 KBD/PEM

The data entry devices are a Keyboard (KBD), a Position Entry Module (PEM), and display control switches (see Figure 1-5 and 1-6). The keyboard is used for real time input of alphanumeric information into the system. The PEM is used to associate specific alphanumeric information and operator actions with a particular aircraft. The display control switches (located on the console display surface proper) are used to provide display category selection.

The KBD/PEM transmits information (serial/asynchronous) in a manner similar to a low speed conventional general purpose data processing terminal device. It combines the data produced by the keyboard, position entry module, and display console switch activities into a single four-character message.

The keyboard is designed as a matrix of sixty-four keys in a seven by ten array. The meaning of each key is determined by the operating program. The alphanumeric keys generate codes that correspond to display alphanumerics. The remaining keys are used to signal functions or as spares.

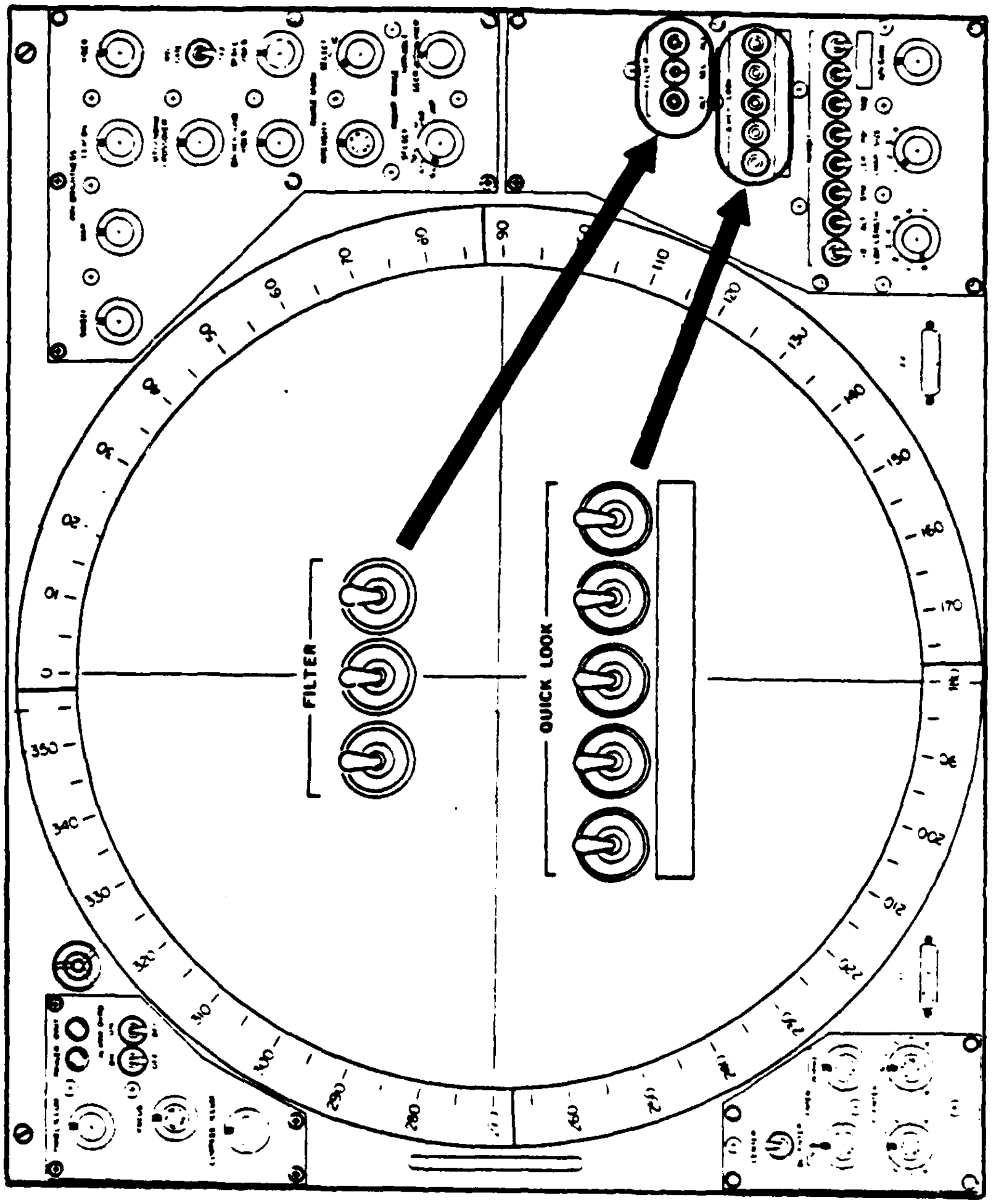


Figure 1-6. RADS Console Quick-Look and Filter Switches

PEM data is transmitted as a function of pressure applied to a two-axis pressure-sensitive joystick. This pressure is interpreted exponentially by the operating program and translated to provide a smooth motion to a position entry symbol. The operating program, by comparing the operator resultant PEM position with the display data base, can correlate display-position-dependent operator tasks with items displayed. The PEM ENTER key (actually an extension of the keyboard) is used by the operator to signify to the operating program that the selected PEM position is to be evaluated.

1.2.7 RADS/BANS Control Functions

For each display type, the control functions utilize the A/N keyboard, quick-look selector switches (see Figure 1-5) and the PEM. The functions are the same for both displays. The display also has variable range/offset capabilities. The keyboard is used by the controller to enter function commands and alphanumeric (A/N) flight data into the DPS. Feedback from the DPS to the CRT will display the entered data in a preview area for inspection prior to DPS processing. The quick-look selector is a momentary switch that enables the controller to select and display the A/N data pertaining to aircraft under the surveillance of another operating position. The display of quick-look data is controlled by the DPS. The PEM is used to enter position coordinate data into the DPS. Normally, this positional data is entered in conjunction with a keyboard message. It can specify the position of a track or an A/N data item. Up to two data entry sets can be operational at each display.

The display is capable of presenting Moving Target Indicator (MTI) video, normal video, beacon video, map video, range marks, and spare video (beacon backup). In case of a failure in the APS signal distribution system, the display can provide analog beacon video received from the radar.

1.2.8 System Display Data

The ARTS IIA system contains many features that aid the operator in controlling aircraft. The following paragraphs summarize these features. Section 2, System Software Description, presents further details.

1.2.8.1 Full Data Block (FDB)

The main presentation technique for the display of synthetic beacon information is by an FDB. FDB presentation includes a single-symbol target position identifier, a leader to tie the single symbol to the data block, and full data block information identified in Section 2.3.

Since only one controller has responsibility for specified aircraft, FDB information for a particular aircraft is presented only on the display of the controller of that aircraft. For all other displays in the ARTS IIA system, the aircraft is displayed by a single symbol. By assigning a unique symbol to each controller, each aircraft under control is easily identified.

1.2.8.2 Select Codes

A passive decoding feature is provided in the system to cover all non-tracked Mode-3/A aircraft. This system permits each display to identify up to 10 code families as select codes. The select codes are indicated by unique aircraft position symbology.

1.2.8.3 Special Position Identification (SPI)

Whenever a tracked aircraft report contains the SPI flag, the FDB will indicate the SPI presence by replacing the ground speed with the characters "ID". For an untracked aircraft with a selected code, the position symbol for that target will blink.

1.2.8.4 Limited Data Block (LDB)

Aircraft processed by the ARTS IIA system that are not in the tracked status are candidates for display as a Limited Data Block (LDB). The LDB presentation includes a single symbol target position identifier, a leader to tie the symbol to the data block, and the limited data block. The data block consists of the aircraft's 3/A octal code and its Mode-C reported altitude.

1.2.8.5 Display Control Switches

The display of Mode-C altitude is based upon the criterion that: the aircraft Mode-C altitude is within an altitude filter limit (display-entered parameter) unless the ALT switch is selected. If ALT is selected, any aircraft replying in Mode-C will display its Mode-C altitude. The SEL (Select Code Filter) switch allows all replies that contain the select code(s) to be displayed. When the ALL (All Code Filter) switch is selected, all detected aircraft will display the Mode-3/A code. All emergency type reports in the system (7700, 7600, 7500) will blink the presentation(s) to alert the controller. Each display is provided with a set of inhibit switches that provide for selective inhibiting of specific fields of the FDB.

1.2.8.6 Preview, Tab and System Display Areas

Special data areas are allocated on the display and are relocatable anywhere on the display by controller PEM action. The data areas include the following:

a. Preview - This area is used for assembly and verification of keyboard-entered data before action is taken on the data by the system.

b. Arrival/Departure - This area provides a tabular listing for aircraft awaiting initial association.

c. System - This area presents specific system parameters to the controller. Included are: time-of-day, system altimeter setting, display selected codes, and the display altitude filter limits.

d. Coast/Suspend - Provides a tabular listing of tracked aircraft that are no longer being processed by the system.

e. Alert List - provides a listing of all aircraft in MSAW/CA alert status.

1.2.8.7 Decoded Display Video

The ARTS IIA makes provision for a computer failure by providing a decoded display video from the DDAS. Display video is a real-time, PPI-oriented output. It provides for the unique presentation (passive decoding) of up to 10 site-selectable, non-discrete Mode-3/A code families. In addition, it recognizes and provides unique indications for aircraft replying with the SPI bit and for the following emergency codes: 7700, 7600, and 7500.

SECTION 2

SYSTEM SOFTWARE DESCRIPTION

2.0 INTRODUCTION

The ARTS-IIA software provides all of the software functions originally included in the ARTS II system, along with additional features described in this document. The new features include tracking, minimum safe altitude warning, conflict alert, and automated training. In addition, a data extraction and reduction function is provided.

Paragraphs 2.1 through 2.7 describe the functions of the existing ARTS II software. These functions have been adapted to support the new features and to utilize the Computer Automation LSI-2/40 computer and its Memory Management Unit (MMU).

The new ARTS IIA features are described in Paragraphs 2.8 through 2.14. Paragraphs 2.8 to 2.11 contain the new operational functions of tracking, minimum safe altitude warning, conflict alert, and training target generator. Paragraphs 2.12 to 2.14 describe the ARTS IIA support software for the training scenario generator, data extraction and data reduction.

2.1 SCHEDULER AND EXECUTIVE CONTROL

The scheduler and executive control function is responsible for the control of all ARTS IIA programs. It provides the following five services to the ARTS IIA:

1. System Initialization
2. Task Scheduling
3. Interrupt Handling

4. Power Failure Processing

5. Memory Parity Error Checking.

2.1.1 System Initialization

System initialization establishes the ARTS IIA operating environment by initializing various tables and buffers, and enabling interrupts. It places periodic programs in the appropriate queue and enables the devices associated with the ARTS IIA. System initialization also prepares the MMU for normal program operation.

2.1.2 Task Scheduler

The task scheduling function controls the other functional elements within the ARTS IIA system. These elements execute according to four methods: interrupt, demand, time periodic, and sector periodic. At the interrupt level, programs run in response to hardware interrupts. Functions executing on demand are initiated as required. Time-periodic functions execute based on time as determined by the realtime clock. Finally, sector periodic programs respond to the sector count, based on antenna azimuth, as it is advanced by input from the DDAS. Tasks are scheduled on the basis of pre-established priorities or prestored frequencies.

2.1.3 Interrupt Handlers

The purpose of the interrupt handlers is to acknowledge each hardware interrupt as it occurs. The handlers first save the current environment, including the MMU status, and perform only the processing required to prevent data loss. A particular handler may require another task to be queued for execution at non-interrupt level. Each handler restores the environment before it returns control to the task that was interrupted.

2.1.4 Power Failure Processing

It is the function of power failure processing to prepare to terminate operations when an interrupt occurs that indicates a marginal power condition, and to restore a normal operating environment when full power returns. When the power-fail interrupt occurs, all registers, including the MMU status registers, are saved in memory; and an orderly termination is made of all I/O activity. When power returns, all registers are restored and a normal I/O operations environment is established.

2.1.5 Memory Parity Error Checking

The executive function will receive an interrupt upon detection of an uncorrectable error. When this memory error is encountered, the system will halt and display a code that indicates a memory error.

2.2 KEYBOARD INPUT PROCESSING

The keyboard input processing function provides the entry interface between the air traffic controller and the system. It services up to twenty-two keyboards, calculates Position Entry Module (PEM) coordinates, services the Quick Look, ALL, SEL (Select Codes), and ALT (altitude) switches, and executes tasks requested from the keyboard. Figure 2-1 shows the layout of the ARTS IIA keyboard.

The PEM is used to enter X and Y position coordinate data into the processor and is normally utilized for implied functions, and in conjunction with a keyboard message.

The quick-look/selector presents toggle switch information that enables the controller to display on his console A/N data relating to aircraft under the surveillance of other operating positions, or to select additional data relating to aircraft already on the display. The ALL, SEL and ALT switches are described in section 1.2.8.5.

Table 2-1 presents the various command types that are processed by the keyboard input processing function. The Table also shows the capabilities of the command within each type.

2.3 DISPLAY OUTPUT PROCESSING

The display output processing function prepares the alphanumeric display data for presentation on the controller's display. It formats the data and places it in a refresh buffer, which is then transferred to the displays via Direct Memory Access (DMA) hardware.

Associated controlled (tracked) aircraft are displayed as Full Data Blocks (FDBs) containing aircraft identity, altitude, and ground speed. Inactive controlled aircraft are displayed in a tabular list format that gives aircraft identification and various status codes. Targets that represent beacon-reporting aircraft not being controlled at any controller position are displayed as Limited Data Blocks (LDBs) or special single symbols. The display of system data includes time, altimeter pressure setting, selected beacon codes, and computer memory readout. Keyboard entries are displayed in the preview area; and if message entries contain errors, the illegal entry comment is displayed in the preview area. The PEM coordinate position is displayed as an alphanumeric character.

CLEAR	BACK SPACE		SPACE					ENTER	
MULTI FUNC	TRACK SUSP	TRACK RSTRT	TTG	INS		ARR CODE	DEP CODE		AL CLR
SYS	PRE	TAB	ALT LIMIT	DROP DATA	READ OUT	EN-ROUTE CODE	VFR CODE	*	SUP
A	B	C	D	E	F	G	↖1	↑ 2	3 ↗
H	I	J	K	L	M	N	← 4	5	6 →
O	P	Q	R	S	T	U	↙7	8 ↓	9↘
V	W	X	Y	Z	/	Δ	↑	0	↓

Figure 2-1. ARTS IIA Alphanumeric Keyboard

Command Types	Capabilities
FLIGHT PLAN OPERATIONS	Create or modify a flight plan Initiate, recall, or accept a handoff Inspect the inactive file (flight plans not yet associated with reports)
DISPLAY CONTROL	Relocate system, preview, or tabular areas Add or drop select codes Set altitude filter limits Change leader direction Request or remove FDB readout Display or modify memory contents Erase readout of memory contents
SYSTEM CONFIGURATION	Update system time and altimeter Resectorize Enable or disable interfacility Enable or disable MT flight plan input
TRACKING	Initiate or terminate a track Suspend a track Modify track data Change track controller
TRAINING TARGET GENERATOR	Initiate or terminate a target Modify target parameters Enable or disable freeze mode Modify or disable wind simulation Modify or disable noise simulation Enable or disable target identifiers display Modify or disable blip/scan ratio Initiate or inhibit automatic final approach Initiate a holding pattern
MINIMUM SAFE ALTITUDE WARNING	Inhibit/Enable MSAW for a specific aircraft Inhibit/Enable MSAW for a control position Inhibit/Enable MSAW for the entire TRACON
CONFLICT ALERT	Inhibit/Enable CA for a specific pair of aircraft Inhibit/Enable CA for an individual aircraft Inhibit/Enable CA for a control position Inhibit/Enable CA for the TRACON area

Table 2-1. ARTS IIA Keyboard Command Types

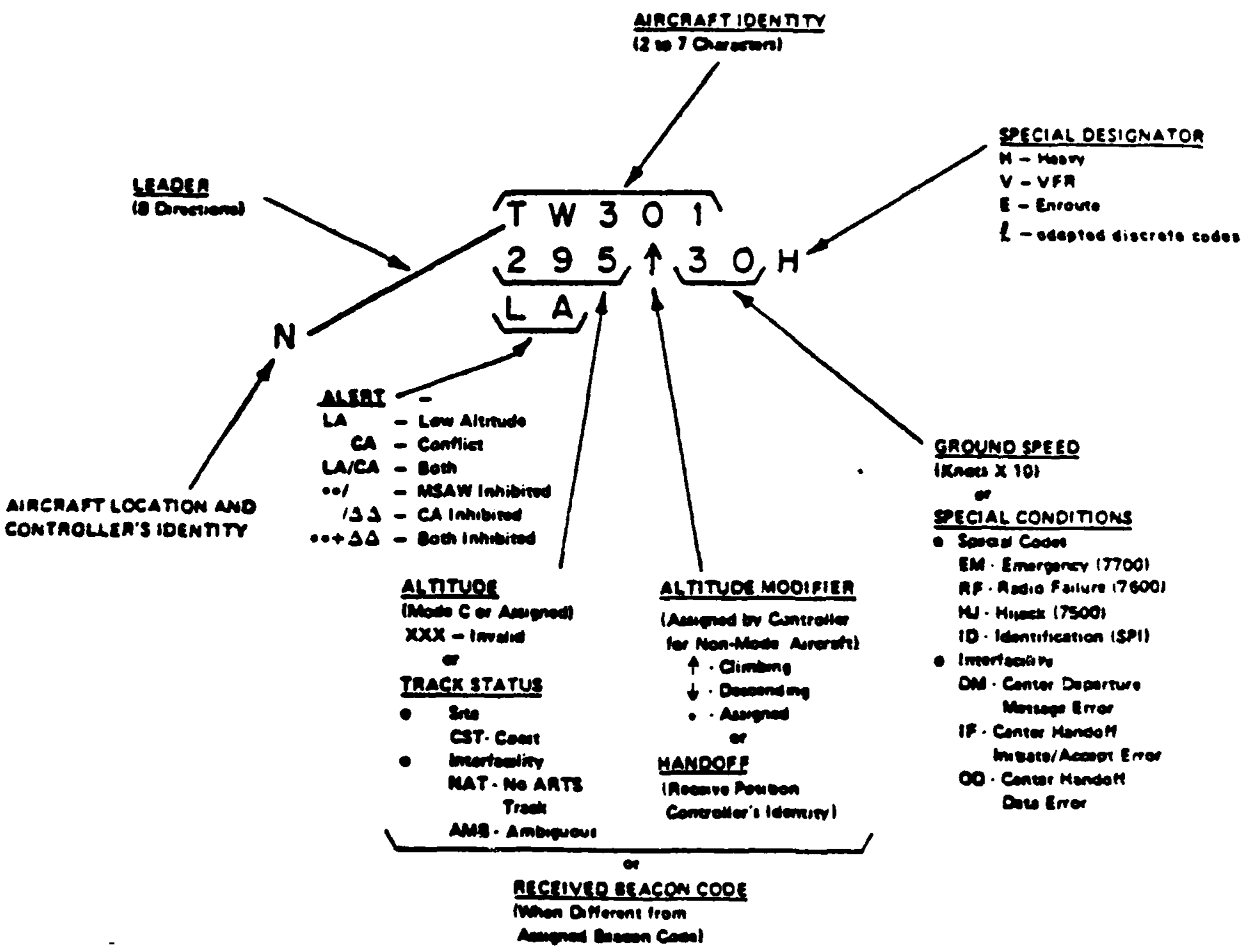


Figure 2-2. ARTS IIA Full Data Block Symbology

2.3.1 Full Data Block (FDB)

The FDB shown in Figure 2-2 consists of a control position symbol, a leader, and a two-line or three-line data format. Targets are displayed as FDBs under the following conditions:

a. Controlled on this display

b. In handoff status addressed to this display

c. Another display has been quick-looked

d. Selected by a keyboard display request

The control position symbol appears at the active track's target report position or at the predicted position if the track file is in active coast.

2.3.2 Limited Data Block (LDB)

The Display Output Processing function uses this format to present Mode-3/A (beacon code) information or Mode-C (altitude) information or both for nonassociated aircraft. Display of this information is requested by individual control positions. The target position symbol displayed follows the nonassociated single symbol criteria described in paragraph 2.3.3. The format for the LDB is shown in Figure 2-3.

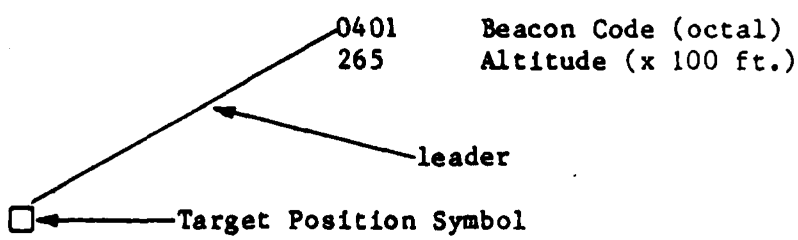


Figure 2-3. ARTS IIA Limited Data Block

2.3.3 Single Symbols

Nonassociated targets that are not displayed as LDBs and tracked targets that are not displayed as FDBs are presented as single symbols. Tracked targets that are controlled at another display position use that position symbol as the target's single symbol. Nonassociated targets use the following symbols under the following conditions:

□	Mode-C target with selected beacon code
*	Mode-C target with non-selected beacon code
Δ	Non Mode-C target with selected beacon code
+	Non Mode-C target with non-selected beacon code
V	VFR selected code

2.3.4 Tabular Lists

The ARTS IIA has three tabular lists: arrival/departure, coast/suspend, and MSAW/CA alert. All three of these lists may be repositioned on the display by keyboard input, and are not affected by the display console range scale or off-center adjustments.

2.3.4.1 Arrival/Departure List

Inactive flights are displayed in this list whenever the estimated time of arrival or proposed departure time is within a fixed number of minutes, unless specially requested by keyboard action. Departure flight plans that have the same aircraft identification as existing or arriving flight plans will not be displayed. If an arrival flight plan is received with the same aircraft identification as a departure flight plan being displayed, the departure flight plan will be removed from the tabular list until the arrival flight plan is dropped from the system.

The list may contain up to 26 alphabetically ordered flight plans (12 may be displayed). Each entry in the list contains a line identifier, an aircraft identifier, and, if available, a discrete assigned code or a non-discrete assigned code, and designators for entrance/exit fix, duplicate assigned beacon code or VFR interfacility.

2.3.4.2 Coast/Suspend List

The coast/suspend list contains tracks that are in coast or suspend status. Active tracks that are not in handoff status and fail to correlate with a report for a number of consecutive scans, or until the track firmness (measure of track consistency) decreases to a fixed value, are automatically transferred to tabular coast status. Tracks that have been manually suspended are automatically transferred to tabular suspend status.

All coasted tracks appearing in the coast/suspend list are considered inactive tracks and are eligible for automatic acquisition. When a track reacquires, the control position symbol displayed with the FDB will be the same symbol displayed when the active track was previously transferred to inactive status.

Each entry in the list contains a line identifier, an aircraft identifier, a coast or suspend character and an optional qualifier to indicate a discrete assigned code, a non-discrete assigned code, a duplicate assigned code or the aircraft altitude. The list may contain up to 32 tracks (12 may be displayed). A flush capability removes tabular coast tracks from the list automatically after a predetermined time. Tracks may also be removed via keyboard input.

2.3.4.3 MSAW/CA Alert List

This list contains up to five aircraft or pairs of aircraft that are predicted to be in unsafe circumstances. The header is continually displayed so that the location of the alert display area can be easily observed by the controller. The MSAW/CA alert list on a particular display contains only those alerts that involve one or more aircraft being controlled from that position.

2.3.5 System Area Display

The display output processing function provides six classes of system data to the controller. They are the current time; the local altimeter setting; the beacon select codes; the altitude filter limits; an indication of an emergency (EM), radio failure (RF), hijacking (HJ) or special aircraft (SA) when received within the beacon code; and computer memory readout information. The initial location of system data on the display console is defined in site adaption, and is not affected by the display consoles range scale selection or off-centering adjustments. The system data area can be relocated by keyboard entry.

The system areas on training displays contain time and altimeter values that are independent of the system values.

2.3.6 Preview Area Display

The preview area display is used to verify the message content of keyboard entries prior to entry of the data into the ARTS IIA. A maximum of 44 characters is allowed in this area. If an illegal keyboard message entry is made, an error message (backwards 'E') is displayed that may be followed by another character to define the error type. The location of the preview area display is not affected by the range selection and off-centering adjustment.

2.3.7 Positional Entry Module (PEM) Display

The PEM display function produces a symbol located at the position determined by the PEM coordinates.

The symbol is located at a position defined by radar coordinates, except when relocating preview, tabular or system area data. For these functions, the PEM symbol position is in display coordinates. Radar coordinates are affected by the range and off-centering control of the display. Display coordinates are not affected by these controls. The PEM display symbol is normally the same as the control position symbol, but can be adapted to any displayable symbol.

2.4 BEACON INPUT PROCESSING

The beacon input processing function operates on the digitized reply information from the Decoding Data Acquisition Subsystem (DDAS), and translates it into target report records. This function separates legitimate aircraft reply data from extraneous replies, and determines the current aircraft position and pertinent target information for the tracking function.

The data received from the DDAS for each mode interrogation period (sweep) consists of a synchronization message, an initial message, and a maximum of 30 reply records. The reply records contain either Mode-3/A or Mode-C replies (not both) and the reply range.

The incoming data at the beginning of a sweep contains interrogation and azimuth data. It also contains five types of possible hardware alarm conditions, which are: azimuth data converter alarm, DDAS overload, azimuth alarm, sensor alarm, and range alarm. The alarm occurrences are monitored and when they reach a predefined threshold, the alarm type is reported as a Teletype™ message.

A sliding window target detection function monitors reply information for each prospective target. When a target is detected, this function determines position, Mode-3/A and Mode-C codes, validity and strength of the target, and stores the report information for tracking function processing purposes.

2.5 INTERFACILITY MESSAGE PROCESSING

The interfacility function processes all communication between an Air Route Traffic Control Center (ARTCC) and the ARTS IIA. This communication includes flight plan messages, status messages, test messages, handoff messages, and related response messages. The interfacility function and the Magnetic Tape (MT) recorded flight plan processing do not usually run concurrently due to possible conflict in flight plans. This is a procedural restriction since there are no software checks to prohibit both functions from running concurrently. The Initiate Transfer (TI) and Track Update (TU) messages originating from the ARTS IIA contain velocity data.

Table 2-2 lists the various types of messages and the originator for each type. Note that some messages may be sent by either the ARTS IIA or the ARTCC.

2.6 FLIGHT PLAN INPUT PROCESSING

The flight plan input processing function provides for the entry of prestored flight plans from magnetic tape, interfacility or from the air traffic controller's keyboard.

Whenever the flight plans contain time, they are stored in an inactive flight plan file and are moved from the inactive file to the arrival/ departure tabular file at the correct time. Flight plans entered into the system without a time criteria are immediately entered into a display arrival/ departure tabular list. The magnetic tape flight plan function is under operator control for activation and may be used in place of the ARTCC flight plan input capability. The MT flight plan processing and interfacility do not usually run concurrently.

2.7 CONSOLE TYPEWRITER OUTPUT PROCESSING

The console typewriter processing function prints messages sent to it by other functions. Each message includes the time of day in hours, minutes, and seconds, the message type, and additional text and/or data value.

This function may use either the Model 43 or Model 37 Teletype™. It prints the following types of messages using the formats shown.

a) System Performance

    HH/MM/SS   TEXT

    Where HH/MM/SS is the current time and
    TEXT is the performance message.

b) System Error

    HH/MM/SS   SYS ERR XXX

    Where XXX is the three-digit code for the system error.

Table 2-2. Interfacility Messages

Originator	Message	Abbreviation
ARTS IIA	Beacon Terminate	(TB)
ARTS IIA	Initiate Transfer	(TI)
ARTS IIA	Data Test (Response)	(DT)
ARTS IIA	Test Data	(TR)
ARTS IIA	Rejection	(DR)
ARTS IIA	Accept Transfer	(TA)
ARTS IIA	Track Update	(TU)
ARTS IIA	Departure Message	(DM)
ARTS IIA	Acceptance Message	(DA)
ARTS IIA	Retransmit	(DX)
ARTCC	Flight Plan	(FP)
ARTCC	Amendment Message	(AM)
ARTCC	Cancellation Message	(CX)
ARTCC	Acceptance Message	(DA)
ARTCC	Accept Transfer	(TA)
ARTCC	Retransmit	(DX)
ARTCC	Rejection	(DR)
ARTCC	Test Data	(TR)
ARTCC	Initiate Transfer	(TI)
ARTCC	Track Update	(TU)
ARTCC	Data Test (Response)	(DT)

c) Magnetic Tape Error

HH/MM/SS MT TEXT

Where TEXT is the specific MT error.

d) Interfacility Errors

HH/MM/SS IF TEXT

Where TEXT is the specific interfacility errors.

e) Keyboard Entry

HH/MM/SS KB TEXT XXXX

Where KB is the keyboard number
TEXT is the specific keyboard message, and
XXXX is the data value when required.

f) Conflict Alert

HH/MM/SS CA XXXX, YYYY

Where XXXX and YYYY are the octal beacon codes of the two aircraft involved.

g) Minimum Safe Altitude Warning Alert

HH/MM/SS LA XXXX

Where XXXX is the octal beacon code of the aircraft involved.

h) Training Target Generator

HH/MM/SS TTG TEXT

Where TEXT is the specific keyboard message.

i) Data Extraction Error

HH/MM/SS DE OFF XXX

Where XXX is a number which represents the reason for DE termination.

j) Tracking

HH/MM/SS   TR RDL

Where RDL means radar data lost.

Console typewriter processing also includes the On-line Teletype" Changer (OTC) program. OTC provides an on-line capability for inspecting or modifying individual memory locations.

OTC is also the vehicle used to enter patches into the ARTS IIA system. Patches may be grouped together, stored on paper tape and used as input to OTC. This method will allow semi-automatic patch entry.

2.8 BEACON TRACKING

Beacon tracking is patterned after the ARTS III Track Oriented Smoothing (TOS) function described in NAS-MD-637. It provides horizontal and vertical altitude tracking. It operates on a sector-periodic basis, where each sector is 11 1/4 degrees of antenna rotation. Tracking uses position and rate of change information to produce current ground speed and predicted position for each track. The predicted position is used on the next scan to form a bin (area) for correlation with aircraft reports. The detected report position is presented to the display.

When the system can no longer correlate a track with a target, the track is placed in coast status. Tracks in coast status are marked so that the controller knows that the position shown may not be the true aircraft position.

2.8.1 Horizontal Tracking

Horizontal (two dimensional) tracking uses the aircraft's reported range and azimuth to derive position and velocity data. The tracker calculates a smoothed position (weighted average of reported and predicted position) and a smoothed velocity. The smoothed position data is used within the horizontal tracker for correlation of the next target report to the track. The smoothed velocity is used to provide speed information on the display. The processing of horizontal tracking is divided into several logically separate segments. Each of the tracking segments is further discussed in the paragraphs that follow.

2.8.1.1 Early Discrete Correlation (EDC)

Early Discrete Correlation (EDC) removes some of the load from other tracking processes by finding tracks that readily satisfy non-ambiguity (beacon discrete code match), time, and distance criteria. These tracks are removed from subsequent track correlation processing, but must still be processed by track updating correction and prediction.

2.8.1.2 Cross-Referencing

The cross-referencing segment of tracking establishes primary and secondary bins around each predicted track position within the sector being processed. The size of these two-dimensional windows is determined by the track's firmness (measure of track consistency).

Cross-referencing generates two lists that describe the relationship and the qualifying score between target reports and tracks. The first is a list of all target reports that fall within a track's primary and secondary bins. The second is a list of all tracks that contain a particular report. Both of these tables are used by two-pass correlation to determine which target report belongs to what track. The qualifying score is a measure of how well the report's beacon 3A and mode C validity code matches the track beacon code and track mode C validity.

2.8.1.3 Two-Pass Correlation

Two-pass correlation attempts to match each track to one target report. It uses the tables and quality score that were built in cross-referencing. During the first pass, each track is checked for the number of target reports that it contains within its primary and secondary bins. This procedure has three possible results for each track: no target reports; one target report; or more than one target report. If no target reports are matched with that track, correlation is unsuccessful and that track is placed in coast status or terminated, depending on its prior status. If only one report matches, then correlation is successful and the track will be processed next by the track correction segment. If that report is in the secondary bin, a deviation track is created. More than one target report within the track-bin is an ambiguous situation. If the quality score alone cannot resolve it, the track will be flagged for second-pass processing in the hope that the ambiguity may be resolved by the extra target reports correlating with some other track.

During the second pass, all tracks that were flagged in the first pass are examined. Tracks that successfully correlate this time, because ambiguity has been removed, will be processed by track correction. Tracks that still fail to correlate will be placed in coast status.

Additional tracks will be created on either side of the coasted track to determine whether the target is turning from its predicted course. Further processing will be done for those turning tracks by the next tracking segment.

2.8.1.4 Initial and Turning Correlation

This segment attempts to correlate turning tracks, deviation tracks, and tracks initiated by automatic acquisition or controller action. The turning or deviation tracks that were created during the previous scan in the last segment are compared with any remaining target reports. If the track matches a target report, it becomes a trial track. If the trial track continues to correlate for a specified number of scans, it returns to normal track status. Normal tracks are those processed by either EDC or two-pass correlation.

Initial tracks are processed by this segment until they correlate for a specified number of scans. Whenever a track passes this test, it becomes a normal track.

Turning and initial tracks that fail to correlate are placed in coast status. If they fail to correlate on subsequent scans, they are terminated. Deviation tracks created on the previous scan that fail to correlate are terminated.

2.8.1.5 Process Unused Beacons

This segment attempts to correlate unused target reports with flight plans. When flight plans exist that have not correlated with any associated targets, the nonassociated list is scanned for a target report that matches the flight plan beacon code. The nonassociated target must also be within the automatic acquisition areas specified by the flight plan. Target reports that correlate are removed from the nonassociated list and added to the associated track file, at which point the track becomes an initial track.

2.8.1.6 Track Correction

Track correction will be performed on all tracks that have successfully correlated with target reports. Track correction is performed by the Track Oriented Smoothing (TOS) technique. This technique uses individual correction parameters along and transverse to the direction of the track. TOS uses the track's predicted position and calculated velocity from the last scan, together with the current reported position, to calculate a smoothed position and a new track velocity. The smoothing parameters are based on the track firmness, and the values produced are used by the prediction segment to estimate where the target will be on the next scan.

2.8.1.7 Prediction

The purpose of this segment is to provide newly predicted positions for use in the tracking algorithm on the next scan. It also provides information for the Conflict Alert (CA) and Minimum Safe Altitude Warning (MSAW) functions.

Prediction uses the smoothed position, calculated velocity, scan time and turn rate (if applicable) to estimate where the track will be on the next scan. Prediction is done for all tracks, including those in coast status. Tracks in coast status use old velocity data and predicted position data to establish a new predicted position.

This segment will also perform automatic drop and automatic handoff functions for an associated track whenever its predicted position falls within either of these areas.

2.8.2 Altitude Tracking

Altitude tracking provides aircraft altitude and altitude rate of change information in support of the MSAW and CA functions. The altitude tracker calculates a smoothed altitude, an altitude rate of change (altitude velocity), and rate of change in climb or descent (altitude acceleration).

Altitude tracking is sensitive to aircraft that are transitioning. Transitioning tracks are those that are predicted to be changing altitude at a rate above some small value or tracks that have no predicted information. Nontransitioning tracks are those whose predicted altitude velocity remains below a specified limit for a certain number of scans.

The altitude tracker uses this track classification and a pressure corrected Mode-C data from the correlated horizontal track to predict altitude parameters for the next scan. The Mode-C information must pass a reasonableness check before it is considered valid. In other words, the altitude change since the last scan must fall within certain limits.

2.9 MINIMUM SAFE ALTITUDE WARNING (MSAW)

The MSAW function for the ARTS IIA is patterned after the ARTS III MSAW algorithm described in CPFS A0.17. The purpose of this function is to provide controller notification of current or impending danger for aircraft relative to ground terrain. It compares the current and predicted altitude with geographic characteristics to determine possible hazardous situations. Only aircraft with a valid Mode-C report and not in coast or drop status are considered for this function. Aircraft having beacon codes within a site adaptive range are not considered.

MSAW uses position and velocity as determined by slant range horizontal tracking, in addition to the current aircraft altitude and altitude velocity as determined by the altitude tracker. Aircraft nominal turning rates and terrain area definitions are also used by the MSAW function.

The terrain map consists of a rectangular grid overlaying the terminal coverage area. Each rectangle within the grid has a corresponding minimum altitude. MSAW begins with a current position check, and a prediction for a number (parameter) of seconds. It then projects from the predicted position, assuming the track begins to climb at a nominal climb angle from that point. This projection is continued for a length of time sufficient to clear high terrain, but subject to a maximum parameter time. Along the path, altitude comparisons are made at each point the path intersects a rectangular grid. When MSAW determines that an aircraft is now below or will within a certain time be below the minimum altitude, MSAW signals an alert. This alert produces both an audible and visible warning. The visual warning will be displayed as part of the full data block and also in the tabular area (see Section 2.3).

MSAW is provided automatically by the ARTS IIA system. However, a controller has the ability to inhibit MSAW for a specific aircraft. The supervisor can inhibit MSAW for a specific controller position (corresponding to a geographic area) or for the entire TRACON.

2.10 CONFLICT ALERT (CA)

The Conflict Alert (CA) function provides visual and aural alerts to controllers when associated Mode-C tracked aircraft are in or projected to come into a potentially hazardous proximity with other tracked Mode-C aircraft. Conflicts will be displayed using the FDB format and MSAW/CA alert list.

The functional design of the ARTS III CA feature as described in CPFS A0.17 will be used as the design for the ARTS IIA CA function within the constraints imposed by implementation in a different system.

The CA function allows inhibiting of specific controlled aircraft, or aircraft pair, or specific controller position, or for all aircraft within an entire TRACON by a supervisor command.

CA uses position and velocity, from the horizontal (planar) tracking function. The altitude tracking function provides altitude and altitude rate-of-change data. Those tracks that have valid altitude data and are not in drop, coast or suspend status are processed by this feature.

To reduce false alarms around the airport and airport approaches, the airport area is divided into three area types (I, II, and III). The site-adaptation package allows different levels of hazard criteria for different areas. The conflict detectors consider the area type as well as the track's current location in order to determine appropriate separation criteria. Airport area divisions provide CA with the capability to utilize detection functions corresponding to the region where the conflict is likely to occur. In addition, CA determines if the conflict is imminent, in which case an alarm is declared immediately. If the conflict is not imminent, the conflict is processed by a secondary detector to minimize false alarms.

2.11 TRAINING TARGET GENERATOR (TTG)

TTG provides testing and training capabilities to the ARTS IIA. It may be used to test the entire system for proper operation or to teach one or more controllers how to operate the system. In test mode, the ARTS IIA operational software ignores any live target data and uses simulated data from TTG instead. In training mode, a part of the system is used for training while the rest of the system controls live targets. It allows a trainer to simulate live traffic situations and to challenge a trainee with scenarios of varying difficulty. The live and simulated target information is processed in such a way that the two sets of data are never confused.

TTG creates a target report for each simulated target from its prestored information. This operation takes the place of beacon input processing for live targets. Changes to target information may be requested via keyboard entry or scenario input. Once target data is changed by a keyboard input, all subsequent commands from the scenario for that target are ignored.

TTG can control a maximum of 64 targets. These targets are uniquely identified by a two-digit Target Identifier (TID) from zero to sixty-three. TIDs may be displayed for an individual target on a particular display or for all targets on a particular display.

TTG keyboard commands fall into two categories: target control commands and program control commands. Errors encountered in either command type produce a backwards "E" followed by a "T" in the preview area of the display.

2.11.1 Program Control Commands

Program control commands provide the ability to control the overall operation of the TTG modules and the general training environment. The format of these commands is:

TTG <command> ENTER.

where TTG and ENTER are single keys on the ARTS IIA keyboard.

The program control commands provide the following capabilities without interfering with live target operational processing and display:

a. Assign or release displays to or from the TTG.

b. Modify the training time. This time will be completely independent from the ARTS IIA system time.

c. Activate or deactivate the TTG function.

d. Modify the training altimeter. This parameter will be independent from the system altimeter.

e. Apply or remove simulated wind effects.

f. Apply or remove simulated noise.

g. Freeze the TTG function. Input will be accepted from the training keyboards, but the targets will not move until freeze is disabled.

h. Display or remove target identifiers.

i. Initiate or abort control of all targets from the scenario tape. TTG commands which fall into categories e, f, g, and j can come from the keyboard or from the scenario tape. The other commands must originate from the keyboard.

j. Modify or disable blip/scan ratio.

2.11.2 Target Control Commands

The target control commands provide the ability to specify target identification and performance parameters for a given target. The format for these commands will be one of two formats:

TTG <tid><command> ENTER

TTG <command><position> PEM ENTER

where, TTG and ENTER are the same as program control command and tid or position is the target identifier.

The target control commands may come from either a training keyboard or from a scenario tape. Once a target receives direction from a keyboard, all subsequent scenario commands for that target will be ignored. The target control commands provide the following capabilities:

a. Initiate or terminate an individual target.

b. Assign or change beacon code or Mode-3A validity, declare a weak target.

c. Assign or modify altitude or Mode-C validity.

d. Set range or heading.

e. Change heading.

f. Assign or modify rate of change for speed, heading, or altitude.

g. Place a target in a holding pattern, a right or left turn or automatic final approach.

h. Automatic hold pattern descent function.

i. Inhibit automatic final approach.

j. Initiate Special Position Identification (SPI).

2.11.3 Training Target Generator (TTG) System Area

The TTG system area display presents time and altimeter settings that are similar to, but are independent of the current system time and altimeter settings.

The training time and altimeter setting message may be entered into the system by a keyboard entry from a supervisory position, and displayed at each training display.

2.12 TRAINING SCENARIO GENERATOR (TSG)

The TSG is an off-line program for producing scenarios for use by TTG. It gives an operator the ability to enter via teletype and store simulated target commands on magnetic tape for later use by the TTG routine. It provides the capability of merging commands previously stored on tape with new commands entered from the Teletype™ as well as the capability to edit commands already stored on magnetic tape. A time is associated with each entry for use as an input control when the tape is read by TTG. The initiate command has additional range and azimuth parameters to indicate where the target is.

2.13 DATA EXTRACTION (DE)

Data extraction provides the capability to extract information on-line from the operational program data base and to record the data on the ARTS IIA magnetic tape unit. The purpose of this function is to provide a tool for debugging and testing the ARTS IIA software. Table 2-3 lists the data types that DE can extract from the ARTS IIA.

The control of this function is achieved through the use of the Teletype™. Each data type can be set to record or not record that data type. The setting of recorded data is through the use of the On-line Teletype™ Changer (OTC) program.

In addition to recording the data, DE selectively filters the data before it is recorded according to parameters held in the data area. The data may be filtered by range, azimuth, beacon code, association status, display, training status, and memory address. These variables can be changed by the OTC program.

The data extracted and recorded on magnetic tape can then be processed later using the Data Reduction and Analysis Program on the software development system.

2.14 DATA REDUCTION AND ANALYSIS PROGRAM (DRAAP)

The DRAAP is an off-line program that executes on the software development system. DRAAP reads, analyzes and reduces data recorded on magnetic tape by the data extraction function.

Each data type can be filtered using the list in Table 2-4. The operator can select all, some, or no filters as they apply to each particular data type. Some filters have upper and lower limits such as time, altitude, range, and azimuth. Other filters require a list of selected items or require only a yes or no.

Summary statistics are maintained for pertinent data in each data type. These statistics are calculated and printed for each scan (if applicable) and at the end of each run. Each printout includes a list of the data types and the selected filters.

Table 2-3. Data Types

1. Data Loss
2. Target Replies
3. Target Reports
4. Sector Time
5. Tracking Data
6. Keyboard Data
7. Automatic Functions
8. Interfacility Data
9. MSAW Data
10. Conflict Data
11. Altitude Tracking Data
12. Central Track File Data
13. Memory Contents
14. Error and Status Data

Table 2-4. DRAAP Filters

1. Time
2. Controller
3. Altitude
4. Aircraft Identity
5. Beacon Code
6. Range
7. Azimuth
8. Training Target Generator
9. Interfacility
10. Association

SECTION 3

SYSTEM PERFORMANCE REQUIREMENTS

3.0 GENERAL SYSTEM PERFORMANCE REQUIREMENTS

This Section summarizes the major ARTS IIA system performance requirements.

Item	Quantity
Operational Range	0 to 55 nmi
Number of Displays	Typical: 6 Displays (5 Operational, 1 Maintenance) Maximum of 11 displays

System Aircraft Distribution:

Item	Quantity
Aircraft per Scan	256
Aircraft per 45 Degrees	100
Aircraft per Beamwidth (Avg. 18 Sweeps)	12
Replies per Unit Time (Process without Errors)	2 replies/21 usec.

Maximum specified system capacity:

Item	Quantity
Total Aircraft and Flight Plans	256
Full Data Blocks	102
LA/CA Data Blocks	18
Tracks	48
Mode-C Tracks	42
Flight Plans	44
Tabular Data Characters	70
Track File Capacity	116

Display Response Time (6 Display System):

Item	Time
PEM Movement, Display Range Changes or Decentering	No Perceptible Delay
Display of Preview Data	1/4 sec.
Other Controller Action	1 sec.
Other Input Data (DDAS, Interfacility)	1.5 sec.

Synthetic Data:

Precision (Report Increment)/Resolution (Dual Report Separation)

Range

Resolution	3/16 nmi
Precision	1/16 nmi

Azimuth

Resolution	2 antenna beam width (approx. 6°)
Precision	0.1 degree (1 part in 4096)

Display Model:

Display load at 24 Hertz (minimum)

Item	Quantity	Description
Full Data Blocks	12	Target symbol, leader, two 7-character lines
Limited Data Blocks	39	Target symbol, leader, 4-character and 3-character line
Single Symbols	25	Target symbol
Tabular Lines	9	Position and 10 characters

3.1 HORIZONTAL TRACKING PERFORMANCE

It is anticipated that the ARTS IIA tracking performance, as specified below, will at least match that attainable by ARTS III.

3.1.1 Track Swap Probability

The track swap probability is defined as the probability that a track will cease to correlate with the correct target, and as a result, establish a track on a nearby target or cause the track to disassociate (drop). The track swap probability is defined as:

$$P = S/T$$

where:

S = number of track swaps

T = total of track swap opportunities

The track swap Probability (P) for discrete code tracks is always zero and for non-discrete code tracks, is less than or equal to 0.15.

3.1.2 Target/Track Position Deviation

The target/track position Deviation (D) is defined as the distance between the track's predicted position and the correlating target reported position. The target/track deviation is specified as a frequency distribution of the magnitude of D and as the 99th percentile value of the magnitude of D. The 99th percentile value of target/track position deviations is no larger than the following:

	Track Code	
Type of Track	Discrete	Non Discrete
Straight	0.95 nm	1.24 nm
Turning (non-military maneuvers)	1.10 nm	1.95 nm

3.1.3 Track Loss Rate

The track loss rate (R) is defined as the overall mean track loss frequency per track-hour for all tracks in the sample. The track loss rate is defined as:

$$R = \frac{C \times 60}{D}; \qquad D = \sum_{n=1}^{N} t^n$$

where:

- R = track loss rate (tracks being dropped because of excessive consecutive coasts per track-hour)
- N = number of tracks in sample
- C = total number of tracks drops for the N tracks
- t^n = length of time that the n^{th} track was active (in minutes)

The track loss rate is no larger than the following:

Type of Track	Track Code: Discrete	Track Code: Non-Discrete
Straight	0	0.37 losses per hour
Turning (non-military maneuvers)	0	10.0 losses per hour

3.1.4 Speed Accuracy for Non-Maneuvering Tracks

The tracker speed accuracy for non-maneuvering tracks (straight at constant speed) is specified as a frequency distribution of the magnitude of the difference (d) between the track's estimate of speed (e.g., $s = \sqrt{(\dot{x})^2 + (\dot{y})^2}$) and the true aircraft speed, and as the 99th percentile value of the magnitude of d. For non-maneuvering tracks, the 99th percentile value of d is less than or equal to 40 knots.

3.1.5 Heading Accuracy for Non-Maneuvering Tracks

The tracker heading accuracy for non-maneuvering tracks (straight at constant speed) is specified as a frequency distribution of the magnitude of the difference (h) between the track's estimate of aircraft heading (e.g., h = arc tan x/y) and the true aircraft heading and as the 99th percentile value of the magnitude of h. For non-maneuvering tracks, the 99th precentile value of h is less than or equal to 19 degrees for aircraft moving at speeds greater than or equal to 100 knots.

3.1.6 Displayed Speed Stability

The displayed speed stability is defined as the distribution of scan-to-scan speed changes. The scan-to-scan displayed speed of the track of an aircraft moving at constant speed does not exhibit large changes. The following defines distributions of scan-to-scan speed changes that are deemed acceptable:

Magnitude of Displayed Scan-to-Scan Speed Change	Type of Track: Straight (In Percent)	Type of Track: Turning (In Percent)
0 knots	50	30
±10 knots	35	30
greater than ±10 knots	15	40

3.1.7 Time to Establish Steady State Tracking After a Turn

The time to establish steady state tracking performance after a turn is defined as the average number of scans required for the tracking errors (i.e., target/track position deviation and speed and heading accuracy) to decrease to steady-state values. The average number of scans to reach steady state after a turn is always less than or equal to 10.

3.1.8 Transient Speed and Heading Errors in Turns

The peak errors in the track's estimates of speed and heading during or after a turn are defined as the maximum differences between the true aircraft speed and heading and the tracker's estimate of that speed and heading. The standard deviations of these peak errors are always less than or equal to 40 knots for speed and 50 degrees for heading for non-military type turns (i.e., turning rates less than or equal to three degrees per second).

3.1.9 Altitude Tracking Performance

In the presence of good data (tracking blip/scan greater than 95 percent), the altitude tracker produces altitude change rates so that the maximum error in a 30-second projection is less than 500 feet. Tracking blip/scan is the ratio of successful track/target correlations to the total number of radar scans in the life of the track.

3.2 RELIABILITY AND MAINTAINABILITY REQUIREMENTS

The maintainability and reliability of the ARTS IIA system will meet the requirements specified in paragraph 3.8.8, Expansion Reliability, of EAA-ER-D-120-012a. The hardware modifications/additions will not degrade the system/subsystem reliability and maintainability requirement.

3.2.1 Subsystem Reliability

Item	Hours
DDAS	3,000
DPS	1,500
RADS	3,000
BANS	1,500
ADC	15,000

3.2.2 System Reliability

The TRACON and TRACAB reliability with peripherals is 1000 hours mean up time.

3.2.3 System Maintainability

The system MTTR is less than 30 minutes (average) to replace a failed module or pluggable unit available from the spare parts complement.

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