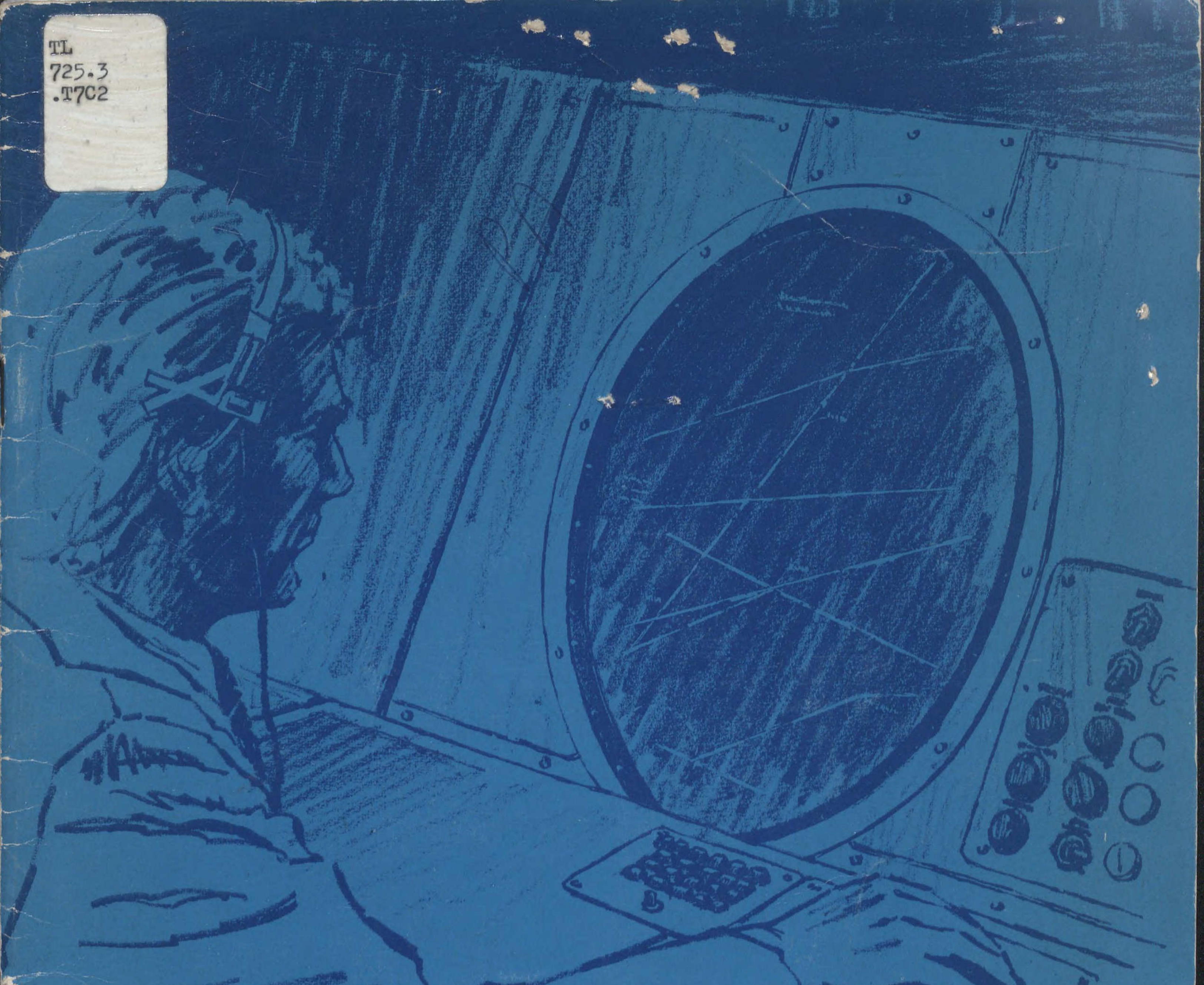


AUTOMATION IN AIR TRAFFIC CONTROL

THE CANADIAN APPROACH

AUTOMATION IN AIR TRAFFIC CONTROL

THE CANADIAN APPROACH

New
or
dup?

A Report on One of
The World's Most Advanced
Air Traffic Control Systems

Further information is available from any Canadian government trade office or by writing directly to:

The Electrical and Electronics Branch
Department of Industry, Trade and Commerce
112 Kent Street
Ottawa, Ontario K1A 0H5, Canada

Enquiries, or visits to view installations and equipment, are welcomed.

INTRODUCTION

The volume of air traffic in Canada and around the world has been rising steadily during the past decade and all indications are that it will continue to increase, possibly accelerate, through the 70s and 80s. Air traffic requires precision control, and the demand on the control system in high traffic density areas has already reached a level at which improved techniques and equipment are essential if safety standards and efficiency are to be maintained.

Studies and experiments have shown that the application of modern high-speed data processing and information display equipment is the technique which will most satisfactorily deal with the control problem. It is no longer economical or practical to cope with increasing work loads and higher speed aircraft by adding large numbers of additional air traffic control (ATC) staff.

Major automated air traffic control systems have been introduced in the last decade in the United States and Europe with varying degrees of success. Most of these systems were derived from equipment and techniques developed for military purposes, and have certain problems. In particular, there is the problem of producing satisfactory software programs for the large computer processors which form the hearts of these systems.

Introduction of the automated systems has raised other major problems such as training and recruiting staff to operate and maintain these highly complex systems. The continuance of satisfactory traffic services with old equipment while implementing the new systems has also been difficult.

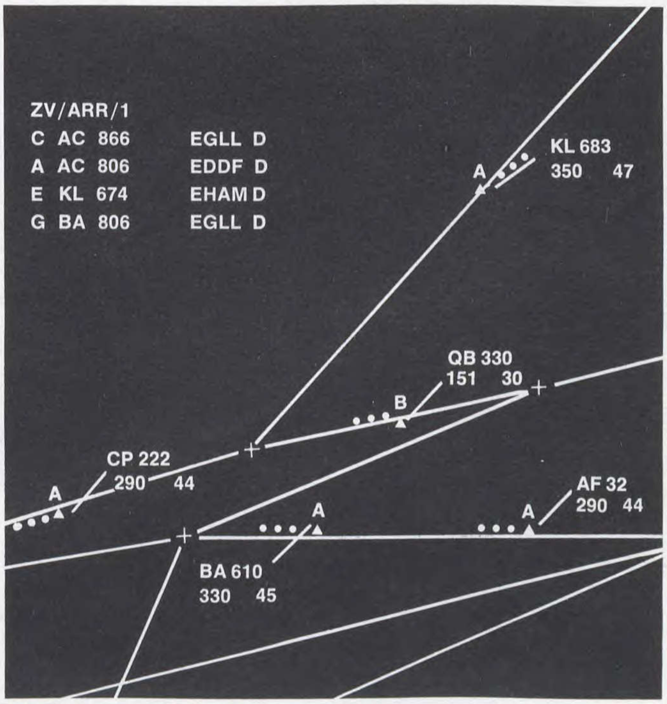
The Canadian ATC Automation Program, recognizing these problems, developed its own system as a solution. This system, JETS (Joint Enroute/Terminal System) is based on a modular approach to creating an automated system through a series of phased implementations of increasing degrees of automation. The program, started in 1971/72, has accomplished the following major steps:

1. Increased overall radar coverage by using remoted radar through the technique of digitizing the radar information so it can be transmitted over conventional telephone lines; and combined primary and secondary radar data.
2. Significantly improved the quality of PPI display presentation of radar data by utilizing state-of-the-art techniques in computer data processing, filtering, and the clear display of alpha-numeric information near the radar target.
3. Automated information acquisition, processing and display, including ancillary information such as flight plans.

Canadian experience and expertise can be readily adapted to solving air traffic control problems of other administrations. The purpose of this publication is to provide an outline description of the Canadian approach to air traffic control automation.

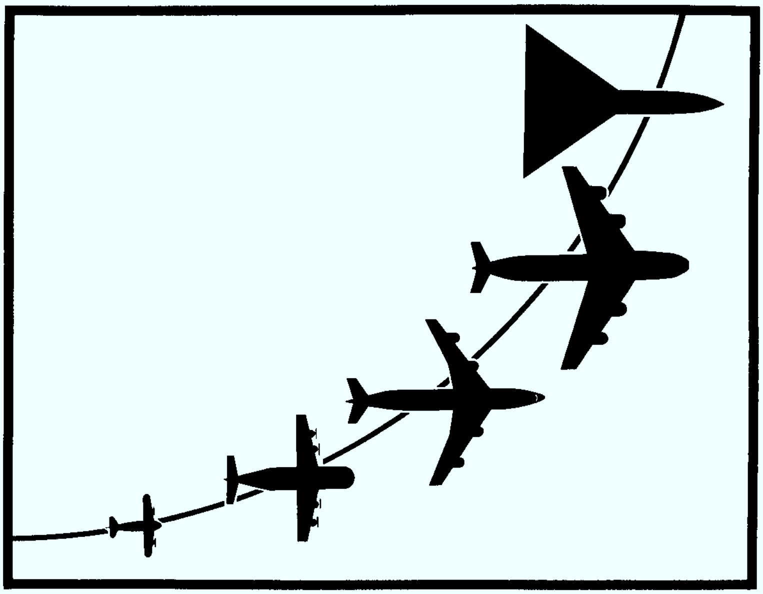
Further information can be obtained by contacting the Canadian Department of Industry, Trade and Commerce, 112 Kent Street, Ottawa, Ontario K1A 0H5, Canada or any Canadian government trade office.

Conventional Display

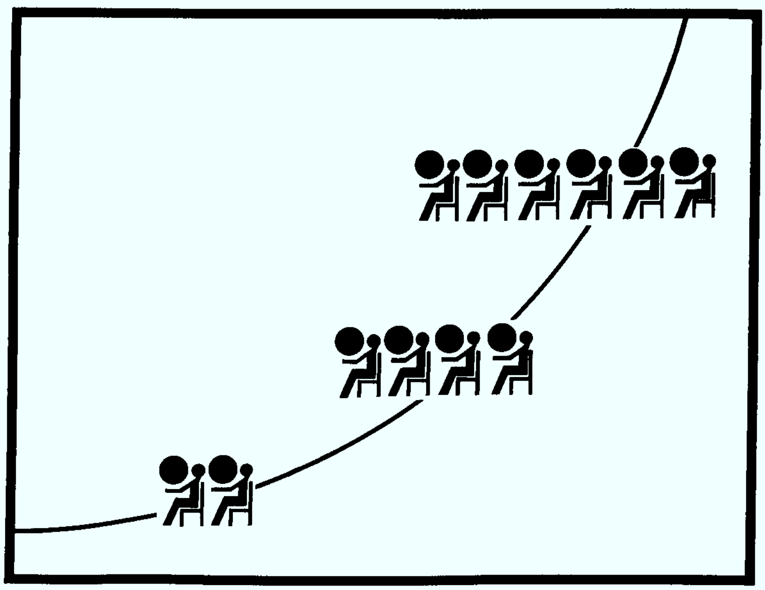


JETS Display

THE PROBLEMS AND THE CANADIAN APPROACH TO THEIR SOLUTION



PROBLEMS:



Mounting volume of air traffic

Ever larger and higher speed aircraft

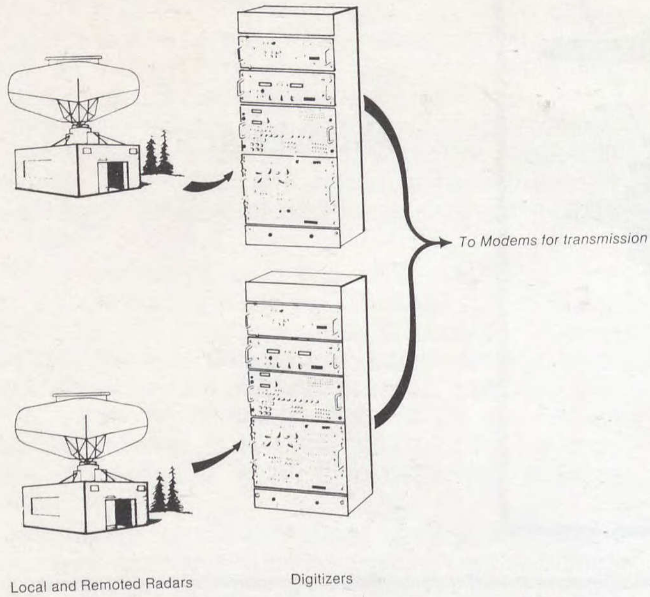
Rising demand for "all weather" facilities

Development of more intricate control and navigation techniques

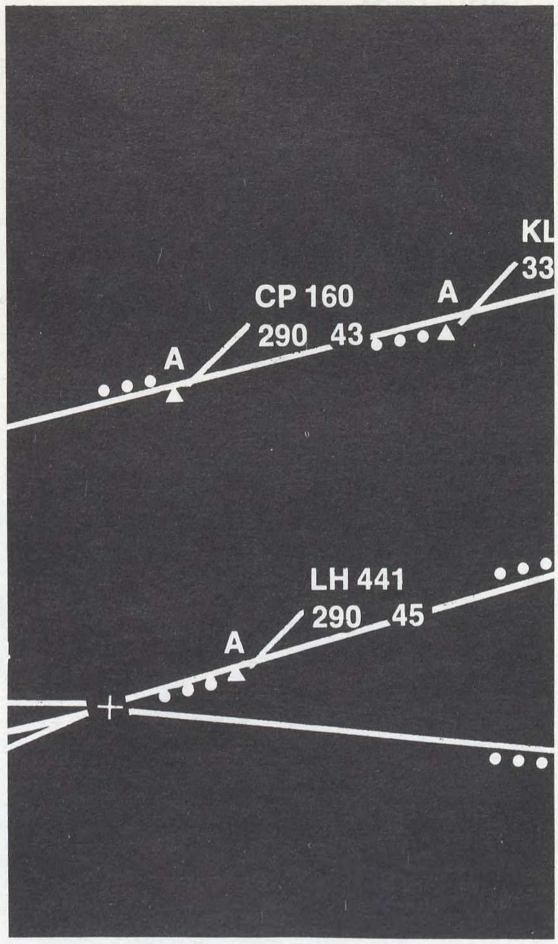
The hiring of additional personnel alone will not solve these problems of air traffic control (ATC). It is no longer economical or practical to cope with rapidly increasing work loads and higher speed aircraft in this manner. The answer lies in the introduction of improved techniques and equipment so that current safety standards and efficiency can be maintained.

THE CANADIAN SOLUTION:

A phased introduction of modular components and software that permits the remoting of existing radars and the introduction of modern high speed data processing and units for the alpha-numeric display of ATC information.

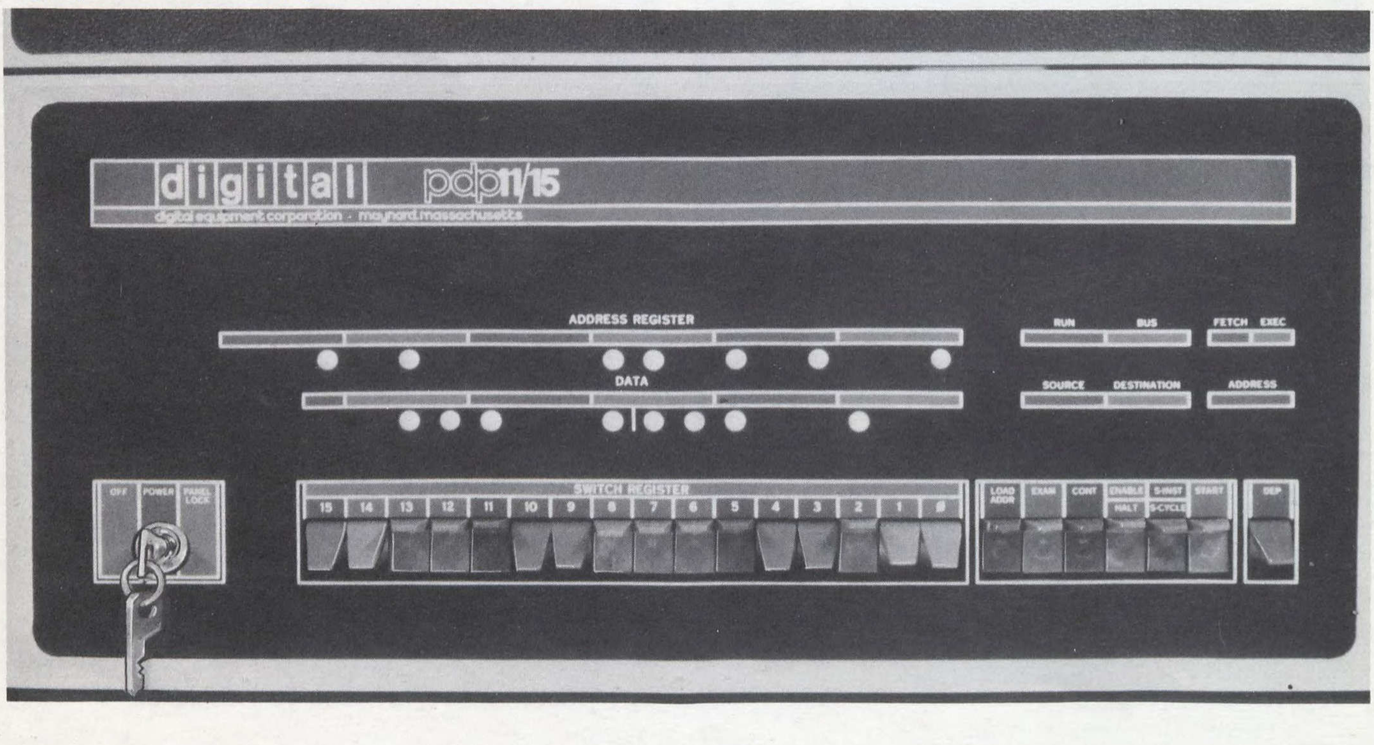


Radar Remoting

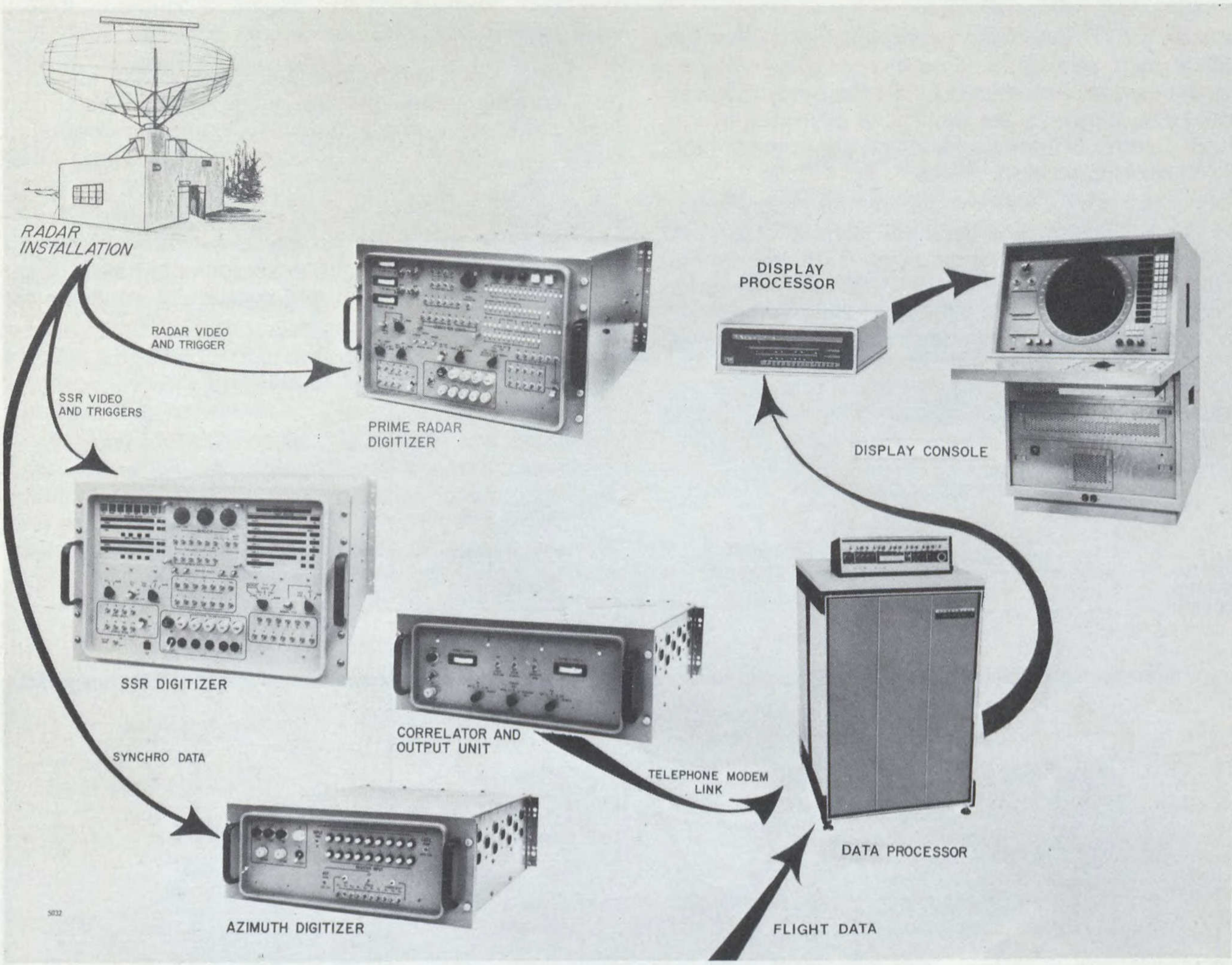


Improved Radar Target Display

High Speed Data Processing



HARDWARE



FEATURES

1. Canadian Expertise

Experienced manufacturers supply air traffic control equipment around the world.

2. Proven Concept

Extensive evaluation of United States and European systems.

Final development preceded by research and development utilizing the best of North American and European technology; a major laboratory model for operational and technical simulation of problems; and the successful evaluation of an operational installation.

3. Operational Simplicity

Designed for evolutionary changeover without major disruption to existing operations. Fail-safe, fail-soft features.

4. Modular System

Equipment can be added to existing systems. Administrations can start with a small, low-cost system and add on as demand increases.

5. Commonality of Equipment

First large-scale integrated system in the world using common equipment for both the enroute and terminal requirement. This reduces complexity, simplifies operations and maintenance and allows major cost savings.

6. Future Enhancement Capability

A multi-million dollar development centre will simulate, develop and test future enhancements of the system to maintain a state-of-the-art facility.

7. Advanced Technology

The system is the latest development of its kind using advanced circuitry, fourth generation computers and other state-of-the-art devices not available at the time most systems now existing were developed.

8. Training

Training centres for both operational and maintenance personnel are available.

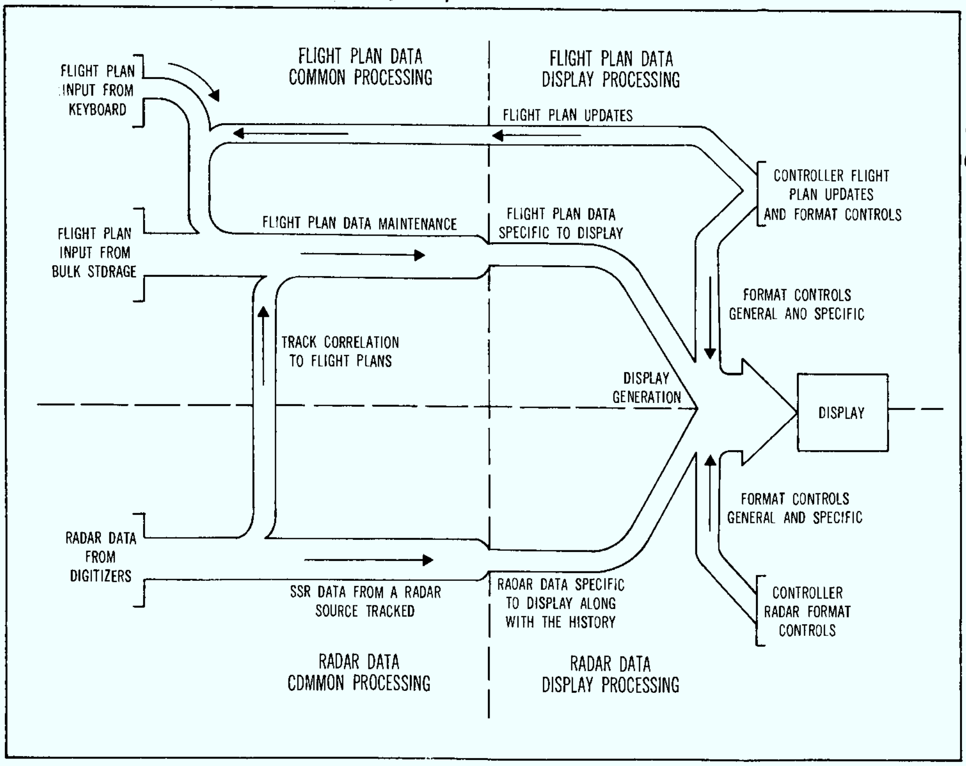
JOINT ENROUTE/TERMINAL SYSTEM (JETS)

Canada's ATC automation programs started in the 60s with a major milestone being the commissioning in 1968 of the Gander Automated Air Traffic System. It was established to augment the control of air traffic in the important Gander Oceanic area which controls the high density North Atlantic flight routes.

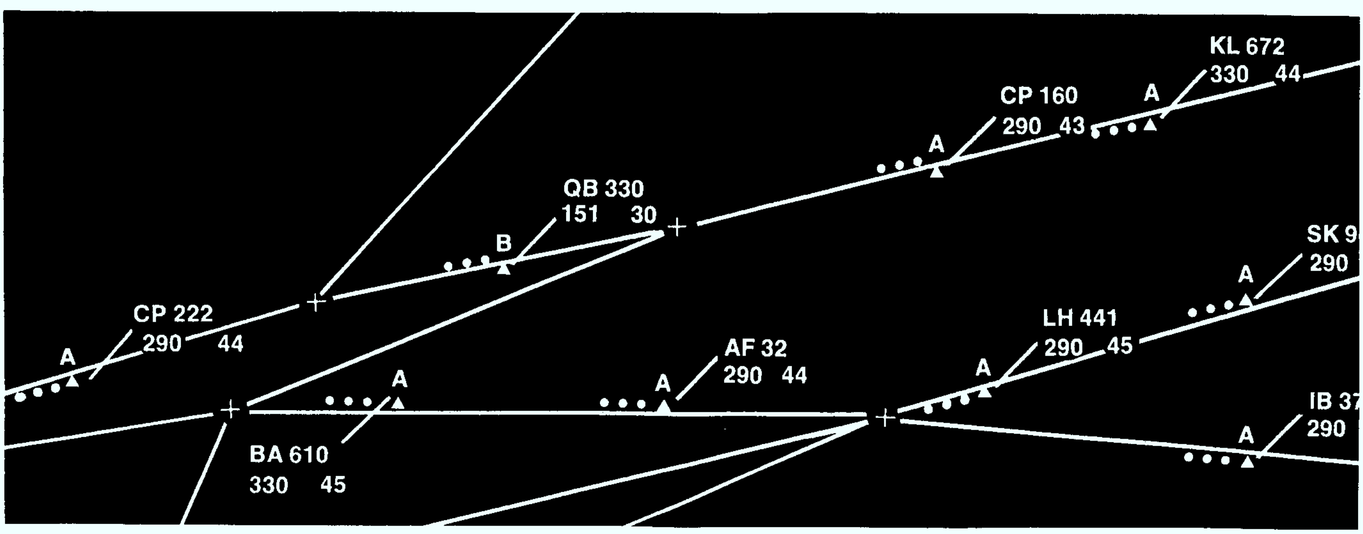
Also in the 60s, a major experimental program began on the digitization and synthetic display of aircraft target data from remote radar sites. This led to the successful commissioning in 1972 of the first radar digitized display system in Moncton, New Brunswick. The system incorporated the major operational features of the JETS approach.

Along with this development, Canada also engaged in associated work directed at developing automatic flight strip processing and display, computer-controlled switching systems for ATC communications and other activities. These features are expected to be incorporated into the Canadian ATC system in the mid-70s.

The success of the prototype systems, combined with further research and development, has brought about the present system and equipment concepts for JETS.



Joint Enroute/Terminal System — General Data Flow



Alpha-Numeric Display of Targets and Target Data

JETS is fundamentally different from other facilities now in operation and is the first large-scaled integrated system of its kind anywhere. The decision to have equipment common to both terminal and enroute was made after extensive studies of other systems such as the United States Automated Radar Terminal System (ARTS III) and the National Airspace System (NAS). From these studies, existing systems were found not to be the optimum solutions for the Canadian ATC environment. Since most system designs were frozen some years ago, the concepts and equipment used ceased to reflect the state of the art. Improved radars, digitizers, mini-computers and other advanced devices now available enable simpler but more efficient and reliable systems to be developed. These new systems and equipment would also be less costly in both capital and operating expenses.

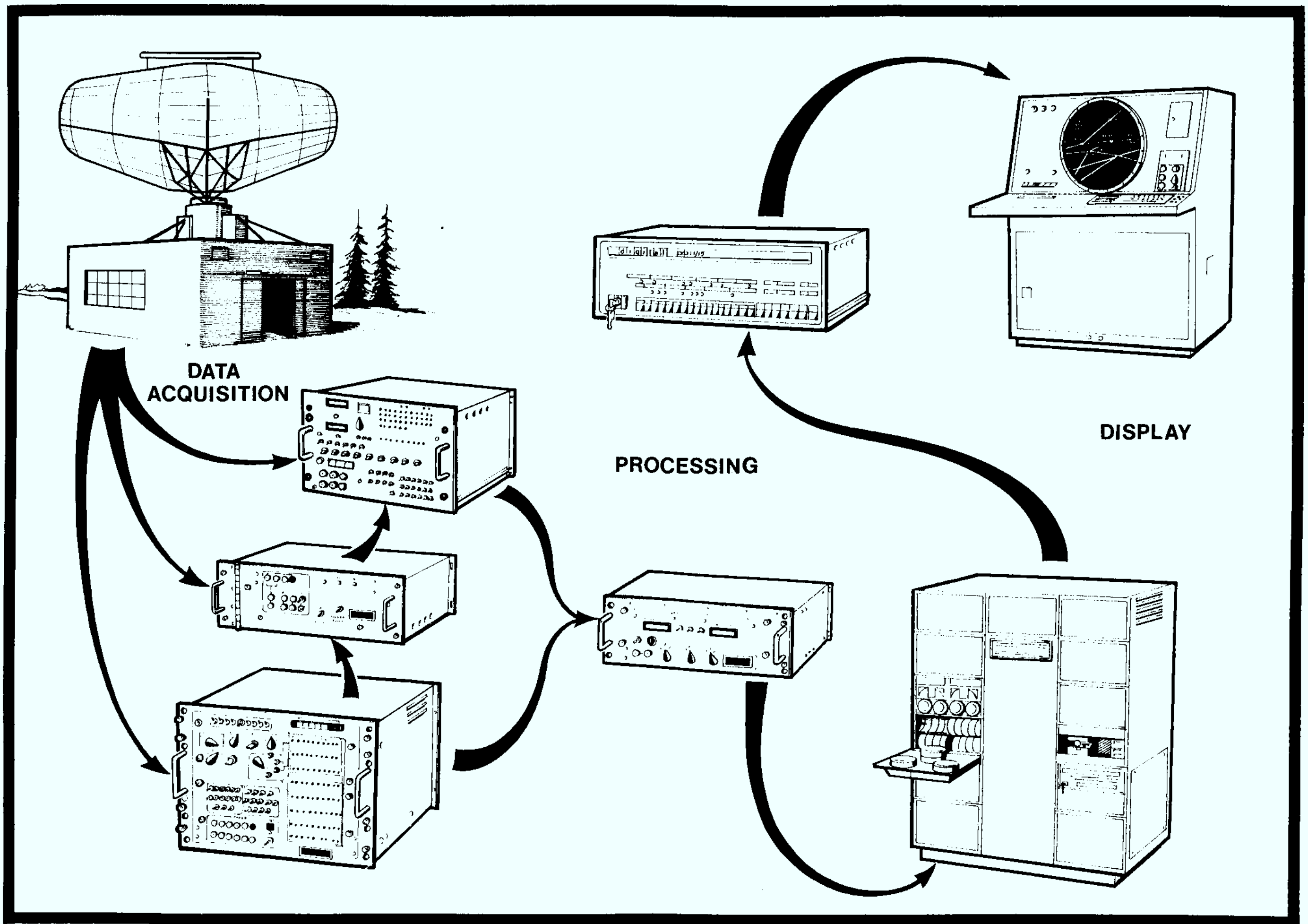
In addition to its advanced system and equipment concepts, JETS is highly flexible. It is modular in design and in operational concepts thereby enabling the system to be developed in stages as demand grows. For example, the modular configuration allows an ATC authority to begin with a minimum system, using most of its existing radar and communications equipment, and add to it over the years until it becomes a major ATC operation with fully remoted, and automated, alpha-numeric displays.

SYSTEM DESCRIPTION

The JETS development is a Canadian modular system capable of being adapted to any ATC requirement from the largest to the smallest. JETS itself is specifically tailored to the Canadian traffic and operational environment. However, the modular components of JETS can be adapted and integrated with existing components of other users' systems. Both systems engineering and software capabilities are available to economically reconfigure a user's facility to add the necessary new hardware and software.

As illustrated, JETS can be divided into three basic subsystems performing distinct tasks. These are:

- Data Acquisition
- Processing
- Display



JETS Subsystem

The effective presentation of radar-derived data and associated alpha-numerics is most efficiently accomplished by converting the radar-derived analogue data to a digital form. Digitized radar also lends itself to efficient long-distance transmission over narrow-band telephone lines thereby permitting remoting of radar data where required. This provides the controller with extended radar coverage for optimum use of air-space and displays more useful information which reduces the volume of communications both ground-to-air and ground.

As illustrated, the system processes the analogue primary radar and SSR data at a remote site and converts it to digital form in a special message format. Information on range, azimuth, altitude, (Mode C and Mode 3/A) is transferred in serial form to modems for landline transmission. At the received end, another set of modems demodulate the signals to their original form for computer processing. Signals are transmitted over dual landlines for reliability and back-up, and the better of the two lines is selected by the central processor through a software analysis and switching program.

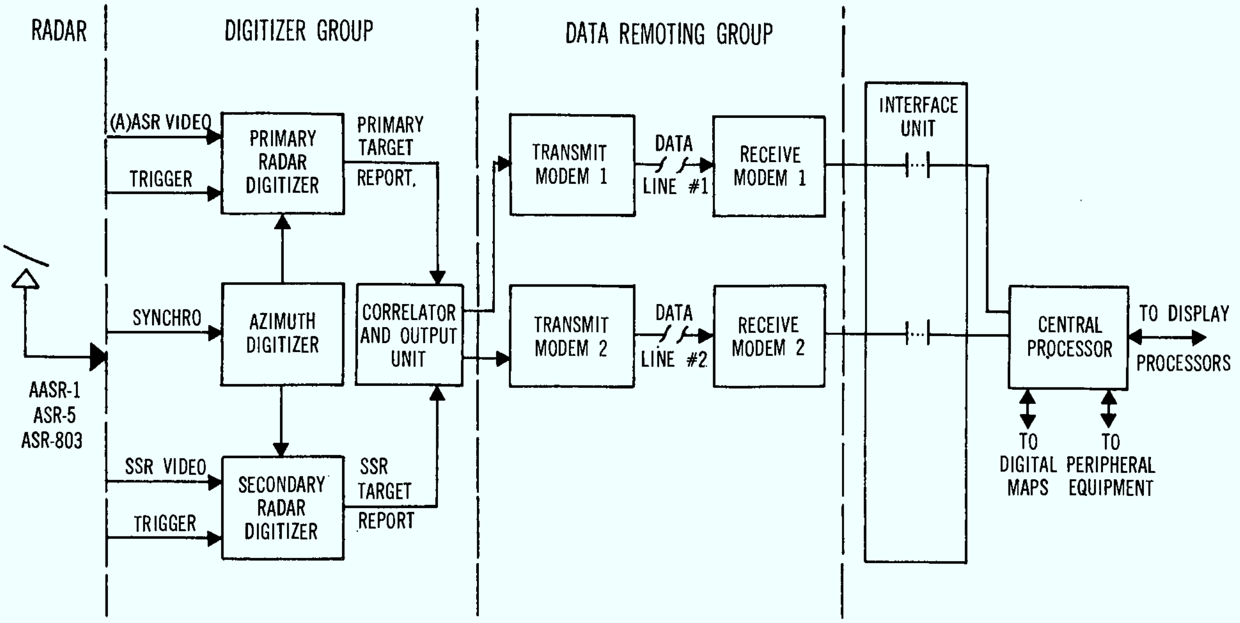
At the control centre, a central processor (digital computer) accepts the digitized radar, together with flight plan information from a central store, and carries out the processing common to all the centre's displays. A separate display processor is used for each display to provide a high degree of flexibility for future system expansion. Each display processor selects the desired data from the central processor, reformats the data for presentation to the display and then refreshes the display at the rate specified.

The display subsystem accepts the data from the display processor and generates the necessary signals to allow the required symbols, characters and lines to be drawn on the screen. In addition, the display includes the control units that permit the controller to interface with the system. The display itself is vastly improved over conventional ones. In addition to the clear presentation of radar targets and related alpha-numeric information, other features include filtering of targets outside of a particular controller's altitude or geographic control area and digital mapping.

Data Acquisition Subsystem

The data acquisition subsystem consists of:

- Primary and secondary surveillance radar;
- Radar digitizers;
- Data transmission components.



Data Acquisition Subsystem

Primary Radar

Although any radar can be used, in Canada, the system operates with a variety of short and long-range radars. The primary terminal radars are designated as ASR-5 and ASR-803. Enroute requirements are handled by an Airport and Airways Surveillance Radar (AASR), designated AASR-1.

The AASR-1 is a medium-range, L-Band, air-search radar system of medium/high power providing plan view presentation of the location of aircraft within a 200-nautical-mile (320 kilometres) radius.

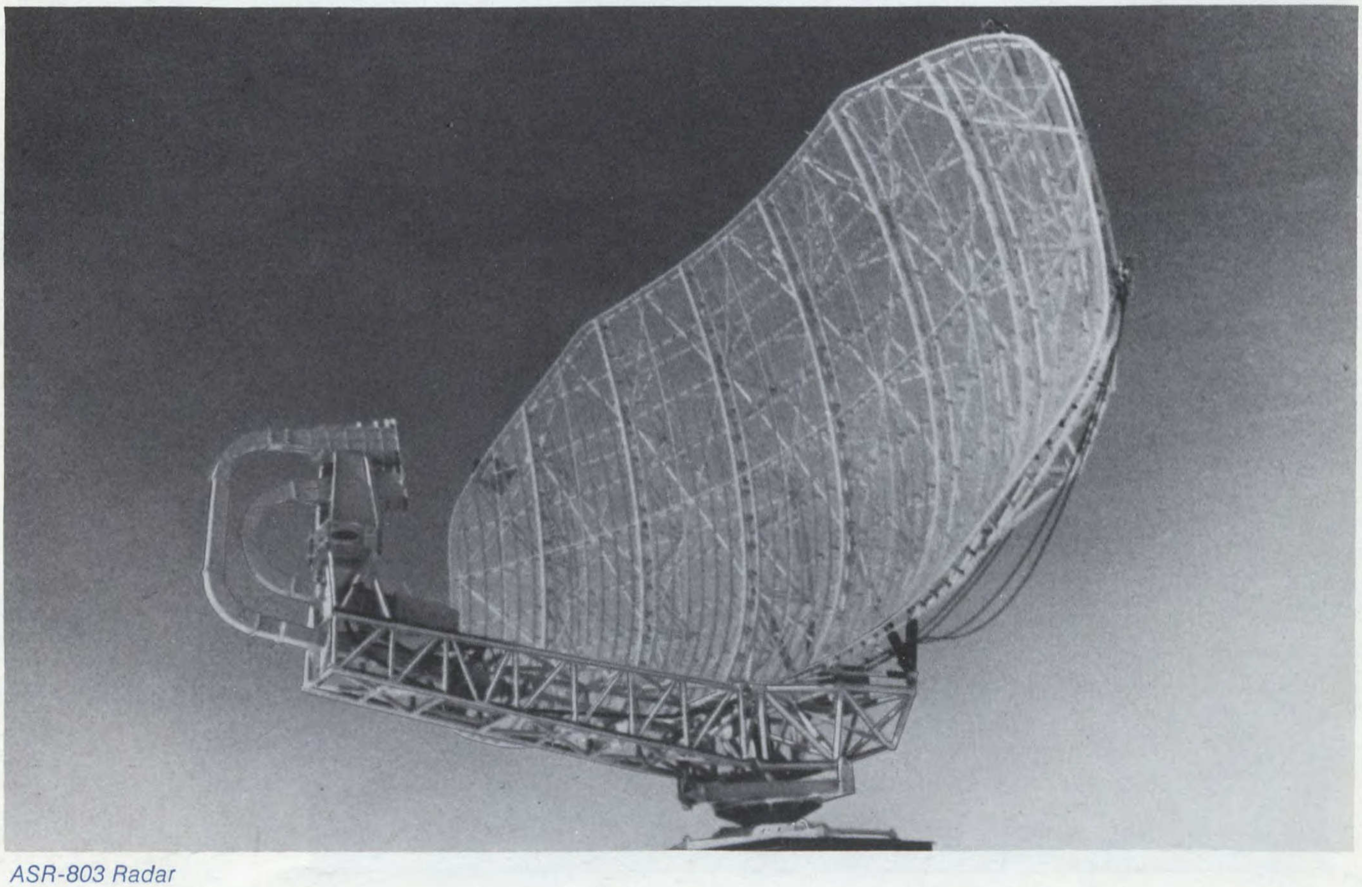
The ASR-5 equipment detects aircraft within 60 nautical miles (96 kilometres) and operates in the S band. It also provides better target resolution than the AASR-1 system.

The latest radar to be installed is a completely new generation, designated the ASR-803, and is one of a family of radar systems designed specifically for ATC. The ASR-803 is an L-band terminal radar with electronics solid state throughout except for the modulator thyratron and the magnetron RF generator. The standard radar is dual channel and can be operated in either frequency diversity for maximum detection capacity or with a single channel radiating. A growth capacity has been designed into the system to facilitate conversion to high power, long-range radar operations. The range is nominally 80 nautical miles (128 kilometres) with an 80 per cent probability of detection at 10^{-6} false alarm rate for a 2-square-metre target from horizon to 40,000 feet (12,192 metres). Particular attention has been given to improving detection capability in the presence of ground clutter and significant improvements have been made in this area, together with low out-of-service time due to equipment faults or failures.

Secondary Surveillance Radar (SSR)

The SSR ground station equipment is a secondary surveillance radar system that works with the primary ATC radar equipment. In addition to supplying range and bearing information, which the primary radar also does, an SSR facility can acquire aircraft identification and altitude by interrogating a transponder-equipped aircraft. The pulse-timing relationship is such that the SSR replies appear on the PPI screen coincident with the primary replies from the same target.

The equipment has a range of 200 nautical miles (320 kilometres) and may be installed with the primary radar or as an independent system. Many options are available such as side lobe suppression and remote controls. The equipment is capable of operation in four civil and three military modes with a three-mode interlace capability. Both active and passive decoding is used.



ASR-803 Radar

Radar Digitizers

The function of the Digitizer Group is to convert the radar information into discrete digital messages that may be sent long distances on telephone lines from remote radar sites. It also enables information processing by the digital computers at the control centre.

The processing of primary and secondary radar data in separate units provides a degree of protection from equipment down time and an independent control of processing parameters. Construction of the units is accomplished with integrated circuit logic that supplies high reliability and ease in repairs by permitting direct replacement of functions at circuit card levels.

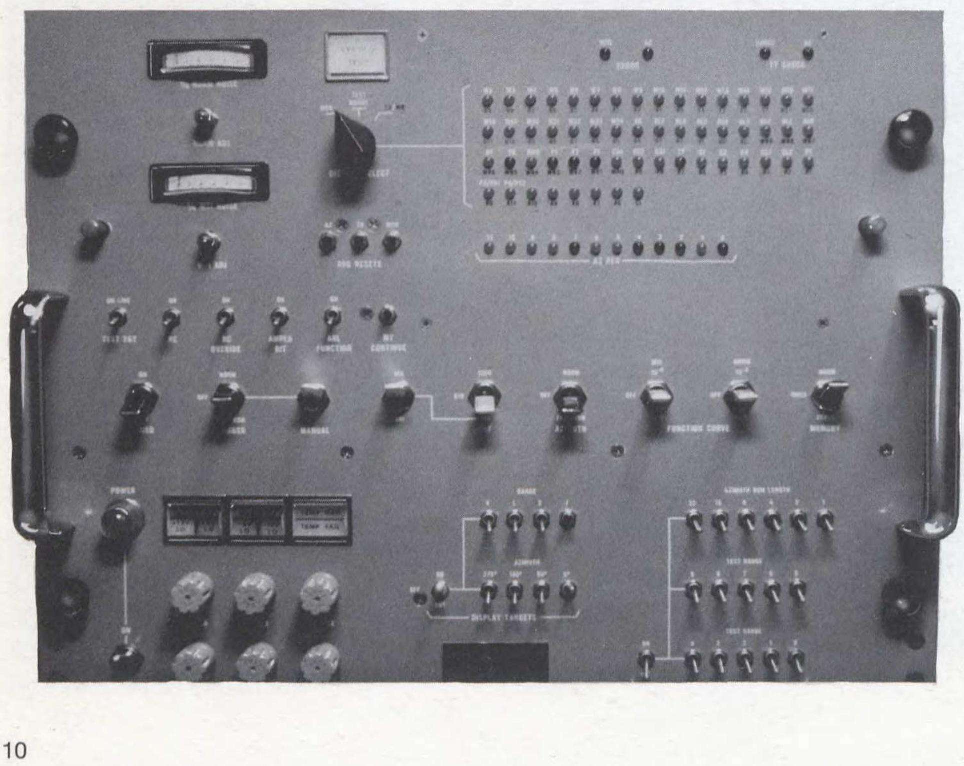
Azimuth Digitizer

The azimuth digitizer is a solid-state, synchro-to-digital converter that accepts the dual speed synchro voltages from the antenna pedestal and digitizes this information into 4096 azimuth change pulses and one azimuth reference pulse for each rotation of the radar antenna. These representations of azimuth are a necessary input to the primary radar and SSR digitizers.

Primary Radar Digitizer

The primary radar digitizer is a video processor specifically designed for detection of primary radar targets. The digitizer accepts video inputs from the radar's normal and MTI channels and furnishes an output in the form of digital target reports — target range and centre azimuth — one report per target per scan. Internal test features are provided for maintenance and self-checking.

Azimuth Digitizer



Primary Radar Digitizer

Secondary Surveillance Radar (SSR) Digitizer

The SSR digitizer is designed to detect the targets in video that are received from the interrogator-receiver and to develop a discrete target report message for each aircraft on each antenna scan. This digital target report message contains target range and centre azimuth plus the identity codes and altitude data derived from the transponder codes.

Special features include degarbling functions to reject erroneous code data, code detection and validation for any two identity codes, precision azimuth centremarking, accurate range measurement out to 200 (320 kilometres) nautical miles (with an accuracy of at least 1/32 miles or 0.05 kilometres), multi-target detection capability, short-run-length rejection capability to eliminate "false alarms" and emergency code capability with a minimum chance of false alarm. The digitizer also provides bracket video output for local maintenance and target reports in range, azimuth, identity codes and altitude.

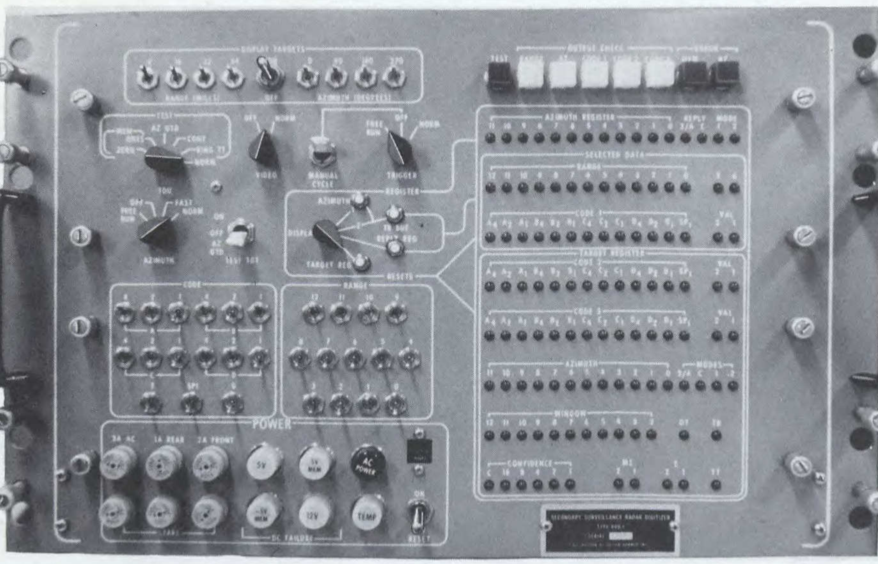
Correlator/Output Unit

The correlator/output unit is the interface between the digitizers and the modem link. Inputs are from the primary and SSR digitizers. The unit can operate with either input or with both of them together. This feature provides backup capability in case the primary or secondary radar digitizers are down for maintenance or repair. When operating with both digitizers, a control option is supplied for the correlation of the primary and SSR target information. This correlation feature prevents unnecessary duplication in sending both primary and secondary target reports on the same aircraft. In this system, if the primary and the secondary targets correlate, priority is given to the secondary information and it is transmitted. The correlated ouput target message is flagged as radar reinforced.

The aircraft position plus identity codes are transmitted as digital messages over long-distance, narrow band communication lines. At the ATC centre, the messages are decoded and entered into the central processor for processing with flight information prior to display.

Modems

Modems are used to transmit the digitized information over conventional, conditioned 3 kHz telephone lines. Transmission rates of either 2400 or 4800 bauds can be used. The system is designed to operate with any standard modem equipment.



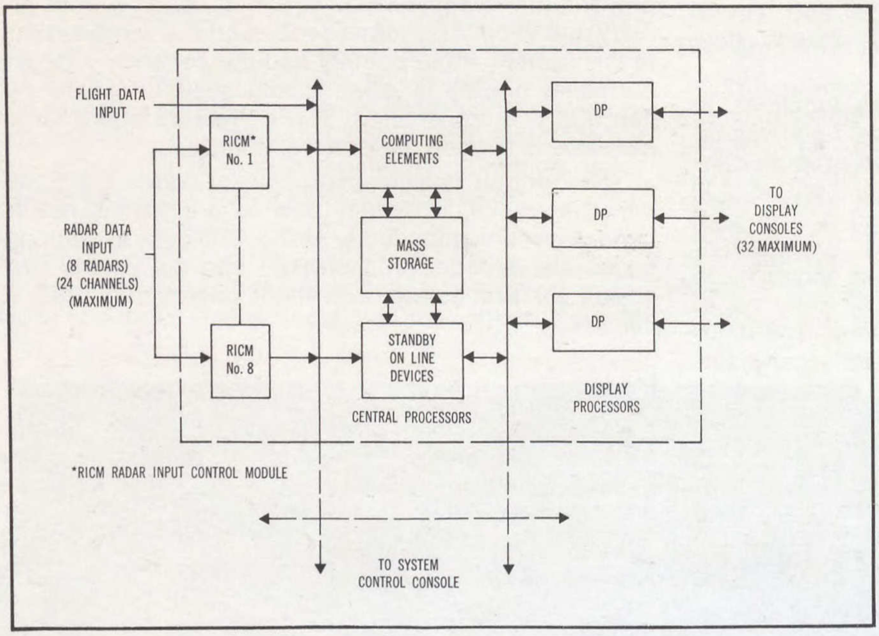
Secondary Surveillance Radar Digitizer

Correlator/Output Unit

Processing Subsystem

The processing subsystem comprises:

- Central Processor
- Display Processors



Processing Subsystem

The Central Processor

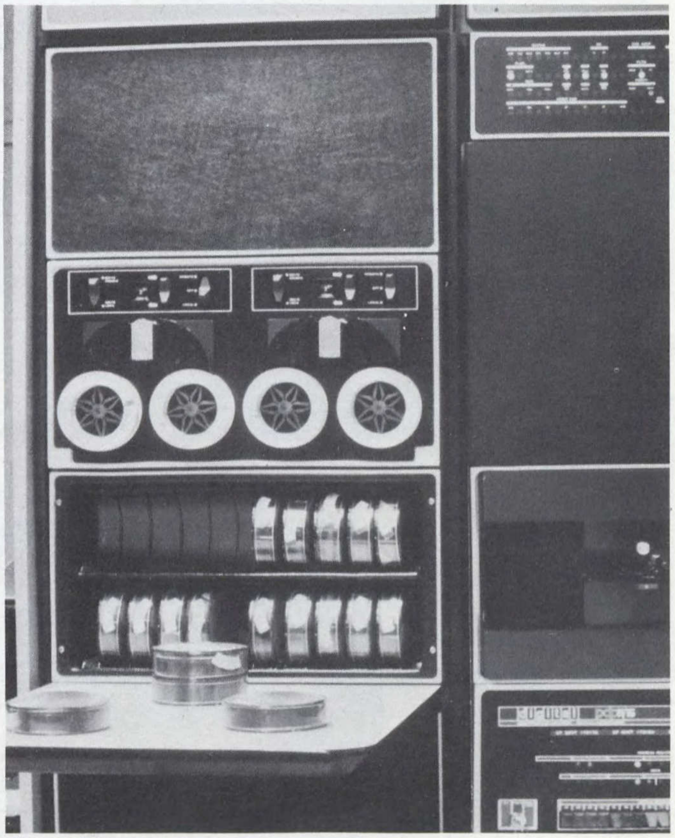
The central processor, the control heart of the system, consists of duplexed digital computers for maximum system availability. Any standard digital computer with the required capacity and other necessary characteristics can be adapted to the system.

The central processor accepts digitized radar data, performs all the common processing and transfers the processed data to each display processor. Examples of the processing carried out by the central processor are co-ordinate conversion (i.e. rho/theta to x-y conversion), line selection and radar tracking. In addition to processing radar-derived data, the central processor accepts and processes system data and information from the display processor.

The broad operational functions of the central processor can be roughly summarized as follows:

1) Radar and flight plan data acquisition, editing and processing.
2) Common storage base for information.
3) Distribution of data to and from display processors.
4) Timing of all system processing functions.
5) Control functions and servicing of local peripherals.
6) Interface between co-located terminal and enroute control systems.

A system control console and other peripherals are provided to permit operational and technical staff to interact with the system and to perform such functions as program loading, input of system data, operational changes, monitoring of system status and system testing.



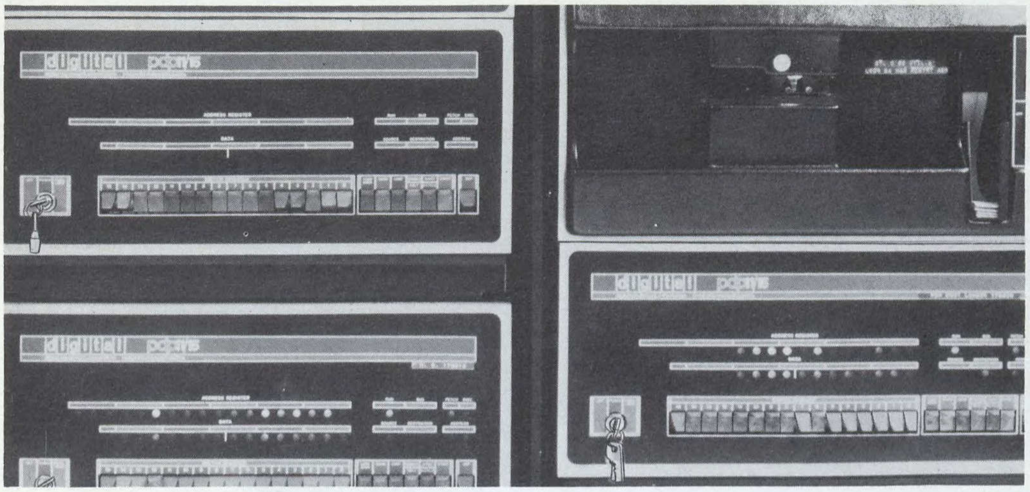
Typical Central Processor

The Display Processor

The display processor is essentially a digital computer providing control of display data. Target reports for the scan in progress are converted to a form useful in the display. The trails are position reports for the previous four scans. Trail data, along with the present position symbol and numerics, provides altitude, identity and target tracks.

Additional display functions are provided to permit visual handoff of control from one display to another, to give altimeter setting and to display up to four data lists and other pertinent information.

Weather clutter outlines can also be shown without obliterating the display and many other variations are available by adding additional modules.

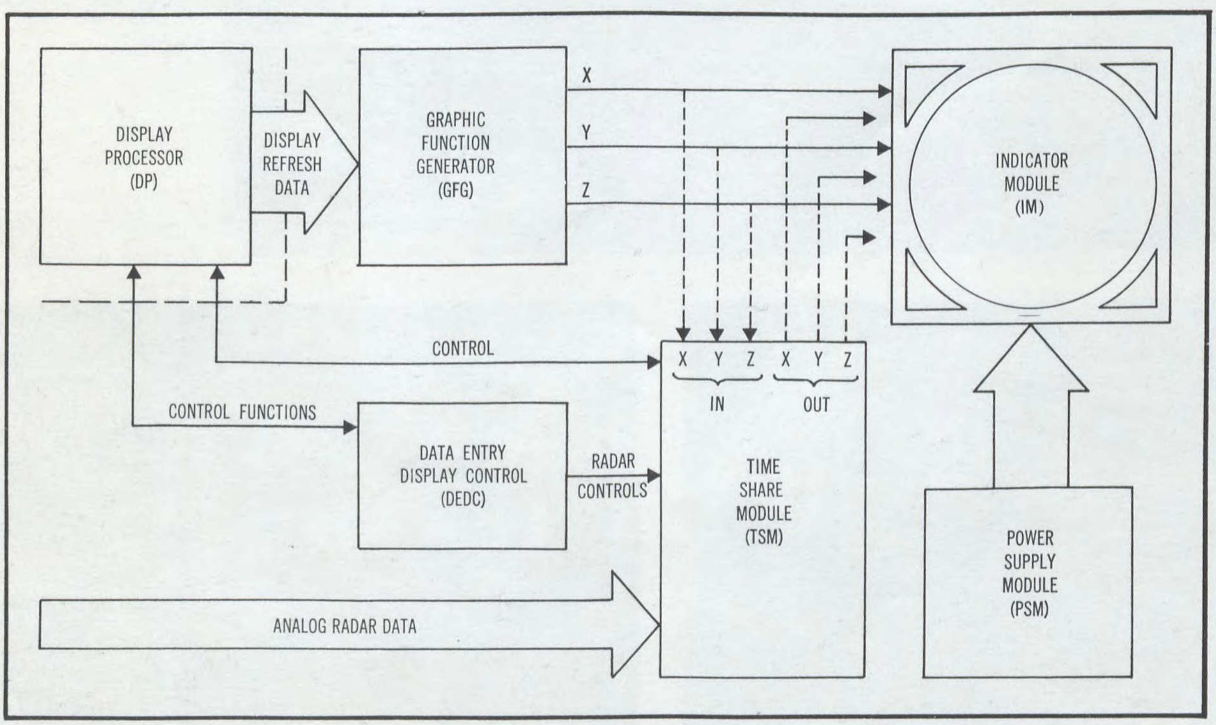


Typical Mini-Computers For Display Processing

Display Subsystem

The display subsystem consists of:

- Radar Display Console
- Graphics Function Generator
- Time Share Module (Optional)



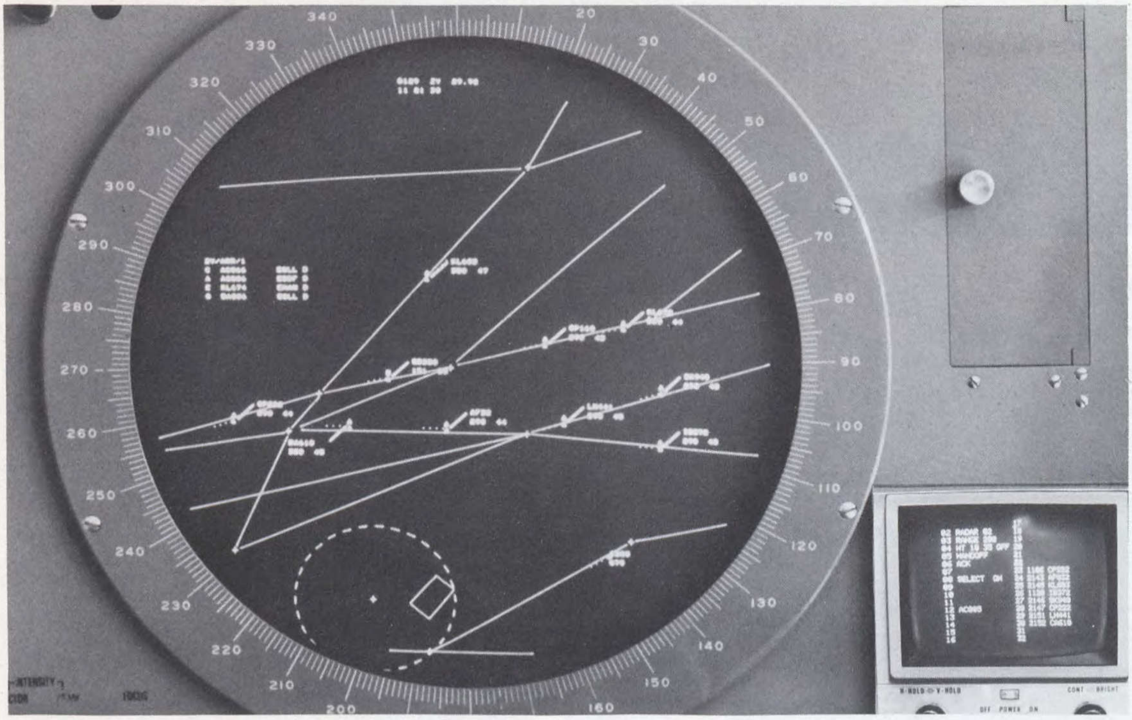
Display Subsystem

Radar Display Console

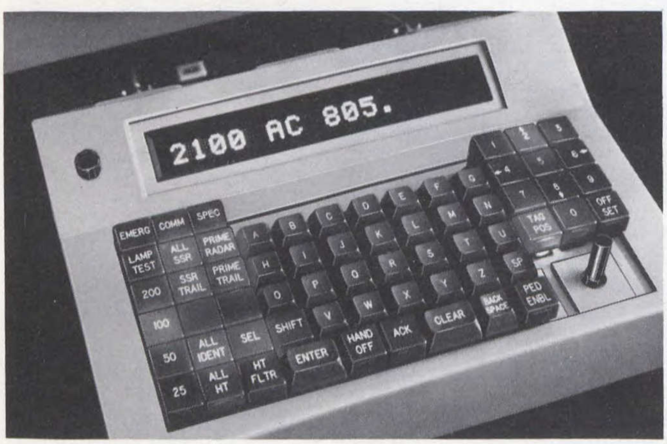
The controller's console includes the cathode ray tube (indicator module) and all associated controls and electronic components. Generally, all consoles are interchangeable and can be used in the horizontal or vertical mode of operation. The display is a special high-speed, single-gun configuration that can operate in a fully digital mode or a time-shared mode.

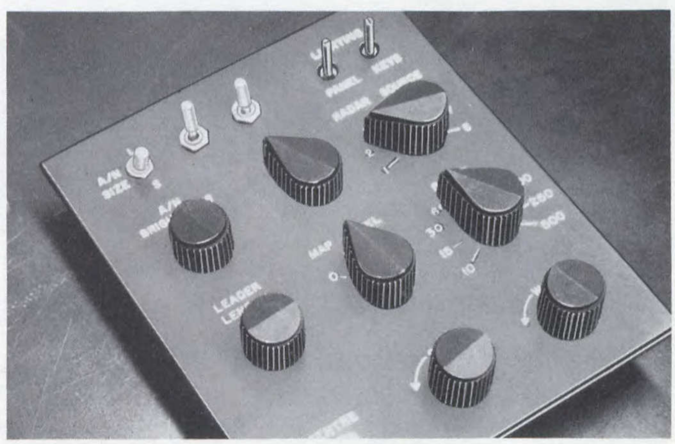
The radar information on the screen includes position symbols for all aircraft in the display range coverage. In addition, for aircraft equipped with ATC transponders, the assigned identity code, aircraft call sign and reported altitude are presented alpha-numerically utilizing a small format directly adjacent to the aircraft position symbol. Position and code on all display targets are updated immediately on each scan of the radar antenna beam past the target. Each time a new target message is received, it is displayed at full brightness for one full scan period. After the scan period, a new target message should be available and the prior report can be dropped from the display screen. Target trail information is retained on the screen at reduced brightness. The trail spots are held up to four scan periods and can provide a visual indication of flight direction. Selection and intensity of the target trail is individually controlled at each display console.

The display controls and data entry devices provide the interface between the controller and the processing and display system. It is essentially an alpha-numeric keyboard and positional entry device with the necessary controls and switching for the radar and display functions.



Typical Radar Display



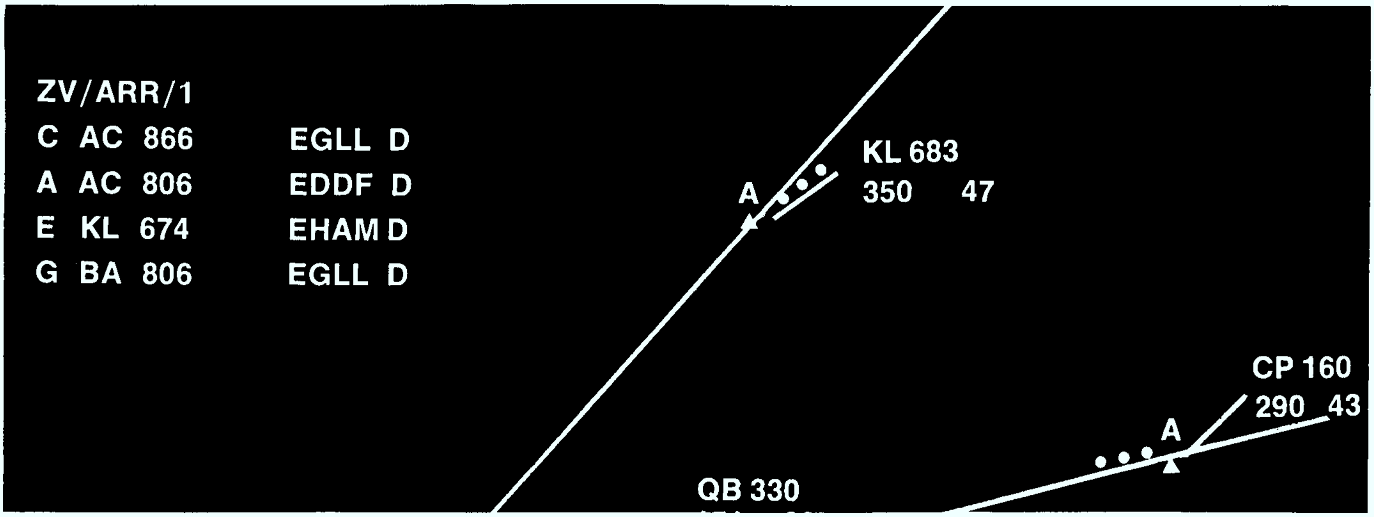


Keyboard

Display Controls

Graphics Function Generator

The graphics function generator forms the interface between the display processor and the indicator module. It also converts digital signals received from the central processing unit into analogue signals which control the x-y positioning of the target information and causes the required alpha-numerics to be drawn.



Typical Alpha-Numerics

Time Share Module (Optional)

The time-share module allows digital information to be presented to the indicator module in conjunction with undigitized radar information. It basically interfaces the raw radar video and digital data from the graphics function generator to the indicator module. It receives raw primary video, decoded secondary radar video, map video and computer-derived data from the graphics function generator, mixes the data into a time-sharing format and presents it to the indicator module for display. The time-share module also receives the appropriate pulses from the azimuth digitizer to produce the sweep necessary for the radar presentation.

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