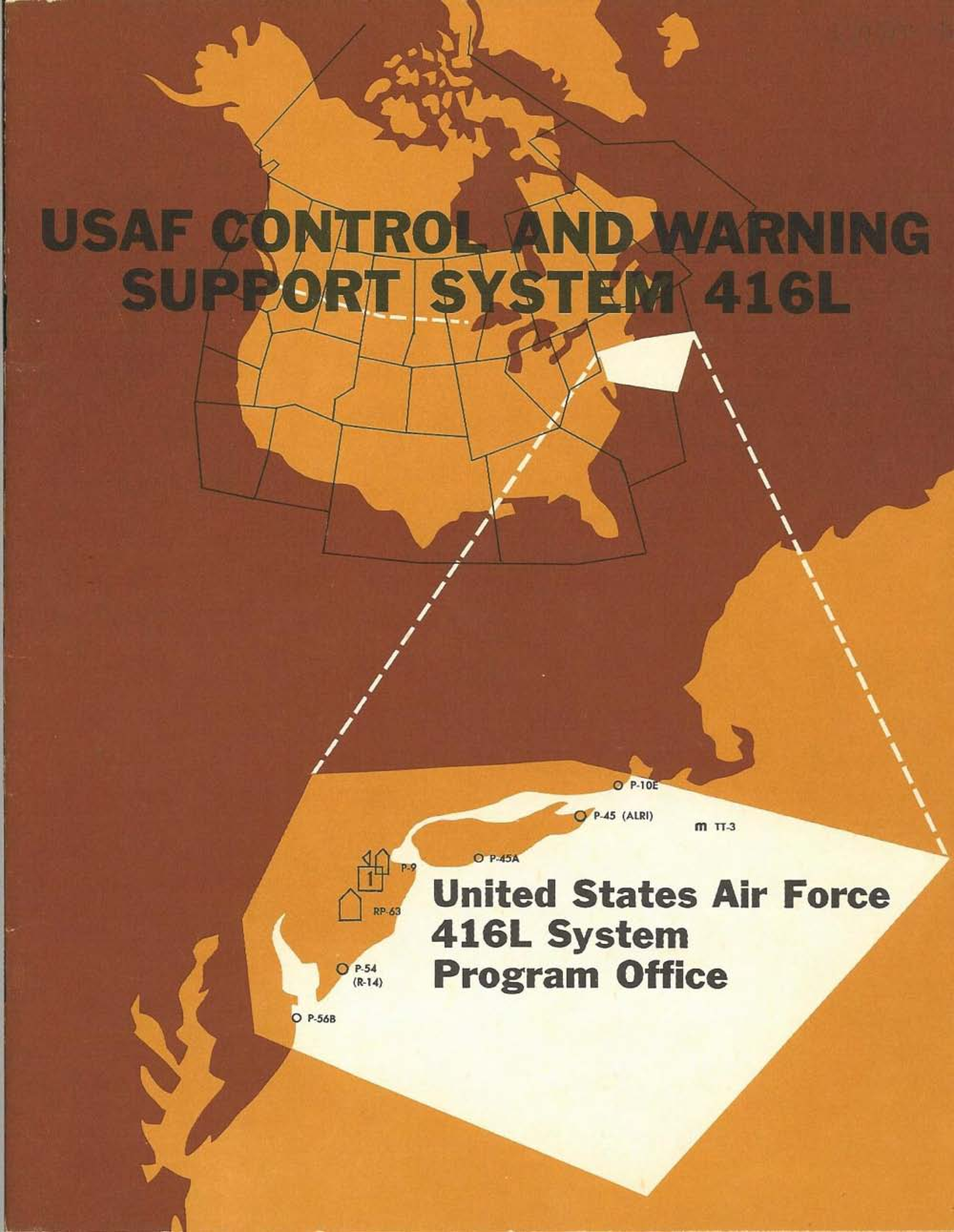
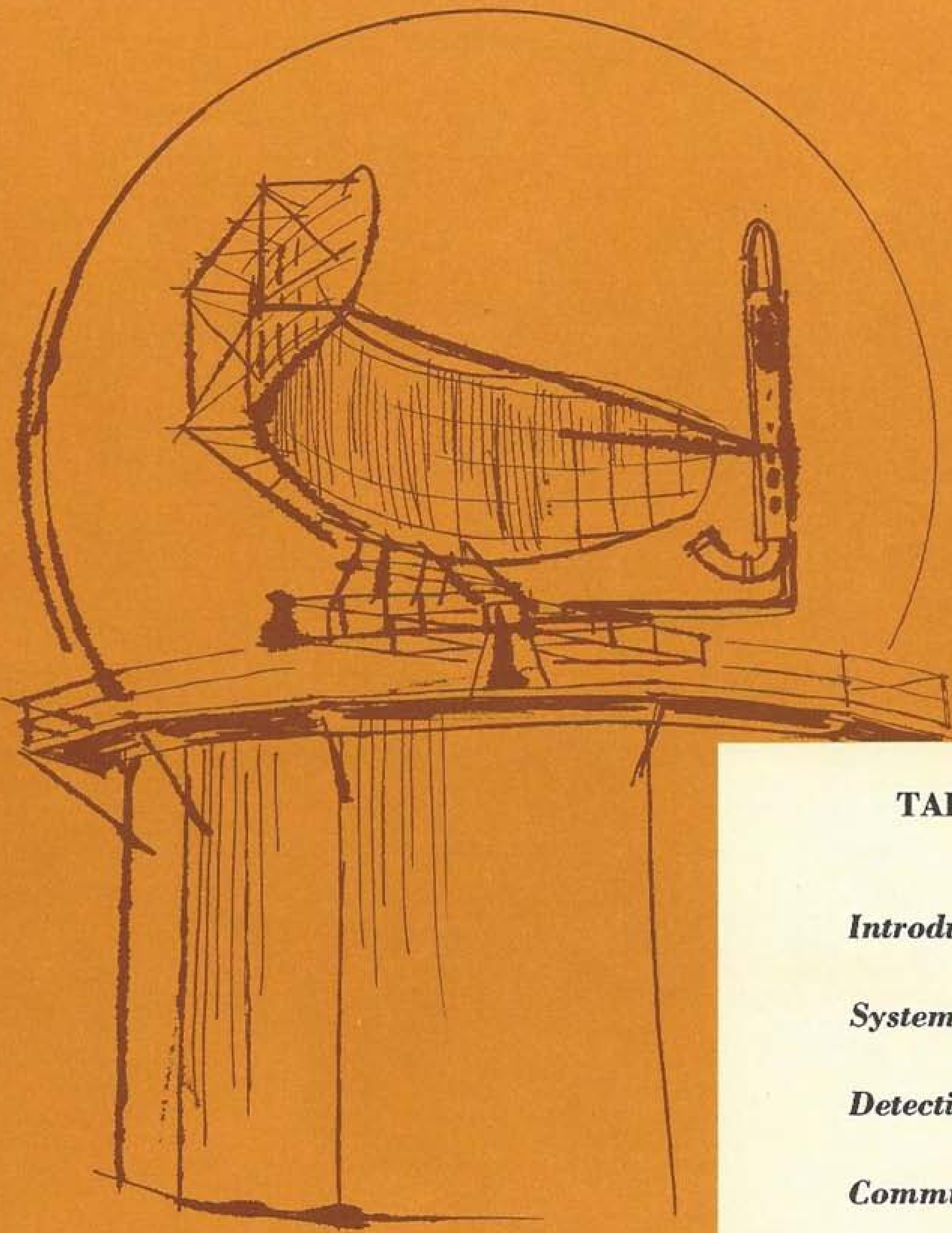
USAF CONTROL AND WARNING SUPPORT SYSTEM 416L



United States Air Force 416L System Program Office



TWENTY FOUR HOURS A DAY, seven days a week, radars of the 416L System reach into distances to detect and identify aircraft. High speed computers quickly determine the course and speed of enemy planes. Within seconds of identification of hostile aircraft, the System can direct missiles and manned interceptors to destroy them.

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INTRODUCTION

During the last decade, defense against air attack has received considerable emphasis in continental defense plans. This is due in part to the phenomenal development of high-speed bombers, but especially because of the increasing versatility and refinement of thermonuclear weapons.

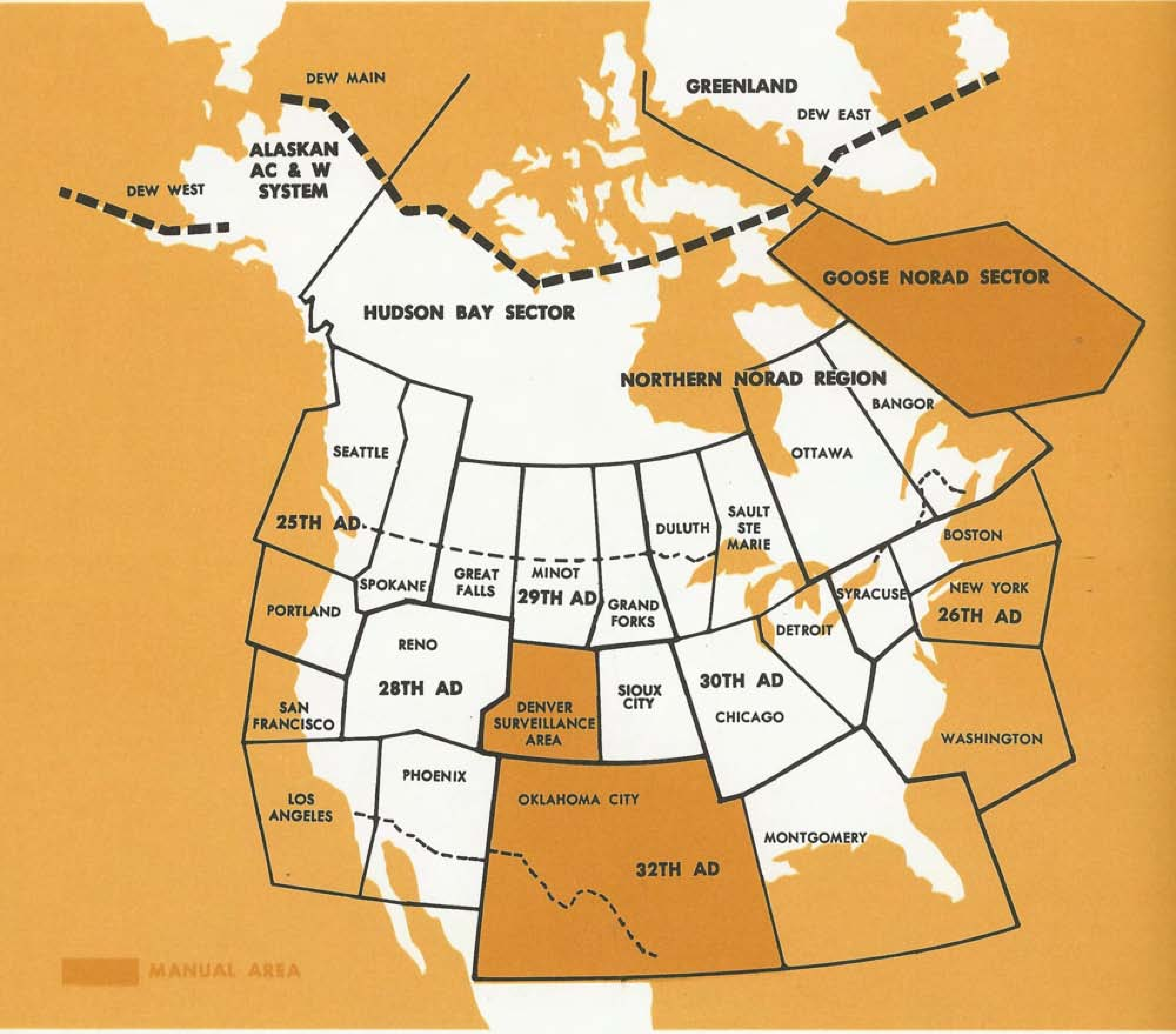
Prior to the Berlin Blockade of 1948, air defense of the United States was carried on by a few scattered radar and fighter squadrons. As the aggressive nature of International Communism became evident, especially with the invasion of South Korea by Communist forces in 1950, the United States Government determined that systematic air defense was required along the coastal approaches to the United States.

Separate command organizations were established within the Air Force and Army for conducting air defense. The number of fighter squadrons and antiaircraft battalions was increased, and additional radar stations were set up to provide coverage for strategic locations. However, it was a manual system with each function of air defense performed by operators. Aircraft tracks were read from radarscopes and marked on a plotting board; flight plans were hand sorted and checked to identify aircraft; and, when necessary, interceptors were scrambled and directed to targets by voice control. Because of these manual operations, the system was subject to severe limitations in capacity, speed and accuracy.

By early 1951, Air Force leaders realized that a technologically new system of air defense was needed to cope with advanced high-speed aircraft and atomic weapons. At the Lincoln Laboratory of the Massachusetts Institute of Technology, scientists determined that large-scale high-speed computers could automatically process aircraft data and develop control information for tracking and conducting intercepts.

Their experiments led to the development of a radar-computer network consisting of a Semi-Automatic Ground Environment (SAGE) portion with computer processing of radar information and weapons commands, and a manual portion in areas not requiring automated facilities. Picket Ships of the U. S. Navy and Nike interceptor missiles of the U. S. Army would become part of the newly created system.

In the Fall of 1958, the Governments of Canada and the United States announced that the SAGE System of air defense would be extended into Canada and that in Canada two Bomarc weapon system installations would be provided. This action established an integrated United States-Canada air defense system under the operational control of NORAD (North American Air Defense Command). The USAF Control and Warning Support System 416L, then, is the ground environment portion of combined U. S. Air Force, Army, Navy and Canadian air defense forces providing defense against air attack by manned bombers.



THE 416L CONTROL AND WARNING SYSTEM has 22 SAGE Sectors, two Manual Sectors, a Surveillance Area and the Hudson Bay Sector. The Dew Line and the Alaskan Aircraft Control and Warning System are also part of 416L. The System is composed of seven NORAD Regions (Air Divisions).

SYSTEM DESCRIPTION

In designing an air defense system, its architects must first consider such factors as: range of weapons, location of targets, type of terrain, possible approach routes, and the probable nature and numbers of air battles. Against these factors, the designers can then match the capabilities of radars, communications, computers and air defense weapons. Next, they must divide the total land mass to be defended into manageable areas, and pick the best locations for operations centers, radar and weapon bases.

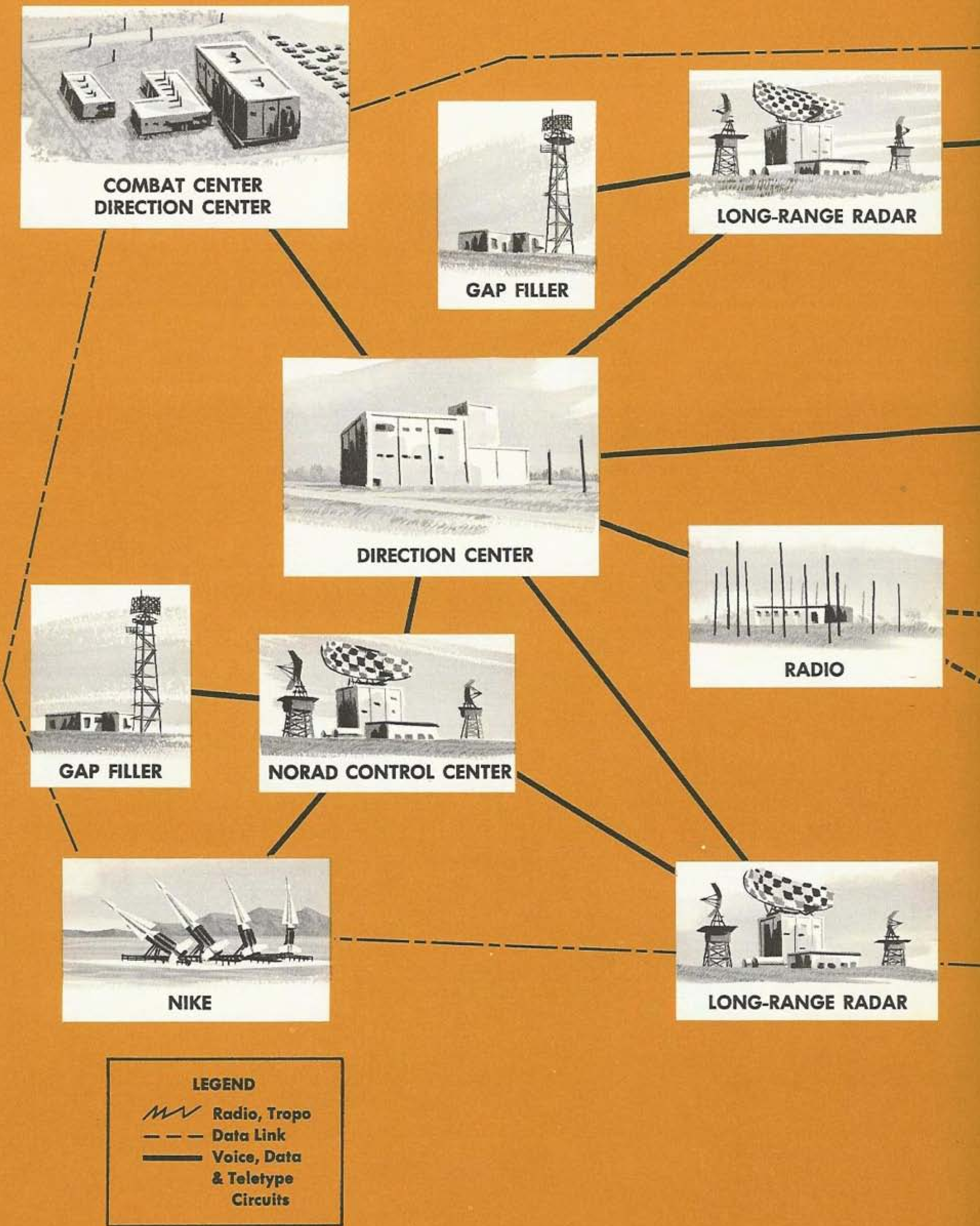
For maximum effectiveness, the USAF Control and Warning Support System 416L divides the United States and Southern Canada into air defense sectors, each able to detect aircraft and direct the air battle. Two or more sectors make up an Air Division or Region with its Headquarters located at a Combat Center.

In a SAGE Air Defense Sector, a large-scale computer, located at a Direction Center, combines input information such as: radar data, weapons status, weather, flight plans and pertinent data from adjacent sectors or the region Combat Center. Aircraft data from radar sites is received, processed and displayed by the computer on TV-style display consoles for operator personnel.

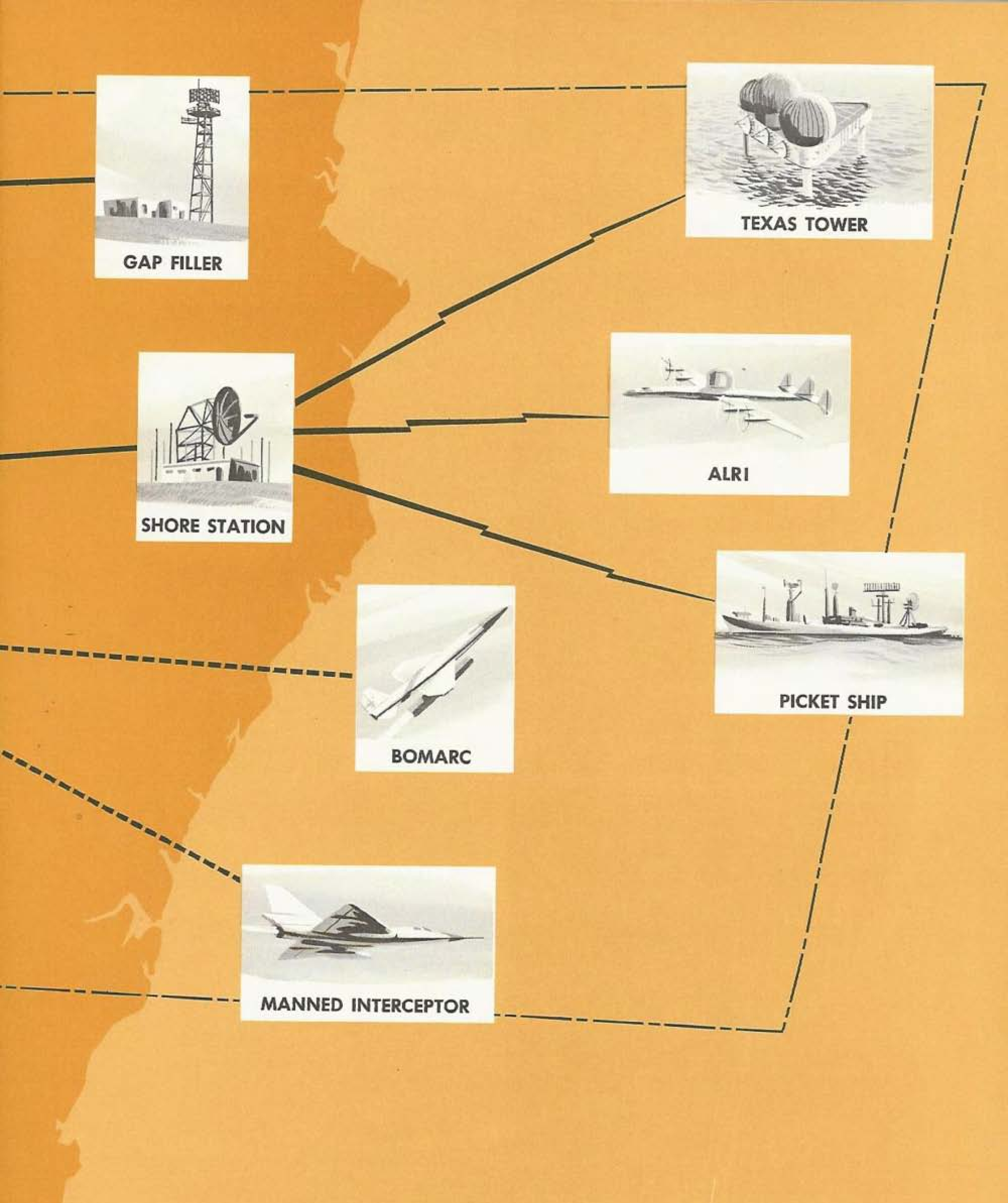
As an aircraft enters the Air Defense Sector, it is detected by radars which automatically forward their findings to the computer at the Direction Center. The computer generates an aircraft track on the consoles and identifies the aircraft as friendly or hostile by electronically scanning flight plans prefiled into the computer.

Through the computer, console operators can transfer aircraft tracks from one console to another depending upon the specific function to be performed. Thus, if an aircraft is determined to be hostile, a Weapons Director assigns the track to an Intercept Director who conducts the air battle. The Intercept Director scrambles manned interceptors or activates Bomarc missiles. The computer generates vectoring signals which are relayed to interceptors through radio data-link equipment. The computer also assists later in guiding the friendly interceptors back to the airbase.

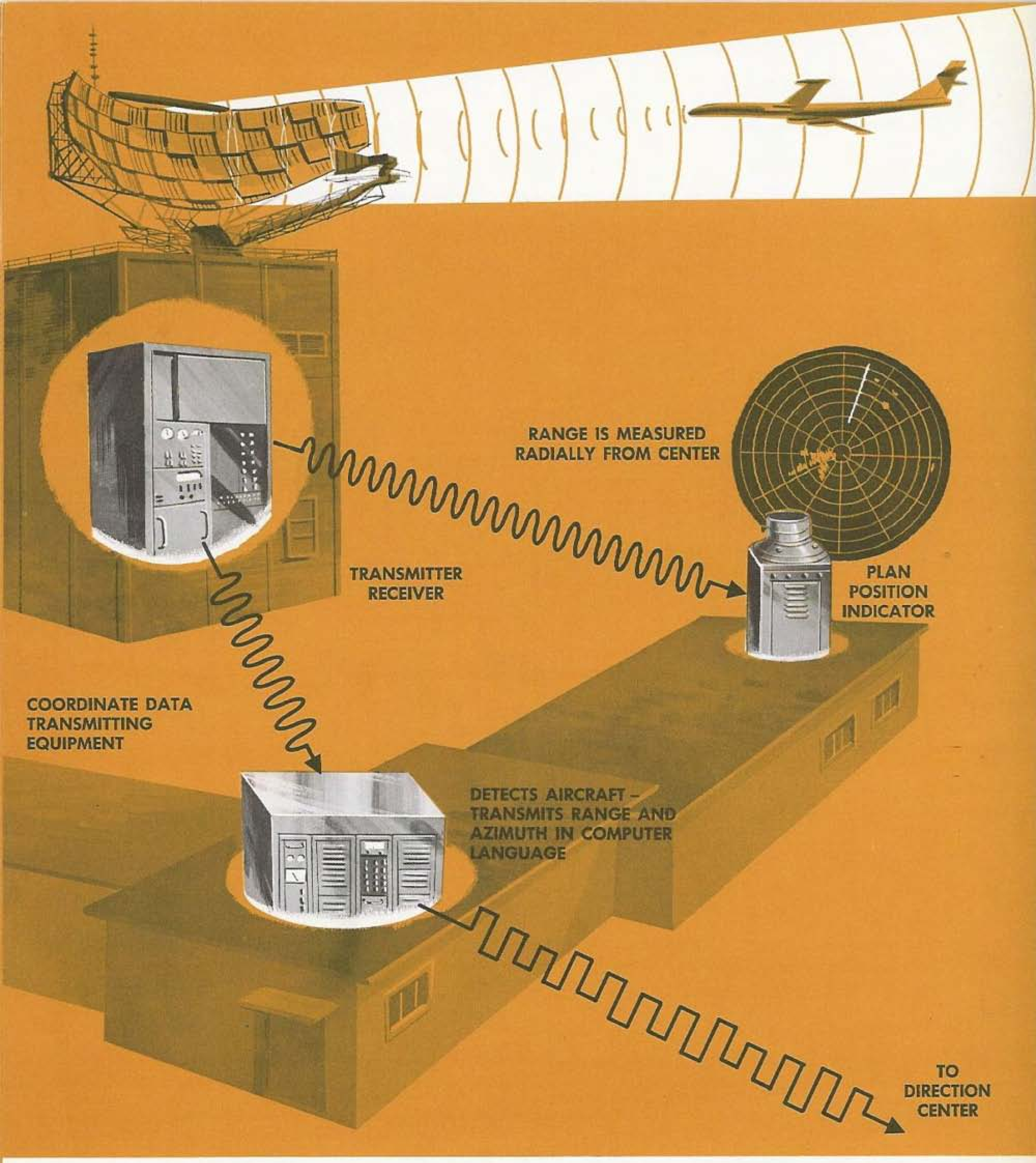
The over-all sector activity is monitored by a Battle Staff using a large-screen display while pertinent information is distributed simultaneously through the computer and communications equipment to Nike missile command posts, adjacent Direction Centers and the region Combat Center.



THE HEART OF the SAGE Air Defense Sector is the Direction Center.



DATA FROM land, sea and air sources are transmitted to the DC for processing and display. Based on these displays, Air Force operators direct the air battle and the assignment of defense weapons.



***SAGE RADAR INFORMATION** is automatically transmitted by a coordinate data transmitter to the computer at the Direction Center. The radar returns are sent in digital form over telephone circuits. In manual operations, a radar display is viewed on a Plan Position Indicator at the radar site.*

DETECTION

In the 416L System, radar equipment is used primarily to search for and pinpoint manned aircraft. A basic radar set consists of a transmitter, a receiver and an antenna to shape and direct the waves. The transmitter generates an extreme number of high-energy pulses separated by thousandths of a second. Reflected radar waves are displayed on a Plan Position Indicator (PPI) or processed automatically in coordinate data transmitting equipment.

Due to the high number of aircraft that must be detected and accurately reported for tracking and identification, automatic equipment has been developed to speed the detection process. This equipment (coordinate data transmitter) is collocated with a radar set and eliminates non-essential radar returns. It speeds the detection process for accurate tracking and identification.

To determine the *range* or distance of the object from the radar set, the time is measured between the transmission and reception of the radar waves. To determine the *azimuth* or direction of the object from the radar set, timing devices in the coordinate data transmitter such as the AN/FST-2 perform arithmetic computations based on the position of the radar antenna as it transmits and receives radar waves.

Once computed, aircraft range and azimuth are then coded for automatic transmission over telephone lines to the computer at the Direction Center. Not all 416L radars have these automatic ties with the computer at the Direction Center. In manual areas no computer facilities are provided. In these cases, operators are required to read radar returns from a Plan Position Indicator and to voice-tell such target data to control centers as required. This is also the case in certain SAGE sectors where a visual display of radar returns is required by the U. S. Army or Federal Aviation Agency.

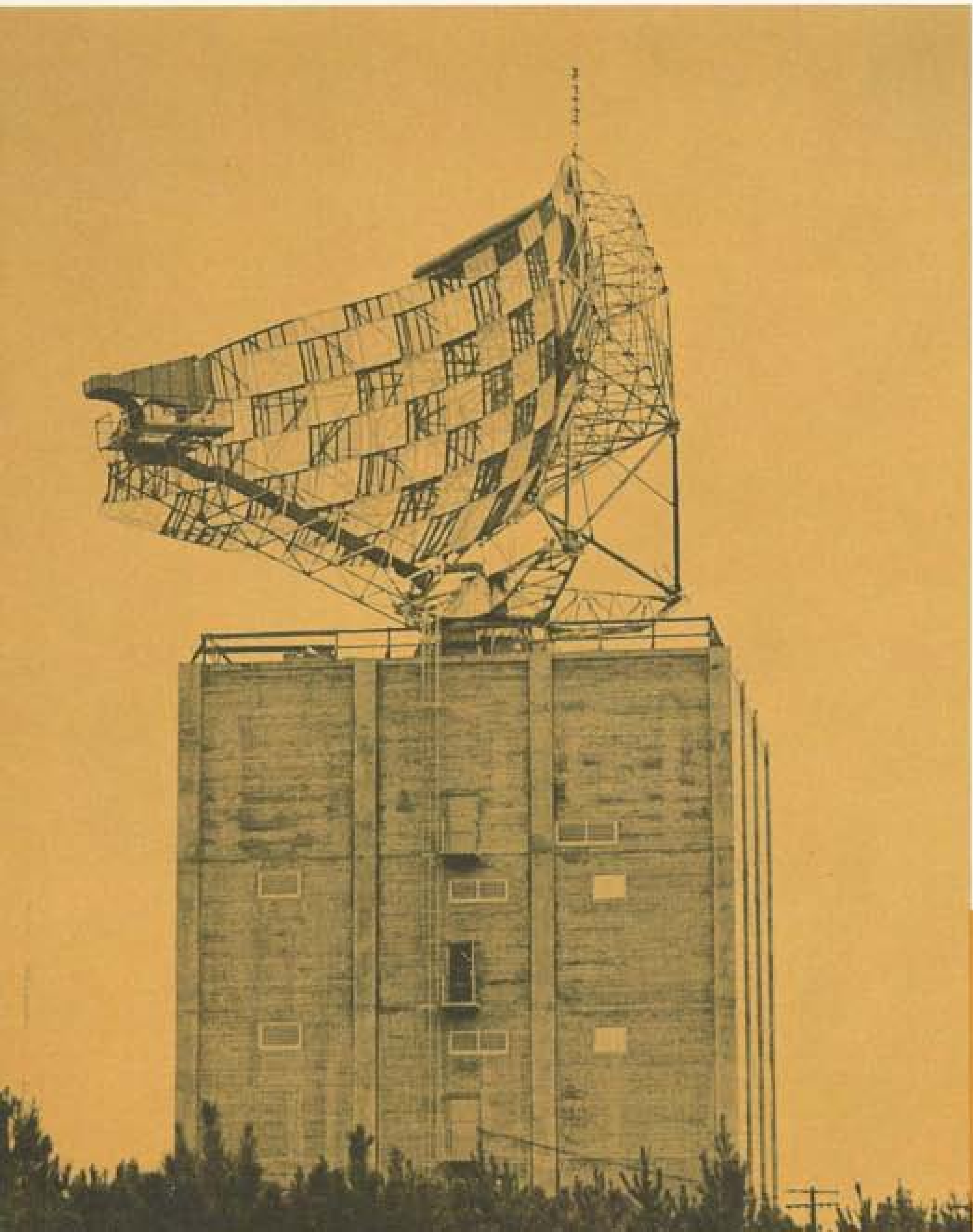
The deployment of radars in the 416L System is based on the effective range and detecting capabilities of the radars and on the tactical requirements of NORAD. In several areas within the 416L System, overlap coverage of more than one radar is provided to insure continuous surveillance in the event of radar difficulties or enemy jamming. Most radars of the 416L System are located at ground sites generally called P, M, SM or TM sites. Some are deployed on Texas Towers and such Seaward Extension elements as Navy Picket Ships and Airborne Early Warning and Control aircraft.

RADAR MAPPING—Seated before video mappers, Air Force personnel control the amount of radar data which is forwarded to the SAGE Direction Center. Automatic electronic mapping will shortly perform this task.

Active Detection The 416L System uses three types of radars in various combinations to actively locate manned aircraft. They are long-range, gap-filler and height-finder radars. The antennas of long-range and gap-filler radars revolve continuously in search of aircraft, but these radars can provide only range and azimuth information. Separate height-finder radars are required to determine accurately the altitude of aircraft.

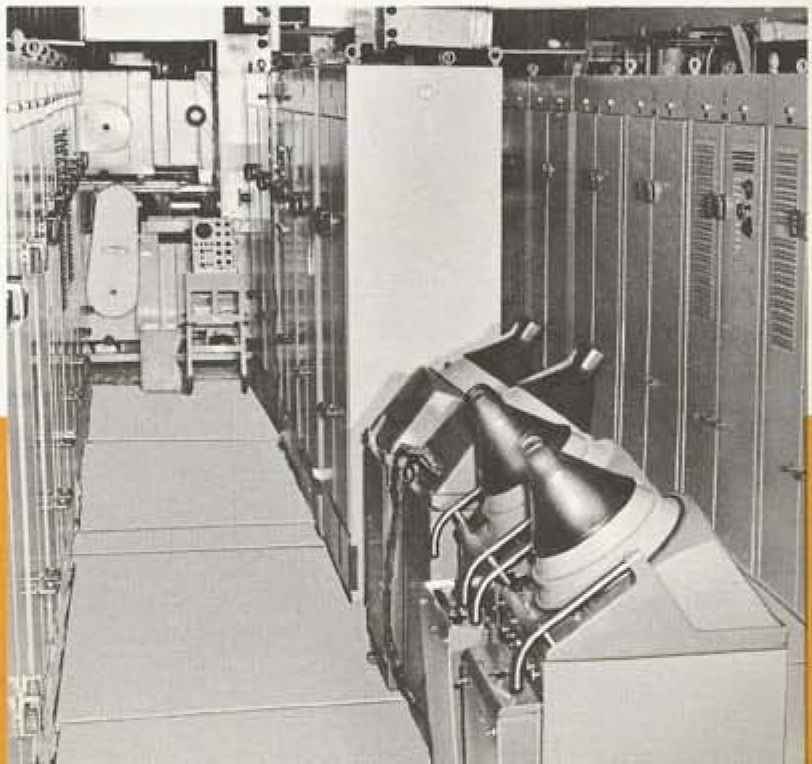
Long-range radars are needed for rapid detection of approaching aircraft to insure time for an intercept to be performed away from critical areas. Improved types of long-range radars are being installed to provide greater capabilities for the system.

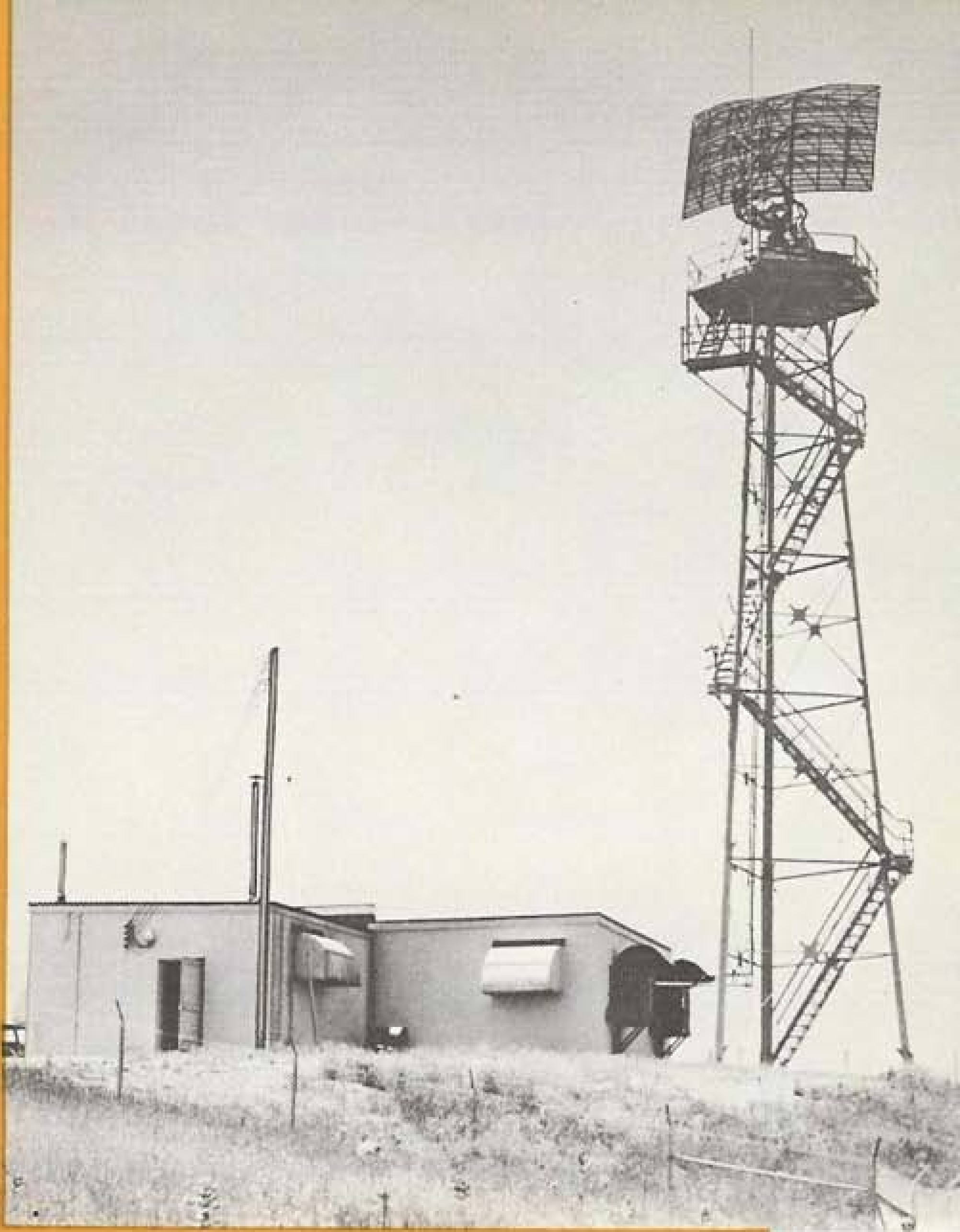
In SAGE operation, an AN/FST-2 Coordinate Data Transmitter is located at each long-range radar site to process information as it comes from the radar set. The AN/FST-2 converts radar returns to a digital form, detects aircraft by a statistical analysis of all the signals received by the radar, computes the range and azimuth of the aircraft, and transmits this information automatically to the AN/FSQ-7 computer at the Direction Center. The AN/FST-2 also processes identification signals and is used for determinations of aircraft height.



AIRCRAFT ARE TRACKED by long range radars. Located on a high tower, this is one of the newly developed search radars used in SAGE.

THE AN/FST-2 is a coordinate data transmitter located at long range radar sites. It processes radar information for transmittal to the Direction Center where the FSQ-7 computer develops the air situations and displays them on Consoles.





A SAGE GAP FILLER RADAR - Its coordinate data transmitter (FST-1) is housed in building at left. Gap filler radars detect aircraft flying at a low altitude. Gap filler sites are unattended.

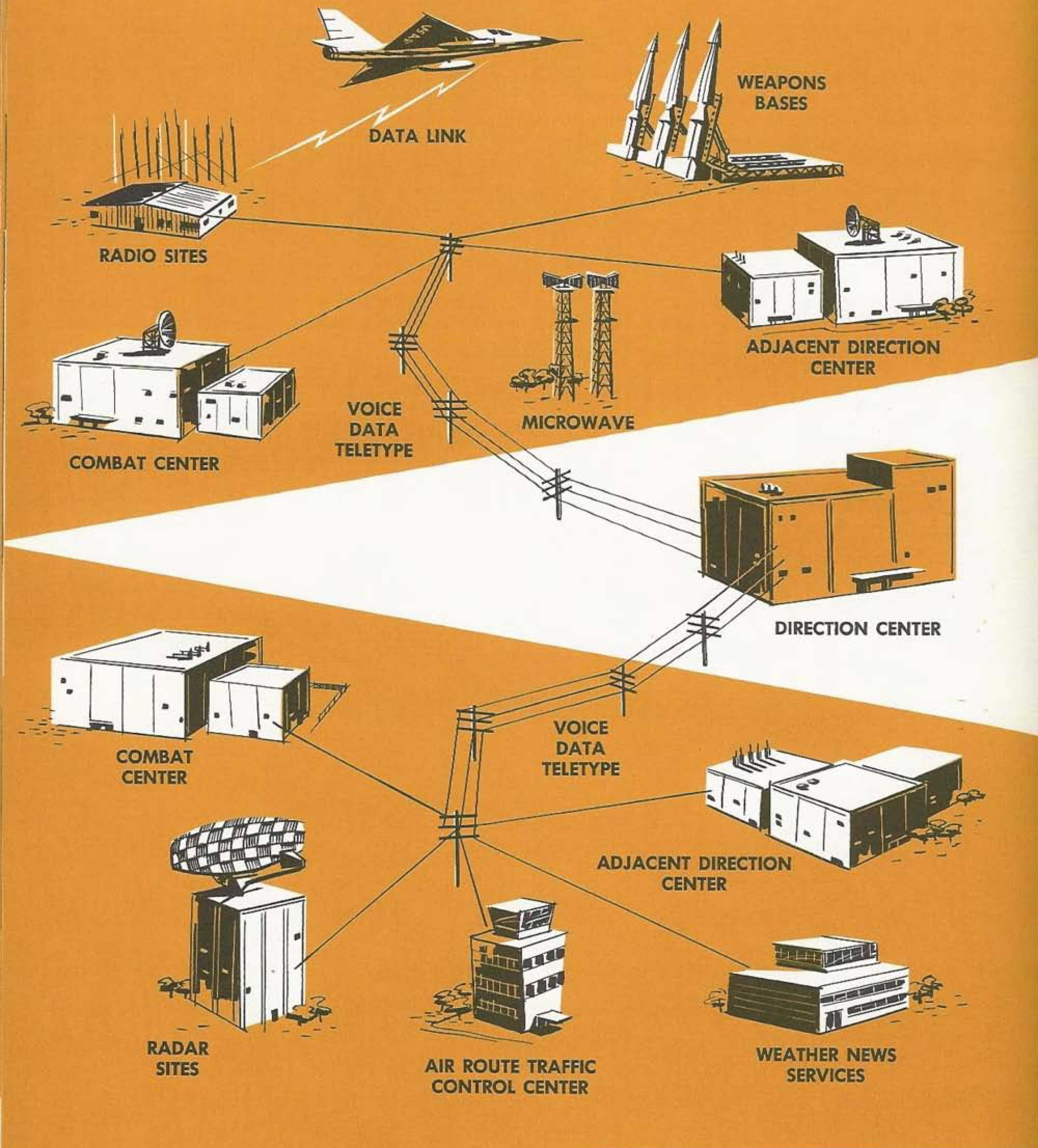
Because 416L radars are highly sensitive, unwanted radar returns are sometimes received from weather conditions aloft. By painting the face of the video mapper with opaque liquid these extraneous radar returns can be eliminated from further processing in the AN/FST-2 which is presently being modified to permit automatic mapping.

Gap-filler radars fill in the low altitude areas not covered by the long-range radars. These radar stations are unmanned, but controlled and monitored by the parent long-range radar. Gap-filler data is processed by the AN/FST-1 Coordinate Data Transmitter and forwarded to the Direction Center. As an improvement to this arrangement, data from certain gap-fillers will be combined or multiplexed at the long-range radar site before transmission to the Direction Center.

Two ***height-finder radars,*** usually the AN/FPS-6, are located at long-range radar sites. As noted, long-range radars do not provide height information. When the height of a specific aircraft is required by Direction Center personnel, a height operator at the long-range radar site determines the aircraft height from a range-height-indicator console and transmits the information to the Direction Center through the AN/FST-2.

Passive Detection Since hostile aircraft may attempt to jam or obscure radar returns, it is planned as a future subsystem, to provide means for tracking such aircraft from its own jamming signals. This subsystem is in addition to the program for improving the capability of 416L System radars to overcome electronic countermeasures.

TWO HEIGHT FINDER RADARS (this is the FPS-6) are located at each SAGE prime site. The radar determines the height of approaching aircraft and transmits this vital information to a Direction Center.



DIGITAL DATA—a binary system of notations or "bits", each with vital target information, speeds over telephone wires from radar site to Direction Center. Telephone lines are also used for voice and teletype communications.

COMMUNICATIONS

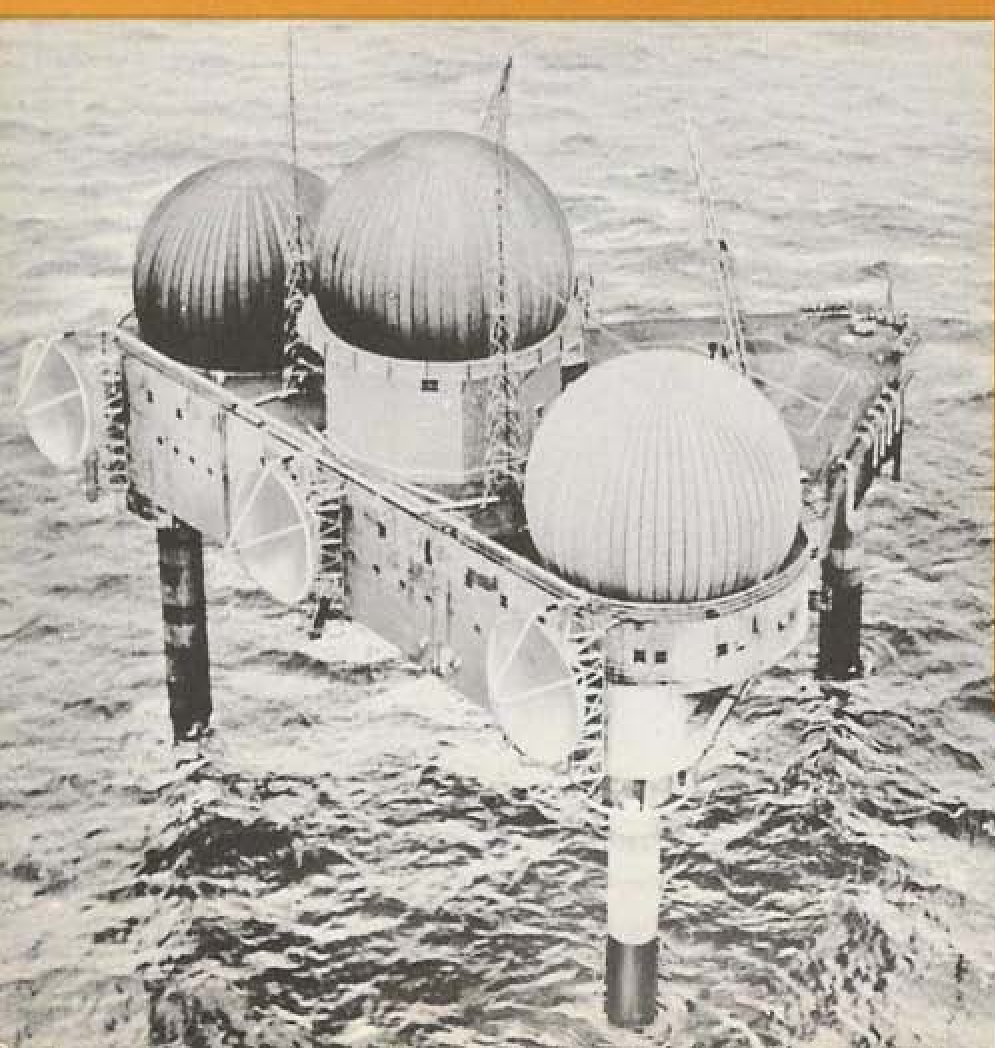
In the manual system of air defense, Air Force operators used voice communications exclusively to plot aircraft tracks, transfer tracks to weapons directors and guide interceptors to hostile aircraft. Human errors and delays with voice communications were frequent, particularly in conducting intercepts. The development of precision radars, high-speed computers and sophisticated weapons for use in the 416L System required a network of diversified and high-quality communications.

To enable the rapid transfer of information from radars to computers to interceptors, a digital data system was developed. Digital data is a form of machine language consisting of binary digits or bits with each bit representing significant information. For example, radar sites forward pertinent aircraft range and azimuth data in digital form automatically to the computer at the Direction Center. The computer processes the digital data and presents a display for any required action by the console operators. Digital data communications are used throughout the SAGE portion of the 416L System, where high-speed transfer of target data and guidance information for interceptors is involved.

In planning the 416L communications network, three factors were considered: type, quantity and urgency of information to be transmitted. Because communications requirements differ for each type of site in the 416L System, every proposed site was analyzed to insure the required number and diversity of communications. For the most part, telephone lines are used between sites to transmit voice, digital data and teletype; however, microwave, data link and tropospheric scatter radio systems are also used. In many instances, critical information is transmitted over alternately-routed circuits as a precautionary measure to rapidly restore communications in case of a line failure.

***WHERE TELEPHONE LINES** are not readily available, **SAGE** utilizes **MICROWAVE** as an integral part of its system.*

***RADOMES COVER THE SENSITIVE** radars on the Texas Towers off the Northeast U.S. Coast. Saucer shaped antennas of the tower's tropospheric scatter radio system can be seen on the tower's near side.*



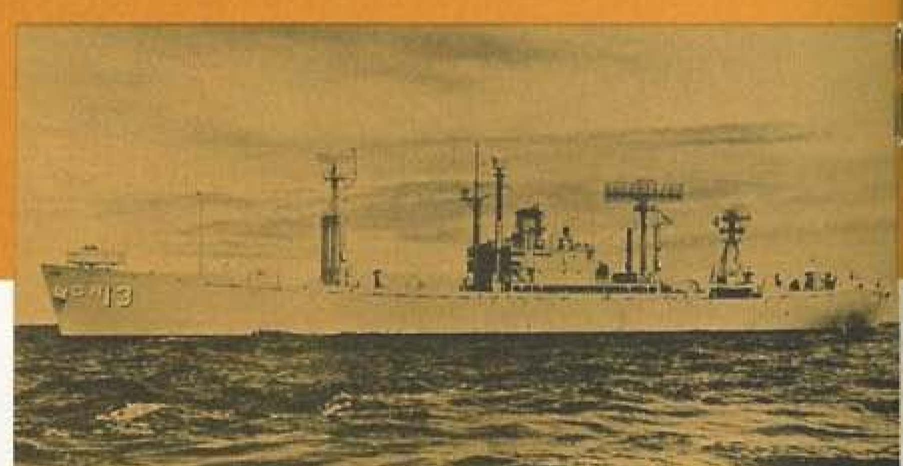
***RADAR EQUIPPED AIRCRAFT** are mobile sites extending the radar coverage of the 416L system. This aircraft is the type that is used in the ALRI subsystem.*

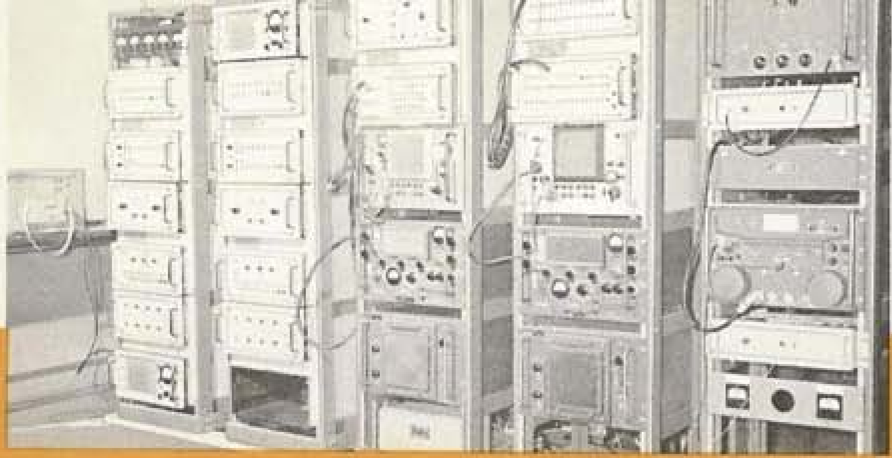
This extensive network, consisting of voice, data and teletype circuits provides the 416L System with the communications to link operations centers and ancillary sites. In Direction and Combat Centers, a complex voice telephone network enables console operators to confer rapidly and easily with other center personnel as well as with ancillary sites.

Radar data and weapons commands in digital form are transmitted over data quality telephone lines or by microwave relay equipment. However, radar data from Texas Towers, Navy Picket Ships, and Airborne Early Warning & Control (AEW&C) aircraft are relayed by radio communications through ground stations to and from Direction Centers.

Texas Towers employ the tropospheric scatter radio technique. At present Seaward Extension elements (Picket Ships and AEW&C aircraft) use voice and teletype radio communications. Some AEW&C air-

***NAVY PICKET SHIPS** patrol far at sea to detect approaching aircraft.*





TIME DIVISION DATA LINK equipment at SAGE Radio sites directs our interceptors to hostile aircraft.

AN AIR FORCE OPERATOR tunes radio equipment used for the voice control of manned interceptors.

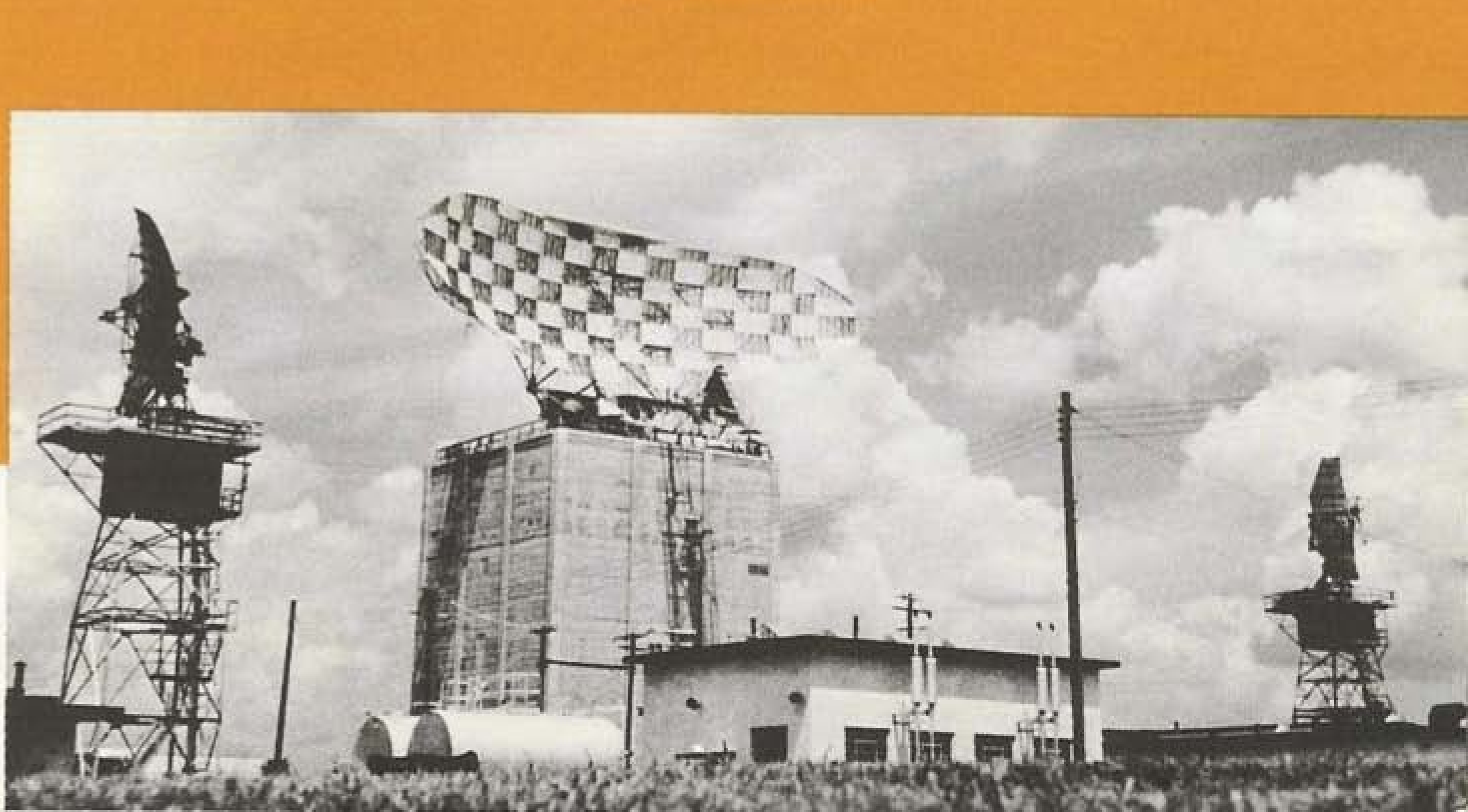
craft are being modified to transmit digital data. These are ALRI (Airborne Long-Range Input) aircraft. Picket Ships will eventually transmit digital coded information through radio equipment.

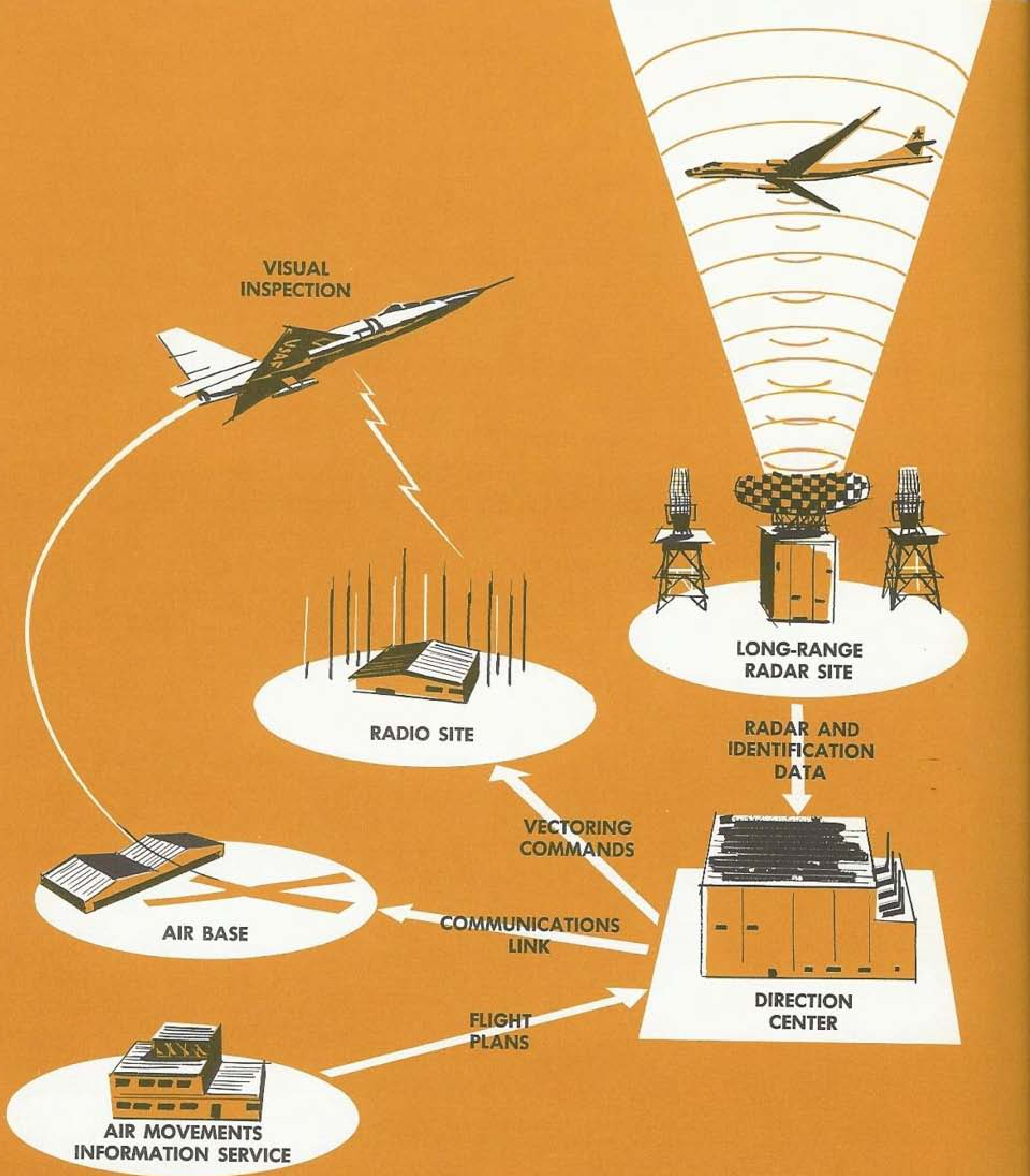
Low-rate information such as weather reports and flight plans are transmitted over teletype circuits. Interceptors are controlled by voice or data link. Data-link commands for manned interceptors and Bomarc missiles are computed and issued automatically to radio sites from the Direction Center. Two forms of data link are used in the 416L System: frequency division data link (FDDL) and time division data link (TDDL). TDDL is replacing the less reliable FDDL as rapidly as ground and airborne equipment becomes available.

The voice control of interceptors is accomplished through UHF radio channels, with 22 channels available in each sector to supplement data link control.

WEAPONS DIRECTION ROOM—When the air situation requires employment of air defense weapons the weapons director will select the base and type or number of weapons to be used against the hostiles or unkown. In this view, on the left is the Weapons Director and to the right are the Intercept Directors and Technicians.

TWO HEIGHT FINDER RADARS flank a search radar at a long range radar site.





BEACON SIGNALS, flight plans and visual inspection provide the 416L system with Aircraft identification.

IDENTIFICATION

Identification of approaching aircraft is the necessary step between aircraft detection and the control of interceptor weapons. The widespread use of commercial jet aircraft, which are comparable in size and speed to military bombers, has made it increasingly necessary to achieve positive identification of all aircraft approaching the North American continent.

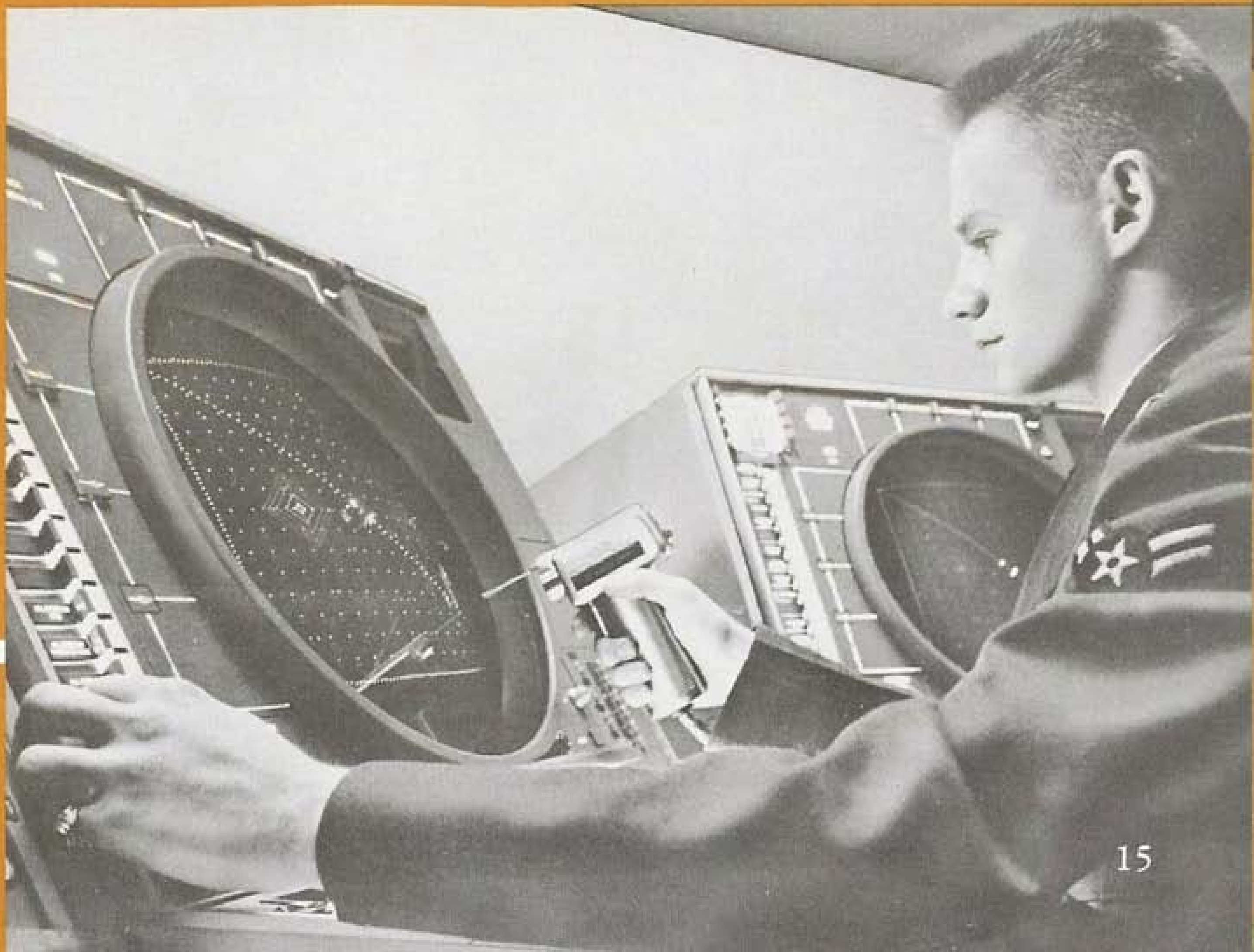
Three methods of aircraft identification are available in the 416L System:

Correlation of radar tracks with *flight plans* received from civilian and military sources.

Decoding of *beacon signals* transmitted from aircraft.

Visual inspection by manned interceptors.

***USING A LIGHT GUN,** an Air Force operator in a SAGE Direction Center selects aircraft tracks for identification and display.*



FLIGHT PLANS for civilian and military flights are provided to the computer at the Direction Center.

AIR FORCE OPERATORS in the manual inputs room insert flight plans, weather data and other non-automatic data into the computer at the Direction Center.

Identification equipment in the 416L System assists Direction Center personnel in determining the identity of approaching aircraft. Through the computer with its consoles, prefiled flight plans and the Mark X system, identification teams perform the identification function of the 416L System.

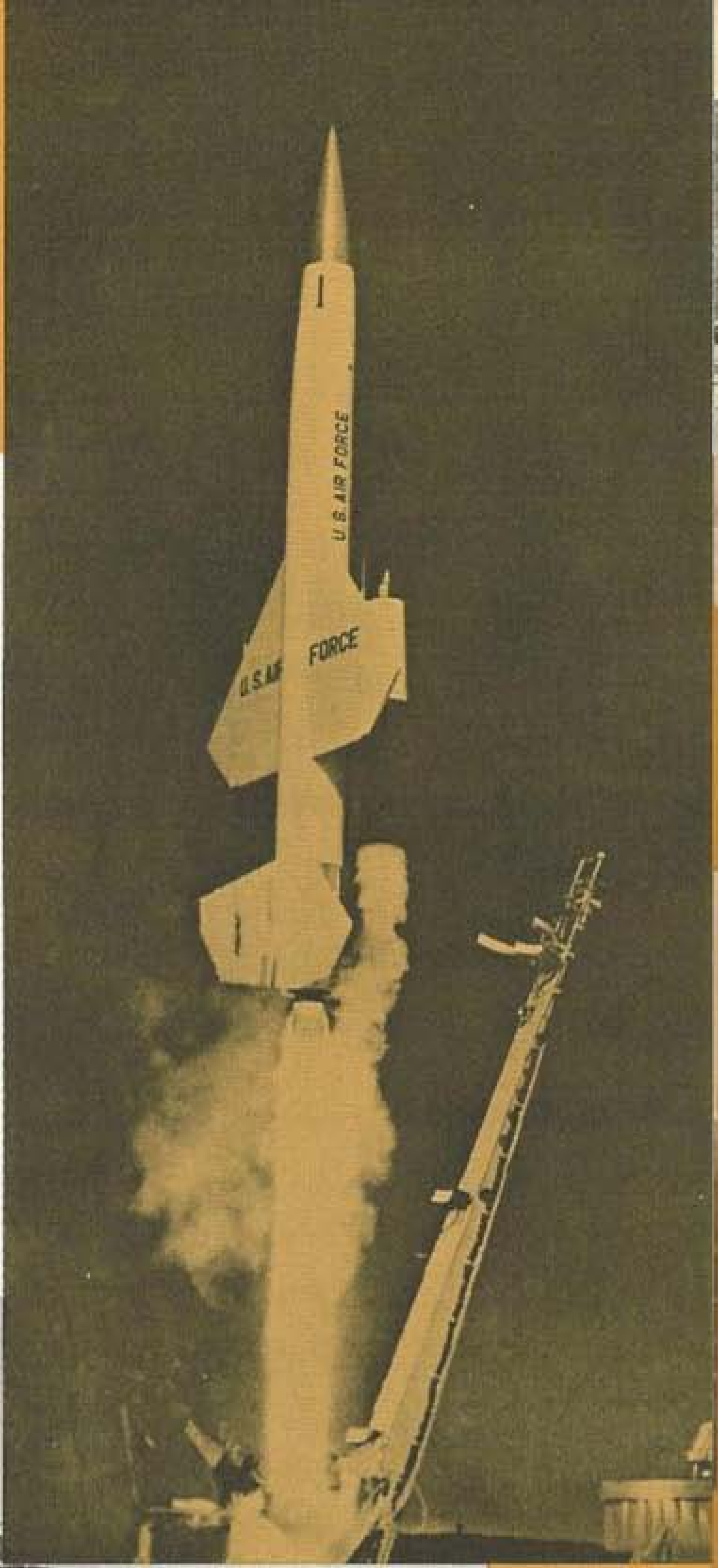
For civilian and military flights, flight plans are provided by the Air Movements Information Service of the Federal Aviation Agency. The flight plans are received in the Manual Inputs Room of the Direction Center and card-fed into the computer for later correlation with aircraft tracks as they appear on display consoles.

A further step in positive aircraft tracking and identification is through Mark X SIF (Selective Identification Feature) beacon equipment. The Mark X system is an improvement to the Identification Friend or Foe (IFF) system in use during World War II. The SIF is an addition to the Mark X system and enables the identification of friend and friend transmitted through unique codes. Upon interrogation from radar sites, a transponder in a missile or manned interceptor transmits a series of coded signals which are processed for display on Direction Center consoles.

If positive identification of an aircraft track is not obtained, the track is declared "Unknown" and steps are taken to scramble a manned interceptor to complete the identification visually. Bomarc and manned interceptor weapons are available immediately should the aircraft be identified as hostile.

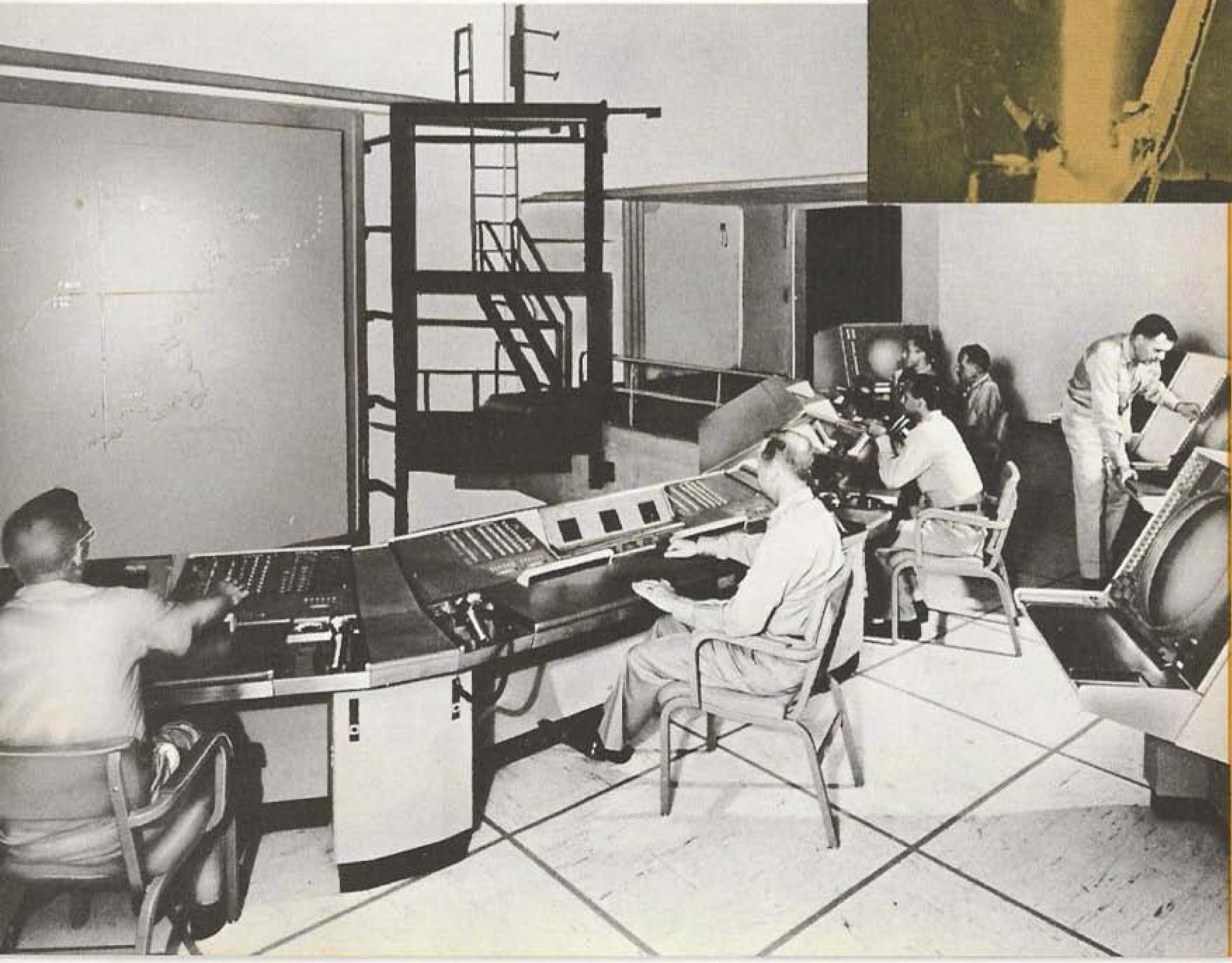
IDENTIFICATION TEAMS REQUEST the SAGE computer to identify aircraft tracks.

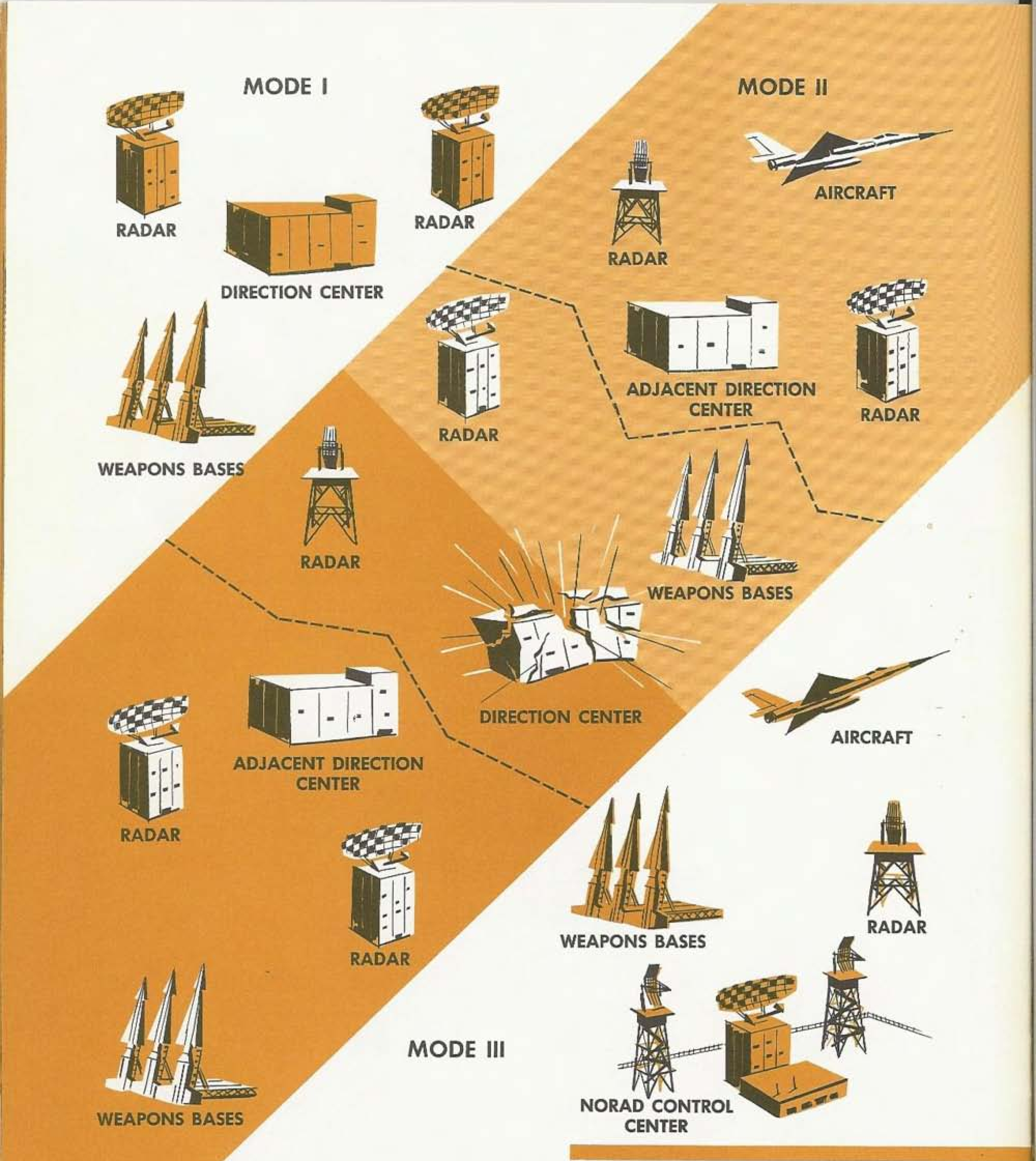
***MANNED INTERCEPTOR—FRONT LINE AIRCRAFT** of tremendous speed and fire power will be part of a SAGE directed defense against hostile aircraft attack.*



***THE AIR FORCE'S BOMARC INTERCEPTOR** missile streaks from its launching area. Armed with a conventional or nuclear warhead, it is controlled by the SAGE Computer.*

***A LARGE SCREEN DISPLAY** enables the Direction Center Commander to direct air defense activities in his sector.*





MODE I—*Each sector performs air defense in its assigned area.*
MODE II—*Adjacent sectors assume control of a disabled sector.*
MODE III—*NORAD Control Centers perform air defense functions.*

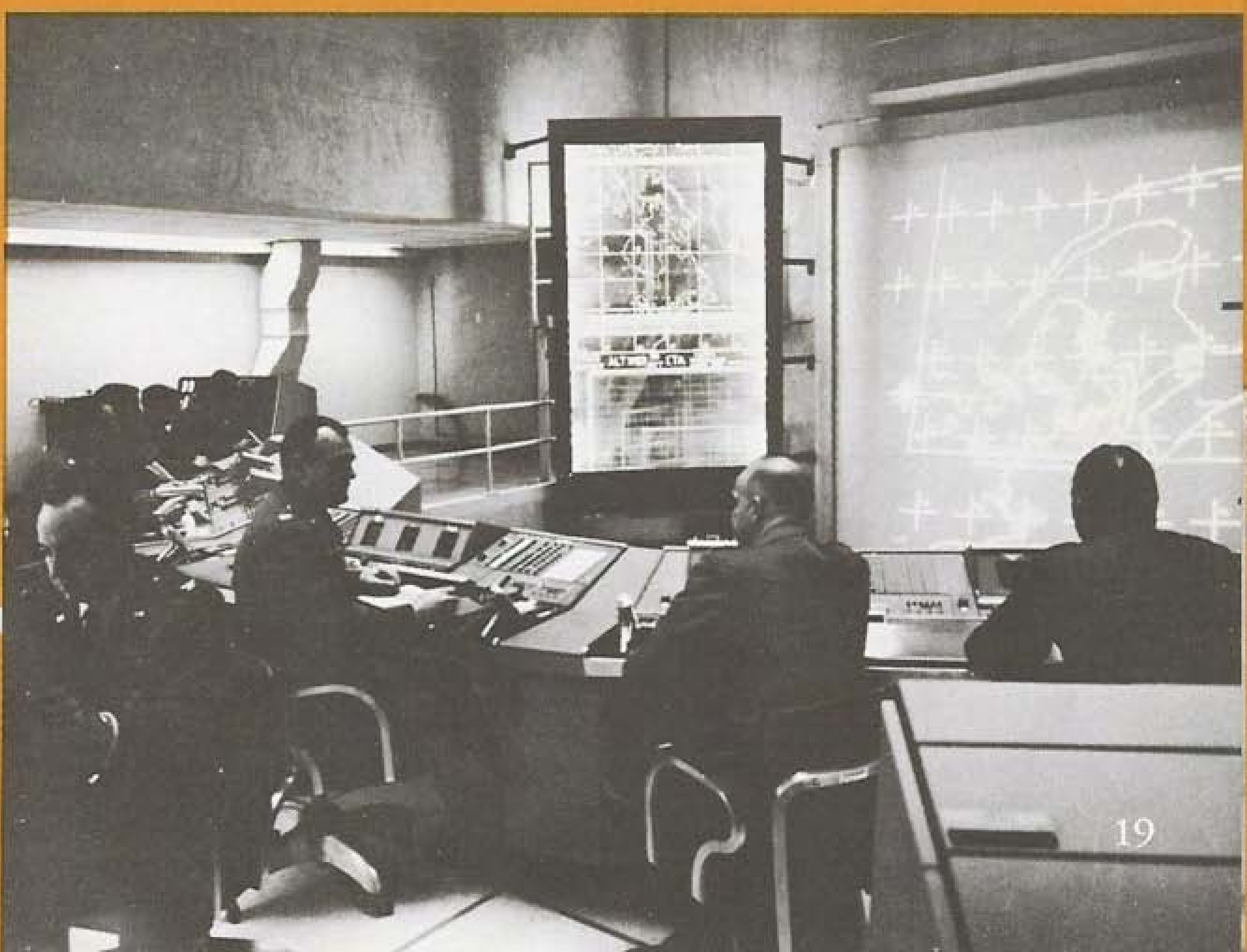
CONTROL

In air defense, control means the ability to activate and direct ground-based weapons to hostile aircraft. The 416L System exercises control of interceptor weapons from Direction Centers and NORAD Control Centers with monitoring of the air situation provided by the Division Combat Center.

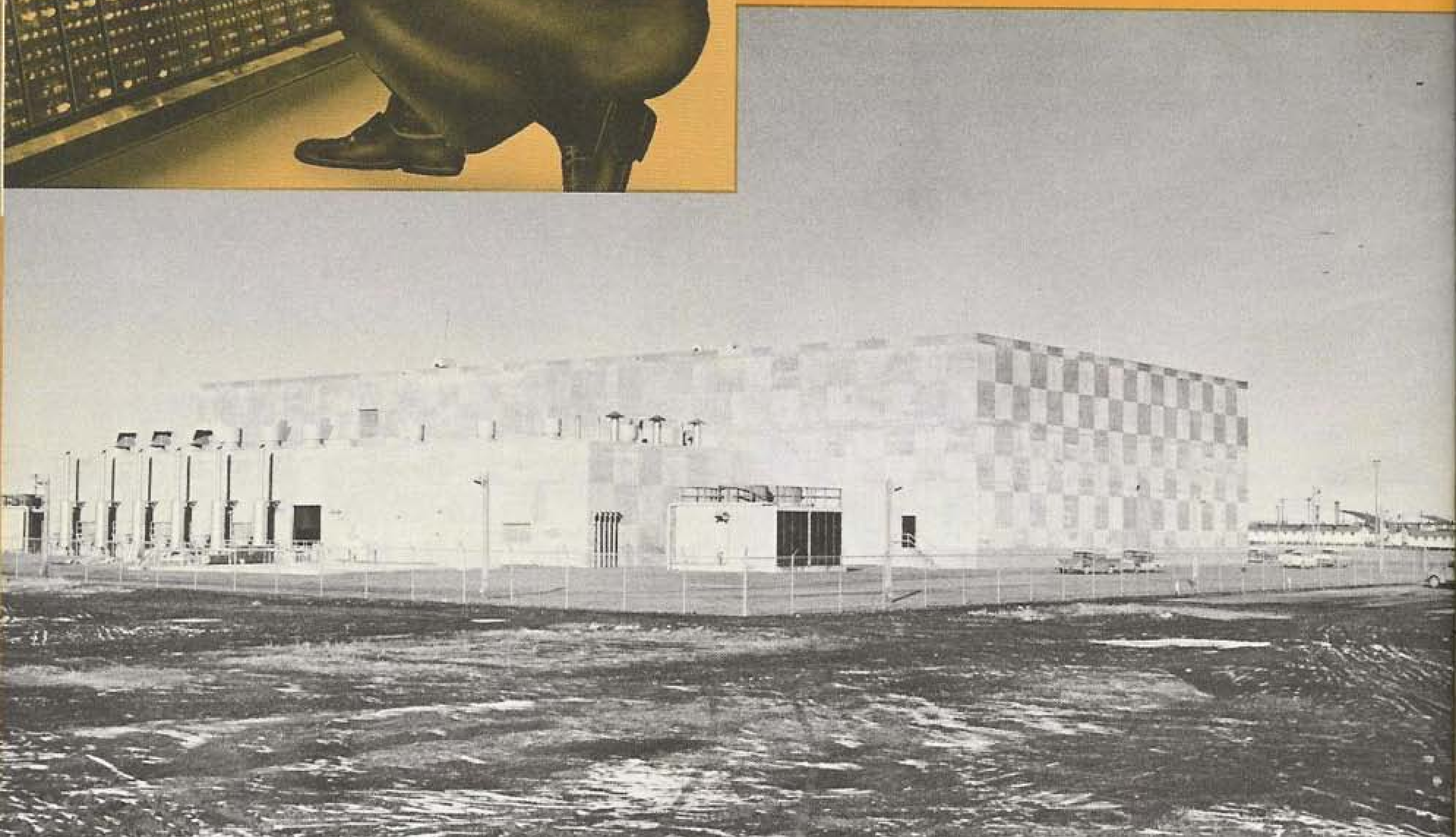
Mode I operation of the 416L System is conducted from each air defense sector which combines radar information and controls interceptor weapons. In the event that a Direction Center in a SAGE area is unable to function, Mode II control of the disabled sector is assumed by adjacent Direction Centers. Mode III is the exercise of control from NORAD Control Centers.

The weapons at the disposal of the 416L System include Bomarc and Nike interceptor missiles as well as Century-series manned interceptors.

***DIRECT CONTROL** of the numerous elements of air defense is a significant feature of the 416L System. This is the Command Post at a Direction Center.*



The principal equipment of control at a SAGE Direction Center is the AN/FSQ-7 computer with its associated display consoles. The AN/FSQ-7 receives the air situation data of the entire sector from long-range, height-finder and gap-filler radars as well as information from computers in adjacent sectors. The computer establishes target tracks which are presented visually on display consoles for necessary action by Air Force operators. Separate consoles are used for air surveillance, track identification, weapons and intercept direction.



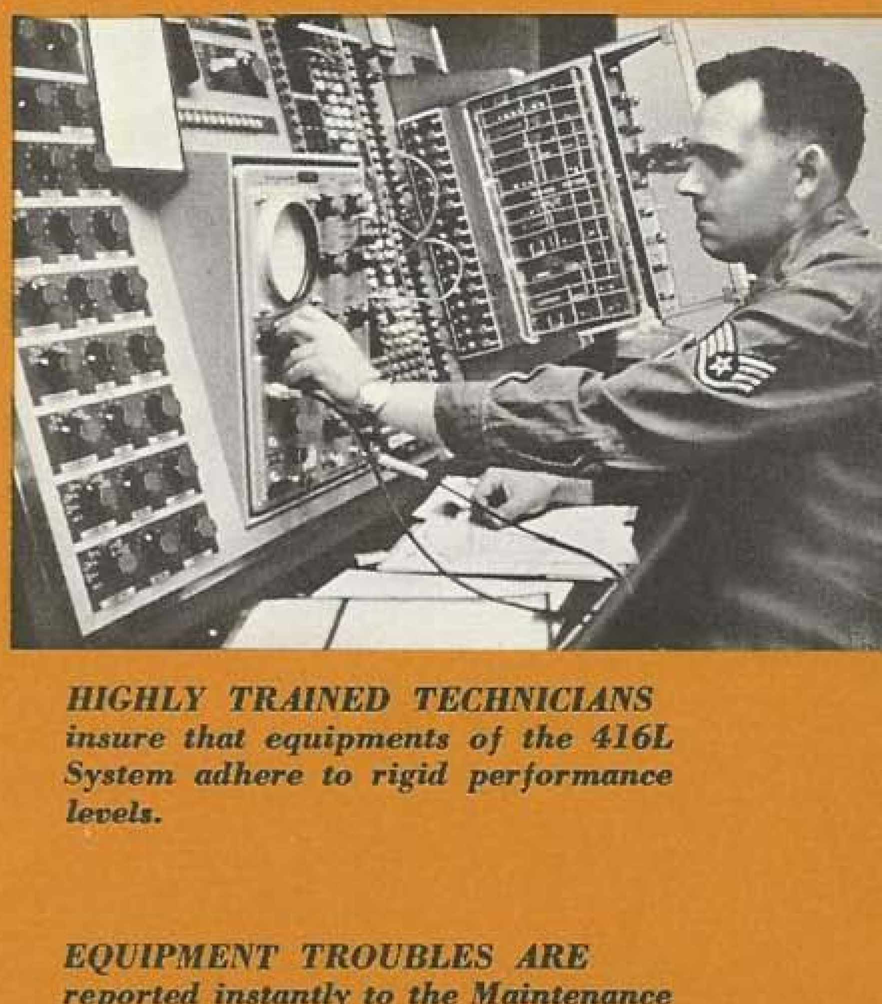
At the Combat Centers, summarized air situation data is received from the individual sectors and monitored by the Division Commander and his staff. An automated display system is provided to display the air situation in the division from which select information is forwarded to NORAD Headquarters. In both Direction Centers and Combat Centers, computer programs (coded instructions) direct each phase of the computer's operation. These programs are changed periodically to include new or improved features of the 416L System.

A NORAD Control Center is a facility which provides the means for aircraft surveillance and identification, and for conducting the air battle within an assigned area. Under normal conditions, the NORAD Control Center operates as a typical long-range radar site. However, Missile Master and Birdie units (Army control equipment for Nike) at the NCC receive SAGE-developed track information for assignment to the Nike batteries. In certain tactical situations, the NORAD Control Center can correlate data from adjacent radar stations and can control interceptors.

To control the amount and quality of data received from radar sources, a Data and Maintenance Control Center (DMCC) at long-range radar sites monitors and directs equipment operation, and reports to the Maintenance Control Section at the Direction Center on the status and performance of electronic equipment. During periods of electronic countermeasures (ECM), the Radar Inputs Countermeasures Officer at the Direction Center directs actions to be taken in accordance with the effect of the ECM on equipment performance.

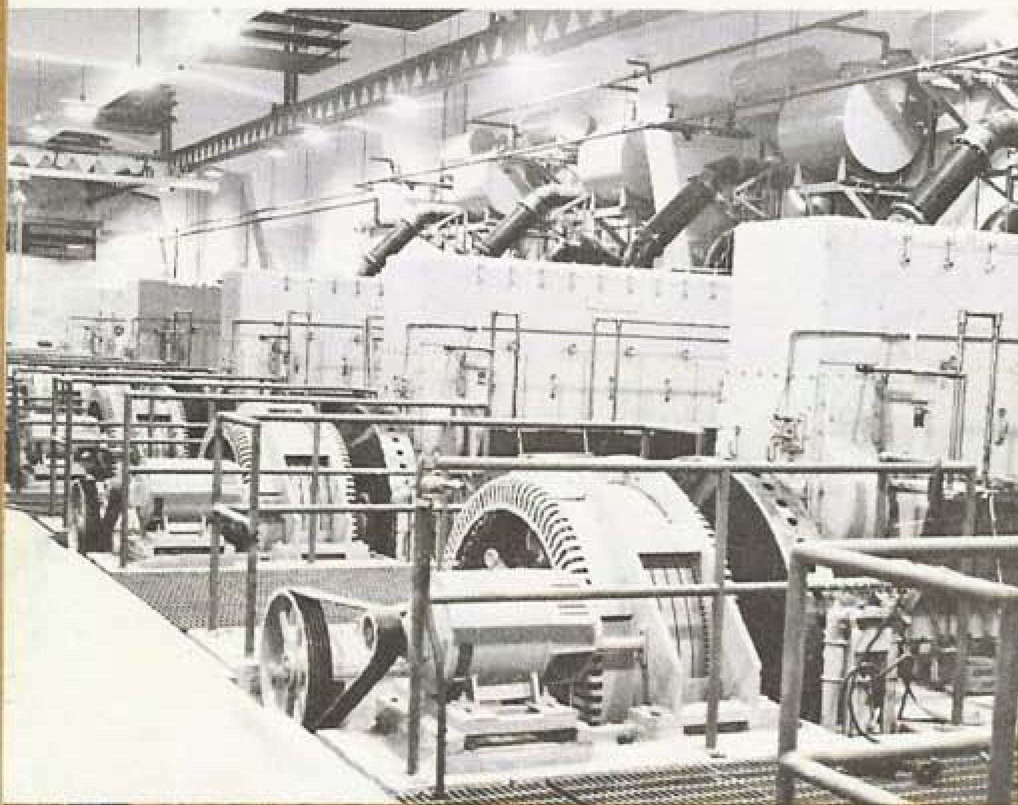
A SAGE DIRECTION CENTER—Air defense information is coordinated at Direction Centers which house the large-scale computer (upper left).

***NIKE INTERCEPTOR MISSILES** guard major cities and industrial areas.*



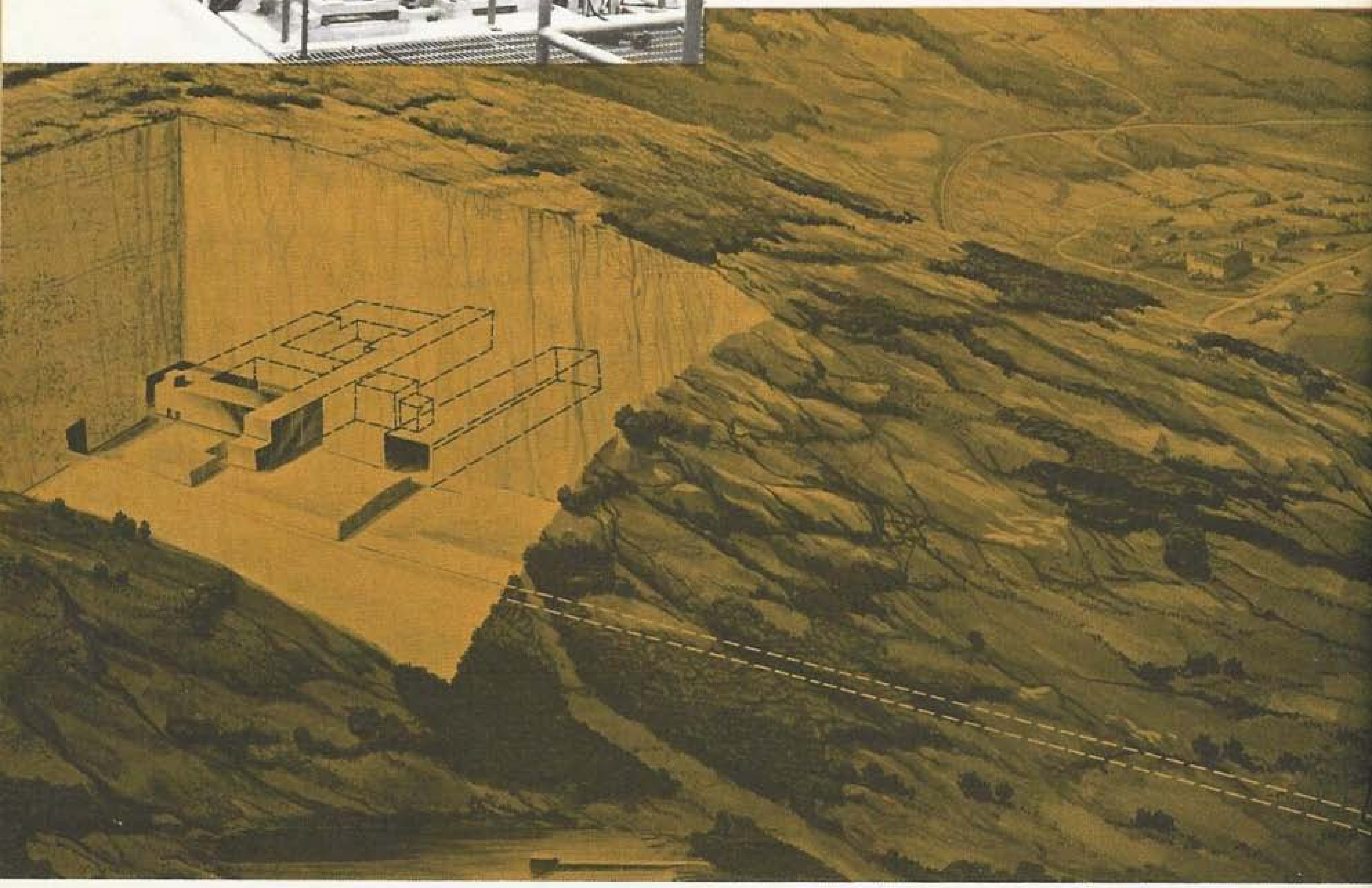
***HIGHLY TRAINED TECHNICIANS** insure that equipments of the 416L System adhere to rigid performance levels.*

***EQUIPMENT TROUBLES ARE** reported instantly to the Maintenance Control Section at the Direction Center.*



Tremendous power requirements are part of each Direction and Combat Center. There are six diesel 650-KW generators pictured here. They use approximately 46,000 gallons of fuel oil a day. A power plant like this would be sufficient to meet the requirements of a town of 15,000 people.

The combination Combat Center/Direction Center in the CADIN site at North Bay in southern Canada is situated under ground. From this "hardened" facility, the commander analyzes the air situation and directs defensive action. In this artist's conception, the left and center tunnels house the CC/DC and the tunnel at the right contains the power plant.



PERFORMANCE

The control and warning system described in this booklet is already in existence and is constantly undergoing improvements in each of its subsystems. Since airborne weapons and the vehicles of delivery are steadily improving, air surveillance and control mechanisms of the 416L System must also continue to evolve.

In the *Detection* subsystem, new high-powered radars which can "see-through" electronic countermeasures are being installed. In the *Communications* subsystem, transmission devices with a high degree of accuracy are being added to Seaward Extension elements, and improvements to data-link facilities are under way. For more precise methods of *Identification*, special combinations of beacon signals are being developed to distinguish between friendly and hostile aircraft. For *Control* of aircraft, improved methods of scrambling manned interceptors and controlling interceptor missiles are being implemented.

As an effective component of the over-all air defense system of the North American continent, the 416L System continues to integrate air defense and air traffic control systems. Since 1958, the United States Air Force and the Federal Aviation Agency have had joint use of radars and control centers for air defense and air traffic control functions.

Other early warning systems are incorporated into the 416L System, notably the Distant Early Warning (DEW) Line and the Alaskan Aircraft Control and Warning System. The 416L System is readily adaptable to improved techniques for ground environment systems in keeping with changing or more exacting requirements of North American air defense.

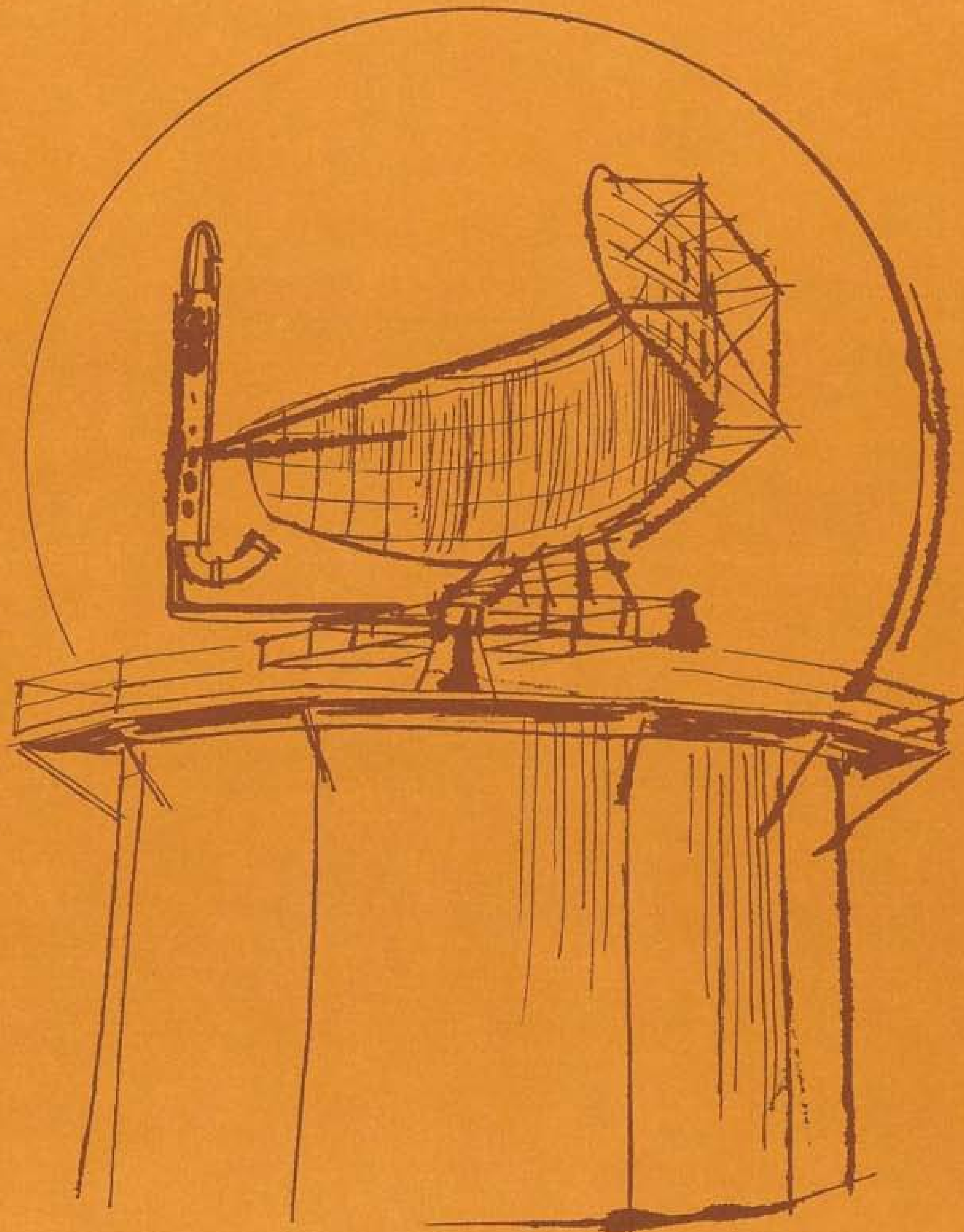
At the same time, the SAGE System proper is being extended into southern Canada under the joint USAF-RCAF CADIN (Continental Air Defense Integration North) Program which will bring a SAGE capability to the existing manual AC&W facilities, and will provide a combined Combat Center/Direction Center in a "hardened" underground environment in the Northern NORAD Region.

416L SYSTEM PROGRAM OFFICE

To implement the U.S. air defense system, the Air Force in 1954 established a SAGE Project Office in New York. Now designated the 416L System Program Office, it is a part of the Air Force's Electronic Systems Division at L. G. Hanscom Field, Massachusetts, where it has been located since March 1960.

To the 416L System Program Office, the Air Force assigned the responsibility for coordinating military and industrial agencies involved in providing the SAGE and ancillary equipment required for the air defense system.

The prime mission of the 416L System Program Office is to assure that an effective control and warning system is provided for the air defense of North America. To meet this requirement, the Program Office monitors the system-oriented activities of all participating field agencies and directs these activities in consonance with an approved system program.



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