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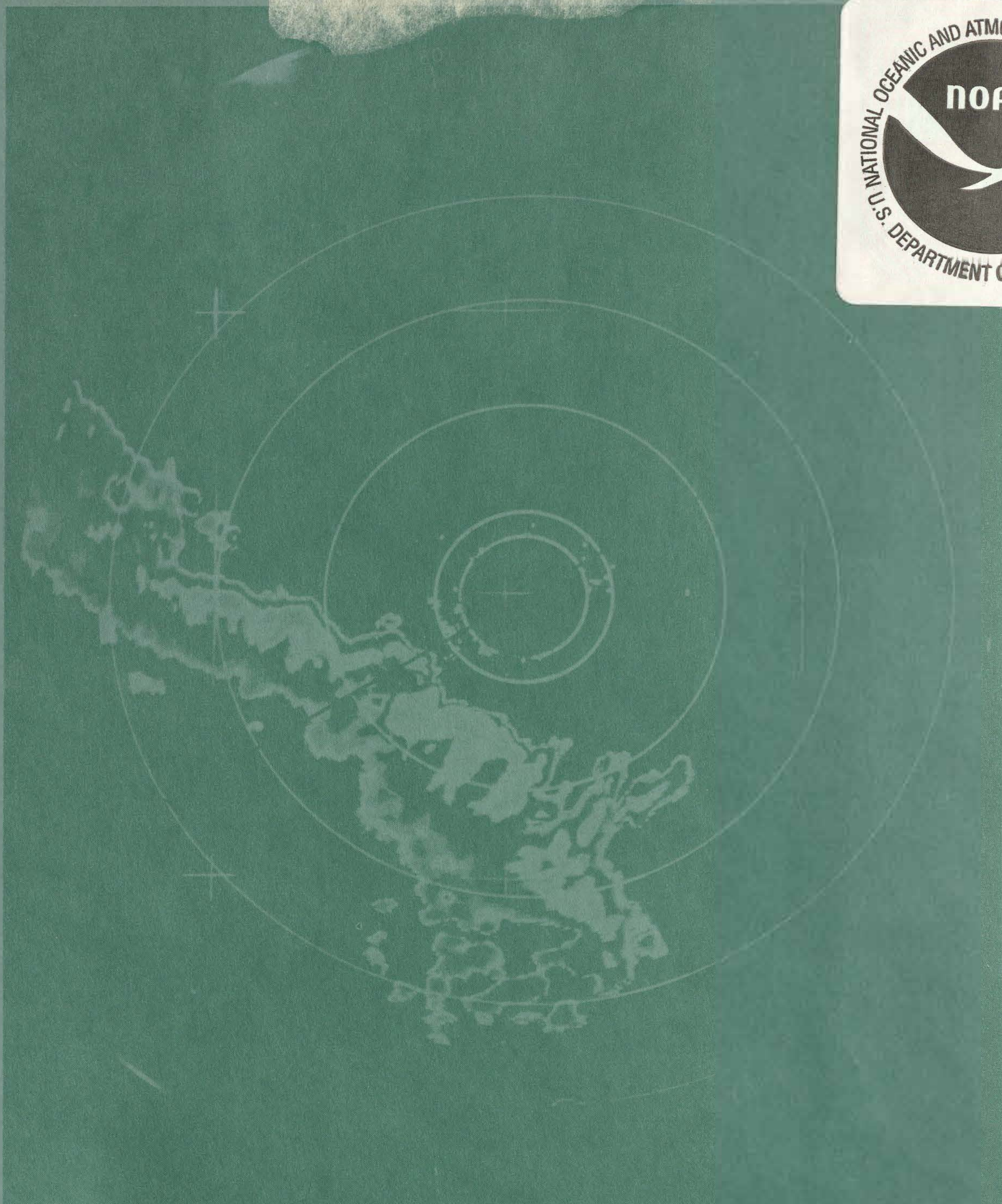
[F]EDERAL COORDINATOR FOR [M]ETEOROLOGICAL SERVICES AN[D] SUPPORTING RESEARCH

Federal Plan For Weather Radars

FCM 73-5

Washington, D.C.
November 1973



Quantized Radar Echoes - Calibrated contours of echo intensity add an important dimension to weather radar. Echo-intensity contour presentation is white, one gray shade, or black, eliminating dependence on gray-scale separation for determining echo intensity. Quantized information makes it easier for the radar observer to derive estimates of the rate of rainfall and to pinpoint the most intense portion of a storm to issue more effective warnings.

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
FEDERAL COORDINATOR FOR METEOROLOGICAL
SERVICES AND SUPPORTING RESEARCH

FEDERAL PLAN FOR WEATHER RADARS

[United States. Interdepartmental Committee for Meteorological Services.]

FCM 73-5

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FOREWORD

This Plan for Weather Radars describes the use of national weather radar resources in providing warnings and forecasts of severe weather for all walks of life within the United States. Radar is an important element of the total observing system needed to provide these vital services to the Nation. The Plan was prepared by the Interdepartmental Committee for Meteorological Services and the Interdepartmental Committee for Applied Meteorological Research. It replaces the Federal Plan for Weather Radars and Remote Displays issued in December 1969.

This Plan has been developed in response to guidelines provided by OMB Circular A-62 and specific findings and recommendations in the Report to the Congress on Disaster Preparedness by the Office of Emergency Preparedness, January 1972, The Agnes Floods by the National Advisory Committee on Oceans and Atmosphere, November 22, 1972, and other disaster survey reports. Concepts developed in earlier Plans have been updated to take advantage of modern technology. Federal agencies concerned with weather radar have participated in preparing this Plan; specifically, the Departments of Commerce, Defense, Interior, and Transportation, the National Aeronautics and Space Administration, and the National Science Foundation.

Clayton E. Jensen
Federal Coordinator for Meteorological
Services and Supporting Research

FEDERAL PLAN FOR WEATHER RADARS

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I. INTRODUCTION

A. PURPOSE

Radar is a major element in this Nation's natural disaster preparedness program. It is the best observing system now available to detect and describe weather events that have the potential for causing natural disasters. Radar information describing weather events is used also in providing the Nation with general weather forecasts and in providing specialized weather support to operations, activities, forces, and installations of government agencies. This Plan presents the needs of the various Federal agencies and the plans for a national radar observing system designed to meet these needs. Improvements in the radar observing system outlined here were developed in partial response to findings and recommendations in the Report to the Congress on Disaster Preparedness by the Office of Emergency Preparedness, the report The Agnes Floods by the National Advisory Committee on Oceans and Atmosphere, and other disaster survey reports, all of which called attention to the vital role radar plays in disaster warnings.

This Plan supersedes the 1969 Plan for Weather Radars and Remote Displays. Since the 1969 Plan was issued, several major technological advances have been and are being made that will enhance the capabilities of weather radar to provide surveillance of severe storms.

- An operational experiment is nearing completion, the results of which will permit quantitative processing of weather radar signals to make radar data more useful for meteorological and hydrological forecasting, especially for detecting severe thunderstorms and in flash-flood-prone areas.

- Modern, solid-state radars are available to replace the obsolete, World War II surplus, local warning radars now being used by NOAA.

- High-speed communications are available to transmit radar data quickly to offices with warning and forecast responsibility.

- With the realization of the Geostationary Operational Environmental Satellite (GOES) system, radar and satellite information can be integrated to enhance the usefulness of the data to enable improved weather forecasts and warnings.

The future use of these technological advances coupled with some deficiencies in using radar remoting to provide data for local warning prompted an examination of the current radar observing system operation. This Plan reflects an updated concept for radar operations, identifies needs, and describes future plans for the radar observing system.

B. RELATION TO OTHER OBSERVING SYSTEM ELEMENTS

Radar is only one element of the total observing system required to detect meteorological phenomena and measure meteorological properties to provide forecast and warning services to the Nation. No single observing element can provide all the information needed for detection and tracking of the full range of atmospheric phenomena. The elements of the observing system consist of moving and fixed platforms which contain sensors and associated equipment to measure and monitor, either in situ or remotely, both meteorological properties and phenomena.

Radar has been developed within the context of the total observing system. Its capabilities have been integrated with those of the other elements. As improvements are made in the capabilities of respective components of the total observing system, adjustments are made to the role of each component and redundancy is minimized. For example, the Geostationary Operational Environmental Satellite (GOES) data and weather radar data are complementary. The GOES will provide a detailed description of the areal distribution of the cloud cover and an indication of vertical extent of the clouds. Weather radar provides precipitation areas associated with severe storms along with details on their horizontal and vertical structure.

C. WEATHER RADAR DESCRIPTION

Most radars used for weather detection purposes are pulsed radars: electromagnetic or radio energy is emitted in short duration pulses (1/2 to 5 microseconds). This energy is transmitted from the radar antenna in the form of a narrow, conical beam. Energy is reflected back to the antenna when a target intercepts the beam. The time between the emitted and the received signal is a measure of the range of the target. The antenna may be rotated or elevated to determine the target's horizontal position and vertical extent. Targets of a weather radar may consist of raindrops, hail, snowflakes, cloud droplets, ice cloud particles or various combinations of these meteorological phenomena.

Radar detects water droplets by measuring the <u>equivalent radar reflectivity factor</u> of volumes of the atmosphere equal in size to the radar's resolution. The radar reflectivity factor is simply the summation of the sixth powers of the diameters of all the water droplets in the volume being sampled. Since the sixth power of the diameter is involved, radar responds to larger droplets much more powerfully than to smaller droplets. For example, one droplet 1 millimeter in diameter produces a radar indication just as strong as 1 million droplets 0.1 millimeter in diameter. This tendency to exaggerate the importance of large droplets is fortunate, since the more hazardous weather (in terms of convective turbulence, gusty or destructive winds and hail) is associated with concentrations of large particles.

Figure 2.--WSR-57 operator's console

In all systems where electromagnetic energy is radiated through a medium such as the atmosphere, some of the energy is lost by scattering and absorption. This process of energy loss is termed attenuation. The amount of attenuation is dependent on many factors. In the microwave region, the most important factors are the wavelength of the radar and the water content in the path of the radar beam.

Most operational weather surveillance radars, hereafter referred to as weather radars, operate at either 10 cm (S-band), 5 cm (C-band), or 3 cm (X-band) wavelengths, while cloud detection radars operate at 1 cm (K-band) or less. As a general rule, the shorter a radar's wavelength, the more sensitive it is to water droplets and the more easily it can detect small drops. However shorter wavelength radars are more subject to attenuation than longer wavelengths.

The selection of an appropriate wavelength for weather radars depends on the intended use of the radars. For detecting snow or light rain over short distances, the X-band is preferable. Because of the attenuation problem, however, radars located in regions where large thunderstorms and squall line systems (with attendant high rainfall rates) occur frequently, require wavelengths of at least 5 centimeters and preferably 10 centimeters. Where the radar is intended to track and map hurricanes and typhoons, an S-band wavelength is virtually a necessity.

Weather radars give the meteorologist a capability to look electronically far beyond the visual horizon and evaluate what is detected. Cloud detection radar provides a capability to measure cloud layers above the lower overcast deck or above surface-based obscuring phenomena. Weather radar provides:

- A continuous and almost instantaneous means of detecting precipitation within range of the set.
- The best means now available for identifying and tracking thunderstorms, squall lines, and tornadoes.
- A means of locating, tracking, and estimating the intensity of hurricanes as they approach the U.S. coastal areas.
- Quantitative information upon which estimates of precipitation rates and amounts can be based.
- A source of three-dimensional information on the location, intensity, and movement of precipitation areas and attendant hazardous conditions.
- A means for indirectly estimating many important meteorological parameters such as turbulence associated with thunderstorms, winds aloft, cloud tops, precipitation types, freezing level, and aircraft icing levels.

Figure 3.--WSR-57 installation at Charleston, S.C., showing tower, radome and building housing modulator, and auxiliary power.

D. BENEFITS OF WEATHER RADAR INFORMATION

The goals of the weather radar program are to improve the effectiveness of warnings and forecasts of severe weather and flash floods and to reduce personal and economic impact of preparing for storms that may not materialize. Improvements in our monitoring, warning preparation, and warning dissemination systems have resulted in a continuous decrease in the number of lives lost from hurricanes and tornadoes (fig. 4). Radar has played a major role in these dramatic decreases as an integral part of community severe weather action plans.

Early identification and tracking of severe storms and hurricanes are necessary to provide adequate lead time in issuing warnings to the public so that appropriate preventive actions can be taken. Weather radar offers the potential for early detection of intense rainfalls capable of causing disastrous flash floods. In addition, weather radar contributes greatly to the safe and efficient operation of the air traffic control system, airlines, and general aviation.

Past experience has been that many of the most effective warnings of severe weather have been issued by offices with their own weather radar. For example, on June 8, 1966, a tornado struck Topeka, Kans., a city with a population of 130,000. The tornado caused 17 fatalities and almost total destruction (property damage over $100 million) through the heart of downtown Topeka. The relatively low loss of life through such a major tornado can be attributed, in part, to the issuance of early and updated warnings. From the beginning the Topeka Weather Service Office tracked the tornado by radar and issued early and repeated warnings to the public.

In contrast to the Topeka case, on May 11, 1953, a tornado struck Waco, Tex., population 90,000, killing 144 persons and causing $42 million in property damage. A tornado watch was issued, but no warnings. If the population of Waco had been the same as Topeka, 130,000, and assuming the same population density, 208 persons might have been killed. Since only 17 people were killed in Topeka, it is estimated that approximately 191 lives were saved as a result of effective warning and community preparedness.

In coastal areas affected by hurricanes, the cost of protecting property and preparing it for the storm can be significantly reduced where there is adequate weather radar coverage to track and identify the hurricane landfall. Weather radars can easily reduce hurricane position errors from more than 20 miles to less than 10 miles through more accurate warnings possible from continuous tracking of hurricanes approaching the mainland. In the Miami area, it costs $1 million a mile to prepare for a hurricane. Thus, millions of dollars could be saved in the cost of preparing buildings against the possible damage of just one hurricane.

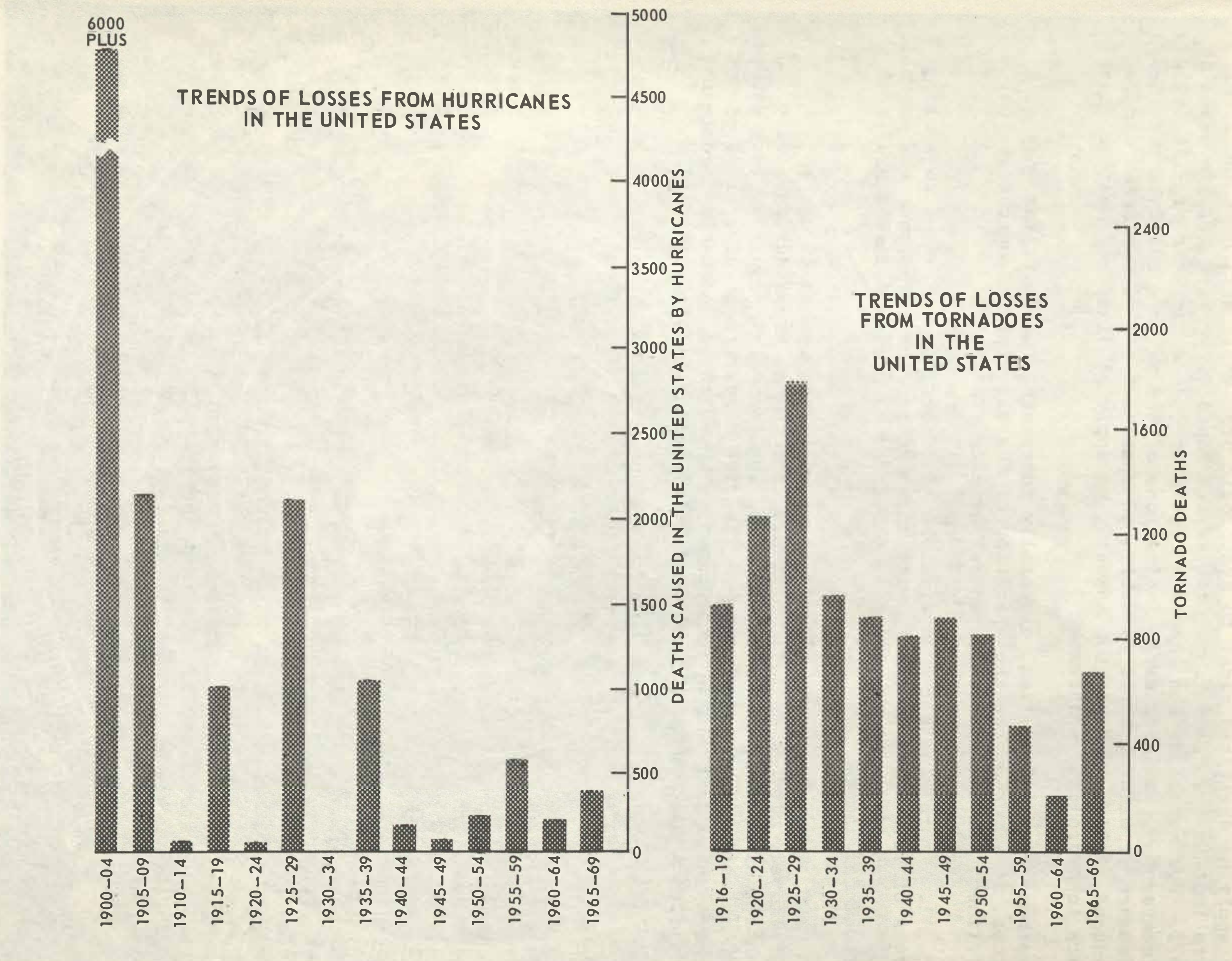


Figure 4.--Tornado and hurricane fatalities.

It is estimated that the Nation's ever-growing flood losses can be reduced by applying digitized radar to hydrologic problems. Well over 200 lives were lost in the flash flood that struck Rapid City, S. Dak., one night in 1972. Weather radar data can significantly reduce the loss of life in such disasters by providing early indications of the intense rainfall for the issuance of warnings. It is estimated that national flood losses can be reduced by 5% or $50 million annually by applying digitized weather radar data to hydrologic problems.

Weather radar information, especially concerning thunderstorms and squall lines, is important to the operation of the air traffic control system, airlines, the military, and general aviation to:

1. Improve safety of operation: Aircraft can be routed to avoid areas of severe thunderstorms with their associated turbulence and possible hail. Avoiding storms can prevent injuries to crew and passengers and structural damage.

2. Improve economy of operation: Aircraft movements can be effectively planned to avoid arrivals in terminal areas during severe weather situations. "Holding and stacking" patterns result in long delays and excessive fuel consumption. Effective longer range diversions around storms avoid last minute time-consuming reroutings. Appendix I contains additional discussion of the benefits of weather radar information.

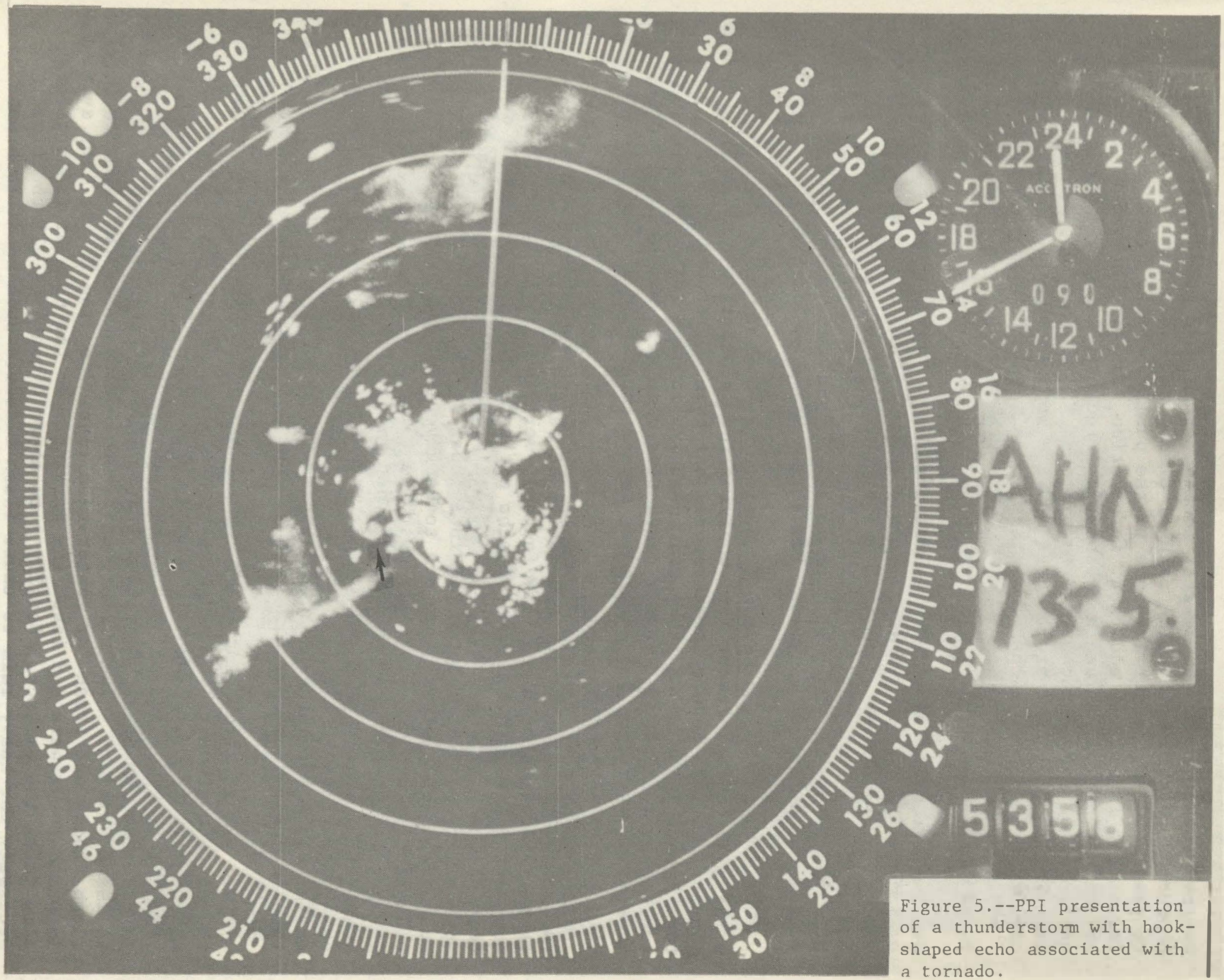


Figure 5.--PPI presentation of a thunderstorm with hook-shaped echo associated with a tornado.

II. WHY WEATHER RADAR?

Weather radar is used to detect, locate, track, and measure meteorological phenomena capable of causing natural disasters. This information is used to prepare warnings for issuance to the public to take protective actions for saving lives. In addition, information from weather radars is used by the meteorological and hydrological forecaster in providing general weather and river forecasts to the Nation. Finally, weather radars of the Department of Defense are used to provide weather support tailored to the air and ground operations of the Air Force, Army, Navy, and Marine Corps.

A. DISASTER WARNINGS

Weather radar is the main observing instrument for monitoring weather occurrences capable of causing severe thunderstorms, tornadoes, and flash floods. Also, radar gives information on the detailed structure of hurricanes. The radar information on all of these types of weather occurrences is used in preparing forecasts and warnings to protect the public and lessen the economic hardships caused by these storms.

1. Tornadoes and Severe Thunderstorms--Weather radar is the primary observing element for supplying the information upon which warnings of tornadoes and severe thunderstorms are based. Meteorologists use radar to monitor thunderstorm areas continuously, looking for radar echo signatures characteristic of severe convective weather. When such echoes are identified, warnings for tornadoes, severe thunderstorms, hailstorms, and high winds are issued.

Radar echo characteristics indicative of severe weather include intensity (equivalent radar reflectivity factor), vertical extent, rate of lateral and vertical growth, and unique echo patterns. Radar can measure or evaluate each of these parameters. Since severe convective storms are short-lived, approximately 10-30 minutes per individual storm, they must be detected as soon as possible if warnings are to be given in time for people to take preventative action. Not only must the tornado or severe storm be detected, it must be observed continuously to determine its direction and speed of movement to warn people to clear from its path. Reports from volunteer observers of those tornadoes not positively identifiable on radar can be associated with observed radar echoes. The radar can then be used to track that echo and provide information for further warnings about the storm.

2. Flash Floods and Floods--To identify the potential for flash flooding and to warn the public of flash flood danger, hydrologists and meteorologists must have information on the rate, duration, and amount of rainfall over an area. The same information is also needed to forecast river stage levels, to determine possible river flooding conditions, and to issue warnings. The primary difference between the requirements for flash floods and those for longer-term river flooding is the time available in which to prepare and issue the warning. In the case of flash floods, time is of the essence. Usually 1 to about 4 hours is all the time necessary for heavy rain to cause flash floods. Such conditions must be quickly identified and warnings disseminated rapidly.

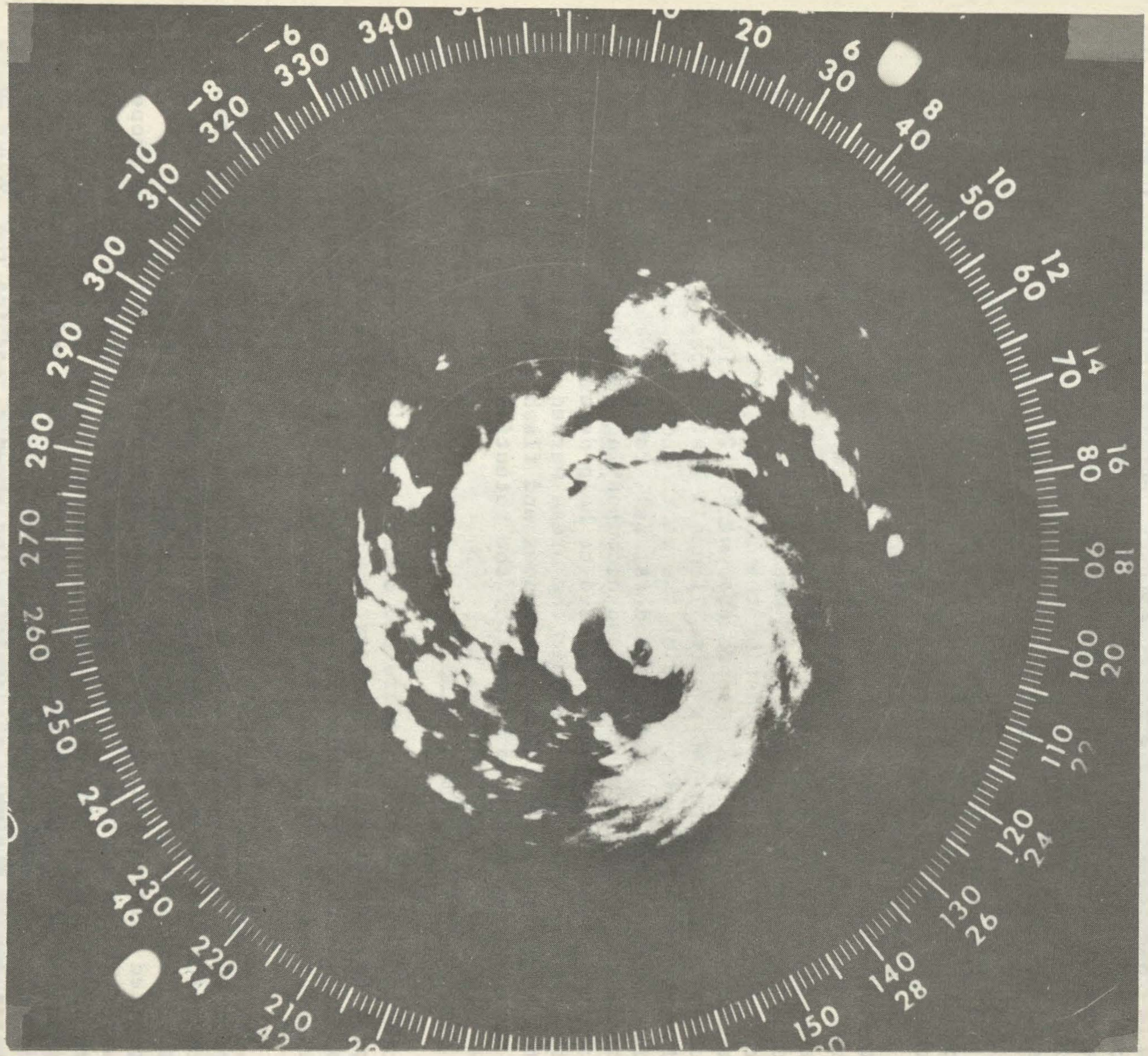


Figure 6.--PPI presentation of a hurricane with an eye and spiral bands of echoes.

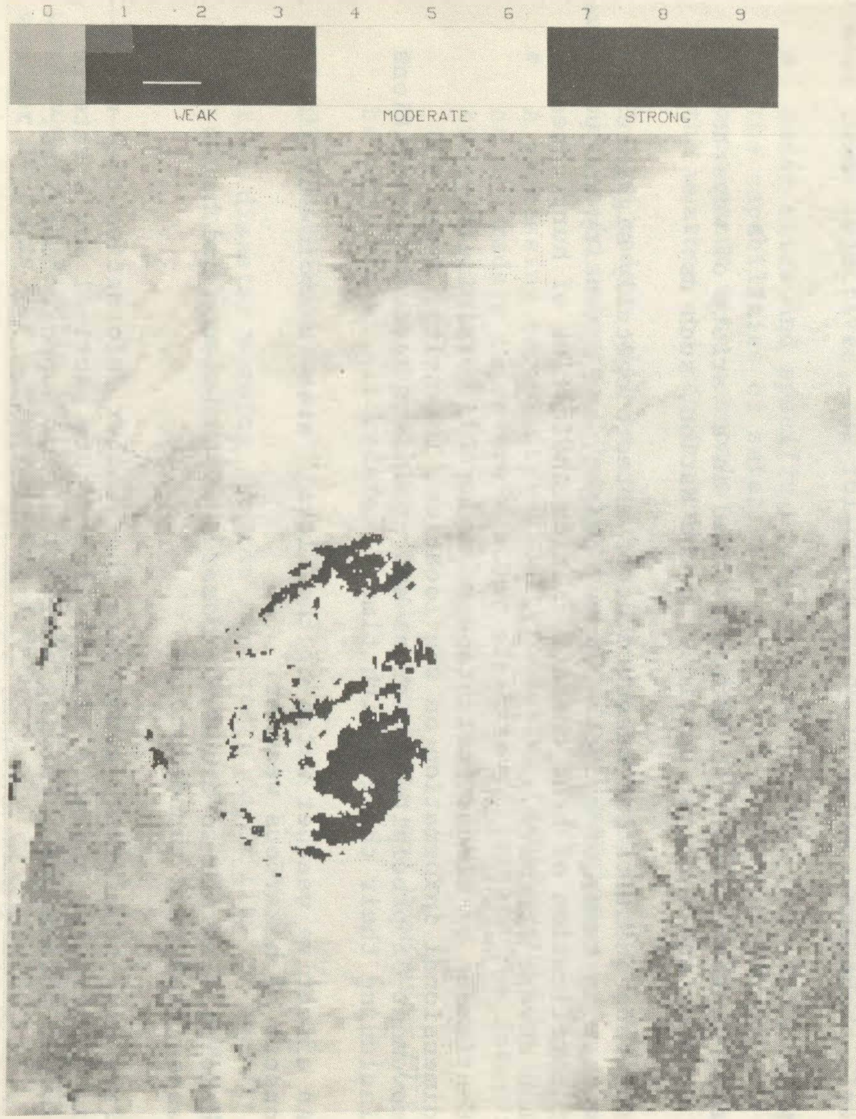
Radar can provide instantaneous estimates of rainfall rates over large areas for warning purposes. However, more accurate information can be determined when radar is used with raingage observing systems. A storm's intensity (equivalent radar reflectivity factor) indicates its rainfall-producing potential. The information for flash flood warnings could be provided using telemetering raingages alone, assuming a much denser spacing of gages than now available. For example, a recent World Meteorological Organization report shows that, for flash flood type storms within an 80 n.mi. radius of a radar location, approximately 1,600 telemetered raingages would be needed to give the equivalent accuracy of rainfall amounts determined by radar.

3. Hurricanes--Weather radar, satellite surveillance, and aircraft reconnaissance are the primary observing elements that complement one another in locating, tracking, and determining the intensity of hurricanes. The satellite is used primarily to detect, locate, and track the cloud patterns accompanying the hurricane while the storm is over the ocean. With aircraft reconnaissance the storm can be located before it approaches the coast and comes under radar surveillance. Primarily, aircraft reconnaissance is used to measure the meteorological properties of the storm to use in forecasting the intensity, direction, and speed of movement. As the hurricane approaches within 200 miles of the coastal area, it comes under precise radar surveillance. Weather radar locates and defines the movement of the eye of the storm and provides specific information on the storm's intensity and rainfall rates. Weather radar is used to track the thunderstorm cells and accompanying heavy rains imbedded in the clouds. This information is used to help determine the future course of the hurricane, and as a result the areas warned can be reduced in size. As the hurricane moves inland, tornadoes and flash floods frequently occur, and weather radar is used to monitor the potential for them.

B. GENERAL WEATHER FORECASTING

Information from weather radars and other observing system elements is used to provide general weather forecast services to the Nation. The use of radar in identifying precipitation patterns and in supporting aviation services is presented in the following paragraphs.

1. Precipitation Patterns--Precipitation of a general nature, either rain or snow, often covers an area larger than the area seen by one radar. To describe the extent of this precipitation, radar observations from several locations are collected systematically and composited. This composited information, along with measurements of meteorological properties obtained by the surface, upper air, and satellite observing system elements, forms the basis for forecasting the future movement, intensification, or dissipation of the precipitation patterns. Weather radar probes the precipitation areas to determine the intensity and vertical extent of the patterns and an estimate of precipitation amounts reaching the ground. Information from radar and satellite systems will be composited in order to increase the usefulness of data for making weather forecasts (fig. 7).



Radar data in black melded with ATS-1 quantized cloud data.

Quantized radar data.

Figure 7.--Computer processed radar and satellite data composite.

2. Aviation Support--Thunderstorms and their associated turbulence and hail present extreme hazards to aviation. Weather radar information is used to advise general aviation interests in planning flights and, once the aircraft is aloft, to assist in avoiding hazardous weather. Warnings of impending severe weather are also necessary to protect aircraft on the ground. In addition, weather radar information is used by the FAA's Central Flow Control Facility to help move commercial aircraft efficiently during weather conditions that might affect flight operations.

C. SPECIAL DEPARTMENT OF DEFENSE APPLICATIONS

Weather radar is used by the Department of Defense as a means to gather weather information critical to the conduct of tactical and strategic operations on the ground, in the air, and at sea. The effectiveness and safety of these operations and associated training and support activities are influenced by thunderstorms, hailstorms, tornadoes, hurricanes, and other atmospheric phenomena detectable on radar. Knowledge of these phenomena allows the military commander to better plan and more effectively execute his operations.

Experience has shown that weather radar is useful in short range target and refueling area forecasting, in scheduling reconnaissance, in conducting a radar meteorological watch for routes, flights, areas, and local and outlying terminals, in advising aircraft in flight of conditions enroute, in providing weather support to flying training operations, and in protecting military forces, equipment, and installations from hazardous atmospheric phenomena.

D. SUMMARY

In summary, weather radar information is used in a variety of ways to provide warning and forecast services to the Nation, such as:

- Accurate quantitative measurement of meteorologically significant echoes in terms of azimuth, range, height, and intensity and positive identification of echo characteristics indicative of hurricanes and severe storms.

- Continuous or almost instantaneous means for obtaining three-dimensional information on the location, intensity, type, and movement of precipitation areas and attendant hazardous conditions including their changes with time.

- An effective weather watch of the "local" area to avoid surprise onsets of hazardous weather.

- Helping aircraft to avoid the hazards of turbulence and hail associated with thunderstorms.

- Providing to military commanders the weather information they need to better plan and more effectively execute tactical and strategic combat operations, training activities, and support functions.

III. OPERATIONAL CONCEPTS

Operational concepts for the planned radar system are based on the following objectives:

- Continuous coverage [1/] of the Nation (basic network) to detect, locate, and monitor the development and movement of significant weather, and alert local warning radar sites which are not staffed for around-the-clock operation.
- Implement local warning radars to detect and track hazardous weather in those areas of the basic coverage where the threat of severe weather and the potential impact is great (considering population, natural resources and industry).
- Augmented capabilities (remote radar displays) at responsible warning offices in areas where the threat of severe weather is infrequent but nevertheless exists.
- Provide radar weather support to Department of Defense operations, forces, and installations to meet the operational requirements of the military commands.
- Provide back-up support for radars in the basic weather radar network through the use of nearby local warning radars. Agency responsibilities are established in a later section.

To meet these objectives, the following guidelines are observed:

- Radar sites and specific equipment are selected in context with the capabilities of satellites and other observing systems and consistent with economic considerations in light of the nature of the weather and requirements.
- S-band radars will be employed to the greatest extent possible in the basic network; C-band radars for local warning.
- A processing capability--Radar Processing (RADAP)--will be provided at all radars in severe weather areas to facilitate the interpretation and communication of data.
- A quantization capability--Video Integrator and Processor (VIP)--will be provided at all radars.

A. DISASTER WARNINGS

An effective disaster warning program requires a capability to rapidly and reliably detect a hazardous situation or indications that it is developing.

1/ Continuous coverage is defined as the ability to monitor significant weather 24 hours per day seven days a week.

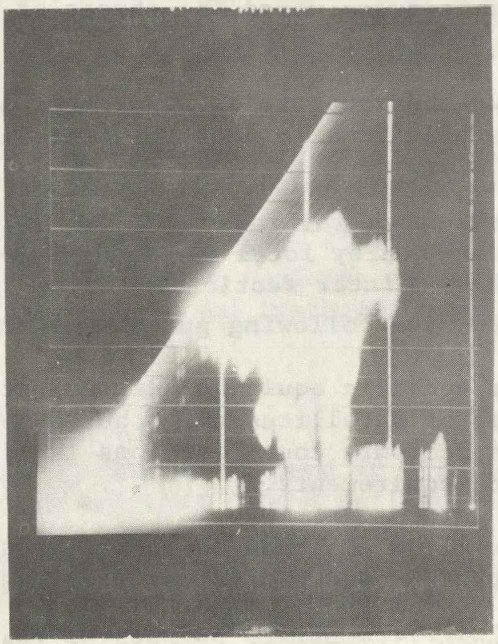


Figure 8.--RHI presentation of a vertical profile through a thunderstorm showing hail fingers.

Weather Service Offices and Weather Service Forecast Offices are assigned warning responsibilities on a county basis. They issue watches and warnings of severe local events such as thunderstorms, tornadoes, and flash floods. Each office having such a warning responsibility will be provided with immediate access to either a basic network radar or a local warning radar. Where a responsible office is near a basic network radar in an area of infrequent hazards, a remote display will be used in lieu of a local warning radar.

Local warning radars will be shorter range, lower powered, and operated in C-band. Although greater attenuation can be expected from the C-band radar, it is satisfactory for the local warning program.

Local warning radars will, in most cases, be located within the coverage of the continuously operated longer range basic network radars. Thus, the local radar station can be alerted to approaching or developing weather by the operators of the basic radars. This is particularly important, since the local warning radars are not usually staffed for around-the-clock operation.

The severe storm warning program requires the tracking of the movement and development of storms. Flash flood warning requires the time integration of quantized and interpreted information. These needs will be met by the addition of the Video Integrator and Processor (VIP) and Radar Processor (RADAP) systems. The latter system provides the additional capability for monitoring, alerting, and documenting. (See section IV, C for a discussion of the RADAP system.)

The local warning program requires the establishment of close coordination and communication among WSFOs and WSOs. Automated communication systems, part of the program under development for Automation of Field Operations and Services (AFOS), will link these service offices as well as the National Severe Storm Forecasting Center, the National Hurricane Center, and River Forecast Centers.

B. GENERAL WEATHER FORECASTING

The support of general weather forecasting requires a periodic view of the location and intensity of precipitation systems. River forecasting requires a time integration of the amount of precipitation being experienced, tied to specific watersheds and river systems. Minimum requirements will be met using the basic network. This capability will be augmented through the use of radars established in support of disaster warnings.

In regions of high rainfall rates, the basic radars will operate in S-band; where heavy rains are rare, C-band radars will be used on an interim basis for economic reasons. Special consideration must be made for the mountainous areas west of about 105°W longitude. In light of the extremely high cost of instrumenting this region with special weather radars and the combination of relatively less frequent occurrences of severe weather with low population density, Air Route Traffic Control radars of the ARSR L-band type are considered part of the basic network.

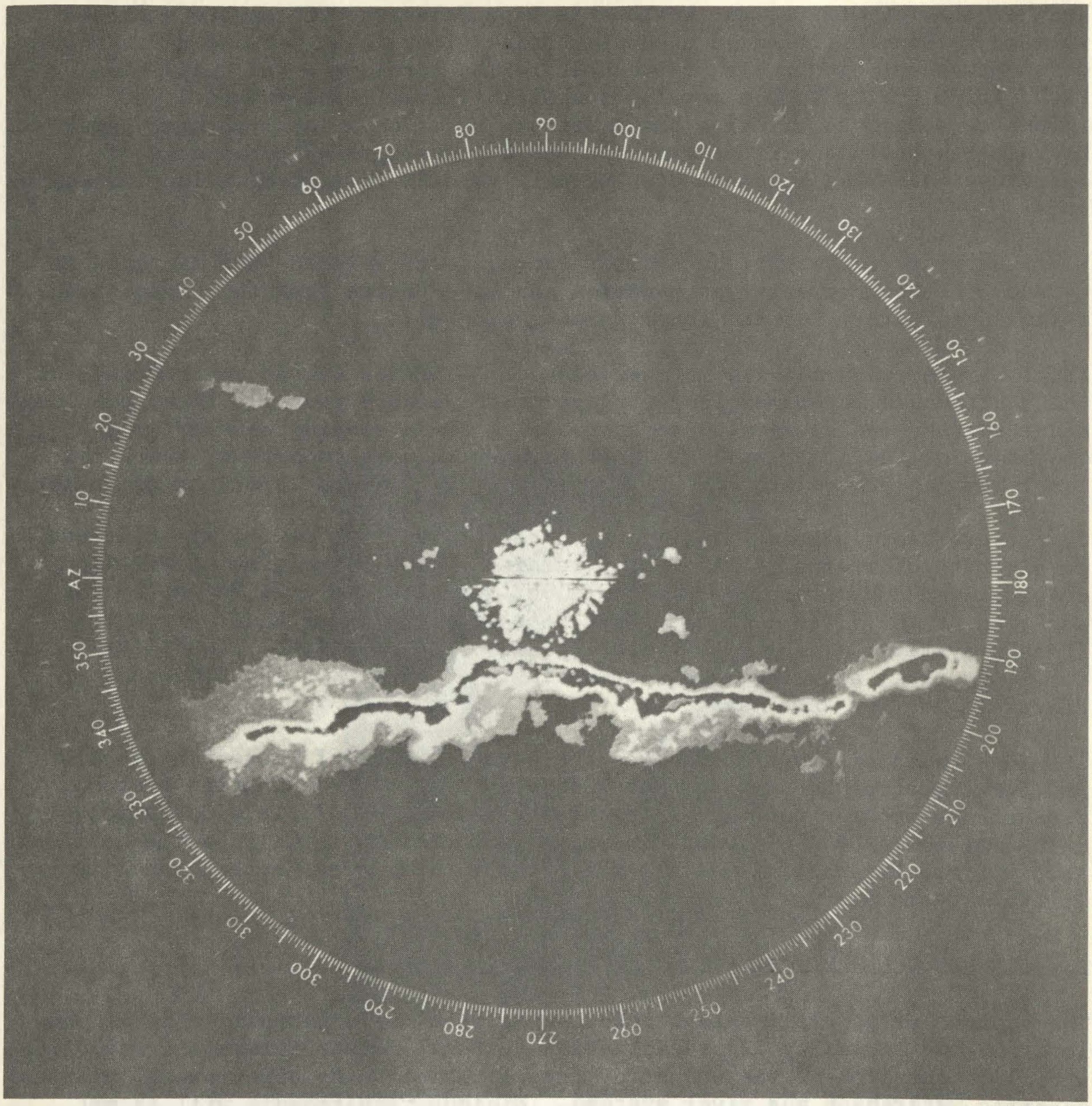


Figure 9.--PPI presentation of a squall line with VIP echo intensity contouring.

A depiction or summary of the situation as determined by radar will be provided periodically (normally hourly) on a national basis (fig. 10). A more frequent access will be provided on a regional basis. Radar summary charts showing the distribution of radar detectable weather over the continental United States are transmitted over the NAFAX and NAMFAX facsimile circuits as frequently as possible and hourly during periods of adverse weather. Manual methods are currently used to produce these summaries and depictions. As soon as possible, the process will be automated and improved through the use of automated quantization (VIP), processing (RADAP) and communications hardware, and techniques. Special applications requiring information at intervals more frequent than hourly will be served by a form of remote interrogation system.

To support general river forecasting the local RADAP systems will be used to interpret the radar in terms of accumulated rainfall over specific watersheds and will automatically and routinely disseminate the information to the appropriate River Forecast Centers.

Aviation safety is a special consideration in the design of and access to the radar system. Flight Service Stations (FSS) will have remote real-time access to basic network radar information in much the same manner as WSOs and WSFOs. In addition, they and flight control facilities will be given access to the routine periodic text messages and composited depictions provided by the National Centers.

C. SPECIAL DEPARTMENT OF DEFENSE APPLICATIONS

To successfully conduct tactical and strategic military operations, training activities, and support functions, decisions must be made at a centralized location where all the facts are known. To ensure that information is readily available and current to the decision maker, command and control systems are being designed and installed which provide an automated data base. This data base must include near real-time weather radar observations from systems located at military installations for the protection of military forces, in-flight weather watches, and combat training operations.

Most decisions, faced by the military manager, require future estimates of weather conditions over a large geographical area. The weather forecaster can provide these estimates through the use of automated forecasting facilities which automatically collect and collate all observed information. Accordingly, significant radar weather information must be communicated in near real-time to the weather central for use in solving the forecast problem. The DOD will need in the 1980s, a digital radar data acquisition system to collect and store radar information at the centralized forecasting facility.

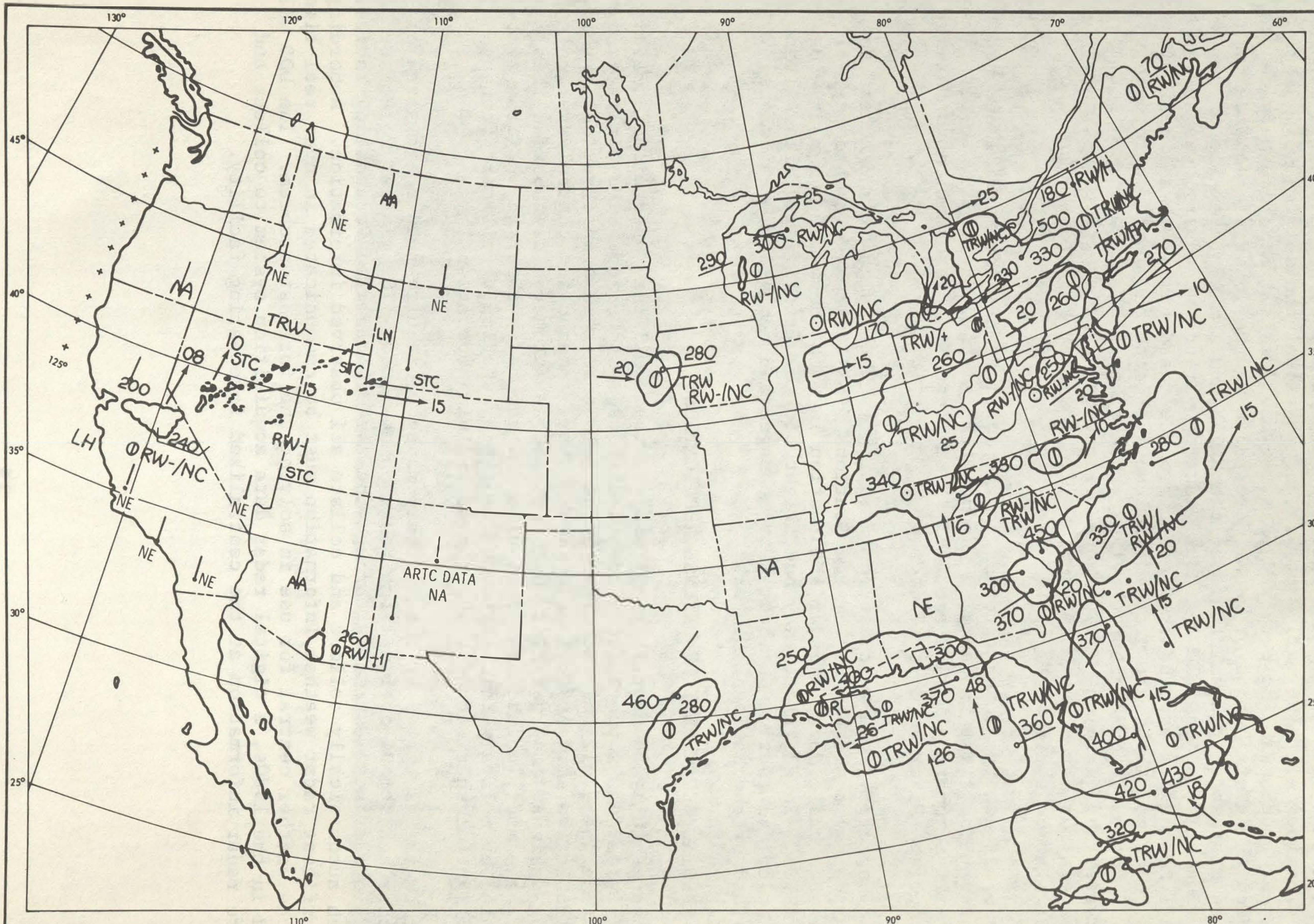


Figure 10.--Composite RADAR chart for facsimile transmission.

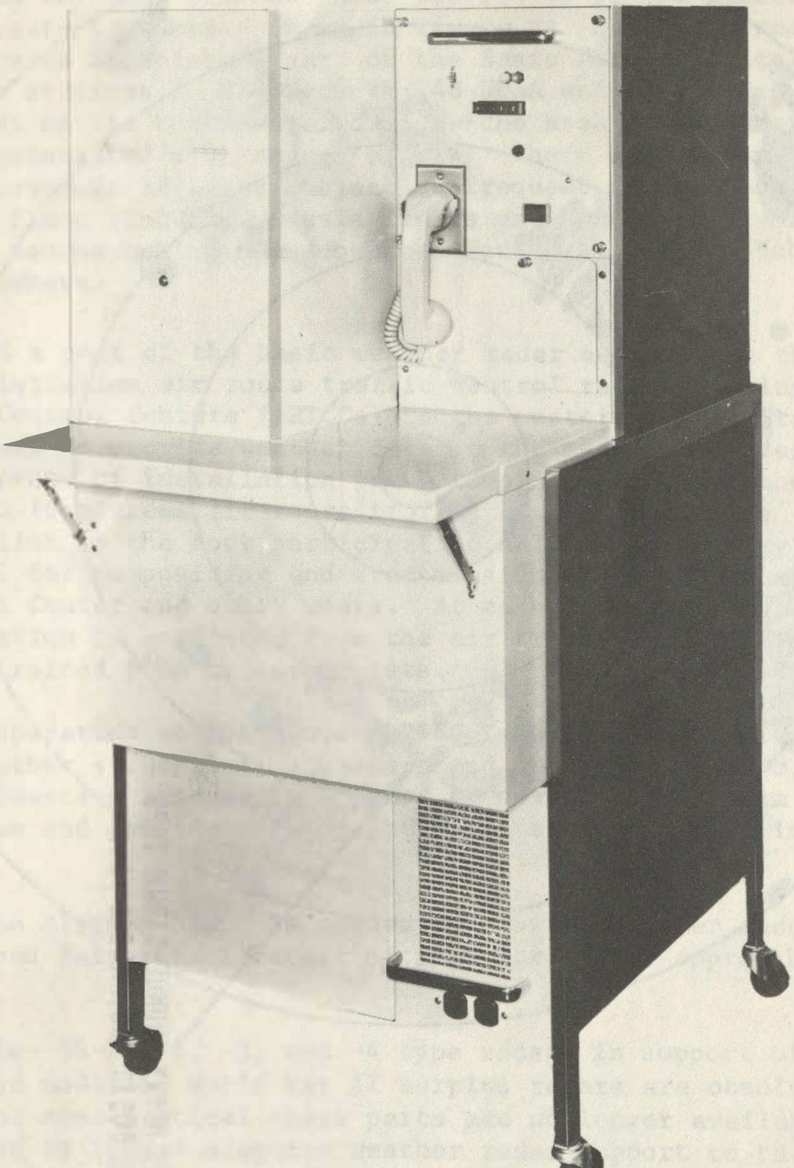


Figure 11.--WBRR transmitter and on-line monitor.

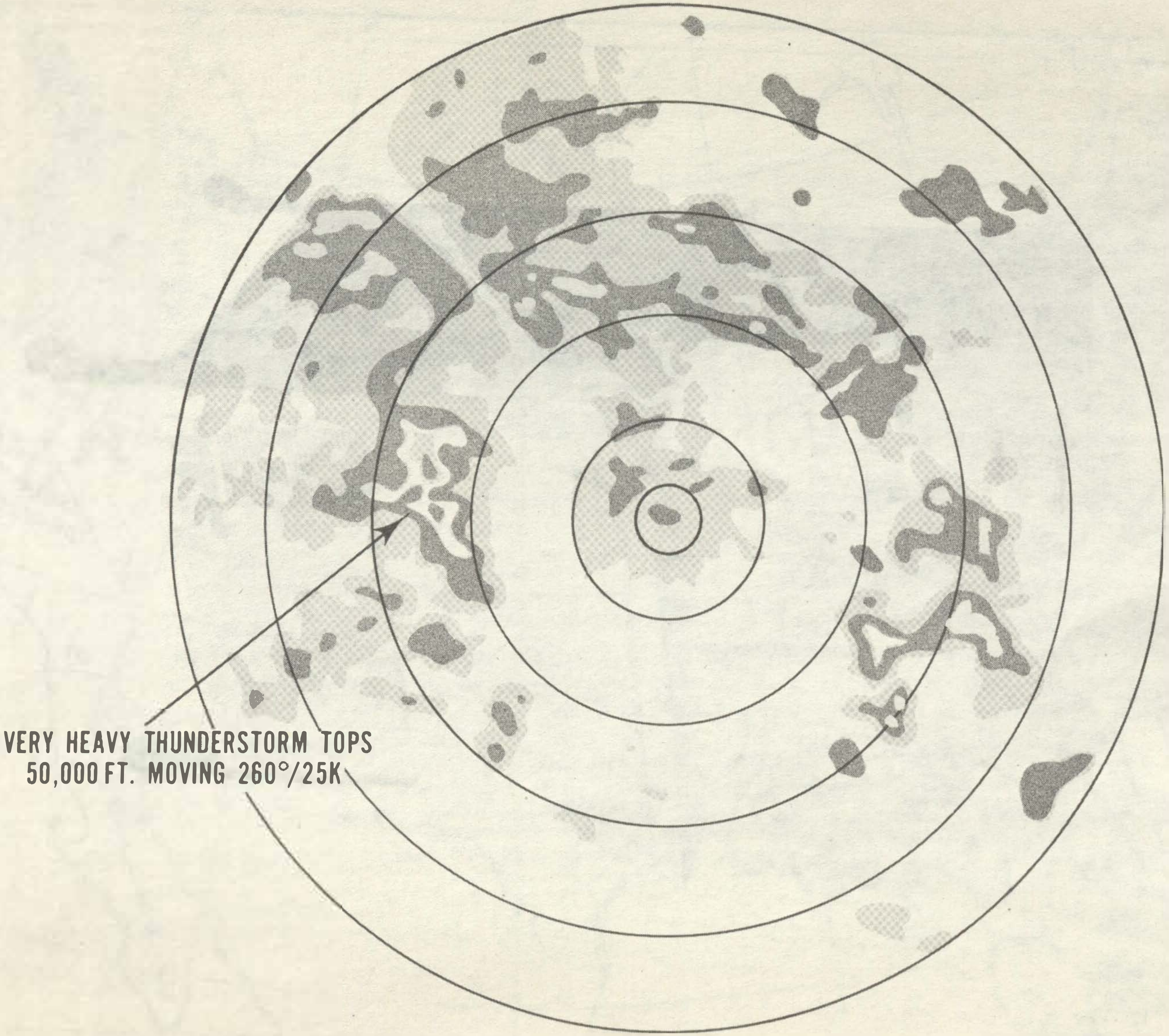


Figure 12.--WBRR remote presentation showing VIP echo intensity contouring (5 intensity levels).

IV. CURRENT PROGRAM AND DEFICIENCIES

A. COVERAGE

An interagency basic weather radar network has been constituted to provide radar services to the Nation. This operational system includes 51 WSR-57 radars operated by the National Oceanic and Atmospheric Administration and 15 AN/FPS-77, AN/CPS-9, and AN/FPS-41 weather radars operated by the Department of Defense on an interim basis. Also participating in the Network are 23 AN/FPS-77 and AN/CPS-9 weather radar facilities of the Department of Defense acting as alternate stations. Shown in figure 13, the basic weather radar network operates as an integral part of the Basic Meteorological Services System. Of the stations in the Network, 48 NOAA and 15 Defense facilities are located east of the continental divide--the area of greatest potential for disasters associated with severe storms. There are five major gaps in weather radar coverage of areas subject to frequent severe thunderstorms, tornadoes, and flash flooding. Basic radars are needed in the following areas: eastern Texas, southern Virginia, southern New York, western Nebraska, and eastern North Dakota.

Also considered a part of the basic weather radar network are the Federal Aviation Administration air route traffic control radars serving four Air Route Traffic Control Centers (ARTCCs) in the western United States. These radars are needed to provide weather data in the mountainous regions of the west, where expense of installation prevents placement of weather radars. The information from these air route traffic control radars is transmitted via microwave link to the four participating ARTCCs for display and to the Salt Lake ARTCC for compositing and transmission to the National Severe Storms Forecast Center and other users. At each participating ARTCC, weather information is extracted from the air traffic control radar scopes by a staff of trained NOAA meteorologists.

An additional operation at the Denver ARTCC is needed to provide radar coverage of weather situations of western and southern Colorado, southeastern Utah, and northeastern Arizona in support of severe local storm forecast and warning programs and for identifying potential areas of lightning-caused forest fires.

Also, use of the Alaskan ARTCC is needed to provide weather radar data to the Anchorage and Fairbanks forecast offices for storms approaching the Alaskan coast.

NOAA now operates 38 WSR-1, -3, and -4 type radars in support of local warning programs. These modified World War II surplus radars are obsolete and difficult to maintain, and some critical spare parts are no longer available. These radars must be replaced to insure adequate weather radar support to the local warning program. In addition, there are 28 locations where local warning radars are needed. The DOD now operates local warning radars as shown in figure 14.

B. FREQUENCY AND DISTRIBUTION OF OBSERVATIONS

Weather radar observations are made hourly on a scheduled basis when precipitation is observed to support general forecasting programs. Observations

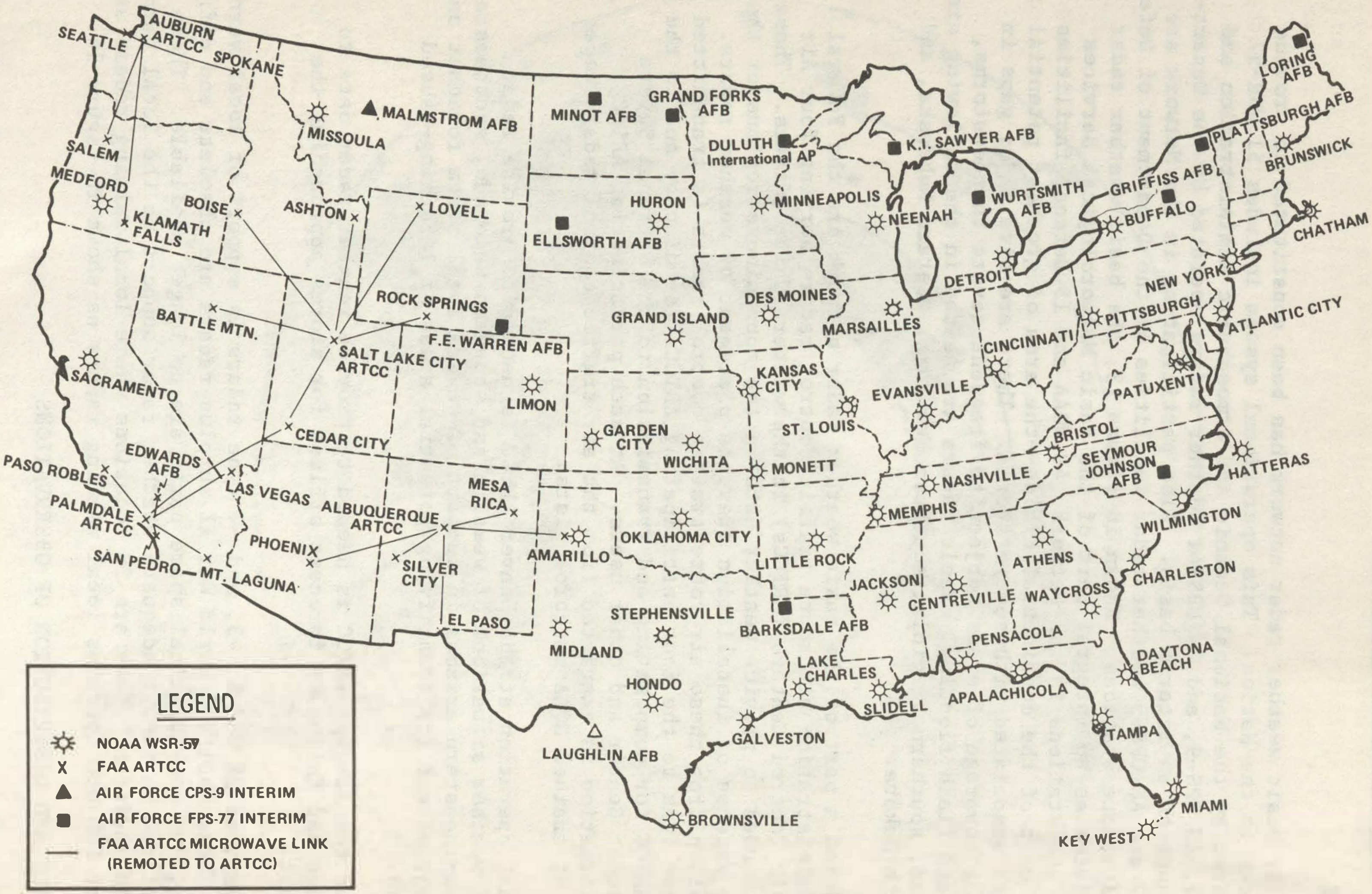


Figure 13.--U.S. Basic Weather Radar Network.

are disseminated to users by composite facsimile maps, teletypewriter reports, and radar remoting systems (WBRR). Each network radar station transmits coded reports hourly, and special reports if necessary, to the Radar Analysis and Development Unit at Kansas City, Mo. Here a composite map is made from the individual radar reports, including certain Air Force reports, and the map is transmitted on the National Facsimile (NAFAX) circuit to the National Weather Service Offices and to other government and nongovernment subscribers. A composite of the FAA air traffic control weather data from the western third of the U.S. is included on the Radar Summary Chart as shown in figure 10.

Weather radar remoting systems are installed on 32 of the basic network radars to transmit the radar scope information to various users. Weather Service Forecast Offices can dial-in to those radar sites having WBRR transmitters to follow, in real time, the development and movement of meteorological conditions affecting their respective areas of interest. In times of developing severe weather this permits the forecaster to issue timely forecasts or revisions of forecasts of these conditions.

WBRR recorders are used:

- At WSFOs to provide on-call data from several radars in the WSFO areas of responsibility. The radar data are used to assist in the preparation of forecasts and warnings of severe local storms, flash floods, and hurricanes.

- At WSOs, where severe local storms are infrequent, to provide the required radar information most of the time over the WSO county warning area. During the infrequent severe local storms, extensive use is made of voice hotline communications between the WSO and the radar station to supplement the remoted radar picture.

- At WSOs, which have a local warning radar, to supplement the coverage of that radar when the local warning radar does not adequately cover the county warning area.

- At the FAA's central flow control facility to aid in routing air traffic to avoid areas of severe weather and to improve the flow of air traffic.

Experience over the past several years has shown that current remote displays do not present weather echoes with sufficient definition and resolution to permit the detailed analysis required to support local warning programs in areas of frequent severe storms.

The individual radar reports which are sent to Kansas City for compositing are also relayed over teletypewriter circuits for additional dissemination. Narrative reports are prepared at all NWS basic network radar stations at least hourly and distributed over local and regional teletypewriter circuits to forecast offices, radio, television, and other users.

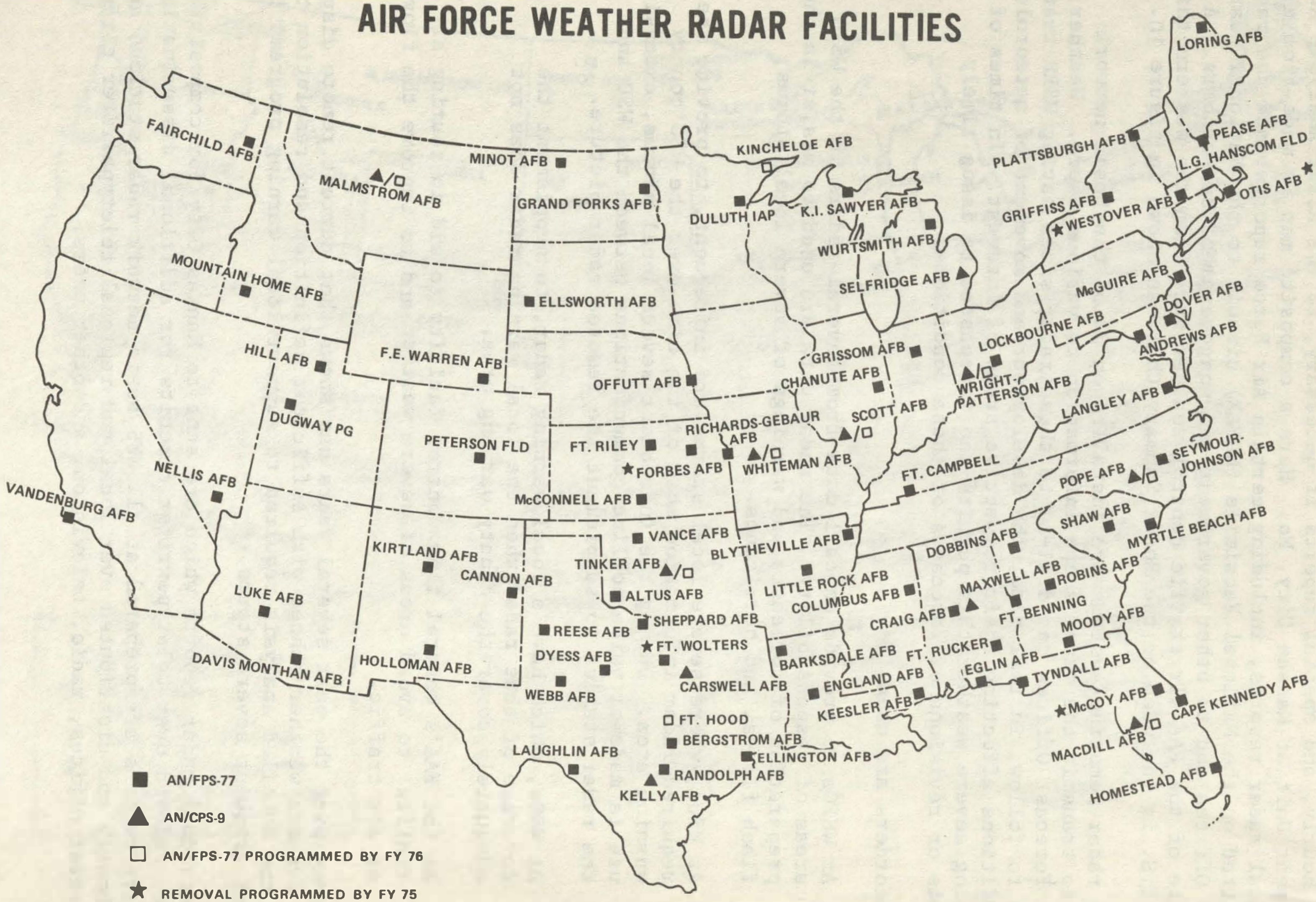


Figure 14.--DOD Weather Radars.

C. AUTOMATION

At present, manual methods are used for taking weather radar observations and then collecting and compositing them for facsimile transmission. Time delays are encountered, and substantial manpower is required. The system developed for automated processing (RADAP) of weather radar data and the program for Automation of Field Operations and Services (AFOS) will allow for mutual exchange of weather radar data, compositing, and melding radar and satellite data.

Estimates of rainfall rates and amounts are made manually to support hydrologists and meteorologists in flood and flash flood warning programs. At some WSR-57 locations video integrators and processors (VIPs) have been installed to aid the operators in determining the intensity of echoes and in estimating rainfall rates and amounts. The VIP provides simultaneous display of six contours of echo intensity on PPI scopes and remote displays. The calibrated contours of echo intensity add an important dimension for the radar operator and to remote displays by providing current quantized information on the intensity of all echoes presented. Use of VIP has significantly improved the detection and warning capabilities provided to the hydrologists and meteorologists responsible for monitoring storm events. Additional VIPs are needed to complete implementation of these equipments on the WSR-57 radars.

Through project D/RADEX, NOAA is developing techniques for automatically processing weather radar data and providing estimates of rainfall amounts by the river basins. Project D/RADEX is discussed in detail in a succeeding section of this Plan. Radar processing equipment (RADAP) and techniques developed as a result of D/RADEX are needed for most WSR-57 radars and local warning radars in flood-prone areas to provide better estimates of rainfall rates and rainfall amounts.

RADAP will automatically determine echo intensities, movement, area coverage, and echo tendencies to aid the operator in providing more accurate and timely data for issuance of local advisories and warnings of severe storm conditions.

D. CURRENT DEVELOPMENTAL PROGRAMS

A NOAA project to digitize and process radar data (D/RADEX) was established in 1970 to utilize more effectively the full potential of radar data. Its fundamental concept is to digitize the data to enable immediate real-time processing and in turn provide the potential capability for interpreting the data quantitatively for a variety of applications and to rapidly communicate the information to both users and other processing systems. The scope of the project includes the development of techniques utilizing computers for applying the radar intelligence to user requirements.

For D/RADEX, digitizers, minicomputers, and other peripheral equipment have been installed at five operational radar sites to acquire data for further research and development and to operationally test the effectiveness of the equipment and procedures. Four sites (fig.15) form a Midwest test bed in the heart of the severe weather region. The fifth site is a special test site at Pittsburgh, Pa., and is used primarily to develop techniques (before implementing them in the larger test bed) and to focus on applications related to flash flood warning services.

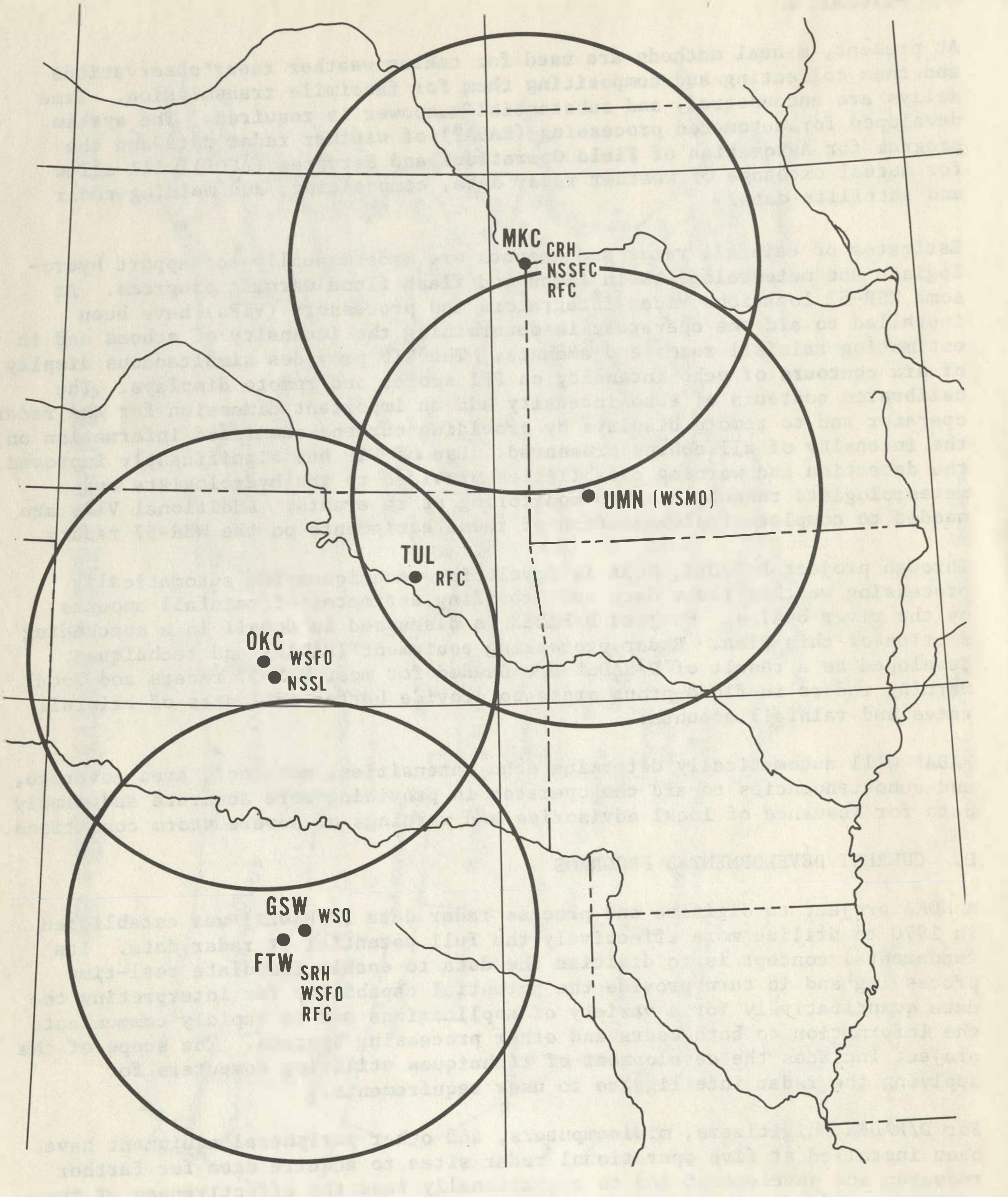


Figure 15.--D/RADEX four station test bed.

Currently undergoing operational tests are procedures and techniques which:

- Display and document the echo intensity for a radius of 125 nautical miles of the radar site.
- Monitor the entire area for peak intensities and keep track of the amount of area covered by various intensities.
- Compute and accumulate the amount of rainfall over all watersheds covered by the radar.
- Merge multisite radar data with simultaneous satellite data.
- Automatically relay data to River Forecast Centers.

This work is being pursued in conjunction with development plans for the extensive Automation of Field Operations and Services (AFOS). In this respect, the overall problems of the distribution of processing functions and the timely delivery of radar information are being studied.

It is expected that the test bed will be operated through FY 1974, at which time that equipment will become operational and specifications for the operational equipment for other sites will be completed.

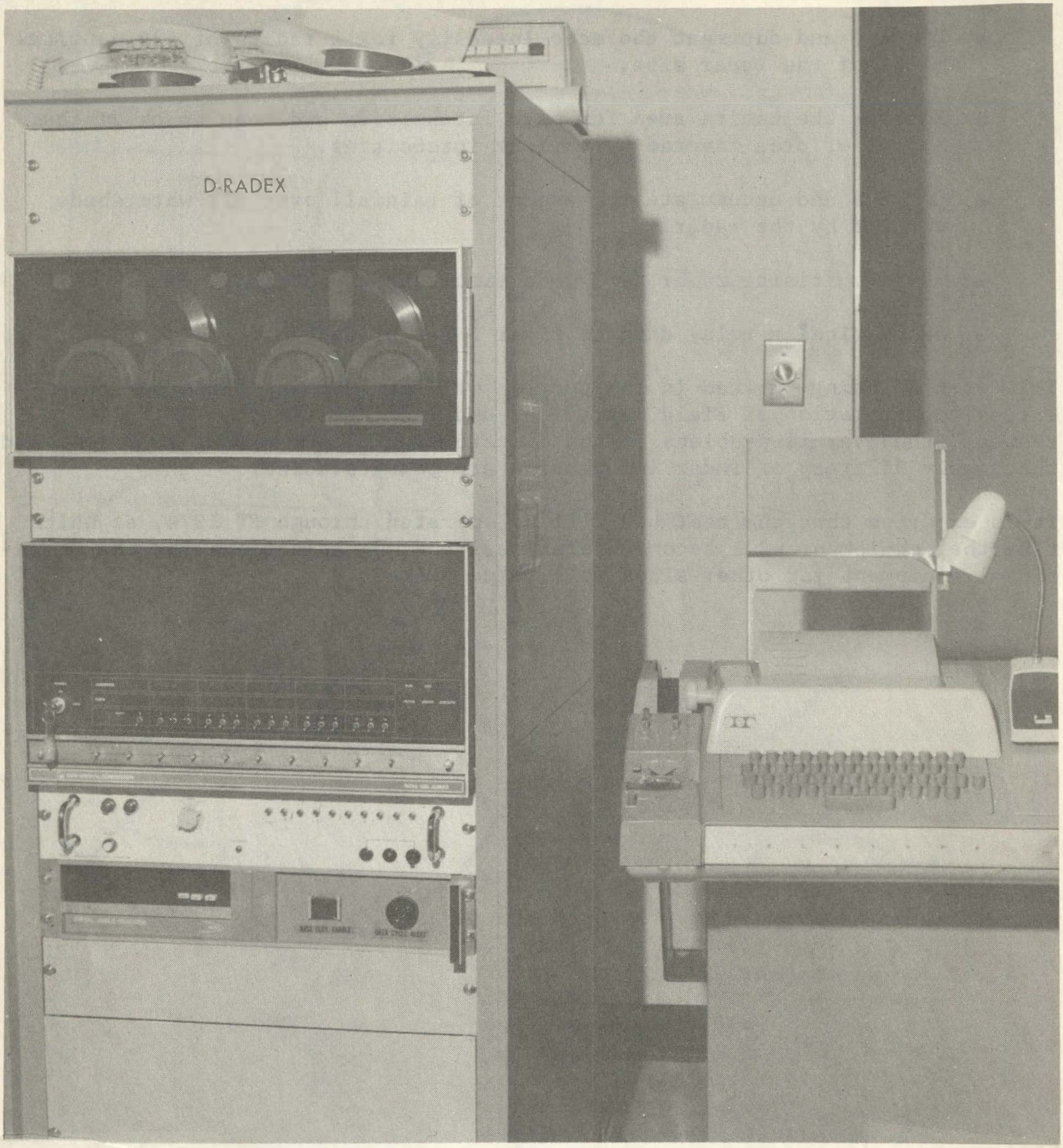


Figure 16.--D/RADEX equipment.

V. FUTURE PLANS

A. IMPLEMENTATION PLAN

The following weather radar program implementation plan is based on the previously stated operational concepts and the limitations and deficiencies of the present program. The plan includes completion of the basic weather radar network, replacement of obsolete local warning radars, addition of a number of local warning radars in areas frequented by severe local storms and flash flooding, acquisition of Air Force tactical weather radars and the implementation of radar data processing equipment, and radar remoting systems. Funds necessary to implement these improvements are given in table 1.

1. Basic Weather Radars--The existing limitation of coverage identified in the basic weather radar network will be eliminated by the addition of five radars. Basic network radars are planned by NOAA for installation in southern Virginia, south-central New York, eastern North Dakota, eastern Texas, and western Nebraska (see fig. 17).

2. Local Warning Radars--NOAA plans to provide most weather service offices in severe weather areas with radars. Local warning radars will replace obsolete World War II surplus radars now in operation at 38 Weather Service Offices, and an additional 28 Weather Service Offices will be equipped with modern local warning radars. These radars also serve as backup to the basic network radars. Table 2 summarizes the local warning radar plan. Locations are also shown in figure 17.

3. Remoting System--Narrow-band radar remoting systems and components are programmed for procurement beginning in FY 1975. Twenty-four basic network radar sites and seven local warning radars in critical weather areas will receive radar remoting transmitters. Forty-seven WSFOs/WSOs will be equipped with radar remoting system recorders to provide weather radar information in support of forecast, warning, and aviation briefing programs. Thus, radar data from all basic network radars will be available to about 100 weather service offices. The radar data will be obtainable on an as-needed dial-in basis at most offices, and some receivers will be connected by a dedicated telephone line to a weather radar site. Table 3 summarizes NOAA's radar remoting system implementation schedule. Some radar remoting receivers will be relocated when local warning radars are installed.

4. Video Integrator and Processor (VIP)--The video integrator and processor has proved its usefulness in the local warning program and in aiding in rainfall estimates. NOAA plans to procure an additional 27 units to complete implementation on the basic network radars. VIPs will be included as part of the local warning radars.

Table 1.--Resources Required to Achieve Programmed Goals*

Programmed Goals		FY 1974 Pos	FY 1974 $K	Phase I Pos	Phase I $K	Phase II Pos	Phase II $K	Phase III Pos	Phase III $K	Phase IV Pos	Phase IV $K	Phase V Pos	Phase V $K
AIR FORCE TACTICAL	Capital				2570								
RADARS	Optns												
BASIC NETWORK RADARS													
S. Va. & E. Texas	Capital		420		420								
	Optns					12	260	12	260	12	260	12	260
S. New York	Capital				420								
	Optns							6	130	6	130	6	130
North Dakota	Capital						420						
	Optns									6	130	6	130
Nebraska	Capital								210		210		
	Optns											6	130
Basic Network Radars	Capital		420		840		420		210		210		0
Summary	Optns		0		0	12	260	18	390	24	520	30	650
	Maint.		0	2	70	3	105	3	105	5	175	5	175
LOCAL WARNING	Capital	0	1500		2690		2298		2051		722		0
RADARS	Optns	0	0	4	62	28	454	36	701	44	895	44	1016
	Maint.	0	0	0	8	2	115	3	155	4	187	4	187
RADAR ADJUNCTS													
VIP	Capital				225								
	Optns				0								
Remoting	Capital				350		580		430				
	Optns				0	0	85	0	235	0	370	0	370
RADAP	Capital				315		700		700		350		
	Optns			0	30	0	120	0	228	0	340	0	390
REPLAY	Capital						150		200		250		
	Optns						0						
Radar Adjunct	Capital	0	0	0	890	0	1430	0	1330	0	600	0	0
Summary	Optns	0	0	0	30	0	355	0	463	0	710	0	760
	Maint.	0	0	0	0	3	99	11	363	19	627	25	825
FAA COOPERATIVE													
Denver	Optns			7	140	7	140	7	140	7	140	7	140
Alaska	Optns					7	142	7	142	7	142	7	142
FAA Cooperative Summary				7	140	14	282	14	282	14	282	14	282
RADAR STAFF	Optns			6	142	6	142	6	142	6	142	6	142
SUMMARY	Capital	0	1920	0	6990	0	4148	0	3591	0	1532	0	0
	Optns.	0	0	17	374	60	1493	74	1277	88	2549	94	2850
	Maint.	0	0	2	78	8	319	17	623	28	989	34	1187
TOTAL		0	1920	19	7442	68	5960	91	5491	116	5070	128	4037
AVAILABLE RESOURCES	Capital & Optns	0	1920	0	1920	17	4794	60	5641	74	4868	88	4081
	Maint.	0	0	0	0	2	78	8	319	17	623	28	989
	Total	0	1920	0	1920	19	4872	68	5960	91	5491	116	5070
NET CHANGE REQUIRED		0	0	+19	+5522	+49	+1088	+23	-469	+25	-421	+12	-1033

*All post 1974 activity is for planning purposes only and does not represent a commitment in scheduling or funding.

PLANNED LOCATIONS OF NEW NETWORK, LOCAL WARNING AND FAA ARTCC RADARS (FY74-FY78)

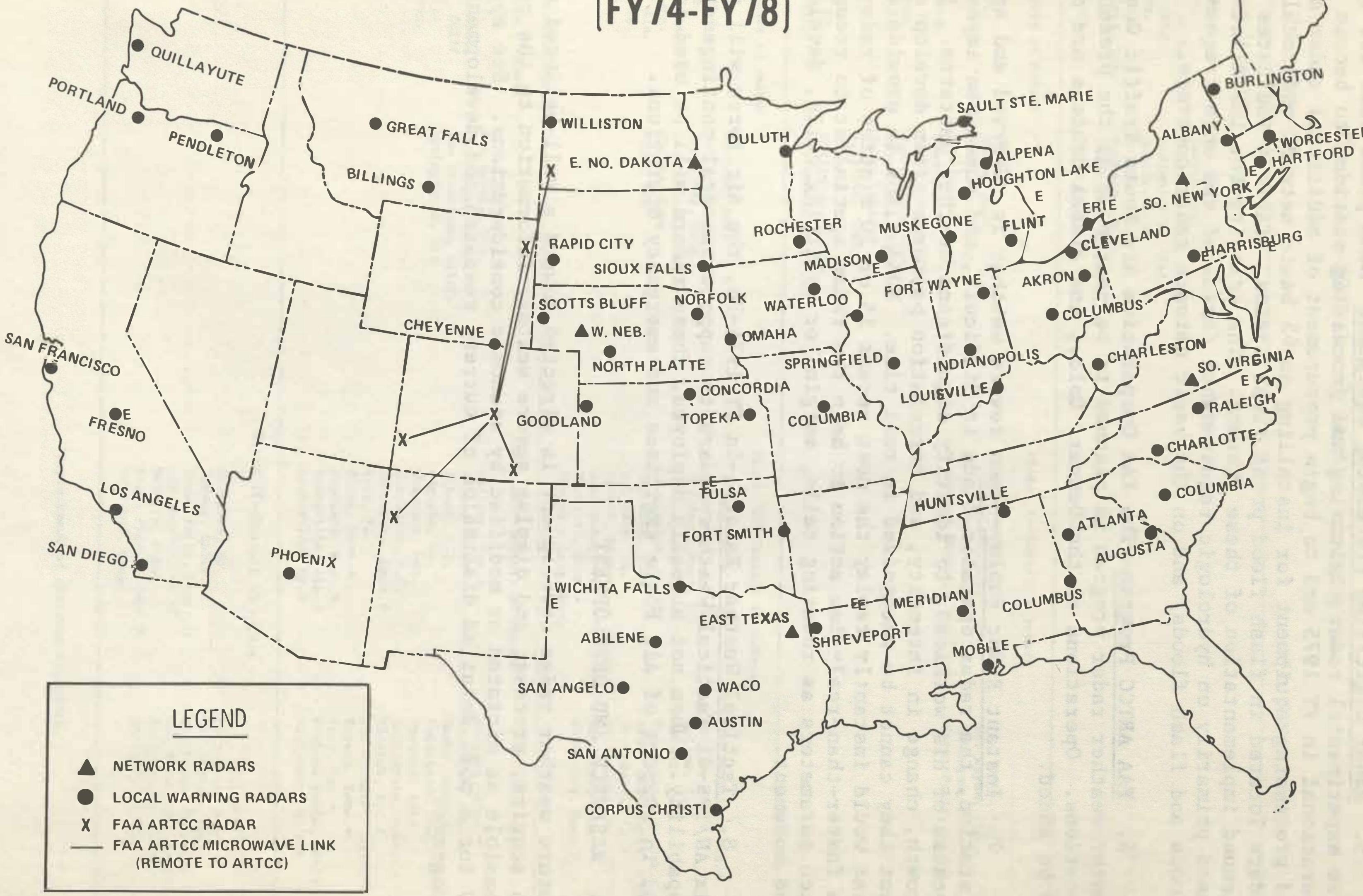


Figure 17.--NOAA Planned Installations.

5. Radar Digitizing Processing Equipment--NOAA plans call for the present five experimental radar digitizing and processing stations to become fully operational in FY 1975 and to begin procurement of additional radar digitizing and processing equipment for installing on 65 basic network and local warning radars located in flash flood prone river basins. Table 4 indicates the planned implementation of these systems. The priority for installation is based primarily on hydrologic requirements (areas of the more frequent floods and flash floods) and on the basic network radar coverage.

6. FAA ARTCC Program--The FAA Cooperative Air Route Traffic Control Center weather radar program is planned to be continued at the present four locations. Operations at the Denver, Colo., and Alaska centers are planned to be added.

7. Instant Radar Replay--When severe weather is observed and approaching a station, the radar operator finds it difficult, and sometimes impossible because of his workload, to identify significant weather patterns. Echo growth, change in intensity, and circulation patterns often develop so slowly that they cannot be recognized in real time. NOAA plans to provide a device that would instantly replay the most recent 15 or 20 minutes of radar data in faster-than-real-time action to help the radar specialist to recognize such parameters as rotating cells, merging or splitting cells, development, and movement.

8. Tactical Weather Radars--In FY 1974-76, the Air Force will procure six AN/TPS-41 Tactical Weather Radars to support tactical contingency combat capability. When not actually deployed, these radars will be used in training and in support of Air Force exercises and emergency operations.

B. RESEARCH AND DEVELOPMENT

Future weather radar development is directed toward a well-balanced system to acquire, process, and display severe weather information to the extent feasible as dictated or modified by economic considerations. See appendix IV for a more detailed discussion of current research and development programs.

Table 2.--NOAA local warning radar plan.

Procurement schedule		Installation schedule	
FY 74--Procure 18 radars			
Alpena, Mich.	Ft. Wayne, Ind.		
Austin, Tex.	Harrisburg, Pa.		
Charleston, W. Va.	Houghton Lake, Mich.		
Cleveland, Ohio	Indianapolis, Ind.		
Columbus, Ga.	Mobile, Ala.		
Columbus, Ohio	Moline, Ill.		
Corpus Christi, Tex.	Muskegan, Mich.		
Duluth, Minn.	Sault Ste. Marie, Mich.		
Ft. Smith, Ark.	Sioux Falls, S. Dak.		
Phase I--Procure 26 radars		Phase I--Install 8 radars	
Akron, Ohio	NWSTTC	Austin, Tex.*	Ft. Smith, Ark.*
Albany, N.Y.	Omaha, Nebr.	Cleveland, Ohio*	Ft. Wayne, Ind.*
Atlanta, Ga.	Pendleton, Oreg.	Columbus, Ohio*	Muskegan, Mich.*
Augusta, Ga.	Quillayute, Wash.	Corpus Christi, Tex.*	Sioux Falls, S. Dak.
Billings, Mont.	Raleigh, N.C.		
Burlington, Vt.	Rapid City, S. Dak.		
Cheyenne, Wyo.	San Antonio, Tex.		
Columbia, S.C.	Shreveport, La.		
Erie, Pa.	Tulsa, Okla.		
Flint, Mich.	Waterloo, Iowa		
Hartford, Conn.	Wichita Falls, Tex.		
Louisville, Ky.	Williston, N. Dak.		
Madison, Wisc.	Worcester, Mass.		
Phase II--Procure 13 radars		Phase II--Install 21 radars	
Abilene, Tex.	Norfolk, Nebr.	Alpena, Mich.	Indianapolis, Ind.*
Charlotte, N.C.	North Platte, Nebr.	Atlanta, Ga.*	Mobile, Ala.*
Columbia, Mo.	Rochester, Minn.	Billings, Mont.	Moline, Ill.
Concordia, Kans.	Scottsbluff, Nebr.	Burlington, Vt.	NWSTTC
Goodland, Kans.	Topeka, Kans.	Charleston, W. Va.	Rapid City, S. Dak.
Huntsville, Ala.	Waco, Tex.	Columbia, S.C*	Sault Ste. Marie, Mich.
Meridian, Miss.		Columbus, Ga.	Shreveport, La.*
		Duluth, Minn.	Tulsa, Okla.*
		Harrisburg, Pa.	Waterloo, Iowa
		Hartford, Conn.*	Worcester, Mass.*
		Houghton Lake, Mich.	
Phase III--Procure 9 radars		**Phase III**--Install 24 radars	
Fresno, Calif.	San Angelo, Tex.	Abilene, Tex.*	Madison, Wisc.*
Great Falls, Mont.	San Diego, Calif.	Akron, Ohio*	Meridian, Miss.*
Los Angeles, Calif.	San Francisco, Calif.	Albany, N.Y.	Omaha, Nebr.*
Phoenix, Ariz.	Springfield, Ill.	Augusta, Ga.	Pendleton, Oreg.
Portland, Oreg.		Cheyenne Wyo.	Phoenix, Ariz.
		Charlotte, N.C.	Quillayute, Wash.
		Concordia, Kans.*	Raleigh, N.C.*
		Erie, Pa.	San Antonio, Tex.*
		Flint, Mich.*	Topeka, Kans.*
		Goodland, Kans.*	Waco, Tex.*
		Huntsville, Ala.*	Wichita Falls, Tex.*
		Louisville, Ky.*	Williston, N. Dak.
		Phase IV--Install 13 radars	
		Columbia, Mo.	Rochester, Minn.
		Fresno, Calif.	San Angelo, Tex.
		Great Falls, Mont.	San Diego, Calif.
		Los Angeles, Calif.	San Francisco, Calif.
		Norfolk, Nebr.	Scottsbluff, Nebr.
		North Platte, Nebr.*	Springfield, Ill.
		Portland, Oreg.	

*Replacement of obsolete equipment.

Table 3.--DOC radar remoting system implementation schedule.

WBRR transmitters		WBRR receivers	
FY 74		FY 74	
None planned		None planned	
Phase I		Phase I	
Daytona Beach, Fla.	Key West, Fla.	Albany, N.Y. WSFO	New York (JFK), N.Y.
Evansville, Ind.	Lake Charles, La.	Asheville, N.C.	New York (LGA), N.Y.
Harrisburg, Pa.	NWSTTC	Charleston, W. Va. WSFO	Oklahoma City, Okla. WSFO
Hatteras, N.C.	Tampa, Fla.	Dallas, Tex.	Omaha, Nebr.
Jackson, Miss.	Wilmington, N.C.	Des Moines, Iowa WSFO	Orlando, Fla.
		Detroit, Mich. WSFO	Peoria, Ill.
		Indianapolis, Ind.	Raleigh, N.C. WSFO
		Little Rock, Ark.	St. Cloud, Minn.
		Minneapolis, Minn. WSFO	St. Louis, Mo. WSFO
		Newark, N.J.	Trenton, N.J.
Phase II		Phase II	
Amarillo, Tex.	Little Rock, Ark.	Allentown, Pa.	Lynchburg, Va.
Binghamton, N.Y.	Minneapolis, Minn.	Beckley, W. Va.	Mansfield, Ohio
Charleston, W. Va.	Moline, Ill.	Colorado Springs, Colo.	Norfolk, Va.
Columbus, Ga.*	Muskegan, Mich.	Dubuque, Iowa	Providence, R.I.
E. Texas*	Oklahoma City, Okla.	Ft. Meyers, Fla.	Rochester, N.Y.
Ft. Smith, Ark.	S. Virginia*	Greensboro, N.C.	Syracuse, N.Y.
Ft. Wayne, Ind.	Wichita, Kans.	Jackson, Miss.	Youngstown, Ohio
Grand Island, Nebr.		Lubbock, Tex.	
Phase III		Phase III	
Alpena, Mich.*	Midland, Tex.	Bridgeport, Conn.	Marquette, Mich.
Austin, Tex.*	Missoula, Mont.	Chattanooga, Tenn.	Roanoke, Va.
Corpus Christi, Tex.*	Sacramento, Colo.	Concord, N.H.	Valentine, Nebr.
Duluth, Minn.	Sault Ste. Marie, Mich.*	Elkins, W. Va.	Williamsport, Pa.
Honolulu, Hawaii	SE N. Dakota	Honolulu, Hawaii	Wilmington, Del.
Houghton Lake, Mich.	Waterloo, Iowa	Huntington, W. Va.	
Medford, Oreg.	W. Nebraska	Lakeland, Fla.	

*Deferred for radar installation.

Table 4.--NOAA Radar Digitization and Processing system (RADAP) implementation schedule

FY 74

None planned.

Phase I

Appalachicola, Fla.	Hatteras, N.C.	NWSTTC
Atlantic City, N.J.	Miami, Fla.	Patuxent, Md.
Binghamton, N.Y.	New Orleans, La.	Tampa, Fla.

Phase II

Charleston, S.C.	Ft. Wayne, Ind.	Moline, Ill.
Chatham, Mass.	Galveston, Tex.	New York, N.Y.
Cincinnati, Ohio	Harrisburg, Pa.	Pensacola, Fla.
Columbus, Ga.	Jackson, Miss.	St. Louis, Mo.
Daytona Beach, Fla.	Key West, Fla.	Waycross, Ga.
Evansville, Ind.	Lake Charles, La.	Wilmington, N.C.

Phase III

Alpena, Mich.	Charleston, W. Va.	Little Rock, Ark.
Athens, Ga.	Corpus Christi, Tex.	Marsailles, Ill.
Austin, Tex.	Des Moines, Iowa	Memphis, Tenn.
Bristol, Tenn.	Detroit, Mich.	Muskegan, Mich.
Brownsville, Tex.	E. Texas	Nashville, Tenn.
Buffalo, N.Y.	Ft. Smith, Ark.	Neenah, Wisc.
Centerville, Ala.	Garden City, Kans.	S. Virginia

Phase IV

Amarillo, Tex.	Huron, S. Dak.	Sacramento, Calif.
Brunswick, Maine	Limon, Colo.	Sault Ste. Marie, Mich.
Duluth, Minn.	Medford, Oreg.	S.E. N. Dakota
Grand Island, Nebr.	Midland, Tex.	Waterloo, Iowa
Hondo, Tex.	Minneapolis, Minn.	Wichita, Kans.
Houghton Lake, Mich.	Missoula, Mont.	W. Nebraska

APPENDIX I

BENEFITS OF WEATHER RADAR INFORMATION

The early identification of severe storms by radars provides valuable lead time in providing warnings to the public, allowing appropriate preventive actions. Weather radar information is an important part of community action plans involving severe weather.

As further evidence of the important role played by weather radar in the natural disaster warning system, pertinent excerpts from major natural disaster survey reports showing the needs for weather radar information follow:

- On the evening of May 11, 1970, there were tornadoes in Wisconsin, Iowa, Kansas, Ohio, and Texas, with the most massive tornado forming and touching down over the heart of Lubbock, Tex. The tornado killed 26 persons, injured 1,500, and totally destroyed more than 1,000 family units and damaged about 9,000 more. Property damage was estimated at more than $125 million. The ESSA (now NOAA) post-storm survey team calculated that as many as 125 lives were saved because of the effectiveness of the warning system. One finding of the survey team was that prompt, professional interpretation of the storm echoes on radar at the Lubbock Weather Service Office was the primary basis for the lifesaving warnings issued to Lubbock officials and citizens. However, this unit is a modified WW II surplus radar which has reached the end of its useful life.

- Hurricane Agnes battered the eastern seaboard of the United States for 4 days in June 1972. It was an unruly storm which severely tested the capabilities and skills of the Nation's weather and flood warning system. When it was finally over, a new record of damage stood: $3.5 billion in property destruction and 118 deaths.

  The National Advisory Committee on Oceans and Atmosphere survey team found the following items in regard to the radar observing system:

  - Radar coverage for the purpose of reporting precipitation amounts over the area should be improved.

  - The limitations of radar observation of rainfall amounts because of isolated operator interpretation (however assisted) should be removed by digitizing the returns and processing them at a central facility.

- Work should be initiated to determine optimum ways of handling radar information to replace the current radar observer interpretation supplemented by the Video Integrator and Processor (VIP).

- In a few hours during the late afternoon and evening of June 9, 1972, a record rain fell on the Black Hills of South Dakota. A stationary group of thunderstorms over the central hills dumped as much as 15 inches of rain in some locations in less than 6 hours.

  The rains resulted in record-breaking floods on streams draining the eastern slopes of the Black Hills. At least 236 people died, and property damage exceeded $100 million in Rapid City and the surrounding recreational areas.

  The NOAA survey team recommended that the Federal Plan for Weather Radars and Remote Displays be revised, and an acceptable local use radar or a remote from a WSR-57 site be substituted for those locations using remotes from Air Force FPS-77 radars. Further, they recommended that the remoting criteria in the Plan should be reviewed and updated to provide definitive information for all types of radars, local warning requirements, and distance of the remote site from the master.

- In the late hours of August 19, 1969, the remnants of hurricane Camille intensified rapidly over the mountains of Virginia, then turned to the eastern part of the State. In an 8-hour period, rain of 12-14 inches fell in the Virginia mountains, and amounts exceeding 27 inches occurred in one area.

  More than 100 people are known to have perished in the ensuing floods in the James River basin, most of them in the flash floods that devastated the mountain areas before dawn on August 20. Telephone lines were destroyed by the floodwaters and landslides preventing river and rainfall reports from reaching Weather Service offices. Warning actions were limited to attempts by police, local officials, and volunteers to alert and evacuate people in the path of the floodwaters.

  The following recommendations in regard to radar were detailed by the survey team:

  - WSR-57 radars be installed in the Bristol and South Boston, Va., areas, and the Washington radar operation moved to Patuxent River to bring radar coverage in Virginia to a level that will give a high degree of assurance of detecting heavy rainfall and severe local storms.

- A prototype radar digitizing system be procured to transmit the large volume of data from radar locations to River Forecast Centers in near real-time and be tested to determine if the system, and computer programs to relate radar data and "truth" reference rain gages, will meet the needs of the Hydrologic Services System.

- A flash flood warning system based on the weather radar network be implemented in 20 States along the Atlantic and Gulf coasts and inland about 300 miles. The system should include:

  -- Automatic rainfall reporting networks, with a minimum of 450 gages, located around 11 existing and planned radars; and

  -- Flash flood warning devices installed upstream from at least 50 communities to provide warnings where other techniques will not suffice.

- At 11:45 a.m. CST Sunday, February 21, 1971, the Police Department of Cleveland, Miss., reported to the Jackson, Miss., National Weather Service Forecast Office that a tornado had been sighted southwest of Cleveland. Between the time of the first sighting and the lifting of all tornado watches and warnings just before midnight, more than 50 sightings of tornadoes and funnel clouds were reported to NOAA Weather Service Offices at Shreveport, La., Jackson, Miss., and Memphis, Tenn. Many cities and towns in the paths of these storms suffered major damage, and the communities of Delta City, Inverness, Cary, Pugh City, and Little Yazoo, Miss., were virtually leveled.

  Civil Defense and Red Cross statistics indicate that in the three-State area affected by the tornadoes--Louisiana, Mississippi, and Tennessee--113 persons were killed, 3,003 were injured, and 611 homes were destroyed. Total property loss was estimated to be $19,000,000.

  The survey team recommended that the Federal Plan for Weather Radars and Remote Displays be reviewed to assure that those National Weather Service offices having tornado warning responsibilities are furnished with the tools essential to fulfilling their mission.

APPENDIX II

WEATHER RADAR SYSTEMS

To meet the requirements that have been presented in the Plan, several types of radars (see table 5) and remoting equipment are available. No single system meets all the requirements; therefore, a variety of equipment must be used.

Basic network weather radars with broad scale and local warning applications have significantly different characteristics than radars used only for local warning purposes. Basic weather radars must have the ability to detect and track severe storms over large areas without significant degradation or attenuation of the signal. Also required are high power, accurate presentation, measurement capabilities, and tunable within the operating band to minimize interference problems. Characteristics of a basic network radar are given in table 6.

An important accessory for weather radars is the integration and contouring device. One such device is the Video Integrator and Processor (VIP), developed by the National Weather Service and installed on about half of the WSR-57 radars. The VIP simultaneously displays six contours of echo intensity on the PPI scopes, including remote displays to aid the observer in rapidly identifying echo intensities and in estimation of rainfall rates. The use of the VIP for remote displays provides information on intensity levels of all echoes, eliminating the need for time-consuming manual methods.

The average cost of the WSR-57 system installed with all of the features shown in table 6 was about $265,000 in the period 1958-65 and is now an estimated $420,000. This included building, auxiliary power, utilities, tower, radome, etc.

Interim network and local warning weather radars are usually less sophisticated, lower powered and operate in C-band. As a result, some attenuation can be expected in heavy rainfall. Table 7 contains the required characteristics of these radars. Some of these type radars are currently in operational use. Their operational characteristics are listed in table 5.

The average cost of the WSR-74 system installed with the optional features shown in table 5 is estimated to be about $130,000. This includes emergency power, utilities, tower, radome, etc.

Table 5.--Characteristics of various radars.

Type	Primary user	Wave-length	Pulse direction and PRF	Peak trans-mitted Power	Type of antenna	Beam width	Type of sweep	Presentation	Maximum PPI range	Ranging accuracy
WSR-57 FPS-41	NWS Navy	10.3 cm	0.5 μsec--658 pps 4 μsec--164 pps	410 kw	12' parabola	2°	Automatic and manual in horizontal and vertical, either direction	PPI, off-center, PPI, RHI, R, A	250 n.mi.	±0.5%
*CPS-9	AF	3.2 cm	0.5 μsec--931 pps 5 μsec--186 pps	220 kw	8' parabola	1°	Manual and automatic in horizontal and vertical, either direction. Sector scan in both planes.	PPI, off-center, PPI, RHI, R, A	400 s.mi.	±0.1 mi.
FPS-106 FPS-81 FPS-77V	Navy Navy AF	5.3 cm 5.4 cm	2 μsec--324 pps	300 kw 250 kw	8' parabola	1.6°	Automatic and manual in azimuth and elevation 5 rpm.	PPI, R, A RHI	200 n.mi.	±0.5% at maximum range.
*WSR-1	NWS	10 cm	1 μsec--650 pps 2 μsec--325 pps	60 kw	6' parabola	4°	Automatic, 12 rpm, manual control of antenna tilt.	PPI, A	180 n.mi.	±1 mi.
*WSR-3 *WSR-4	NWS	10 cm	1 μsec--650 pps 2 μsec--325 pps	60 kw	6' parabola	4°	Automatic, variable speed to 12 rpm, reversible, automatic & manual control of antenna tilt.	PPI, A, RHI	180 n.mi.	±1 mi.
*Decca-41	NWS	3.2 cm	0.2 μsec--250 pps 2 μsec--250 pps	30 kw	2.6' high 14' wide	2.8° vert. 0.6 horiz.	Automatic, 5 rpm, manual elevation.	PPI	250 n.mi.	±1%
WSR-S1	NWS	5.4 cm	3 μsec--320 pps	250 kw	6' parabola	2.0°	Automatic and manual in horizontal and vertical, either direction. Gyro stabilized antenna.	PPI, RHI, R, A	250 n.mi.	±0.5%
MR-782	NWS	5.4 cm	2 μsec--250 pps	250 kw	8' parabola	1.5°	Automatic and manual in horizontal, manual in vertical, either direction.	Combined PPI/RHI	250 n.mi.	±0.5%
WR-100-5	NWS	5.4 cm	3 μsec--320 pps	250kw	8' parabola	1.5°	Automatic and manual in horizontal, manual in vertical, either direction.	PPI, RHI, R, A	250 n.mi.	±0.5%
WSR-74	NWS	5.4 cm	3 μsec--260/360 pps	250 kw	8' parabola	1.5°	Automatic and manual in horizontal, manual in vertical, either direction.	PPI, RHI, R, A	200 n.mi.	±0.5%
FPS-20 FPS-67	AF FAA	23 cm	6 μsec--360 pps	5,000 kw	40' wide 16' high	1.3° azi. 22° vert.	Automatic in azimuth	PPI	250 n.mi.	±1 mi.
ARSR-1E	FAA	23 cm	2 μsec--360 pps	5,000 kw	40' wide 11' high	1.35° horiz. 6.2° csc^2 vert.	Automatic PPI.	PPI	250 n.mi.	±1%
ARSR-2	FAA	23 cm	2 μsec--360 pps	5,000 kw	47' wide 23' high	1.2° horiz. 3.75° vert.	Automatic PPI.	PPI	250 n.mi.	±1%
FPS-103	AF	3.2 cm	2.5 μsec--400 pps	50 kw	2.5 parabola	3.6°	Automatic in horizontal 15 rpm. Manual in vertical	PPI	150 n.mi.	±1%

*Obsolete

Table 6.--Characteristics of a basic network radar.

Operating band: S-band (2,700-2,900 MHz)

Peak transmitted power: 500 kW (minimum)

Receiver sensitivity: -108 dbm

Pulse length: 4 microseconds plus an optional 0.5 microsecond pulse length for the high resolution necessary to detect critical storm features such as tornado "hooks."

Beam width, both horizontal and vertical: 2°

Radome, to permit operation in high winds.

Range normalization $\left(\frac{1}{\text{range}^2}\right)$ to 125 n.mi.

Capability to measure backscatter signal strength.

Calibration and measurement of backscatter signal strength to allow accuracy of measured rainfall rate within a factor of two.

Antenna elevation angle positioning accuracy ± 0.50°.

Antenna azimuth angle positioning accuracy ± 0.50°.

Range accuracy ± 1% of range.

PPI display ranges 50, 125, 250 n.mi.

RHI display ranges of 50, 125 n.mi.; height scale to 70,000 ft.

A-scope display ranges of 50, 125, 250 n.mi.

R-scope gate width variable between 5 and 25 n.mi.

Photographic PPI with camera

Video Integrator and Processor

Antenna azimuth rotation rate 3 to 5 rpm (both automatically and manually controllable in azimuth).

Antenna elevation scan rate 6 cpm (both automatically and manually controllable in elevation), sector variable 0°-90°.

Table 7.--Required interim network and local warning radar characteristics.

Operating band: Generally C-band (5,600-5,650 MHz)

Peak transmitted power: 250 kW (minimum)

Receiver sensitivity: -104 dbm

Pulse length: 2 or 3 microseconds

Beam width, both horizontal and vertical: 1.5°

Radome, to permit operation in high winds.

Range normalization $\left(\frac{1}{\text{range}^2}\right)$ to 125 n.mi.

Azimuth and elevation accuracy: ± 0.5°

Range, maximum displayed: 200 n.mi.

Displays: PPI, RHI, A

Antenna azimuth rotation rate: 3 rpm automatic
0-3 rpm manual

Antenna elevation scanning: -2 to +60° @ 4 cycles/minute, manual slewing

Video Integrator and Processor.

Air Traffic Control and Air Defense Radars

Long-range search radars of the FAA and Air Force can provide information on weather echo locations and useful estimates of echo intensity.

These radars are designed to do a specialized job--detecting aircraft and weather echoes are suppressed. However, they may be operated in modes that allow useful meteorological data to be obtained. Areas and patterns of moderate to heavy precipitation can be obtained, but quantitative data cannot. Also, echo height cannot be measured. Data are obtained by NWS meteorologists from a dedicated radar scope at the air traffic control centers. Meteorological information can be obtained from two types of FAA air traffic control radars. The characteristics of these radars are given in table 5.

The Air Force operates a number of long-range search radars having characteristics similar to FAA air traffic control radars as a part of the North American Aerospace Defense Command (ADC). By joint agreement, the National Weather Service personnel are assigned to selected ADC radar sites to make observations under specified hazardous conditions (principally hurricanes).

Weather Radar Remoting Equipment

There are three major types of weather radar remoting equipment in use by Federal agencies.

Wide-Band Remoting Systems

Wide-band remoting is used when it is necessary to have a radar scope (usually a PPI) an extended distance from the radar set to present radar information in real time without discernable degradation of detail. Either video coaxial cabling or a video microwave link is used between the radar set and the remote location. This type of remoting is expensive, costs an average of $50,000 per installation, and has significant disadvantages. For example, the remote display is not retained when the operator changes from normal PPI scan to another mode of operation, and voice communication between the remote and console operator requires a separate telephone channel. Remoting of this type is generally limited to about 1 mile because of the cost of the cable and installation. The terminal equipment (linedriver and remote scope) costs about $15,000, whereas cable, trenching, and ductwork cost about $60,000 per mile.

Narrow-Band Video Remoting Systems

Weather radar images can be transmitted over standard voice-grade telephone lines. This real-time remote presentation of storm patterns aids in accurate rapid analysis and enhances the timeliness and effectiveness of general weather forecasts.

Radar information is transmitted between the radar console and remote receiver locations using the principle of slow-scan television. The system provides three gray levels and when used with echo intensity contouring portrays up to six intensity levels.2/ Receiver display options are:

- A single 7-inch PPI display unit.

- TV displays, using conventional Closed Circuit Television (CCTV) monitors from a receiver unit. As many as six TV displays can be operated from the receiver. As a further option, the receiver may be equipped with data insertion capability to permit tailoring the TV displays to local needs.

- Facsimile copies (10x10 in.) with preselected programs to update continuously or at intervals of 5, 10, 20, or 60 minutes. Time of receipt is automatically printed on each copy received.

Communications options are:

- Continuous connection between the remote receiver and transmitter using dedicated circuits when routine, uninterrupted data flow is desired.

- Use of standard telephone systems to dial any remote transmitter and receive the current PPI display in less than 2 minutes.

- A combination of the two preceding modes when a location needs routine support from a radar and occasionally needs data from other radars equipped with transmitters.

The WBRR-68 radar remoting system 3/ costs about $34,000 for each transmitter and $4,000 for each receiver. The annual average operating cost of a system (one transmitter and two receivers linked by a dedicated telephone line) is about $6,500, and maintenance costs about $11,000.

2/ The term "intensity" actually refers to "radar reflectivity-factor".

3/ Previously designated Weather Bureau Radar Telephone Transmission System (WB/RATTS).

Facsimile Remoting Systems

Standard weather facsimile equipment is used as transmitting and receiving units. This type of remoting is employed in the western portions of the U.S. using FAA air traffic control center radars. The radar operator makes a tracing of the PPI presentation; adds interpretive information such as echo heights, intensity, and movement; and transmits the resulting weather radar map to one or more remote receivers.

These presentations are transmitted hourly to the collating center at Salt Lake City and to other users in the National Weather Service, Western Region, including many FAA offices. Because the data are of low resolution and generally associated with broad-scale systems, relatively simple, inexpensive equipment is employed. The facsimile transmitters cost about $3,000, recorders about $4,000, and the average annual line costs for each of the five air traffic control centers is about $44,000.

APPENDIX III

BASIC WEATHER RADAR NETWORK

Name	Call	Location		Agency	Radar	Alternate
Albuquerque, N.M.	*A	35°04'N	106°54'W	FAA	ARSR	None
Amarillo, Tex.	AMA	35°14'N	101°42'W	NWS	WSR-57	None
Amarillo, Tex.	*A	35°14'N	101°40'W	FAA	FPS-20	None
Apalachicola, Fla.	AQQ	29°44'W	84°59'W	NWS	WSR-57	Tyndall AFB (FPS-77)
Ashton, Idaho	*S	44°34'N	111°27'W	FAA	ARSR	None
Athens, Ga.	AHN	33°57'N	83°19'W	NWS	WSR-57	Dobbins AFB (FPS-77)
Atlantic City, N.J.	ACY	39°27'N	74°35'W	NWS	WSR-57	McGuire AFB (FPS-77)
Barksdale AFB, La.	BAD	32°30'N	93°40'W	AF	FPS-77	None
Battle Mountain, Nev.	*S	40°24'N	116°52'W	FAA	ARSR	None
Boise, Idaho	*S	44°26'N	116°08'W	FAA	ARSR	None
Boron, Calif.	*P	35°05'N	117°35'W	FAA	FPS-67B	None
Bristol, Tenn.	TRI	36°27'N	82°08'W	NWS	WSR-57	None
Brownsville, Tex.	BRO	25°54'N	97°26'W	NWS	WSR-57	None
Brunswick, Maine	NHZ	43°54'N	69°56'W	NWS	WSR-57	None
Buffalo , N.Y.	BUF	42°56'N	78°44'W	NWS	WSR-57	None
Cape Hatteras, N.C.	HAT	35°16'N	75°33'W	NWS	WSR-57	None
Cedar City, Utah	*S*P	37°36'N	112°52'W	FAA	ARSR	None
Centreville, Ala.	CKL	32°52'N	87°15'W	NWS	WSR-57	Maxwell AFB (CPS-9)
Charleston, S.C.	CHS	32°54'N	80°02'W	NWS	WSR-57	None
Chatham, Mass.	CHH	41°39'N	69°57'W	NWS	WSR-57	Otis AFB (FPS-77)**
Cincinnati, Ohio	CVG	39°04'N	84°40'W	NWS	WSR-57	Wright-Patterson AFB (CPS-9)
Daytona Beach, Fla.	DAB	29°11'N	81°03'W	NWS	WSR-57	None
Des Moines, Iowa	DSM	41°32'N	93°39'W	NWS	WSR-57	None
Detroit, Mich.	DTW	42°14'N	83°20'W	NWS	WSR-57	Selfridge AFB (CPS-9)
Duluth, Minn.	DLH	46°50'N	92°11'W	AF	FPS-77	None
Ellsworth AFB, S. Dak.	RCA	44°09'N	103°06'W	AF	FPS-77	None
El Paso, Tex.	*A	31°41'N	106°12'W	FAA	ARSR	None
Evansville, Ind.	EVV	38°03'N	87°32'W	NWS	WSR-57	None
Frances E. Warren AFB, Wyo.	FEW	41°09'N	104°48'W	AF	FPS-77	WSO, Scottsbluff, Neb. (WSR-3)

**Programmed for removal by FY 1975.

Name	Call	Location		Agency	Radar	Alternate
Fort Worth, Tex.	GSW	32°50'N	97°03'W	NWS	WSR-57	Carswell AFB (CPS-9)
Galveston, Tex.	GLS	29°18'N	94°48'W	NWS	WSR-57	None
Garden City, Kans.	GCK	37°56'N	100°43'W	NWS	WSR-57	None
Grand Forks, AFB, N. Dak.	RDR	47°58'N	97°24'W	AF	FPS-77	None
Grand Island, Neb.	GRI	40°55'N	98°19'W	NWS	WSR-57	Offutt AFB (FPS-77)
Griffiss AFB, N.Y.	RME	43°14'N	75°24'W	AF	FPS-77	WSO, Binghamton, N.Y. (WSR-3)
Hondo, Tex.	HND	29°22'N	99°10'W	NWS	WSR-57	Randolph AFB (FPS-77)
Huron, S. Dak.	HON	44°23'N	98°13'W	NWS	WSR-57	None
Jackson, Miss.	JAN	32°19'N	90°05'W	NWS	WSR-57	Meridian NAAS (FPS-81)
Kansas City, Mo.	MKC	39°06'N	94°35'W	NWS	WSR-57	Richards-Gebaur AFB (FPS-77)
Key West, Fla.	EYW	24°33'N	81°45'W	NWS	WSR-57	None
K.I. Sawyer AFB, Mich.	SAW	46°21'N	87°24'W	AF	FPS-77	None
Klamath Falls, Ore.	*W	42°04'N	121°59'W	FAA	FPS-67B	None
Lake Charles, La.	LCH	30°07'N	93°13'W	NWS	WSR-57	None
Las Vegas, Nev.	*P	36°19'N	115°34'W	FAA	FPS-67	None
Laughlin AFB, Tex.	DLF	29°22'N	100°47'W	AF	FPS-77	None
Limon, Colo.	LIC	39°12'N	103°42'W	NWS	WSR-57	Peterson Field, Colo. (FPS-77)
Little Rock, Ark.	LIT	34°44'N	92°14'W	NWS	WSR-57	Little Rock AFB (FPS-77)
Loring, AFB, Maine	LIZ	46°57'N	67°53'W	AF	FPS-77	None
Los Angeles, Calif.	*P	33°56'N	118°24'W	FAA	ASR-4	None
Lovell, Wyo.	*S	44°49'N	107°54'W	FAA	ARSR	None
Malmstrom AFB, Mont.	GFA	47°31'N	111°10'W	AF	CPS-9	None
Marseilles, Ill.	MMO	41°22'N	88°41'W	NWS	WSR-57	None
Medford, Oreg.	MFR	42°05'N	122°43'W	NWS	WSR-57	None
Memphis, Tenn. (NAS)	NQA	35°21'N	89°52'W	NWS	WSR-57	Blytheville AFB (FPS-77)
Mesa Rica, N.M.	*A	35°14'N	104°12'W	FAA	ARSR	None
Miami, Fla.	MIA	25°43'N	80°17'W	NWS	WSR-57	Homestead AFB (FPS-77)
Midland, Tex.	MAF	31°56'N	102°12'W	NWS	WSR-57	Webb AFB (FPS-77)
Minneapolis, Minn.	MSP	44°53'N	93°13'W	NWS	WSR-57	None
Minot AFB, N. Dak.	MIB	48°25'N	101°21'W	AF	FPS-77	None
Missoula, Mont.	MSO	47°02'N	113°59'W	NWS	WSR-57	None
Monett, Mo.	UMN	36°53'N	93°54'W	NWS	WSR-57	None
Mt. Laguna, Calif.	*P	32°53'N	116°25'W	FAA	FPS-7	None

Name	Call	Location		Agency	Radar	Alternate
Nashville, Tenn.	BNA	36°15'N	86°34'W	NWS	WSR-57	None
Neenah, Wisc.	EEW	44°13'N	88°33'W	NWS	WSR-57	None
New York, N.Y.	NYC	40°46'N	73°59'W	NWS	WSR-57	None
Oklahoma City, Okla.	OKC	35°24'N	97°36'W	NWS	WSR-57	Tinker AFB (CPS-9)
Paso Robles, Calif.	*P	35°24'N	120°21'W	FAA	ARSR	None
Patuxent, Md. (NAS)	NHK	38°17'N	76°25'W	NWS	WSR-57	Andrews AFB (FPS-77)
Pensacola, Fla.	NPA	30°21'N	87°19'W	NAVY	WSR-57	None
Phoenix, Ariz.	*A	33°59'N	111°48'W	FAA	ARSR	None
Pittsburgh, Pa.	PIT	40°32'N	80°14'W	NWS	WSR-57	None
Plattsburg AFB, N.Y.	PBG	44°39'N	73°28'W	AF	FPS-77	None
Rock Springs, Wyo.	*S	41°26'N	109°07'W	FAA	ARSR	None
Sacramento, Calif.	SAC	38°35'N	121°29'W	NWS	WSR-57	None
St. Louis, Mo.	STL	38°45'N	90°23'W	NWS	WSR-57	Scott AFB (CPS-9)
Salem, Ore.	*W	44°55'N	123°34'W	FAA	ARSR	None
Salt Lake City, Utah	*S	41°02'N	111°50'W	FAA	ARSR	None
San Pedro, Calif.	*P	33°35'N	118°20'W	FAA	ARSR	None
Seattle, Wash.	*W	47°31'N	122°24'W	FAA	ARSR	None
Seymour Johnson AFB, N.C.	GSB	35°20'N	77°58'W	AF	FPS-77	Pope AFB, N.C. (CPS-9)
Ship Hotel	4YH	38°00'N	71°00'W	NWS	WR100-5	None
Silver City, N.M.	*A	32°59'N	108°58'W	FAA	ARSR	None
Spokane, Wash.	*W	47°35'N	117°05'W	FAA	FPS-67B	None
Slidell, La.	SLI	30°19'N	89°46'W	NWS	WSR-57	New Orleans NAS (FPS-81)
Tampa, Fla.	TPA	27°58'N	82°32'W	NWS	WSR-57	MacDill AFB (CPS-9)
Waycross, Ga.	AYS	31°15'N	82°24'W	NWS	WSR-57	None
Wichita, Kans.	ICT	37°39'N	97°25'W	NWS	WSR-57	McConnell AFB (FPS-77)
Wilmington, N.C.	ILM	34°17'N	77°55'W	NWS	WSR-57	None
Wurtsmith AFB, Mich.	OSC	44°26'N	83°22'W	AF	FPS-77	None

*S - Monitored by the FAA/NOAA Joint-Use Radar Unit, Salt Lake City, Utah ARTCC
*P - Monitored by the FAA/NOAA Joint-Use Radar Unit, Palmdale, California ARTCC
*A - Monitored by the FAA/NOAA Joint-Use Radar Unit, Albuquerque, New Mexico ARTCC
*W - Monitored by the FAA/NOAA Joint-Use Radar Unit, Auburn, Washington ARTCC

ALTERNATES TO THE BASIC WEATHER RADAR NETWORK

Alternate Names	Call	Location		Agency	Radar	Alternate to
Andrews AFB, Md.	ADW	38°48'N	76°53'W	AF	FPS-77	Patuxent, Md.
Binghamton, N.Y.	BGM	42°13'N	75°59'W	NWS	WSR-3	Griffiss AFB, N.Y.
Blytheville AFB, Ark.	BYH	35°58'N	89°57'W	AF	FPS-77	Memphis, Tenn.
Carswell AFB, Tex.	FWH	32°49'N	97°26'W	AF	CPS-9	Fort Worth, Tex.
Dobbins AFB, Ga.	MGE	32°21'N	85°00'W	AF	FPS-77	Athens, Ga.
Homestead AFB, Fla.	HST	25°29'N	80°23'W	AF	FPS-77	Miami, Fla.
Little Rock AFB, Ark.	LRF	34°55'N	92°09'W	AF	FPS-77	Little Rock, Ark.
Macdill AFB, Fla.	MCF	27°51'N	82°30'W	AF	CPS-9	Tampa, Fla.
Maxwell AFB, Ala.	MXF	32°23'M	86°22'W	AF	CPS-9	Centreville, Ala.
McConnell AFB, Kans.	IAB	37°37'N	97°16'W	AF	FPS-77	Wichita, Kans.
McGuire AFB, N.J.	WRI	40°00'N	74°36'W	AF	FPS-77	Atlantic City, N.J.
Meridian NAS, Miss.	NMM	32°33'N	88°34'W	NAVY	FPS-81	Jackson, Miss.
Nellis AFB, Nev.	LSV	36°15'N	115°02'W	AF	FPS-77	Las Vegas, Nev.
New Orleans NAS, La.	NBG	29°50'N	90°01'W	NAVY	FPS-81	Slidell, La.
Offutt AFB, Neb.	OFF	41°07'N	95°54'W	AF	FPS-77	Grand Island, Neb.
Otis AFB, Mass.*	FMH	41°39'N	70°31'W	AF	FPS-77	Chatham, Mass.
Peterson Field, Colo.	COS	38°49'N	104°43'W	AF	FPS-77	Limon, Colo.
Pope AFB, N.C.	POB	35°12'N	79°01'W	AF	CPS-9	Seymour Johnson AFB, N.C.
Randolph AFB, Tex.	RND	29°32'N	98°17'W	AF	FPS-77	Hondo, Tex.
Richards-Gebaur AFC, Mo.	GVW	38°50'N	94°34'W	AF	FPS-77	Kansas City, Mo.
Scott AFB, Illinois	BLV	38°33'N	89°51'W	AF	CPS-9	St. Louis, Mo.
Scottsbluff, Neb.	BFF	41°52'N	103°36'W	NWS	WSR-3	F.E. Warren AFB, Wyo.
Selfridge AFB, Mich.	MTC	42°36'N	82°49'W	AF	CPS-9	Detroit, Mich.
Tinker AFB, Okla.	TIK	35°25'N	97°23'W	AF	CPS-9	Oklahoma City, Okla.
Tyndall AFB, Fla.	PAM	30°04'N	85°35'W	AF	FPS-77	Apalachicola, Fla.
Webb AFB, Tex.	BGS	32°13'N	101°31'W	AF	FPS-77	Midland, Tex.
Wright-Patterson AFB, Ohio	FFO	39°05'N	84°03'W	AF	CPS-9	Cincinnati, Ohio

*Programmed for removal by FY 1975.

RESEARCH AND DEVELOPMENT PROGRAM

Department of Commerce, National Severe Storms Laboratory

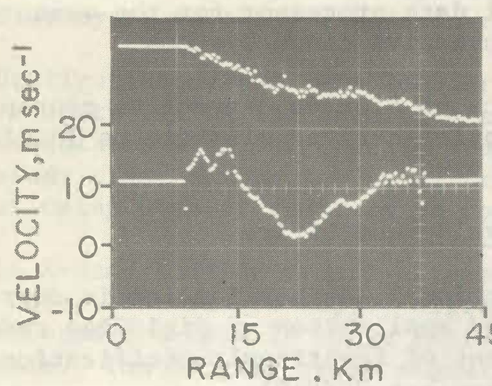
The National Severe Storms Laboratory (NSSL), Norman, Okla., one of NOAA's Research Laboratories, is responsible for increasing our understanding of severe convective phenomena including hailstorms, tornadoes, and heavy rain and for developing improved methods for detecting, identifying and predicting these phenomena. The Laboratory develops applications of Doppler and conventional radars for mesoscale observation of precipitation type and intensity and the distribution of winds and turbulence, and it combines the data of radar and other sensors with theory to gain understanding of atmospheric processes, to improve operation of commercial and military aircraft, and to improve the forecasting of floods, strong winds, and hail.

NSSL staff are working closely with NWS personnel in the D/RADEX experiment to facilitate the transfer of advanced weather radar technology to the operational weather observing and forecasting system. Studies to improve the application of radar to interpretation and prediction of rainfall rate and severe storm characteristics are continuing in cooperation with the NWS Office of Hydrology and the FAA Systems Research and Development Service respectively.

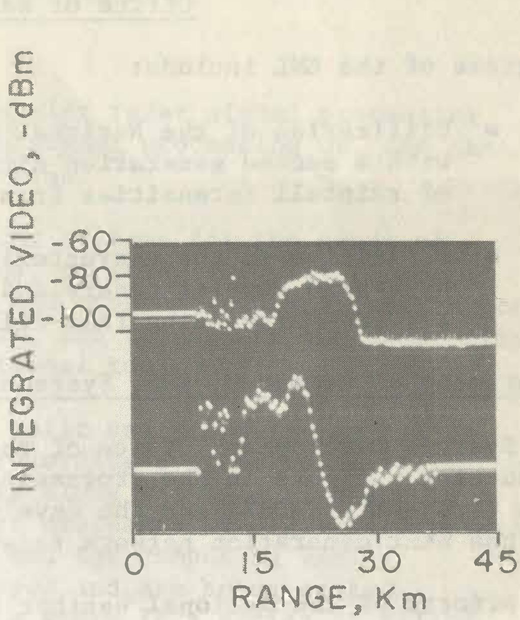
One high-performance S-band Doppler radar system with a PPI display of velocity contours is providing real time indications of the centers of strong vortices, such as tornado cyclones (fig. 18). Doppler data is archived on magnetic tape in conjunction with detailed data acquired with surface and upper air stations, instrumented tower and aircraft, provides the bases for comprehensive examination of the storm wind field and physical processes.

Improved methods for acquisition and processing of the data of conventional and Doppler radars will continue to be sought. A second 10-cm Doppler radar is being completed to facilitate determination of total velocity components. Emphasis will continue on applications of hard-wired electronic components to produce digital data directly in semi-processed form, and on computer programs for synthesis of meteorological data from a variety of sources in objective, comprehensive analyses for rapid and accurate detection and short range forecasting of severe storms.

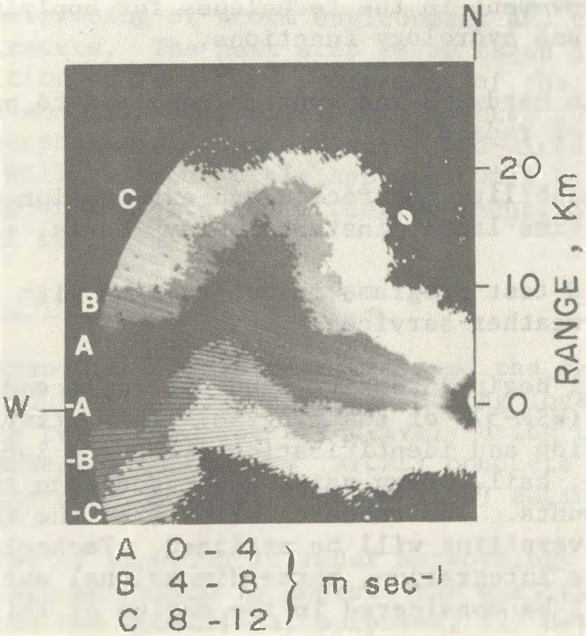
Developments of great significance for the forecasting service are foreseen and improved understanding may lead to the beneficial modification of severe storms.



(a) Radial velocity-range.



(b) Integrated video-range.



(c) A sector of a PPI isotach display showing mean radial velocity contours--strobing indicates negative velocities or motion toward the Doppler.

Figure 18.--Real-time display of Doppler data.

Department of Commerce, Experimental Meteorological Laboratory
Office of Weather Modification

Programs of the EML include:

- Utilization of the National Weather Service WSR-57 radar at Miami with a second generation digital data processor for the measurement of rainfall intensities from convective cloud systems.

- Definition of the characteristics of Florida convective precipitation by X-band Doppler radars and Doppler-derived wind fields in clouds and the surrounding rain-filled air.

Department of Commerce, NWS, Systems Development Office

The Systems Development Office of the National Weather Service is currently conducting projects in the processing and application of digitized radar data (Project D/RADEX) and the development of functional specifications for the next generation network radar (Project NEXRAD).

The efforts of the National Weather Service will focus principally on the following areas:

- Development, test, and evaluation of the real-time integration of satellite and radar data and the distribution of resulting information.

- Continued improvement in the techniques for applying the data to the storm warning and hydrology functions.

- Improvements in hardware and systems required to permit the remote interrogation of radars.

- Develop the capability for recall and examination of prior data on essentially a time lapse "instant replay" basis.

- Institute field test programs in conjunction with the larger scale automation of weather services.

In FY 1974 the NWS will begin intensive study of replacement radars for the present primary radar (WSR-57) of the program. This effort will be directed toward detection and identification of severe local storms, particularly tornadoes, hail, heavy rain, and turbulence and estimates of rainfall rates and amounts. The research efforts of the ERL, the Department of Defense, and by universities will be utilized. Technology such as Doppler, pulse-to-pulse integration, three-dimensional analysis and advanced digital processing will be considered in the design of this next generation weather radar.

In the period FY 1975-78 a suitable replacement radar will be identified and developmental work will begin for the operational next generation weather radar.

Department of Commerce, Wave Propagation Laboratory

Programs of the WPL include:

- Development of Doppler radar and Doppler radar signal processing techniques with special emphasis on signal processing of, and the display of velocity fields in real time.

- Utilization of two 3-cm Doppler radar systems for the study of velocity fields in convective storms, to study velocity fields associated with large-scale storms and orographic precipitation, to study clear air motion using tracers, and to explore the possibilities of using Doppler radar as an operational tool.

Two mobile X-band Doppler radars have been built and are being tested in Boulder, Colo. The radars employ digital recording systems for storing Doppler information from 24 range increments along the line of sight in 0.25 seconds. The Doppler radar signals are processed by digital computers. Programs for computing the Doppler spectra and for computing and displaying velocity fields have been developed and are being tested. Automatic scanning of a selected volume of a storm in a series of tilted planes is incorporated in the radar system.

Within the near future, plans call for making extensive use of the Doppler radars and digital systems to investigate the three-dimensional field of particle velocities in convective storms and mesoscale systems. These plans also include the probing of storm environment and clear air by use of suitable air motion tracers. The next step to be taken in equipment development will be the addition of real-time processing of the Doppler radar signals and real-time analysis of the velocity spectra to the present equipment. Special-purpose minicomputers with hard-wired fast Fourier transform algorithms will be used. This approach will also provide statistical processing of the data and effective reduction of the recorded samples by a factor of 10.

Department of Defense, Air Force

Air Force Systems Command (AFSC) has been assigned the function of developing improved instrumentation for Air Force use in making local observations of weather and to develop techniques for effectively using these observations. Air Force Cambridge Research Laboratory (AFCRL) conducts exploratory development programs and Electronic Systems Division (ESD) engineering development.

The specific objectives of research in radar meteorology at AFCRL are: (1) development of instrumentation to improve the quality of radar measurements for both research and operational purposes; (2) development of techniques for identification of regions of dangerous turbulence and damaging hail within approaching storms; (3) development of data processing techniques for the utilization of pulse Doppler returns; and (4) micro-wave scattering and attenuation in adverse weather.

The research efforts which are in progress in radar meteorology include:

- The development of techniques to permit better operational use of the quantitative measurement capability of the AN/FPS-77. Improved processing and display techniques and the benefits of digitally integrated radar video data for use in meteorological observation and precipitation are being evaluated.

- Doppler radar investigation of precipitation processes and wind field (including shear and cloudy-air turbulence) in convective storms, directed toward development of Doppler radar techniques for identification of severe thunderstorms; development of techniques for utilization of motion components measured within convective storms in contributing to information on dynamics of airflow.

- The definition of the spatial and temperal fine-scale radar structure of ice clouds and precipitation using the high resolution radar facility at Wallops Island, Virginia, and determination of the characteristics of the hydrometeors within the storm.

- The study of precipitation growth, phase change, and transformation of particle size distributions throughout the depth of the storm systems using vertically-oriented Doppler radar measurements of stratiform storms.

- The development of techniques for economical processing of Doppler spectra for eventual operational use.

Most current studies are expected to continue. Anticipated improvements in instrumental capability will provide significant advances in these investigations. For example, improvements in antenna-scanning and returned-power integration techniques of the Wallops Island radar facility, combined with fine-scale atmospheric measurements obtained with an aircraft, will provide better estimates of the hydrometeor characteristics of all types of storms.

Development and evaluation of real-time spectral processing techniques, such as the Pulse Pair Processor, will proceed by incorporation of the flexibility and data processing capability offered by advanced digital methods, leading toward real-time identification and objective evaluation of hazardous winds and turbulence in convective storms.

The contribution of radar data to improved forecasting techniques will be emphasized through integration of computerized reflectivity distributions with a network of mesoscale observations, through study of the trend of the vertical distribution of disturbed flow or shear in thunderstorms, and by relating the wind field and divergence in wide-spread snowstorms to the onset, intensity, and cessation of precipitation. The variability of reflectivity and attenuation in the melting-level bright band in widespread rainstorms will be studied and related to drop-size distributions.

Development of a radar data acquisition system for use in the next generation of weather radars during the 1980s will be initiated. Weather radar observational and forecasting techniques for use during the 1980s will be developed and evaluated.

Department of Defense, Army

The Atmospheric Sciences Laboratory, U.S. Army Electronics Command, Ft. Monmouth, N.J. has engaged in the following efforts:

- Mobile Weather Radar Development: A mobile weather radar and ancillary display equipment capable of observing and measuring precipitation, and clouds formed by natural physical processes and nuclear detonation, including new operational and display techniques for both natural and nuclear clouds has been developed.

- Weather Radar Techniques Development: The general objectives and goals of this R&D effort are to establish improved relationships between meteorological variables and radar measured parameters necessary for field army applications, and develop techniques which utilize weather radar input for making tactical army decisions. Future plans are:

  To complete the procurement package for the Mobile Weather Radar AN/TPS-41.

  Develop techniques usable in the field and data formats to provide the field commander with optimal applications of the weather radar data as they relate to tactical considerations such as air mobility, trafficability, artillery, and STANO (Surveillance, Target Acquisitions Night Observation).

Department of Defense, Navy

In the field of supporting research in radar meteorology, the Meteorological Division, Naval Air Systems Command, has the function of providing technical support to the Naval Weather Service Command. The mission of the Naval Weather Service Command is to provide meteorological support to the operating forces of the U.S. Navy and oceanographic forecasts for all DOD elements in support of military operations. One aspect of this support is the application of radar to state-of-the-sea measurements.

Equipment designed to analyze radar sea clutter information electronically and to provide readouts in terms of sea state has been developed and is under evaluation at the Pacific Missile Range. The objective of this development is equipment which can be attached to Navy shipboard radars to provide readouts of wave height and period. In addition, a ground-based single-station spheric detector and readout system has been developed and is being evaluated at the Fleet Weather Facility Jacksonville. The detector monitors 500 kHz sferic activity occurring within 200 miles of the station.

Based on tests of the prototype models, equipment for operational use will be developed in the future.

Department of the Interior

There is a requirement to develop radar instrumentation needed for weather modification research and pilot operations. Meteorological radars are used to provide historical and real-time records of the volume containing hydrometeors of different radar reflectivities and the relative motion of clouds and hydrometeors. Historical data are required for the analysis of precipitation processes both natural and modified. Real-time data are required to recognize opportunities where precipitation can be modified and to evaluate the effectiveness of cloud seeding operations.

Work is underway in the Department on three projects which include:

- A modified Nike-Ajax 3-cm radar for use with a PDP-8 computer and an echo profiler (28 data channels) to produce simplified three-dimensional records and displays of reflectivity data. Current activity is emphasizing optimization of the profiler and computer programs.

- Data processing equipment under development to transmit radar profiler data from remote radar sites to a centrally located computer.

More useful three-dimensional records and displays for operational control will be developed in future years. Remote processing of radar data to link several local area radars to a weather modification control center will be continued. The basic Doppler radar unit will be used as an element of a stereo Doppler complex to produce two- and three-dimensional wind field records. The basic unit will be digitized and telemetry equipment developed to control two or three Dopplers from a central computer.

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