WEATHER BUREAU
Western Region

Salt Lake City, Utah
December 1968

Joint ESSA/FAA ARTC Radar Weather Surveillance Program

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Technical Memorandum WBTM WR-35
(Revised)
U.S. DEPARTMENT OF COMMERCE / ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION

WESTERN REGION TECHNICAL MEMORANDA

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*Out of Print
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A western Indian symbol for rain. It also symbolizes man's dependence on weather and environment in the West.

U. S. DEPARTMENT OF COMMERCE
ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
WEATHER BUREAU

Weather Bureau Technical Memorandum WR-35

JOINT ESSA/FAA ARTC RADAR WEATHER SURVEILLANCE PROGRAM

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WESTERN REGION
TECHNICAL MEMORANDUM NO. 35

SALT LAKE CITY, UTAH
JUNE 1970 (REVISED)

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF FIGURES AND TABLES

JOINT ESSA/FAA ARTC RADAR WEATHER SURVEILLANCE PROGRAM

I. HISTORY

The expansion of the Weather Bureau's WSR-57 radar network has been proceeding slowly in the western portion of the United States, although requirements for radar surveillance are high. This is due to the high cost of installation in mountainous terrain; consequently, it will take a number of years before a radar network dedicated to weather will be realized. In an effort to find an interim solution to fulfilling these radar data requirements, we considered the possible use of FAA radars.

The idea of utilizing FAA Air Traffic Control radars for weather surveillance had occurred to others in the past, but the development of the idea lacked impetus. The opinion of most was that the FAA radars could provide only limited weather information because of their design characteristics. However, the availability of weather echoes on the controller's scopes suggested their possible use in directing aircraft operations. Work on exploring this possibility began in 1965, when the ESSA National Severe Storms Laboratory (NSSL) conducted a study to compare the detection capability of the FAA's ARSR-ID and ASR-4 radar systems with the WSR-57 weather radar 1/. One conclusion from this comparative study was, "Without MTI* and CP*, thunderstorm depiction by the WSR-57 and the ARSR-ID (with amplitron) differed by only 3 db", i.e., at 100 nautical miles the WSR-57's minimum detectable rainfall rate is .003 in/hr; the ARSR-ID is .006 in/hr, an insignificant difference.

The NSSL comparative study indicated the FAA (ARSR) radar and the WSR-57 were comparable in detecting precipitation in "Oklahoma Thunderstorms" but this did not necessarily establish the ARSR-ID as a suitable weather radar. The NSSL study pointed out that "the capability of the FAA radar to probe details of storm formations is considerably less than that of the Weather Bureau radar due to the latter's pencil-beam radiation. The ARSR-ID, on the other hand, possesses a fan-beam radiation pattern spread out in a vertical plane for ATC* purposes; this precludes examination of the vertical structure of storms". Further, the comparability study considered only highly reflective thunderstorm-type precipitation. It did not evaluate the capability of these radars to detect adequately the lighter forms of precipitation and snow which are characteristic of the West. In addition to these limitations, there are numerous operational limitations which reduce the precipitation detection capability.

*MTI - Moving Target Indicator
*CP - Circular Polarization
*ATC - Air Traffic Control

Recognizing the limited capabilities of the FAA radar system for detailed probing of weather targets but encouraged by their general comparability with the WSR-57, the Weather Bureau pursued the concept of joint-use with the FAA.

The Weather Bureau's interest in a joint-use program was greatest at the Salt Lake City ARTC* Center since this Center monitors seven radar systems covering the entire Intermountain Region. Figure 1 shows the Weather Bureau's radar network in the West as it existed in 1965 and the location of the FAA radar systems monitored by Salt Lake. It is in this mountain region that the eventual establishment of "weather radar" sites will be most costly and most difficult to maintain.

The feasibility of utilizing FAA ARTC radars operationally for weather surveillance was far more involved than simply establishing their capability to detect precipitation. There were many operational problems which had to be resolved. Could a Weather Bureau staff of radar meteorologists operate from within an ARTC Center without interfering with the FAA mission of controlling aircraft? Could useful weather information be gathered and interpreted from the FAA radars in spite of the use of anticlutter circuits and in view of various standard operating modes required for air traffic control?

In early 1965, the Weather Bureau presented a proposal to the FAA to conduct an evaluation of the operational feasibility of utilizing ARTC radar for weather surveillance. This proposal received enthusiastic support from the FAA. Of particular importance was the personal interest in this proposal demonstrated by the Chief of the FAA Salt Lake Center and the Meteorologist in Charge of the Weather Bureau Forecast Office. Their subsequent support permitted a very thorough evaluation which lasted nearly 8 months. The following conclusions were made as a result of the evaluation 2/:

1. A joint-use weather surveillance program could be conducted from an ARTC Center without interfering with the mission of the FAA; and

2. Useful weather radar data could be obtained from FAA radars;

3. The NSSL study results appeared valid for weather types found in the West; and

4. A number of very important advantages were to be gained by operating from an ARTC Center:

    a) Because the Center monitored returns from seven radar systems, it was possible to composite the data over a very large area and thus better interpret mesoscale weather patterns,

*ARTC - Air Route Traffic Control

WEATHER RADAR SURVEILLANCE - WESTERN REGION 1965

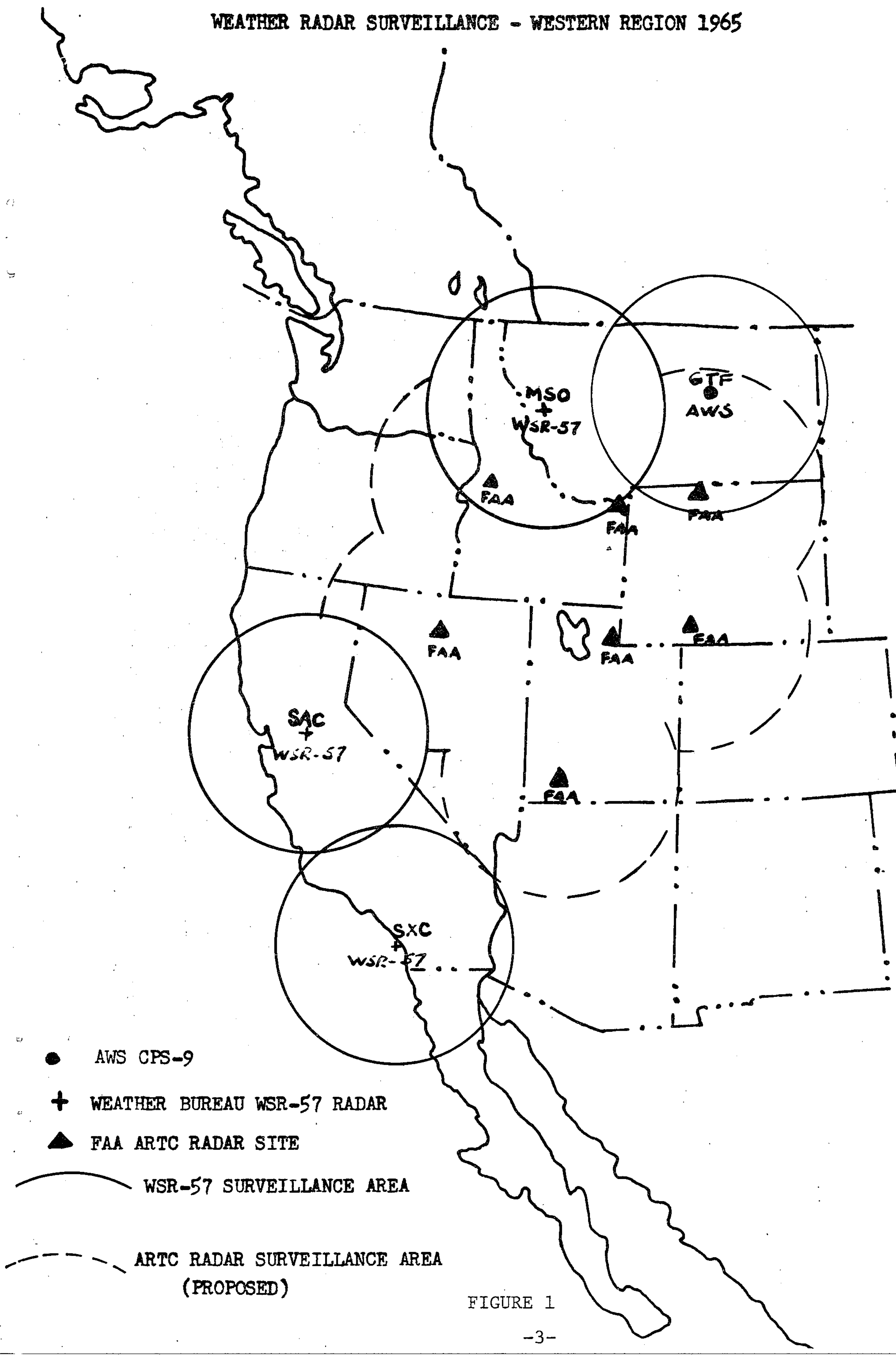


FIGURE 1

b) Radar observers working in the Center were in an excellent position to solicit, interpret, and disseminate pilot reports, and

c) Meteorologists in the Center could provide meteorological expertise directly to the controllers when requested.

After the completion of the Salt Lake evaluation and upon the recommendations of the Weather Bureau Western Region, the Federal Aviation Administration and the Weather Bureau established the first joint-use weather radar surveillance program at the Salt Lake City ARTC Center in the summer of 1966.

The program began with a staff of three radar meteorologists. Two positions were funded by the Weather Bureau and one by the Air Resources Laboratory, supported by the AEC at Las Vegas, Nevada. The ARL contribution was in return for tetroon radar tracking services provided by the Salt Lake City staff. Thus, with a crew of three, a routine, 8-hour-per-day observational program was begun on August 1, 1966. In December of 1967, the staff was increased to four radar meteorologists and duty hours expanded to 16 hours per day.

After 20 months of successful operation at the Salt Lake City Center, a similar weather radar surveillance program was inaugurated early in 1968 at the Los Angeles ARTC Center located in Palmdale, California 3/. As was the case at Salt Lake City, this program began in a modest way with only two radar observers providing a very limited observational program. With the closure of the Catalina Island WSR-57 radar station in the spring of 1968, some of the Weather Bureau's resources were diverted to the Los Angeles ARTC joint-use program. By September of 1968, the Los Angeles Center radar weather unit was operating a fully implemented 16-hour-per-day program. In January 1969 another weather radar program was established at the Albuquerque ARTC Center, and in June 1970 a unit was established at the Seattle ARTC Center.

Figure 2 shows the combined area of radar weather surveillance currently provided in the West by the Weather Bureau and FAA radars.

II. ORGANIZATION OF JOINT-USE PROGRAM

For the sake of simplicity, our discussion of organization and service programs, etc., will be confined mainly to the activities at the Salt Lake City Center. The organization, procedures, and programs are essentially the same at the Los Angeles, Albuquerque, and Seattle Centers, differing only in detail and local program requirements.

The FAA/WB Radar Unit is under administrative and technical supervision of the Meteorologist in Charge of the Weather Bureau Forecast

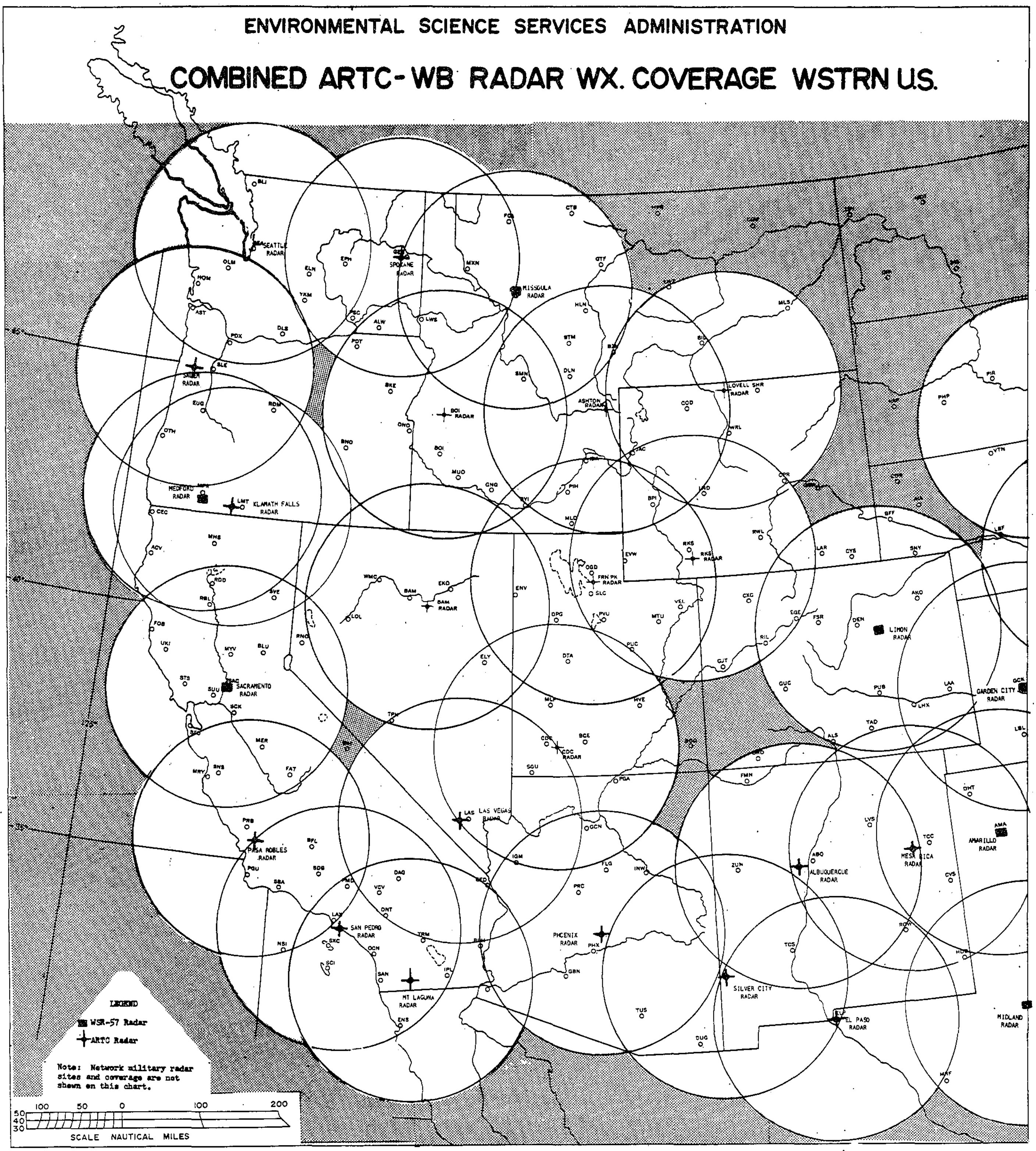

ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
COMBINED ARTC-WB RADAR WX. COVERAGE WSTRN US.
SEATTLE RADAR
SPOKANE RADAR
MISSOULA RADAR
SALEM RADAR
BOI RADAR
ASHTON RADAR
LOVELL SHR RADAR
MEDFORD RADAR
KLAMATH FALLS RADAR
RKS RADAR
FRN PK RADAR
BAM RADAR
LIMON RADAR
SACRAMENTO RADAR
GARDEN CITY RADAR
CDC RADAR
LAS VEGAS RADAR
PASA ROBLES RADAR
AMARILLO RADAR
MESA RICA RADAR
ALBUQUERQUE RADAR
SAN PEDRO RADAR
PHOENIX RADAR
MT LAGUNA RADAR
SILVER CITY RADAR
EL PASO RADAR
MIDLAND RADAR
LEGEND
WSR-57 Radar
ARTC Radar
Note: Network military radar sites and coverage are not shown on this chart.
100 50 0 100 200
50
40
30
SCALE NAUTICAL MILES

FIGURE 2

Office at Salt Lake City. It is an integral part of the Forecast Office although it is physically located in the ARTC Center and there is no interchange of personnel. The Radar Unit is headed by a supervisory Radar Meteorologist who is responsible to both the Meteorlogist in Charge of the Forecast Office and the Chief of the ARTC Center for the proper conduct of the weather surveillance program.

III. DESCRIPTION OF THE ARTC CENTERS

The Salt Lake City ARTC Center is located one mile from the Weather Bureau Forecast Office. The Los Angeles ARTC Center is located more than 50 miles north of the Los Angeles Forecast Office. Liaison between the ARTC Centers and the Forecast Offices is in no way restricted because of their physical separation. Excellent communications facilities have been provided which will be discussed later.

The ARTC Centers are housed in standard "center" type buildings as shown in Figure 3. The main control room, Figure 4, is the location of the radarscope displays used by the controllers. Usually the high-altitude controllers (flights higher than 24,000 feet) utilize scopes on one side of the room and the low-altitude controllers utilize the other side of the room.

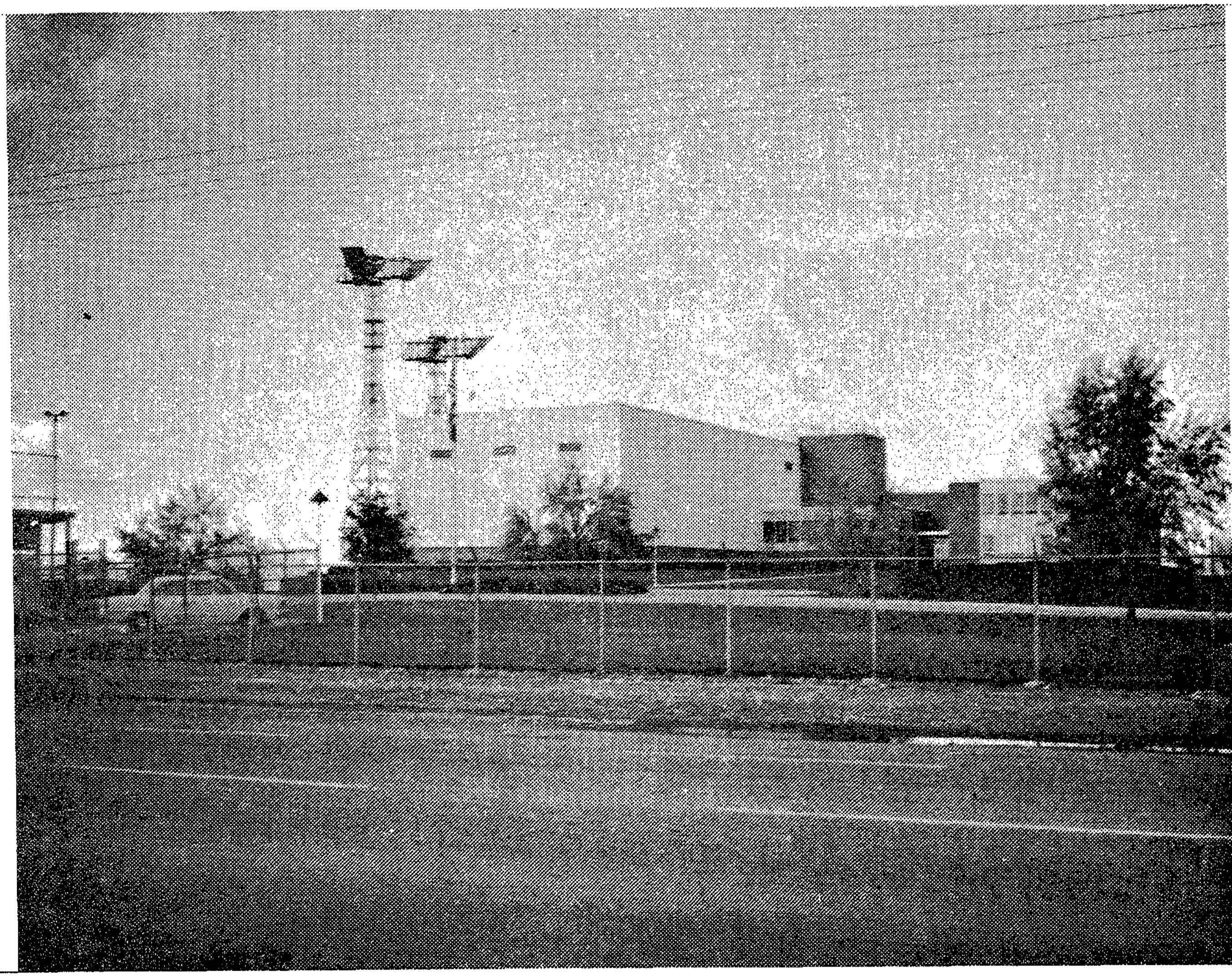
The equipment room, Figure 5, is located immediately below the main control room and houses all the radar control and radio equipment used in the Center.

In the Salt Lake Center, seven radar systems are monitored: five are at Los Angeles, six at Albuquerque, and four at Seattle. The master consoles, Figure 7, used by the maintenance people to monitor the performance of the radar systems are situated in a row in the equipment room, which is located immediately below the main control room, Figure 5. The Weather Bureau quarters are located in the equipment room, Figure 6.

Telephone and intercom communications to the main control room and to the seven radar sites are available at each of the console positions. These facilities are used for the collection of pilot reports and coordination of radar control.

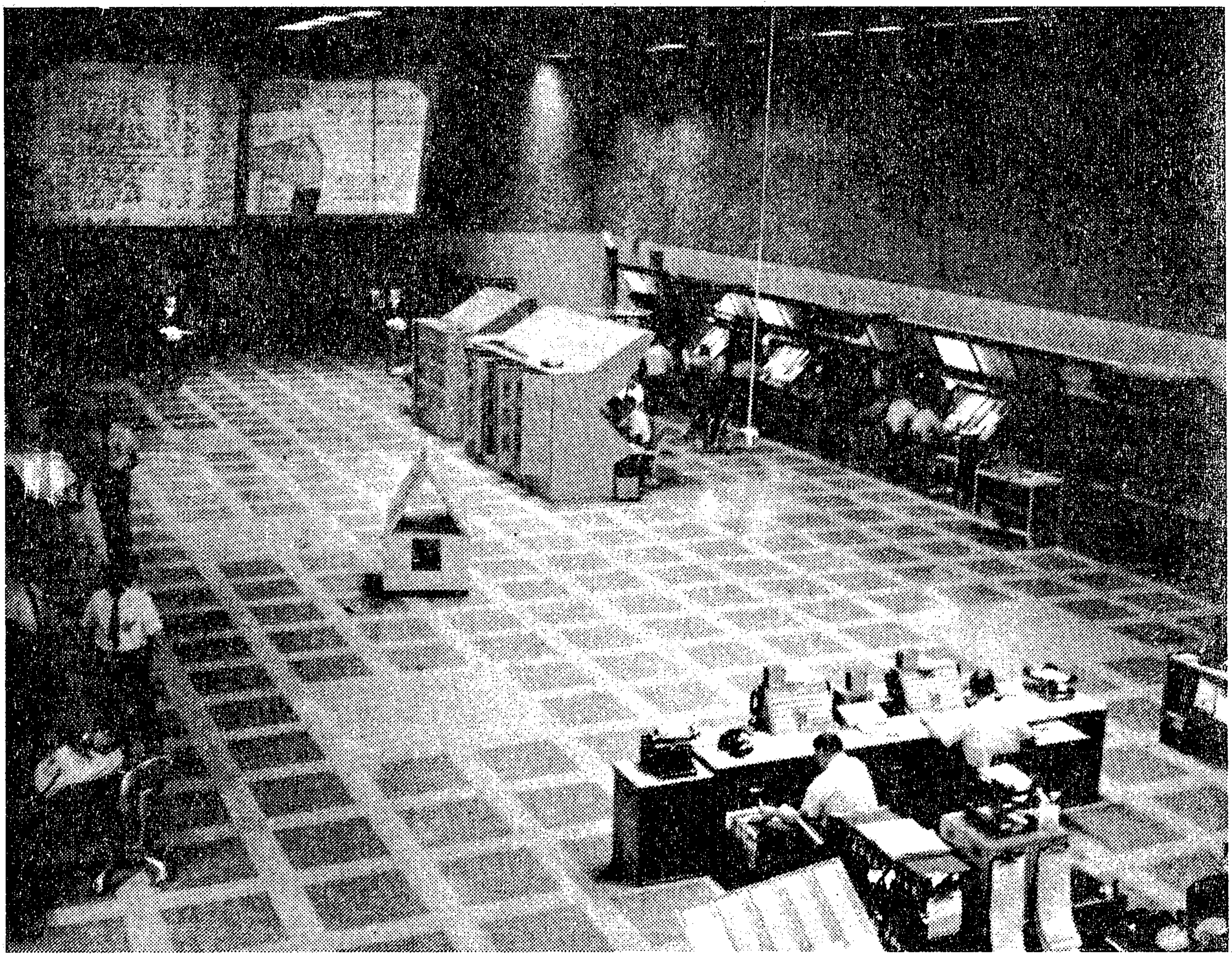
The maintenance scopes are the primary scopes for video presentation and in some instances contain all controls necessary to adjust the operating characteristics of the radar system. Since some of the controls influence the operating condition of the entire radar system, they cannot be manipulated without prior consent of the FCO* who must clear the operation with the appropriate controller. These controls must be operated by a technician. However, the radar meteorologist must have a thorough knowledge of the characteristics of the radar and the presentation on the scopes in order to ensure optimum surveillance of meteorological phenomena.

*FCO - Facilities Coordinating Officer



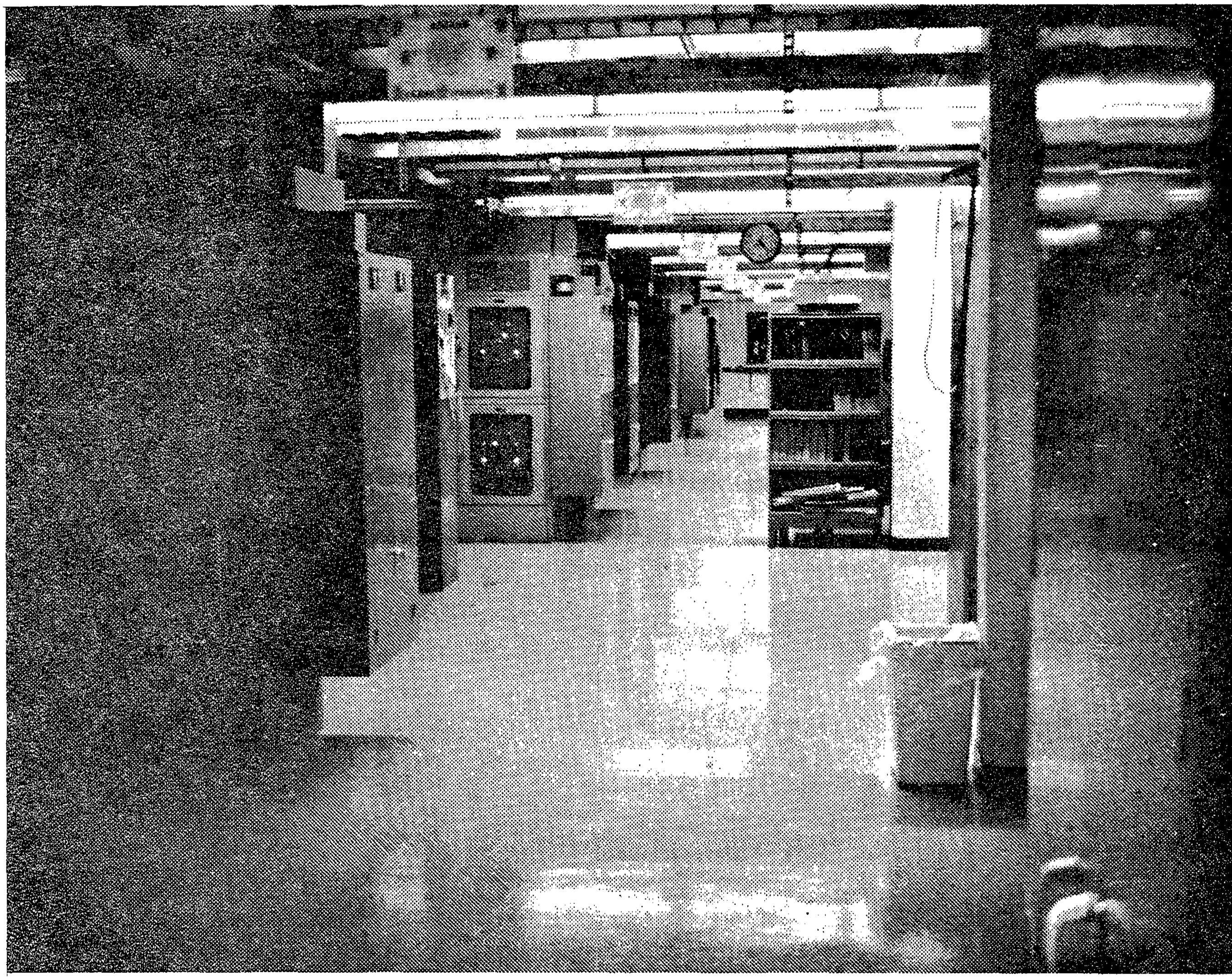
SALT LAKE CITY ARTC CENTER

FIGURE 3



CONTROL ROOM, SALT LAKE CITY ARTC CENTER

FIGURE 4

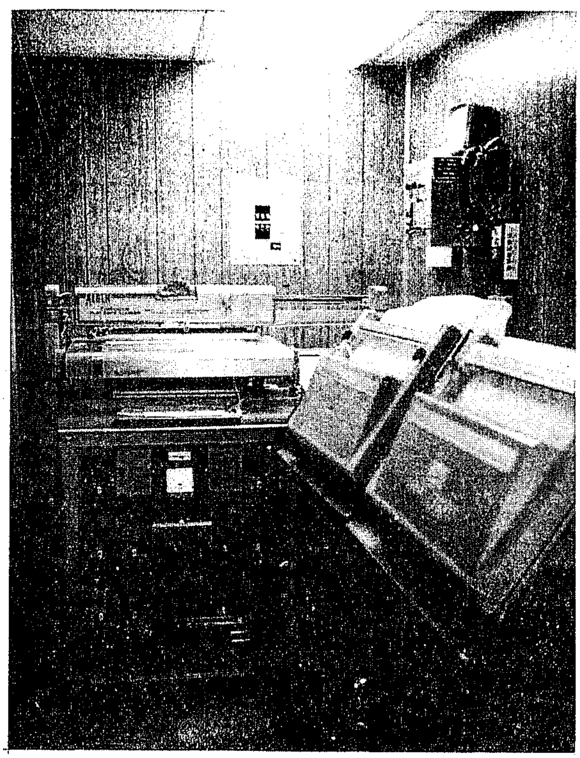


EQUIPMENT ROOM, SALT LAKE CITY,ARTC CENTER

FIGURE 5

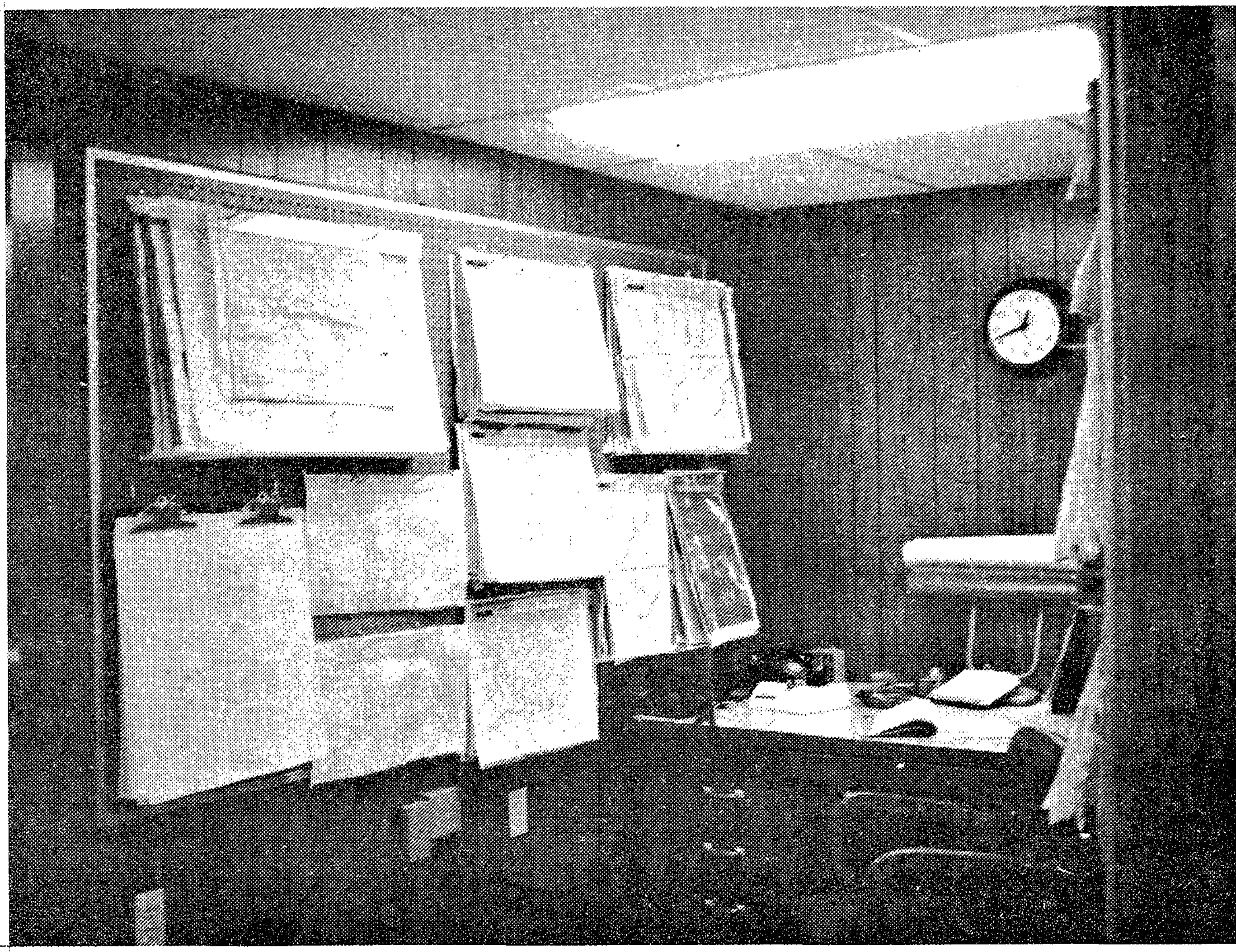
SALT LAKE CITY ARTC CENTER WEATHER OFFICE

FIGURE 6A



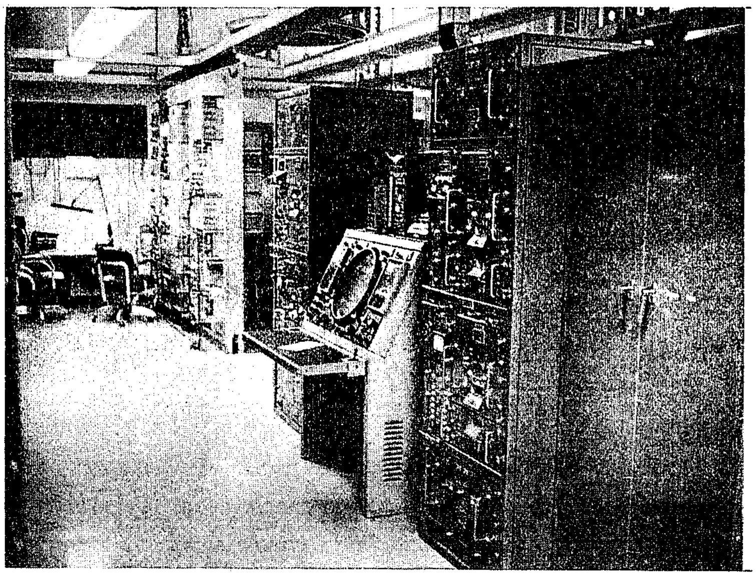
WEATHER OFFICE COMMUNICATIONS

FIGURE 6B



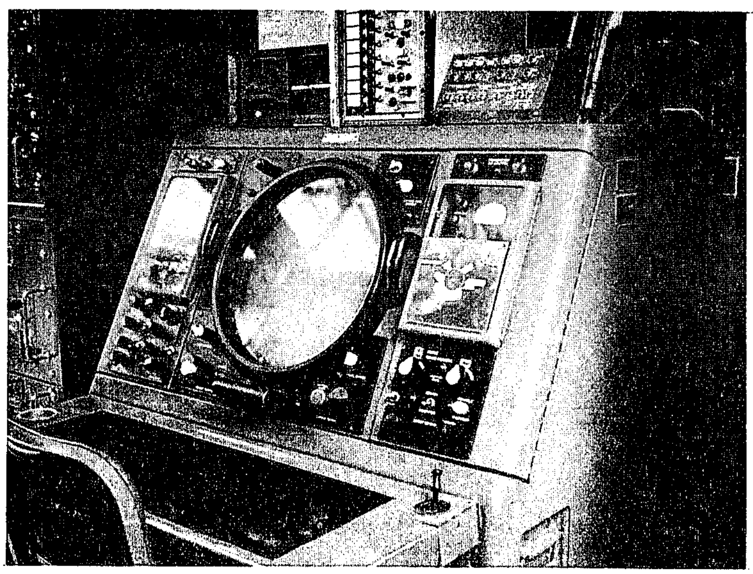
BRIEFING DISPLAY

FIGURE 6C



AIR TRAFFIC CONTROL RADAR CONSOLE

FIGURE 7A



AIR TRAFFIC CONTROL RADAR CONSOLE

FIGURE 7B

IV. SECURITY

Strict security regulations are in effect throughout the buildings and grounds of the ARTC Center because of the radar and other classified equipment located there. Weather Bureau personnel are required to have security clearance and wear a badge at all times while within the confines of the ARTC Center. Any visitors to the Center must have a visitor's badge and must be escorted at all times. In addition, some details regarding the detection capability and the operating of the radar are classified and cannot be discussed or published for public dissemination.

V. ARTC RADAR SYSTEMS

A. Types and Characteristics

The ARTC system utilizes several different types of radar for long-range surveillance. In this discussion we shall consider only the more common ARSR-2 radar system. Like all radars used in the ARTC network, the ARSR is an "L-Band" or 23 cm system.

1. ARSR-2

Control of air traffic requires accurate tracking at all speeds in the presence of weather and clutter. The ARSR-2 radar utilizes advanced design techniques to partially (in some cases entirely) eliminate unwanted weather and clutter returns. Long-range detection is enhanced by parametric and amplitron amplifiers 4/.

Coverage provided by this system is determined by a variety of antennas, all of which have a high gain, narrow azimuth beamwidth, and wide elevation beamwidth required for effective air surveillance 4/. The broad vertical beamwidth feature of the ARSR-2 is not considered desirable for weather surveillance. Its effect on precipitation detection will be mentioned later.

ARSR systems are especially well suited for location in mountainous terrain because of their anticlutter circuitry. This circuit, commonly known as Moving Target Indicator (MTI), utilizes two-pulse and three-pulse cancellers and staggered pulse repetition frequently to provide excellent ground clutter rejection and subclutter visibility 4/.

The ARSR system employs two modes of polarization of the radiated waves. These are linear polarization (LP) and circular polarization (CP). The circular polarized waves reduce weather returns displayed on the radarscope. A detailed discussion of the effect of circular polarized waves on weather returns is provided [below] under section E-3 Anticlutter Circuits.

TABLE I

RADAR CHARACTERISTICS

	ARSR-2
Wavelength	23 cm
Peak Power	5 megw
Antenna Gain	34.0 db
Pulse Length	2 us
Minimum Detectable Signal	-114 dbm
PRF	360 pps
Range	200 nm
Horizontal Beamwidth	1.2°
Vertical Beamwidth	3.75°
Polarization	Linear & Circular

B. Location of SLC Monitored Radars

There are seven radar systems microwaved into the Salt Lake City ARTCC. They are located on Francis Peak near Farmington, Utah; Cascade, Idaho (near Boise); Lovell, Wyoming; Rock Springs, Wyoming; Ashton, Idaho; Battle Mountain, Nevada; and Cedar City, Utah. These radar sites and their approximate locations are shown on Figure 2.

Each system has a maximum range of 200 nautical miles and collectively they embrace the general area known as the Intermountain Region. All systems monitored at Salt Lake are the ARSR-2 type or modified ARSR-Is. Because of the mountainous terrain, all radars are located at high elevations (about 10,000 feet msl).

C. Location of LAX Monitored Radars

There are five radar systems microwaved into the Los Angeles ARTC Center located at Palmdale, California. They are located at San Pedro Hill near Los Angeles; Paso Robles near San Luis Obispo, California; Mt. Laguna near El Centro, California; Angels Peak near Las Vegas, Nevada; and Cedar City, Utah. The Cedar City radar is monitored at both the Salt Lake and Los Angeles Centers. These radar sites and their approximate locations are shown on Figure 2.

Like the radars in the Salt Lake network, their maximum range is 200 miles and they are all located on hills or mountaintops. Unlike Salt Lake City system, however, the locations are at much lower elevations.

D. Location of ABQ Radars

There are six radar systems microwaved into the Albuquerque ARTC Center. They are located at Phoenix, Arizona; Silver City, Albuquerque, and Mesa Rica in New Mexico; El Paso and Amarillo, Texas.

E. Location of SEA Monitored Radars

Four radar sites are monitored at the Seattle ARTC Center. They are located at Seattle and Spokane, Washington; and at Salem and Klamath Falls, Oregon.

F. Weather Detection Capability

The "L" band (23cm) radars used by the ARTC Centers have certain design parameters which are not considered optimum for weather detection and analysis. The manner in which the equipment is operated also has a direct effect on the detection of precipitation, e.g., antenna tilt, antenna RPM, and the employment of anticlutter circuitry (MTI-CP-STC). In this discussion we shall consider some of these problems and their effect on the weather surveillance program.

1. The wavelength of the radar system used by the ARTC Centers is 23 cm. Normally, this wavelength would be considered too long for optimum weather detection, particularly lighter forms of precipitation with small drop diameters 6/. However, the peak power transmitted is about 10 times the power emitted by the WSR-57 (10 cm) radar, which nearly compensates for the loss of precipitation detection normally associated with such relatively long wave length radar.

2. The beamwidth of the ARSR system is 1.5 degrees horizontal and 3.75 degrees in the vertical adjusted to span an arc of 45 degrees. The broad vertical beamwidth is not desirable for meteorological targets since it precludes detailed probing of the storm in the vertical and presents a beam cross section that can seldom be filled by a meteorological target at long range.

Also, the strength of the return signal from a meteorological target is partly dependent on the amount of beam volume filled by the target. If the target completely fills the radar beam, the energy is attenuated by a factor of $1/R^2$. As the degree of beam filling is decreased, the factor attenuation approaches $1/R^4$. The problem of beam filling is further complicated by the radar transmitter location on top of high mountains and the FAA requirement to tilt the antenna upward as high as 1.5 degrees. Because of these factors, low-level precipitation such as winter rain and snow showers will occur below the radar beam at extended ranges and go undetected.

3. Anticlutter circuits are employed by controllers to eliminate unwanted targets from their scopes which may obscure aircraft targets. Weather echoes sometimes fall into this category. Two special circuits have been provided to help eliminate unwanted targets. These are MTI to remove stationary ground targets, and CP designed to reduce the signal returned by precipitation targets.

(a) Moving Target Indicator. All ARTC radar systems are equipped with MTI. The ARSR systems have two video signals brought into the master console--"Normal" and MTI. The "Normal" video carries all the signals as received by the radar system from the target essentially unaltered by suppression circuitry. The MTI channel carries a video signal that has been processed to eliminate targets which are stationary.

In essence, the MTI video is completely free of any ground-clutter targets. This desirable feature (from the standpoint of air traffic control) is also beneficial for weather surveillance in mountainous terrain. Extensive ground return in these areas would completely obscure weather targets. Unfortunately, MTI has an undesirable effect on the signal back-scattered from precipitation. MTI, which utilizes the doppler shift principle, will reduce the return signal strength from weather targets. The degree of degradation is variable dependent on the component of motion of the hydrometers either way from or toward the radar antenna. The NSSL study 1/ estimated the reduction in signal strength due to MTI to be about 9 db.

(b) Circular Polarization. The ARSR systems employ two modes of polarization of the radiated waves. These are linear polarization (LP) and circular polarization (CP). Circular polarized waves reduce weather returns displayed on the radarscopes. This technique takes advantage of the fact that raindrops are more symmetrical than most other targets. Obviously the degree of cancellation is dependent on the shape of the precipitation particles. The more spherical the particles, the greater the cancellation. Cancellation in excess of 30 db has been claimed for dense rain clouds. However, cancellation of less than 15 db is obtained from nonspherical precipitation such as large snowflakes 5/. The comparative study conducted by NSSL 1/ discussed earlier indicated that the sensitivity of the ARSR-1D was reduced approximately 12 db by circular polarization. The exact comparability of the ARSR-1D studied by the NSSL and the ARSR-2 equipment used by the ARTC Centers is not certain since the ARSR-2 employs a narrower vertical beamwidth (3.75° vs 6.5°).

The use of circular polarization presents a serious problem since its use affects the entire radar system and all scope displays on that particular system. The decision to employ CP must remain with the controller without coercion from the weather observer. Certainly no degradation of the controller's ability to observe aircraft targets on his scope display can be tolerated. However, when operation is limited to CP, considerable important weather data is lost.

When the joint-use program first began, switching polarization was a problem; but as the controllers and radar meteorologists gained experience in working together, the radar systems were operated more and more in the linear mode. The controller found that most weather echoes did not degrade their display;

and that, in many cases, it was desirable to display the weather echoes since aircraft approaching or finding themselves in the weather could request and receive a vector out of the weather.

From the standpoint of the radar weather observer, the operation in CP was even beneficial at times since these echoes which survived the suppression of CP certainly indicated areas where heavier precipitation was occurring. Herein lay a bonus which permitted an estimation of precipitation intensity. For example, if the radar system could be switched to linear polarization long enough to outline the light precipitation return and then switched back to CP, two intensity contours could be constructed, separating light precipitation from heavier precipitation.

Only a very brief time is required to switch the radar system from one mode of polarization to the other.

Experiments during actual operational conditions indicated switching could be accomplished for the brief periods needed to make weather observation without seriously interfering with the controller's use of the radar display.

It is now standard practice at both the Salt Lake and Los Angeles Centers to switch polarization in the course of weather observations when significant or widespread precipitation is occurring. If control of aircraft is critical through these areas, the weather observation will be delayed until the controller is satisfied that it is safe to make the switch.

(c) STC (Sensitivity Time Control). STC is a special circuit designed to reduce the signal strength of targets at short ranges from the radar or is, in effect, a range normalization circuit. ARTC radars utilize an STC curve based on signal attenuation for a point target, i.e., $1/R^4$. Weather radar, on the other hand, due to the beam filling nature of meteorological targets, utilizes a curve based on attenuation $1/R^2$. The FAA practice of applying signal suppression along the $1/R^4$ curve out to ranges of 60 to 80 nautical miles in areas where ground clutter is a factor has serious effects on weather detection.

In fact, *when STC circuits are employed, practically no weather activity can be detected within 30 miles of the radar site.*

Procedures to circumvent this problem are essentially the same as those used for switching from LP to CP. Requests are made to turn STC off for a very short period of time to allow the weather observer time to trace the echo activity from the radarscope. If air traffic will not permit the momentary switch, the observation is taken and an appropriate remark added to the transmitted message to convey that the weather data is limited due to lack of optimum weather detection capability.

4. Precipitation Detection. In the opinion of the writers, based on their more than eight years of experience with WSR-57 radar and 2 years' experience with FAA radar, there is very little difference in the detection capability of the areal extent of precipitation between the ARSR-2 radar and other weather radars used by the Weather Bureau, except that the ARSR system lacks the special design and circuitry needed to make quantitative measurements and detailed analyses of storms which are possible with the WSR-57.

The ARSR-2 system appears to be slightly better than the WSR-57 for the detection of snow. Experience at the Salt Lake Center has shown that when temperatures are 25 degrees or higher, the ARSR-2 radar will detect snow at a range of 150 nautical miles. The WSR-57 fails to detect snow at this range unless the temperature is at least 32 degrees F.

A study conducted by the Salt Lake Radar Unit shows that most thunderstorms will be detected by the ARSR-2 out to a distance of 200 nm, provided there are no intervening mountains to block the radar beam. For further information on the detection of precipitation by the ARSR-2, the reader is referred to a recent paper by Mr. Robert Belesky 7/.

VI. OBSERVATIONS

A. General

The operational procedures for making an observation of radar weather echoes from ARTC radars are in a constant state of flux. As new equipment is received and as more is learned about the capability of the radars, procedures are improved and modified. The procedures now in effect have evolved over the past years from a mere tracing of weather echoes to a detailed, integrated analysis of radar weather data composited from twenty (20) separate systems. This involves considerable manipulation of the radar controls and analysis of supportive data from aircraft and cooperative military radars. Specific instructions for taking, recording and disseminating ARTC radar observations are included in the Weather Radar Manual.

B. Equipment Status

The first requirement when making an observation is to determine the operating status of each radar system. All indicator lamps are scanned by eye and the various features noted. If, for example, it is noted that the system is operating on magnetron, the peak power of the transmitter is reduced by a factor of 10. This obviously will reduce the detection capability of the radar system. The radar meteorologist will determine the reason for the nonuse of the amplitron and, if possible, have it restored.

C. Data Extraction

After each radarscope display has been set up for best weather echo display, each echo is traced (in every detail possible) onto an acetate overlay especially prepared for the surveillance area. The more intense echo areas (detected in CP mode) are also outlined and appropriately designated. Since detailed probing of individual echoes is not possible from ARTC radar systems, data extraction from all scopes takes a relatively short period of time (15 to 20 minutes).

After tracing the echo patterns from all radarscopes, the observer returns to the weather office and solicits pilot reports with special emphasis on areas of radar echo activity. In the Los Angeles ARTC Center, the weather radar observer hand-carries the overlays to the control room and solicits pilot reports directly from the controllers. This procedure has met with enthusiastic approval of the controllers.

The pilot reports are used to add quantitative information to the radar report to support or more adequately describe the echo data. For example, aircraft tops of clouds are used in place of the missing "echo tops"; reports of hail or funnel clouds are included, or perhaps areas of severe turbulence.

The weather radar office in the Center is also provided with a Service A teletype machine. At each observation time, the observer scans the weather sequences for information which will assist him in his analysis of the weather-radar echoes as well as verification of precipitation.

D. Compositing of Echo Data

After radarscope tracings are complete and all supportive information from teletype and pilot reports is collated, the overlays are placed in an optical reducer. This reduces the 1:2M scale of the radarscope to 1:7:5M (the 1:7:5M scale map is the scale used by the MCK RADU* for compositing radar echoes). In this way all echo data from the system monitored at the Center are composited on one chart. Obviously one or more radar systems will occasionally observe the same echo. Because of the inherent problems involving curved earth and radar slant range, these echoes will not appear in exactly the same location or have the same shape. The radar observer must make a subjective determination of the precise location of each echo.

All pertinent information such as cloud tops, turbulence, icing, occurrences of hail, type of weather, wind gusts, and other similar data is indicated on the composite chart in the appropriate area. Also, areas of intensification or dissipation are noted as well as the location of moderate to strong echo activity. When the echo configuration signifies a dominant synoptic feature such as a front or trough, or possibly a squall line, this information is also entered on the chart. An attempt is made to analyze completely the chart as to synoptic features, local-scale features, significant developments and weather phenomena to aid as many potential users as possible.

Ultimately, all radar data in the western network is composited onto a single chart by the Salt Lake City ARTC Radar Unit. To do this hourly and in real-time requires considerable coordination between the Radar Units. Each unit is responsible for completing some phase of the total compositing job, i.e., Seattle will composite the Medford and Missoula WSR-57 reports on their chart before transmitting to Salt Lake. Each unit has a prescribed time to transmit their overlay to the Salt Lake Center; the schedule is shown on Table 2. Figure 8 is a sample of the completed hourly composite map prepared by the Salt Lake Unit. The chart includes data gathered from 20 ARTC radars and three WSR-57s. (The Medford WSR-57 radar will not be operational until the Spring of 1971.) Until the RAFAX* circuit is extended to Sacramento and Medford, their reports will continue to be entered on the composite chart in the SD plotted RAREP format. Figure 9 shows the legend for both plotted SD reports and composited echoes.

E. Dissemination of Radar Data

The weather communications facilities provided at ARTC Centers fall into two categories: (1) Communications for the collection and coordination of data gathering, and (2) communications for the dissemination of radar intelligence.

1. Data Collection and Coordination Facilities: A telephone hand set on the Center's "300 system" is provided in the weather office connecting to all of the controller positions

*RADU - Radar Development Unit
*RAFAX - Special Western Radar Facsimile Circuit

TABLE 2

COMMUNICATIONS SCHEDULE
(Tentative)

CIRCUIT A

H + 30-35	MFR to SEA
H + 40-45	MSO to SEA
H + 50-55	SEA to SLC
H + 60-65	SLC to MKC - Data Phone

CIRCUIT B

H + 30-35	ABQ to PMD
H + 40-45	SAC to PMD*
H + 50-55	PMD to SLC

*When Facsimile Circuit is completed

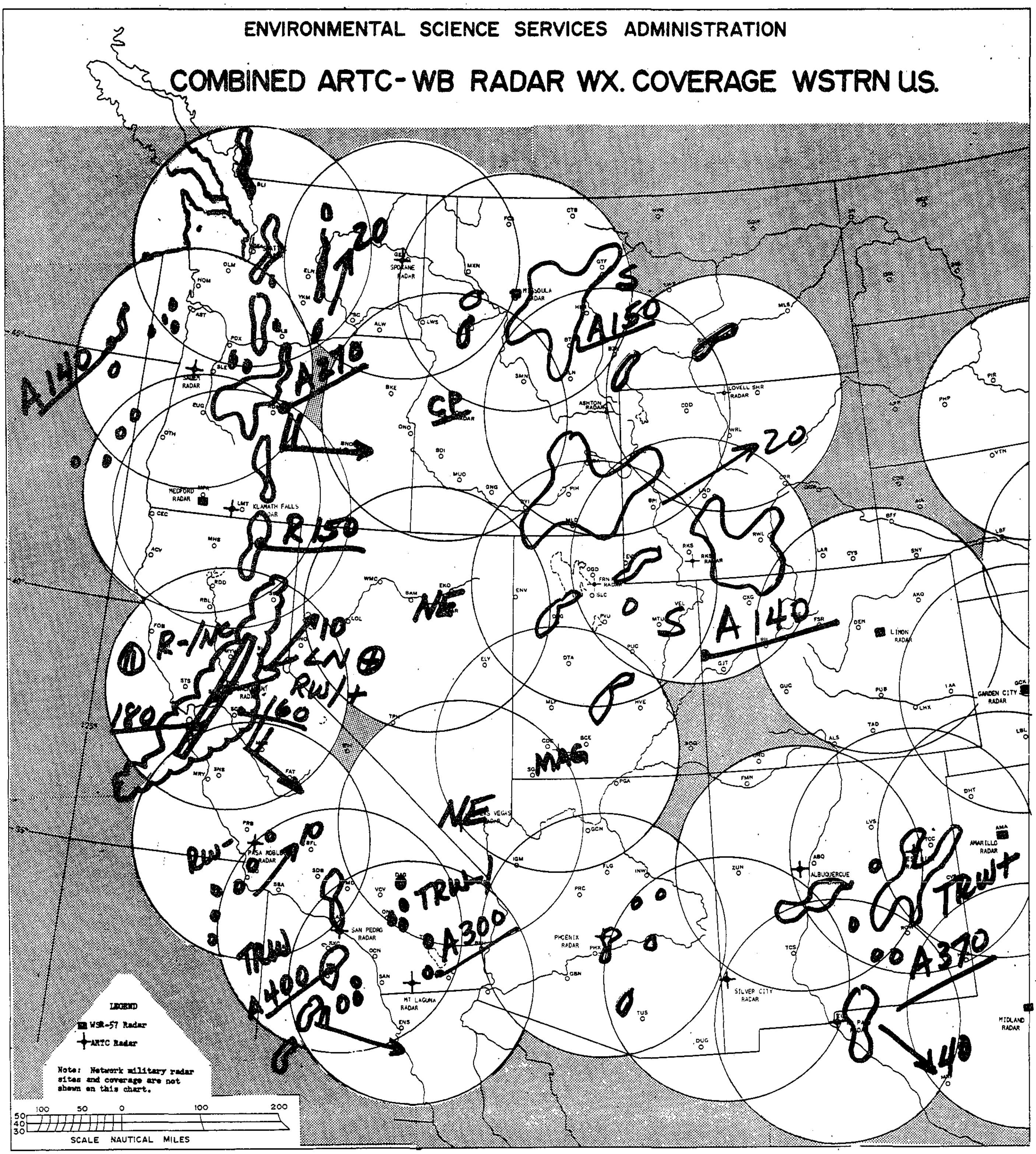

ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
COMBINED ARTC-WB RADAR WX. COVERAGE WSTRN US.
LEGEND
WSR-57 Radar
ARTC Radar
Note: Network military radar sites and coverage are not shown on this chart.
100 50 0 100 200
SCALE NAUTICAL MILES
SPOKANE RADAR
MISSOULA RADAR
LOVELL SHR RADAR
MEDFORD RADAR
KLAMATH FALLS
LIMON RADAR
GARDEN CITY RADAR
AMARILLO RADAR
ALBUQUERQUE
SAN PEDRO RADAR
PHOENIX RADAR
MT LAGUNA RADAR
SILVER CITY RADAR
MIDLAND RADAR
PASA ROBLES RADAR
A140
A270
A150
CP
R150
NE
S
A140
MAG
NE
TRW
A300
TRW
A400
A370
TRW+
R-INC
LN
RW/+
180
160
RW-
20
20
10
10
40

FIGURE 8

RADAR SUMMARY CHART LEGEND

U.S. DEPARTMENT OF COMMERCE
Maurice H. Stans, Secretary

ENVIRONMENTAL SCIENCE SERVICE ADMINISTRATION
Robert M. White, Administrator

WEATHER BUREAU
George P. Cressman, Director

GENERAL

Two methods of data depiction appear on these charts. East of the Rockies radar reports are plotted and grouped in certain configurations. West of the Rockies, actual echo patterns from ARTC radar sites are shown. Most of the symbols used are common to both sections of the map.

SURFACE WEATHER ASSOCIATED WITH ECHOES

T	Thunderstorm	E	Sleet
R	Rain	L	Drizzle
RW	Rain Showers	ZR	Freezing Rain
S	Snow	ZL	Freezing Drizzle
SW	Snow Showers	A	Hail

PRECIPITATION INTENSITY

——	Very Light	+	Heavy
—	Light	++	Very Heavy
No Sign	Moderate	U	Unknown

Intensity of echoes is given in terms of the estimated precipitation intensity. No intensity is ascribed to drizzle, hail or snow. Echoes located farther than a specified range, usually 125 nautical miles, are given an intensity of unknown or "U".

INTENSITY TREND

+	Increasing	NEW	New Development
—	Decreasing	NC	No Change

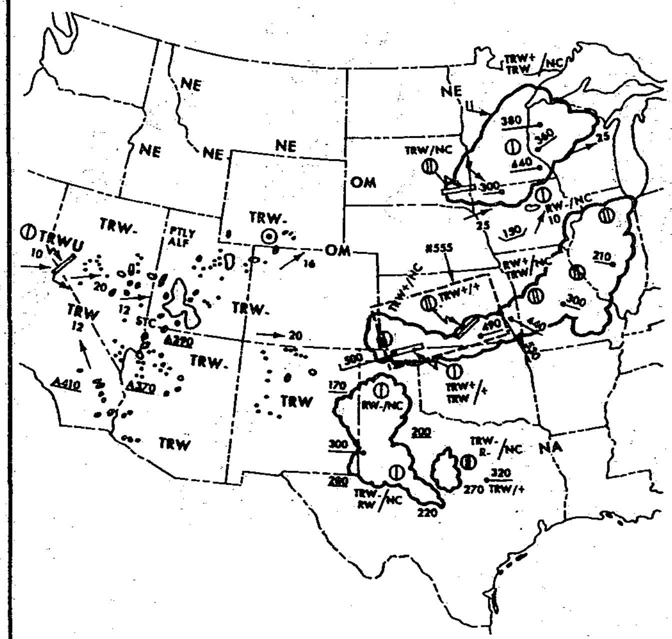
Intensity trend follows the precipitation intensity and is preceded by a slash mark.

STATUS OF EQUIPMENT

NE No echoes
NA Observation not available
OM Equipment out for maintenance
CP Moderate to strong echoes reported only
STC Reduced detection capability within 30 miles of radar
MAG Radar on reduced power

Last three items from ARTC reports only

SAMPLE RADAR SUMMARY CHART
WW NR 555 Valid Til 0200Z



MOTION OF ECHOES

V V Cell Movement - Speed in knots
Area or line movement--(10 kts/barb)
Ltl Movmt Little movement

ECHO HEIGHTS

hhh Height of echo tops
hhh Height of maximum echo top
hhh Heigh of echo bases
hhh Height of melting level
Ahhh Visual cloud top seen by aircraft

Heights are in hundreds of feet MSL. Layers aloft associated with other echoes will be preceded by the contractions ptly alf.

CHARACTER OF ECHOES

Area of echoes
Line of echoes
Solid-Over. 9 coverage
Broken-Over .5 to .9 coverage
Scattered- .1 to .5 coverage
Widely Scattered-less than .1 coverage
Strong or very strong cell identified by one stations
Strong or very strong cell identified by two or more stations
Actual echo boundary copied from ARTC scopes

SEVERE WEATHER WATCH AREAS

Area of AVIATION SEVERE WEATHER WATCH with entry of number and valid time.
When a public severe weather watch has been issued the lines defining the area are dashed.

FIGURE 9

in the main control room as well as the supervisor and maintenance liaison positions. The "300 system" is utilized for the collection of pilot reports and to coordinate changes in the radar system status, e.g., changing from circular polarization to linear.

Service A teletype is provided to permit monitoring of observed weather conditions in the radar area of surveillance. A regular telephone line is provided for general use. National Weather facsimile is provided to assist radar meteorologists in the analysis of radar-detected precipitation patterns. These facsimile charts are also used in briefing controllers on synoptic weather events. A hot line to other ARTC Centers is also provided to permit coordination of echo data and transmission schedules.

2. Dissemination:

Radar data from the ARTC Center is disseminated in a number of different ways and in differing formats to best serve the many users. The primary means of data dissemination is through the communication of radar graphics or composite chart. Coded radar reports are not prepared by the ARTC Units. Each Center is equipped with three basic means for data communication:

(a) Telephone
(b) Teletype
(c) Facsimile.

(a) Telephone. Because of the unusually large area of radar surveillance at ARTC Centers, the unit generally serves more than one WBFO or River Forecast Center. In some instances these WBFOs are in different Regions. Therefore, considerable telephone briefing and coordination are conducted between Radar units and the forecast offices. Of course, the telephone is used almost exclusively when issuing alerts or warnings to WBOs or directly to communities and agencies having public responsibilities.

(b) Teletypes. In most cases the Radar Unit is provided with a RAWARC* drop and a local public service teletype loop. These circuits are used for routine issuances of radar bulletins and summaries. The RAWARC is utilized for severe weather warnings and coordination.

*RAWARC - RAREP and Warning Coordination System

(c) Facsimile. The western inter-ARTCC facsimile circuit (RAFAX) serves as the backbone for data communication from the Center. This circuit has been designed to serve two basic functions: (1) To collect and composite all radar echo data from the ARTC Radar Units and from WSR-57 radar stations in the western radar network. These data are composited at Salt Lake City and transmitted to RADU via the data phone link for inclusion on the National Weather Facsimile Radar Summary Chart. (2) To provide a real-time data link between Radar Units, WBFOs, and RFCs. Forecast offices can request special radar overlays and data via this link whenever needed for critical weather situations. Figure 10 shows the RAFAX circuit, including subscribers.

VII. SERVICE PROGRAMS

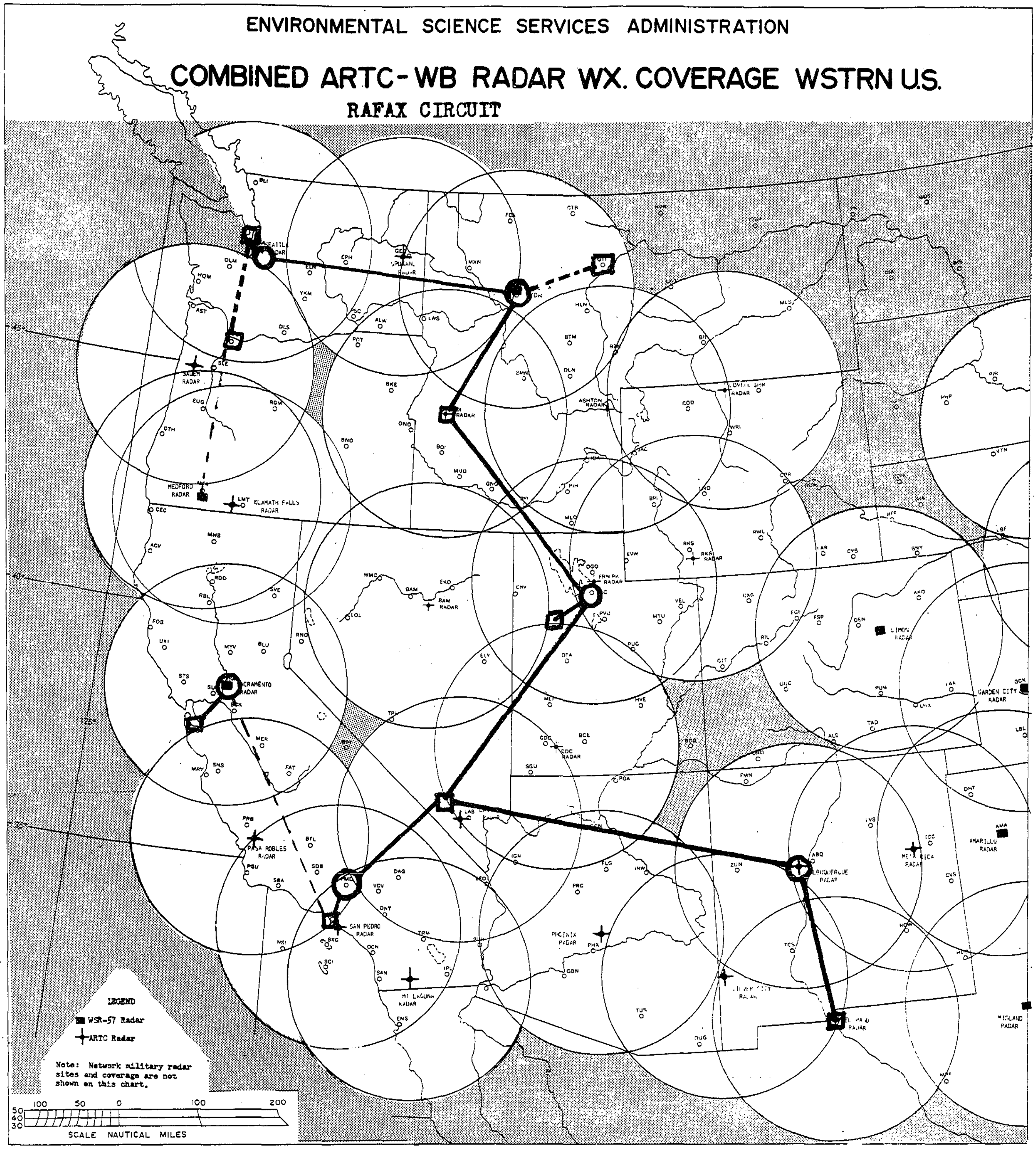
A. Public Service

Nearly all radar services to the general public are channeled through the Weather Forecast Office (WBFO). In this way the integrity of the forecasts is protected and radar weather summaries and advisories incorporate the thinking of the duty forecaster. Further, the WBFO has well-established outlets for disseminating weather information to the public. The general public is best served through the routine forecasts, special warnings, and advisories, all of which reflect the radar weather input. Direct public contact with the radar unit is avoided since there is neither time nor information to provide requests for forecasts, etc. Such requests, when received, are referred to the WBFO. Direct contact by other forecast offices, RDOs, and RFCs during critical weather events is encouraged.

A special service to the general public is provided through the preparation of a composite radar overlay chart for display on local television. These charts are provided to the TV channels through the WBFO.

The detection, early warning, and tracking of severe weather echoes are of prime concern to the radar observer. The individual radar presentations are watched carefully for significant developments which may lead to severe weather. This is particularly true when a severe weather "box" has been issued in the radar surveillance area or when the weather charts show a potential for such development. When echoes are detected under these conditions, the Forecast Office is alerted via telephone and a special overlay chart is prepared and transmitted.

Observation frequency is stepped up, if necessary, until critical weather patterns have dissipated. If conditions warrant, a statement is prepared in collaboration with the duty forecaster at the WBFO, and disseminated to the public through appropriate WBFO communication facilities.



O S/R

□ RO

---- Planned Circuit Extension

FIGURE 10

Since the area of radar surveillance is so large, critical weather may be detected in a forecast area not under the responsibility of the supervising WBFO. In this event, the Radar Unit places a call to the WBO having responsibility.

A folder containing maps of every state under the Radar Unit's area of surveillance is available to the radar observer. Each map is divided into areas according to the county areas of responsibility. The telephone numbers of the responsible stations are entered on the map. The radar observer has only to locate the area of development or concern and the responsible station and take appropriate action.

B. Aviation Services

Radar weather service to aviation is provided primarily through regular aviation forecasts and advisories. Standard briefing services are enhanced through the availability of radar data and pilot reports on Service A teletype, special radar facsimile graphics, and National Facsimile radar summary charts. In addition, each Radar Unit provides meteorological expertise to controllers at the Centers.

The special warning service for the FAWS areas, including those outside the supervising WBFO's area of responsibility is provided. This is similar to the warning service for the general public discussed earlier. Significant weather echo patterns are watched closely and, if warranted, are brought to the attention of the appropriate FAWS Center. Such calls in the past have resulted in the issuance of numerous airmet and sigmet advisories.

A primary duty of the Radar Unit is to collect pilot reports in the Center and pass them along to the FAWS unit. The collection of pilot reports by the Radar Unit has three benefits: (1) provides more quantitative information in the radar report, as discussed earlier. (2) Permits soliciting of pilot reports (through the controller) which have special applicability to critical weather in the area. (3) Expedites receipt of pilot reports at the FAWS Center (in real time) by shortcutting the more devious route involving Service B. The requirement to transmit these reports on Service B is not negated by this procedure but merely gets the pilot report to the FAWS Center a little faster.

C. Hydrology

In spite of the limitations of ARTC radar with regard to measuring precipitation intensity, considerable use can and has been made of these data by hydrologists.

Services to the hydrologist fall into two general categories: (1) Flash-flood potential advisories, and (2) Real-time briefing during general flooding conditions.

The flash-flood program involves the early detection of potential flood-producing thunderstorms and the issuance of appropriate warnings and advisories. When possible, alerting the public to potential flash-flooding is handled through the WBFO and River Forecast Center (RFC). If time is critical, the radar meteorologist will warn the affected area weather office and then coordinate these actions with the WBFO and RFC.

Under conditions which produce general flooding on large river drainages, direct liaison is established with the appropriate RDO. Frequent briefings are provided as well as any special data, etc., which may be requested.

The successful utilization of ARTC radar data depends on the establishment of an operating plan with the RFC and RDOs located in the radar area of surveillance. This plan includes reliable communication channels and procedures to be used in emergency situations, areas of general or flash flooding as determined by the RDO. The Radar Unit cannot be expected to know antecedent conditions in every river basin in the radar area.

D. Fire Weather

Close cooperation is maintained between the Radar Unit and the Fire Weather forecaster at the WBFO. Forecasts prepared by the Fire Weather forecaster often reflect information received from the Radar Unit. In addition, the echo distribution over Utah, Idaho, Nevada, and portions of the surrounding states is encoded in a special format using a square grid technique for teletype transmissions to various fire control agencies (Figure 11). These include the Bureau of Land Management, the U. S. Forest Service, and the National Park Service.

The echo distribution is given by using numbers and letters to represent the particular squares where echoes are located. Amplifying remarks are included to indicate direction of movement, intensification, and trend of activity 8/.

The Radar Unit has the capability to transmit composite radar charts over the fire-weather radio. Radio transmission of overlays normally takes place when there is a going fire and the "camper unit" has been dispatched to the scene.

The Radar Unit also notifies the Fire Weather forecaster via telephone of the first echo activity of the day and the area over which it occurred. In the morning, the Fire Weather forecaster will make a

RADAR WEATHER REPORTING GRID MAP

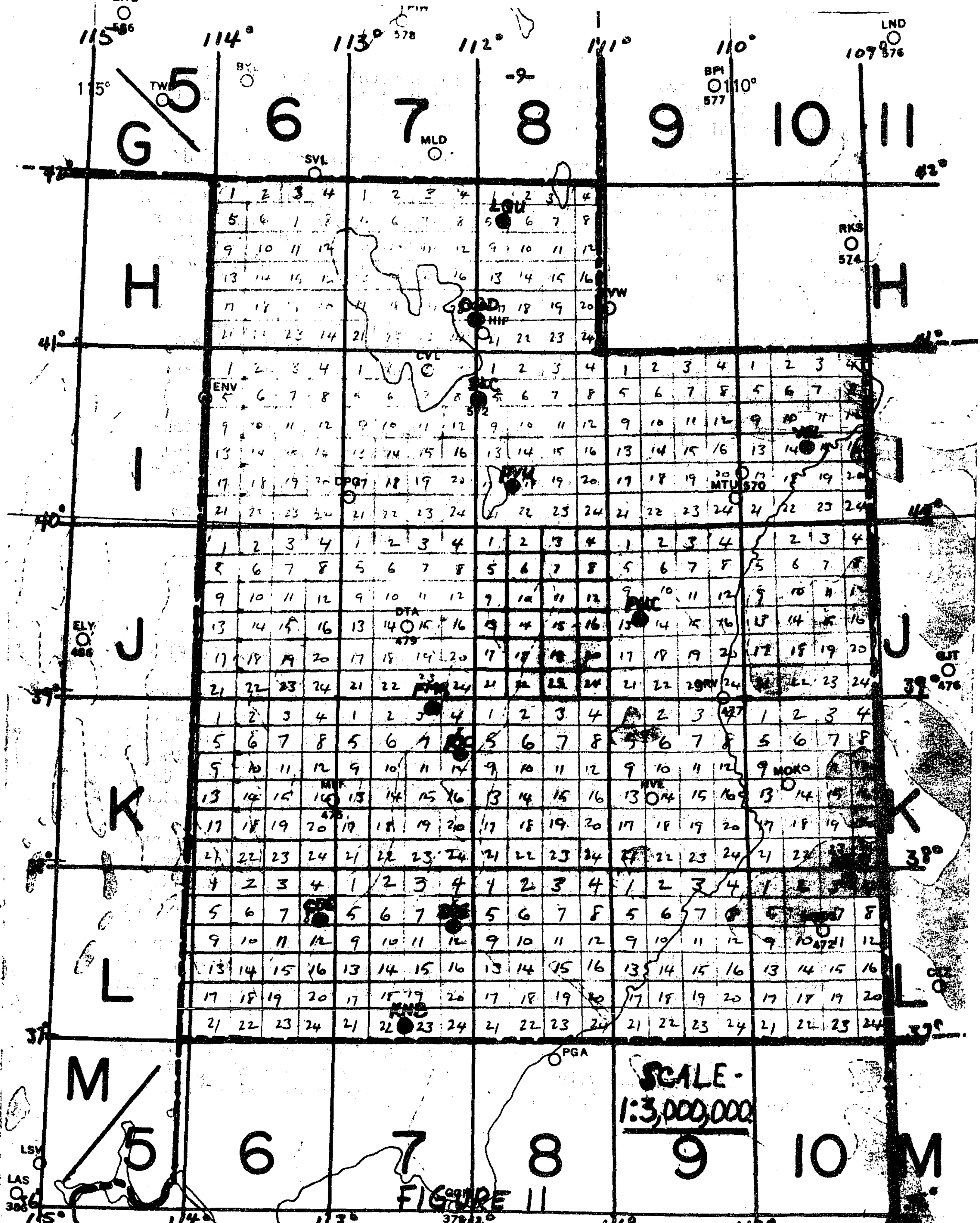


FIGURE 11

composite of echo activity from radar facsimile charts received during the night so that the fire control agencies can dispatch aircraft over the area to spot any fires that have started during the night.

Maps of the fire weather districts and the forest boundaries are available to the radar operator as well as a list and locations of all fire-weather reporting stations.

E. ARTCC

The air route traffic control system involves the control of aircraft through a series of sectors. Each sector has a controller who ensures the separation of all traffic within that sector and answers requests for flight information from in-flight aircraft. Included in that request may be vectoring service and weather information. The radar operator makes a copy of every overlay chart he prepares and delivers it ot the watch supervisor's desk in the control room. This gives each controller the distribution of precipitation echoes over his sector area. Not only can he see what is going on in his own sector, but he can be made aware of other activity beyond his sector which may be of interest to aircraft he is working.

The proximity of the Radar Unit to the controllers has made it easy for them to request advisory service from the Radar Unit. This, however, has not been encouraged too much due to the absence of Radar Unit personnel during the nighttime hours.

Controllers have considerable latitude in their radarscope adjustments. Most of these adjustments are independent of the scopes used by the Radar Unit. However, there is a monitor scope close by the main Radar Unit scope which is used by the radar weather observer to monitor the presentation on the controller's scope. When weather activity forms or moves into a particular sector, a controller may not be aware of this (if his scope has been adjusted to eliminate the weather clutter). It is the radar weather observer's responsibility to ascertain this and notify the watch supervisor. The reason for this is to make sure the controller is aware of the weather in his sector. This back-up service was established at the request of the Center Chief.

Another service provided to the ARTC Center involves operation of the Center complex. If thunderstorm activity is threatening or imminent, the watch supervisor is advised. If he deems it appropriate, he will have the power source for the complex switched from commercial to standby generator. This ensures that vital Center functions will not be interrupted.

F. Air Resources Laboratory (ARL), Las Vegas

The ARL has been utilizing the ARTC Center radars for a number of years to track tetroons. These are constant-altitude plastic balloons which carry a specially designed target for maximum reflectivity of the radar energy emitted by the ARTC Center radars. Previous to the installation of a Weather Bureau Radar Unit at the Center, the ARL would detail men to the Center to track the tetroons whenever there was an atomic test event at the Atomic Energy Commission (AEC) Nevada site. When Weather Bureau personnel were assigned to the Center, an agreement was made between the ARL and WRH whereby one position was to be funded by the ARL in exchange for tracking information by the Radar Unit. Whenever a test occurs that requires tetroon tracking, all personnel participate in the exercise, sometimes throughout a 24-hour period if the test carries a high priority.

G. Applied Studies

The utilization of radar for weather surveillance offers many interesting challenges for those inclined toward applied technical studies. In a new program such as this, there are many unknown quantities; research is a valuable tool both to the operational functions and to the science of radar meteorology. Because radar meteorology is virtually in its infancy, nearly any venture involving radar is new and unexplored. Since the use of 23 cm wavelength-high power ARSR radar for weather detection had no precedent, the first task of the radar unit was to see just how well the radar was capable of depicting meteorological targets and under what conditions. A project began shortly after the establishment of the Unit which computed probabilities of the radar detecting precipitation in any given area. This was done for rain, snow, and thunderstorms. The results of this study were published in Western Region Technical Memorandum No. 7.

Radar studies aimed at climatological objectives are being conducted. One study consists of a grid of squares over the state of Utah in which marks are made for each occurrence of precipitation within the grid square. The number of occurrences is tabulated for various time intervals. Isolines of equal number of occurrences will be drawn which will represent the distribution of precipitation over the state for that time period. As a side study, the pattern of radar precipitation is being compared with the distribution of precipitation amounts as recorded by reporting stations. The pattern compares very well and in some cases a relationship in total precipitation and in total occurrences can be seen.

For hydrology, plans have been formulated and work is under way to study the precipitation occurrences over a small river basin and to compare this with river runoff from that basin. Since there can be no quantitative intensity measurements made from the radar data, an annual or monthly precipitation figure will be used with the number of hours of precipitation as shown by radar and applied to the runoff as shown by the river gage reading.

VIII. CONCLUSION

In this somewhat enthusiastic description of the ARTC weather radar program, it has not been the intent of the authors to "oversell" ARTC radars from weather surveillance. Obviously, a similar network of "Weather Radars" could provide a far superior program.

This successful use of ARTC radar exemplifies what can be achieved by exploiting the limited weather detection capabilities of ARTC radar. Weather Bureau Forecast Offices report that they are providing better weather services to aviation and the general public because of the availability of these radar data.

The future use of ARTC radars for weather surveillance will depend largely on the establishment of a "Weather Radar" network in the West and on the future reconfiguration of the FAA's National Air Space System. In the interim, the ESSA/FAA Joint ARTC Weather Radar program will continue to provide essential radar data to the forecaster and stand as an excellent example of cooperation between two Government agencies in providing public services.

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*Out of Print
**Revised