Next Generation Weather Radar (NEXRAD)

Programmatic

Environmental Impact Statement

November 1984

Prepared for

The NEXRAD Joint System Frogram Office



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U.S. DEPARTMENT OF COMMERCE National Oceanic and Atmospheric Administration

NATIONAL WEATHER SERVICE Sever Spring, Md. 20910

November 5, 1984

CONSTRUCTION AND OPERATION OF THE NEXT GENERATION WEATHER RADAR (NEXRAD) SYSTEM

FINAL PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT

Abstract

This document describes the probable environmental impact of constructing and operating a new weather radar system. NEXRAD, the Next Generation Weather Radar, is being developed jointly by the Departments of Commerce, Defense, and Transportation to acquire, process, and distribute improved weather radar information. It will consist of approximately 145 radar units distributed across the United States. In addition to a radar antenna and tower, each installation may include facilities and equipment necessary to support the functions of a user of the weather radar information. The specific sites for the radars will be chosen through a site selection process considering radar coverage requirements, geographic suitability, roads and utilities, operational factors, and potential impacts on the environment. The impact analysis indicates that construction and operation of the NEXRAD will have no significant adverse environmental impacts. All anticipated impacts are or can be limited to minor local effects. Supplements to this Programmatic EIS will be prepared for those sites finally selected for radars where significant impacts are possible.

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GLOSSARY

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Association for the Advancement of Medical Instrumentation
AAMI
AAWIPS
        Automated Weather Interactive Processing System
        American Conference of Governmental Industrial Hygienists
ACGIH
        Automation of Field Operations and Services
AFOS
ANSI
        American National Standards Institute
        Air Route Traffic Control Center
ARTCC
        Airport Surveillance Radar
ASR
AWDS
        Automated Weather Distribution System
AWS
        Air Weather Service
BBB
        Blood-Brain Barrier
        Bureau of Radiological Health
BRH
        Covenants, Codes, & Restrictions
CC&R
CNS
        Central Nervous System
CW
        Continuous Wave
DNA
        Deoxyribonucleic Acid
DOC
        U.S. Department of Commerce
        U.S. Department of Defense
DOD
TOG
        U.S. Department of Transportation
DPC
        Displayed Pulse Count
F۵
        Environmental Assessment
ECAC
        Electromagnetic Compatibility Analysis Center
CED
        Electroexplosive Device
EEG
        Electroencephalogram
EIS
        Environmental Impact Statement
ELF
        Extremely Low Frequency
EMC
        Electromagnetic Compatibility
EMF
        Electromagnetic Field
EMI
        Electromagnetic Interference
EMR
        Electromagnetic Radiation
EPA
        Environmental Protection Agency
FAA
        Federal Aviation Administration
FCC
        Federal Communications Commission
FCMSSR
       Federal Committee for Meterological Services and Supporting
        Research
GCA
        Ground Control Approach
GMF
        Government Master File
HEW
        U.S. Department of Health, Education, and Welfare
НF
        High Frequency
        Interdepartment Radio Advisory Committee
IRAC
JDOP
        Joint Doppler Operational Project
JEDE
        Joint Program Development Plan
JSPO
        Joint System Program Office
NIEMR
        Nonionizing Electromagnetic Radiation
HZOIM
        National Institute for Occupational Safety and Health
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NMC National Meterological Center NOAA National Oceanographic and Atmospheric Administration Naval Oceanography Command NOC New Source Performance Standards NSPS NTIA National Telecormunication and Information Administration NEXRAD Technical Requirements ЯТИ National Weather Service NWS Office of Telecommunications Policy OTP OEL Permissible Exposure Limits PHA Phytohemagglutinin Pulse Repetition Frequency PRE Prevention of Significant Deterioration PSD Principal User Processing PUP RDA Radar Data Acquisition RF Radiofrequency RFEM Radiofrequency Electromagnetic RFR Radiofrequency Radiation RML Radar Microwave Link RPG Radar Product Generation RSEC Radar Spectrum Engineering Criteria Specific Absorption Rate SAR SER Specific Metabolic Rate WHO World Health Organization WSFO Weather Service Forecast Office

Weather Service Office

WSO

SUMMARY

FINAL PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT
Construction and Operation of the NEXRAD Weather Radar System

Description of the Action

NEXRAD is the Next Generation Weather Radar being developed jointly by the Departments of Commerce, Defense, and Transportation. The NEXRAD system will consist of approximately 145 radar units distributed across the United States for the purpose of acquiring, processing, and distributing improved weather radar information to help reduce loss of life, injuries, property damage, and interruption of economic activity.

Each NEXRAD unit will consist of one Radar Data Acquisition (RDA), one Radar Product Generation (RPG), and one or more Principal User Processing (PUP) subsystems and the necessary communications among them.

Many NEXRAD units are likely to be installed at locations where weather radars already exist. These existing radars will be deactivated when the NEXRAD radars begin operating. Although existing buildings and equipment will be used as much as possible, the NEXRAD antenna and its tower will require new construction.

Construction requirements at each installation will vary greatly, depending on the capacity of existing National Weather Service (NWS) and Air Weather Service (AWS) facilities as well as the site's physical characteristics. At existing sites that have both a radar and a user facility, only replacement of the radar and its supporting equipment may be required. On the other hand, a new NEXRAD radar may be installed at and an existing user facility relocated to a new site. New radars may also be built at existing facilities now having no radar nearby or at locations remote from existing facilities.

A typical new site designed to accommodate all subsystems will have an antenna tower, an equipment building to house the transmitter and receiver, and utility lines as well as an access road. The site will be surrounded by a chain-link security fence. The radar antenna will be enclosed in a nearly spherical radome about 10 m in diameter mounted on a tower that may be up to 30 m tall, depending on the local terrain and man-made obstructions. New sites will probably require less than 1 acre of land.

An initial list of candidate sites for NEXRAD radars has been drawn up for study. The sites on which radars will eventually be constructed will be chosen through a site selection process that considers radar

coverage requirements, goodnaphic suitability, roads and utilities, communication distance requirements, operational factors, and potential impacts on the environment. Although the final candidate sites are not now known, many radars are expected to be located at or near airports. Some may be located at user facilities that are not at airports, and a few may be situated at isolated sites.

Environmental Effects

A range of possible impacts that might be caused by construction and operation of a NEXRAD radar, including health effects of radio-frequency radiation (RFR), electromagnetic interference, and effects on the biophysical and socioeconomic environment, was investigated. None of these effects is expected to be significant except under certain specific circumstances. These effects are summarized below.

Radiofrequency Radiation and Human Health

Detailed calculations were made to estimate the magnitude and distribution of the RPR from a NEXRAD transmitter, and the resulting values were used to estimate the possible effects of RPR. In addition, a recent in-depth, critical review of the available literature on the biological effects of RFR in the range from 0 to 300 GHz was used to draw conclusions regarding possible RFR bioeffects of the NEXRAD radar, which will operate in the band from 2,700 to 3,000 MHz.

People may be exposed to the main beam while airborne or to low-intensity RFR at ground level. However, because an interlock will prevent transmission when the antenna is stationary, continuous direct exposure will not occur. An airplane in the general vicinity of a NEXRAD radar may be scanned by the main beam for periods of about 0.3 s per sweep. Calculations show that within about 550 ft of the antenna, the maximum pulse power density in the main beam may be as high as 8,000 mW/cm²; beyond that distance the pulse power density diminishes by the inverse-square law and will be approximately 300 mW/cm² at 3,000 ft. The time-averaged power density will be 0.23 mW/cm² at 100 ft, 0.035 mW/cm² at about 300 ft, and still lower at greater distances. These calculated average power densities, which do not take account of the shielding properties of metal aircraft, are below prevailing U.S. standards for permissible human exposure, and there is no evidence that exposure to such levels would be harmful.

The maximum pulse power density near ground level will not exceed $200~\text{mW/cm}^2$. The maximum time-averaged power density will be less than $0.03~\text{mW/cm}^2$ and, beyond about 200~ft, will be less than $0.001~\text{mW/cm}^2$. These values of RFR are significantly less than any pertinent RFR exposure standard.

A comparison of the expected RFR exposures from the NEXRAD radar with results in the relevant literature indicates that there is no reliable scientific evidence to suggest that for the cases considered,

exposure to RFR from the NEXEAD radar will be deleterious to the health of even the most susceptible members of the population such as the unborn, infirm, or aged.

Electromagnetic Interference and Hazard Effects

The NEXRAD transmitter will be built to transmit between 2,700 MHz and 3,000 MHz. In the United States, the 2,700- to 2,900-MHz band is shared by about 630 government radars for use in airport surveillance, air traffic control, and weather surveillance. NEXRAD could affect these and other systems using the same portions of the electromagnetic spectrum and also systems not intended to receive electromagnetic energy, including TV, radio, and other radars, as well as cardiac pacemakers, electroexplosive devices (EEDs), and fuel handling systems. In all cases, the operating frequencies, powers, and locations of the existing equipment will be considered in selecting the frequency for the NEXRAD radar to avoid mutual interference. For this Programmatic Environmental Impact Statement (EIS), hazard estimates have been made for a general case; detailed calculations, which are highly dependent on the specific NEXRAD deployment situation, will be made for each final NEXRAD site.

The upper adjacent band, from 2,900 to 3,100 MHz, is also used for government radars. The lower adjacent band, from 2,690 to 2,700 MHz, is allocated for radioastronomy; no U.S. radars are authorized to transmit there. NEXRAD installations will comply fully with rules designed to avoid interference with the Radio Astronomy Service.

Interference to other systems by the harmonics of the NEXRAD signal is possible, but because interference situations are site-specific, they can be considered in detail only when particular installations are studied. For example, the NEXRAD third harmonic could fall on a fre quency used by the Federal Aviation Administration (FAA) for radar microwave communication links. These strictly local matters will be analyzed in depth when individual NEXRAD installations are being planned.

Like all other radars currently operating in the 2,700- to 3,000-MHz band, each NEXRAD radar could cause some interference to the reception of broadcast TV and radio in its immediate vicinity. No studies are known to specifically treat such interference. The number of dwelling units located within about 1 mile of each candidate site will be considered during the selection process.

No definitive information is available regarding the susceptibility of currently used cardiac pacemakers to fields in the NEXRAD radar's frequency range, but such radars do not appear to pose a significant risk to pacemaker owners. Most pacemakers are designed to sense naturally occurring electrical signals produced by the heart and to send out a pacing pulse only when the heart's pacing pulse seems to be missing; such a pacemaker might confuse low-rate electromagnetic pulses with the natural cardiac signals that it is designed to sense. However, pulse rates used by NEXRAD and similar search and surveillance radars are too

high to be mistaken by a pacemaker for the heart's own signal. If they were to produce any effect at all, it would probably be to cause the pacemaker to begin harmless fixed-rate pacing rather than to remain in the usual pulse-only-when-needed mode.

NEXRAD is not expected to pose a hazard to existing or planned fuel handling operations. The Air Force directs that fuel handling operations should not be undertaken in electromagnetic fields exceeding a pulse power density of 5 W/cm². This value can be found only within NEXRAD's main beam at distances closer than about 730 ft. The beam will usually be well in the air at that distance and will not illuminate ground-based fueling operations unless they are performed on elevated terrain near the site.

The Air Force also has a standard for determining safe separation distances between radars and areas where EEDs are stored, handled, or transported. At the recommended safe separation distances, EEDs are considered safe, although this does not imply that the EEDs are unsafe at slightly shorter distances. EEDs illuminated by the main beam can safely be stored or transported at distances beyond about 730 ft from the NEXRAD antenna. Exposed EEDs are safe according to Air Force criteria at distances beyond about 1,300 ft. (Civilian criteria suggest a minimum distance of 1,000 ft.) The safe separation distance for EED storage or transport could present a problem to aircraft. Therefore, at each prospective NEXRAD installation, the possibility of hazardous main-beam illumination of nearby elevated terrain and of EED-equipped military aircraft will be investigated.

Biophysical Effects

Construction and operation of the NEXRAD system will not result in any significant impacts on the biophysical environment. At existing sites, less than 1 acre of already disturbed land will probably be sufficient to accommodate the new radar and any other alterations. As much as 5 acres may be needed at new sites that require wells, on-site wastewater disposal, and access roads. Only in these larger, probably rural sites could some animals be displaced by destruction of habitat or by a desire to avoid humans. Unless the site is in a sensitive area, these effects are not likely to be significant.

The contribution of the NEXRAD backup power plant and commuting personnel to air pollution will be very small, especially compared to other emissions around most sites. In remote locations, the NEXRAD emissions may be noticeable, but they are not major sources and are not likely to adversely affect air quality to any significant degree.

Water requirements are small and will be met by local utilities where practical. Alternatively, wells will be drilled on site. If construction occurs near water bodies or water courses, contamination is possible, although potential impacts can be prevented or controlled by good construction practices. The small amount of sanitary wastewater

that will be generated by NEXRAD personnel will easily be handled by local treatment systems. If necessary, septic tanks or leachfields will be used as prescribed by applicable regulations.

Socioeconomic &ffects

Construction and operation of the NEXRAD installations will have minor effects on the demographics and economic conditions of the areas in which they are located. The effects of the construction phase will be temporary, while those of the operating phase will be long term. Possible effects include changes in employment conditions, the demographic characteristics of the local population, the demand for and supply of housing, and the costs of providing public services and facilities.

The cost of each NEXRAD location will be \$2 to \$2.5 million. This cost includes the hardware, facilities, site preparation, and construction. Construction of each NEXRAD installation is expected to take from 5 to 12 months. In most cases, the construction workforce will be hired from the communities surrounding each site. Effects on local demographics and economic conditions will probably be negligible. Sites located in rural areas and surrounded by very small communities (i.e., less than 1,000 residents) or not within commuting distance of populated areas may be exceptions. At such sites, construction workers would have to be provided with housing and public services and facilities. These effects would be temporary, however, and could be minimized by careful phasing of the construction activities.

At existing sites, operation and maintenance of the NEXRAD radar will be carried out by current staff. At new sites, the staff will generally not be residents of the communities near the sites. When a user facility is moved to be collocated with a radar, employees and their dependents are likely to relocate to the new site area, thereby increasing the population of the surrounding communities by a maximum of about 44 individuals. With the exception of very small ones, communities within commuting distance of the sites will probably be able to meet the demands for housing and public services and facilities created by these new residents. Local purchases of goods and services by NEXRAD personnel could induce the creation of between 8 and 32 local jobs, depending on how developed the area is.

The potential problem of incompatibility of the radar facility with adjacent land uses will be addressed, in part, by care in the site selection process; obvious incompatibilities will be avoided whenever possible by selecting another site. Remaining problems will be addressed with the assistance of responsible authorities, which range from local governments to federal agencies. All commonly issue permits to establish conditions on the use of land for which they are responsible.

Aesthetic considerations are not likely to be an issue for sites in most urban locations. At non-airport sites, the NEXRAD radome and tower

may have a negative visual impact. Where possible, considering site features and operational requirements, the radar tower will be built in the least obtrusive location on the site and with the minimum height necessary to achieve the required radar coverage.

Excavation for construction of NEXRAD facilities may uncover cultural artifacts. During the surveys made as part of the site selection process, evidence of cultural resources will be sought. None are expected to be found on existing radar sites because this land has already been disturbed. Special care will be taken at new, relatively undisturbed sites, especially in isolated locations, to prevent inadvertent damage. If artifacts are found, prescribed procedures for recording and preserving or recovering them will be followed.

Alternatives Considered

The following alternatives to the proposed NEXRAD system were considered:

- No action or postponement of action
- Continue the existing system
- New non-Doppler system
- New coherent non-Doppler system
- Mixed system of new Doppler and non-Doppler radars
- Environmental satellite system.

The environmental impacts of the NEXRAD system can be avoided only by not proceeding with the proposed action. The alternatives involving various combinations of Doppler and non-Doppler radars would all cause essentially the same environmental impacts as the proposed action. The satellite alternative would have somewhat different impacts; whether they would represent a net reduction of overall impacts cannot be judged by available information.

From an operational point of view, none of the preceding alternatives is capable of meeting the goals that the proposed NEXROD system will achieve. Each suffers from one or more deficiencies: it would fail to meet severe weather and aircraft safety requirements as well as the proposed NEXRAD system; it would be less cost-effective; or it would be impractical because key technologies may not be developed in the foreseeable future.

Conclusion

In general, construction and operation of the NEXRAD system will have no significant adverse environmental impacts. All anticipated impacts are or can probably be limited to minor ones. Careful attention to environmental site selection criteria and site layout will ensure that avoidable impacts are, in fact, avoided and that other impacts are minimized. For sites where potentially significant adverse impacts are foreseen, but the sites are nevertheless highly desirable

for other reasons, the impacts will be analyzed in depth. In these cases, mitigation measures will be developed, and supplements to the Programmatic EIS will be prepared.

1 PURPOSE AND NEED FOR ACTION

NEXRAD is the Next Generation Weather Radar being developed jointly by the Departments of Commerce, Defense, and Transportation (DOC, DOD, and DOT, respectively). The NEXRAD system will consist of approximately 145 radar units distributed across the United States. The purpose of the system is to acquire, process, and distribute improved weather radar information to help reduce loss of life, injuries, property damage, and interruption of economic activity.

The radar system will be designed to meet the common need among the three departments for information on the location, intensity, and move ment of weather phenomena throughout the United States. Hazardous weather phenomena, such as tornadoes, severe thunderstorms, heavy precipitation, tropical cyclones, hail, high winds, and severe turbulence, are of principal interest. The NEXRAD system will improve the accuracy, timeliness, and credibility of severe weather warnings. It will also provide information useful for monitoring and assessing general weather conditions, such as rainfall amounts and distribution.

The NEXRAD system represents a major improvement over the capability of existing weather radars, primarily through the application of the Doppler principle; the use of solid state technology; and improved data processing, communication, and display devices. Existing radars measure reflections from the precipitation droplets in clouds and the time be tween transmission of the pulse and reception of the reflected signal. Analyses of these data indicate the location and intensity of thunderstorms and areas of heavy rain. Movement can be determined by time lapse computation. However, the reflection pattern from the storms can be interpreted only subjectively to estimate the likelihood of damaging winds and tornadoes. Unfortunately, this approach to severe weather detection is unreliable and typically provides a very short warning time.

The Doppler effect is the shift in the frequency of sound or electromagnetic waves when reflected from a moving object. The frequency shift can be used to estimate the velocity of the object. Applied to weather radar, the velocity at which precipitation droplets are moving toward or away from the radar can be determined. Because NEXRAD radars will apply the Doppler principle and automated signal processing, they will be able to detect wind fields inside storms and to greatly improve warning time and accuracy for severe thunderstorms and tornadoes.

The key operational goals and objectives of the NEXRAD system are to:

- Increase the average tornado warning time from the present 1-2 min to at least 20 min.
- Improve the accuracy of descriptions of the location and severity of thunderstorms and the ability to distinguish between severe and less-than-severe storms.
- · Improve the detection of damaging winds and hail.
- Improve the safety of aircraft operation by detecting and measuring the wind shear and turbulence associated with thunderstorms.
- Provice improved rainfall estimates for flash flood warnings.
- Reduce the size of warning areas to minimize unnecessary warnings.
- Substantially reduce the number of false hazardous weather warnings.
- Minimize the failure to detect hazardous weather due to radar outages.
- Optimize the efficacy of information provided to forecasters and other personnel by improving distribution and display of radar information.
- Detect hazardous weather conditions throughout the SO states and at overseas locations specified by users.
- Maintain annual operations and maintenance costs at the same level as that of the radar system to be replaced (excluding the cost for radars in areas not at present covered).

2 PROPOSED ACTION AND ALTERNATIVES

2.1 The NEXRAD Program

2.1.1 Historical Information

In 1976, the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Air Force began an evaluation of the potential of Doppler radar technology for a new generation of weather radars. The Federal Aviation Administration (FAA) joined the effort in 1977. The Joint Doppler Operational Project (JDOP) investigated the use of Doppler radar data to identify tornadoes. Tests in 1977, 1978, and 1979 showed that a Doppler radar offers marked improvement in early and accurate identification of thunderstorm hazards, especially tornadoes and squall lines. Consequently, the JDOP staff recommended that the next-generation meteorological radar should employ Doppler technology.

Subsequently, a Working Group on Next Generation Weather Radar was established under the direction of the Federal Coordinator for Meteorological Services and Supporting Research (FCMSSR) as the focus for interagency weather radar development and planning activities. In 1979, the working group outlined an approach for the development, procurement, and operation of a joint national weather radar network. The Federal Coordinator approved the approach and directed that a Joint System Program Office (JSPO) be established, staffed, and funded by the three participating departments. Its role would be to plan, program, and manage the development, procurement, and installation of NEXRAD.

The Federal Coordinator concluded, in an analysis carried out late in 1979, that a valid basis existed for replacing the aging weather radars currently in use with Doppler weather radars. Although the fundamental technology to support NEXRAD had been developed, a substantial amount of work remained to transfer Doppler radar technology to operational use in the field. The Federal Coordinator suggested that both a mix of Doppler and non-Doppler radars as well as a full Doppler system be considered. The Federal Coordinator also concluded that the common needs for weather radar data within the federal government and the advantages of a joint agency program made joint acquisition and use highly desirable.

The JSPO was formally created in November 1979 within DOC because that department was assigned the lead role for the NEXRAD program. The program manager is accountable to the NEXRAD program council, which is composed of three representatives of the participating departments, and the Federal Coordinator, who chairs the council. The JSPO is staffed by a program manager from NOAA, three deputies representing DOC, DOD, and

and DOT, and technical and support personnel from the same three agencies.

The JSPO prepared a Mission Need Statement, approved in August 1980, expressing the joint weather-related mission needs for an advanced weather radar with improved capabilities for detecting hazardous weather conditions. The JSPO then developed the Joint Program Development Plan (JPDP), which includes the scope of the NEXRAD program, a summary of agency mission needs, an acquisition strategy, and an estimate of resource requirements. A statement of the Joint Operational Requirements, defining the specific weather radar requirements of the three departments, was approved in January 1981. Based on this document, the first NEXRAD Technical Requirements document was prepared and issued in August 1981.

2.1.2 System and Agency Missions

The National Weather Service (NWS) in DOC is the principal civilian meteorological agency of the federal government. It is responsible for the detection and public warning of hazardous weather such as severe thunderstorms, tornadoes, hurricanes, floods, flash floods, winter storms, damaging tides, and any other meteorological events with possible harmful effects. NWS provides weather information to civilian aviation, marine, and agricultural and forestry operations; the river and flood prediction program; and a variety of commercial activities. NWS operates many weather radars and uses information from other radars operated by DOD and DOT.

Within DOD, the Air Force Air Weather Service (AWS) provides world-wide meteorological and aerospace environmental services to the Air Force, Army, and unified and specified military commands. The Naval Oceanography Command (NOC) provides these services to the Navy, Marine Corps, and unified commands. These organizations are responsible for providing and relaying severe weather warnings to protect DOD resources and personnel, manage flood control reservoirs, provide weather information to aid decision-making at specific locations, and support military aviation. DOD operates weather radars in the United States and overseas and uses information from these and from DOC and DOT radars in the continental United States.

The FAA is responsible for the safe and efficient use of U.S. airspace. It provides information on the location and intensity of potentially hazardous weather conditions to pilots and others concerned with aviation. In recent years, greater emphasis has been placed on providing real-time hazardous weather information. The FAA has no weather radars. It obtains its information from its air traffic control radars, which are not designed for weather detection, and from NWS radars via remote displays, other NWS products, and NWS personnel located at FAA facilities.

2.1.3 Program Development Tasks

The NEXRAD program consists of a number of major development and acquisition tasks, as shown in Figure 2-1. The system definition phase, now complete, resulted in specification of system design requirements. This phase concluded with proposals from industry for the competitive validation phase. The program is currently in this phase, during which two contractors are developing preproduction engineering models for test and evaluation. Limited production will be undertaken by one contractor. Full production will begin when initial test and evaluation have been completed on the first unit installed at an operational test facility.

Approximately simultaneously with the initiation of limited production, facilities preparation will begin for the initial units. System operations will begin after installation, acceptance, and training. Initial operations are scheduled to begin in 1988, with full system operation reached in 1992.

Concurrent with the technology development and system acquisition activities, locations for installation of NEXRAD radars are being selected. The site selection process will be carried out in three phases. Using readily available information, an initial site assessment will be carried out to evaluate the suitability of one or more candidate sites in a given geographic area. One or more of the sites judged satisfactory will then be the subject of a preliminary site survey, which involves a field visit to gather information directly. Later, an in-depth site survey will be carried out for the most promising candidate site in each geographic area.

2.1.4 Environmental Review

This Programmatic Environmental Impact Statement (EIS) is the foundation of the environmental process for the NEXRAD program. The basic facilities and equipment features of the proposed action are known well enough to judge their potential impacts in general terms. However, the sites at which the radars will be located have not been selected so it is not possible to assess whether the potential impacts may occur and be significant. Therefore, the JSPO has incorporated into the NEXRAD program a provision to prepare addenda or supplements to the Programmatic EIS, known as Environmental Assessments (EA). The decision to prepare an EA for a particular site will be made by the JSPO based on the results of the preliminary site survey (the second step in the site selection process) in which the environmental impact worksheet in Appendix E will be used as a checklist. An assessment will be appropriate if particular site features or necessary variations in the site plan raise the possibility of significant adverse impacts that were not anticipated in the Programmatic EIS. If the site is highly desirable from other points of view, an EA will be prepared after the in-depth site survey -- the third step in the site selection process--using additional information pertiment to the impact, or impacts, of concern gathered during the survey.

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PHASE	SYSTEM DEFINITION	VALIDATION	LIMITED PRODUCTION	FULL PRODUCTION	MAJOR DECISION MILESTONES

FIGURE 2-1 NEXRAD PROGRAM

2.2 Proposed Action--NEXRAD System

2.2.1 Existing Weather Radar Network

The existing basic weather radar network covers most of the 48 conterminous states for warnings of severe thunderstorms, tornadoes, heavy rainfall and snowfall, and hurricanes. The network consists of 51 WSR-57 and 5 WSR-74S radars operated by the NWS, 2 FPS-77 radars operated by the AWS, and 22 air traffic control radars operated by the FAA. Figure 2-2 shows the location and coverage of these network radars. An effective range of 125 nmi is shown for the NWS and AWS radars. This is the maximum effective range at which severe weather phenomena such as hail, mesocyclones, tornadoes, wind shear, and turbulence can be detected with high confidence. Coverage is not shown for the FAA radars because they were not designed for primary use as weather radars.

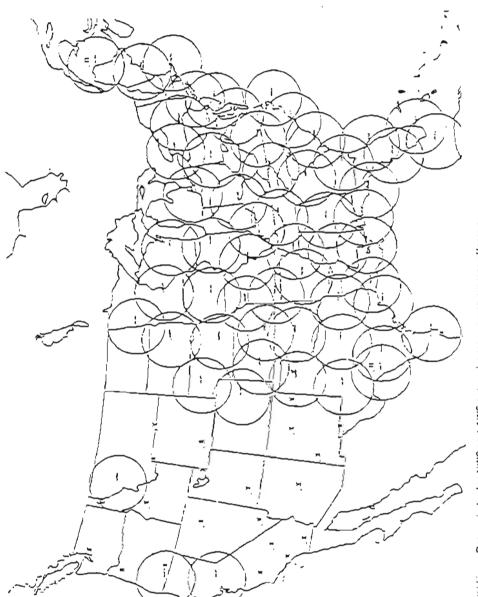
These radars operate 24 hours per day to detect and monitor the development and movement of significant weather activity and provide information to DOC, DOD, and FAA field offices for local warnings. Hourly and special radar observations are provided by network radars in an alphanumeric format and as narrative interpretations of the data. NWS personnel use remote displays from the radars at four western Air Route Traffic Control Centers (ARTCCs) to manually prepare radar maps for both network and local warning purposes in the western intermountain area. The hourly radar observations are automatically compiled at the National Meteorological Center (NMC) and distributed nationally via facsimile and teletype.

Thirty-seven of the NWS network radars can also transmit lowresolution reflectivity images and annotated remarks to other locations using conventional telephone lines. DOD, DOT, and nongovernment users use this remote capability through both dedicated and dial-up circuits.

Local warning radars are operated by DOC and DOD to supplement the basic network in areas of high storm risk or where network coverage is inadequate. There are now 65 DOC and 84 DOD local warning radars in the conterminous United States, as shown in Figure 2-3. DOD requirements at 22 other U.S. locations are met with remote devices. DOD also has 26 local warning radars at bases outside the United States and unspecified requirements at an additional 6 overseas locations.

Some local warning radars are designated as backups to basic network radars and perform the functions of a network radar if the latter fails. The effectiveness of this arrangement is limited because of the characteristics of local warning radars and because these radars are not staffed full time.

Limited weather information is also available from all air traffic control radars for air traffic control purposes. It is obtained when severe weather radar echoes overwhelm the radar's weather suppression circuitry or when the controller overrides the suppression circuits to view the weather echoes.



NOTE: Range circles for NWS and AWS network, since show an average effective range of 125 nm. FAA sins are labeled X.

FIGURE 2-2 BASIC NATIONAL WEATHER RADAR NETWORK: 56-NWS. 2-AWS, 27-FAA RADAR SITES

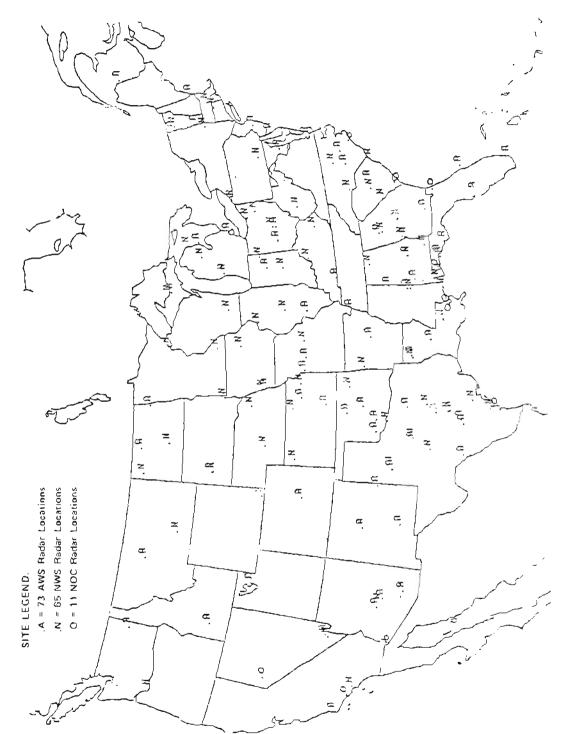


FIGURE 2-3 LOCAL WARNING RADARS

The departments involved in the development of the NEXRAD system are acting to extend the operational life and to enhance the performance of existing radars until the NEXRAD radars become operational. DOD is modifying its FPS-77 local warning radars to extend their useful life into the mid- to late 1980s, when NEXRAD is expected to replace them. The modifications involve converting some electronic subsystems from vacuum tubes to solid state electronics to remove troublesome, costly-to-maintain items. DOT is acquiring transmitters to install on DOC radars to transmit radar images in digital format over telephone circuits for color displays at FAA Air Traffic Control Centers and selected Flight Service Stations. This arrangement will meet some high-priority DOT needs until the NEXRAD system goes into operation.

2.2.2 The NEXRAD System

The NEXRAD system will consist of a national network of NEXRAD units located throughout the United States. The major functional components of each NEXRAD unit will be Radar Data Acquisition (RDA). Radar Product Generation (RPG), and Principal User Processing (PUP) subsystems.

The RDA subsystem will consist of a Doppler radar located at the radar site and the hardware and software required to perform the signal processing, clutter suppression control, monitoring and error detection, and display, calibration, and archiving functions related to radar operation.

The RPG subsystem will consist of all hardware and software required for rapid generation, storage, and distribution of products for operational use. It will also include hardware and software required for control, status monitoring and error detection, archiving, and hydrometeorological processing. To the extent required, this subsystem will include display and data entry hardware and software for human participation in the creation of products.

The PUP subsystem will consist of all hardware and software required for the request, display, local storage, and local annotation and distribution of products by operating personnel of the principal user agencies. It will also include the hardware and software required for local control, status monitoring, and archiving.

These components will be arranged physically in a variety of ways (ranging from collocation to separation at distances requiring remote communication links) according to user area and point coverage requirements and the location and suitability of user facilities. Whenever feasible, all three components will be collocated. NEXRAD network sites will often be collocated with an NWS operational facility, such as a Weather Service Forecast Office (WSFO), while local warning sites will often be collocated with or near a facility operated by the governmental department with this requirement. This will require construction of towers; provision and installation of power generation, air conditioning, and like equipment; construction of access roads when necessary; and perhaps modification or construction of buildings.

Communications hardware and software will be needed to transmit and receive weather radar data via dedicated or dial-up narrowband (i.e., telephone) links and also for wideband links between radar and principal user sites that are not collocated.

The NEXRAD system will include support facilities to ensure satisfactory equipment operation and depot maintenance. These facilities will also provide training for operational and maintenance personnel and will support development, test, and evaluation activities. One depot for maintenance and repair and three supply depots will be established. NWS and DOD will operate separate facilities for operations and maintenance training. An operational support facility will also be established at Norman, Oklahoma, in late 1985 to begin planning for the operational support of the NEXRAD system.

2.2.3 System Operation

The NEXRAD system will generate four categories of products: base, derived, alphanumeric, and derived data array. Base products consist of reflectivity and the mean and standard deviation of radial velocity estimates presented in a format suitable for color graphic display. Derived products are processed radar data concentrated to supply large volumes and varieties of data in a form suitable for color graphic displays and, where possible, requiring minimum interpretive effort. Alphanumeric products are radar data processed for users without graphic displays. Finally, derived data array products provide data in a non-displayable format for transmission outside the NEXRAD system for further processing.

The principal users of the NEXRAD system will be operating agencies within DOC, DOD, and DOT that use weather radar data to perform their functions. The specific organizations to be served are the NWS within DOC, the AWS and NOC within DOD, and the FAA within DOT. Other users will include other government agencies (state, local, and other federal) and private sector users such as airline companies, consulting meteorologists, news media, and university laboratories.

The NEXRAD system will connect to the NWS Automated Weather Interactive Processing System (AWIPS-90) to supply NEXRAD products to river forecast centers and national centers such as the National Meteorological Center, National Hurricane Center, and National Severe Storms Porecast Center. The system will supply NEXRAD products to DOD via telephone lines to the Naval Environmental Display Station, Automated Weather Distribution System, Air Force Global Weather Central, and the European and Korean Forecast Offices. The NEXRAD system will interface with the Center Weather Processor in each ARTCC via telephone lines. This system will process and distribute NEXRAD weather radar data to various other FAA systems.

2.2.4 The NEXRAD Unit

Most radars are designed and operated to detect large objects such as ships, airplanes, or missiles. In contrast, the purpose of the NEKRAD system is to detect weather features including rain or hail and storms such as hurricanes and tornadoes. This difference of purpose has a strong influence on the design of the signal processing components of the receiver but little effect on the transmitter.

In a general way, the NEXRAD unit will be similar to the radars that it is to replace. In both cases, the transmitted signal consists of a series of short pulses separated by relatively long silent intervals for listening. The electromagnetic radiation is formed into a slender pencil beam by a circular parabolic reflector that is scanned through 360 deg in azimuth by continuous rotation about a vertical axis. The principal differences with the older system are that both the diameter of the transmitting antenna and the peak power of NEXRAD will be roughly twice as large, and the minimum time between successive pulses will be roughly half as great. The frequency range in which the NEXRAD radar will be able to operate is 2,700 to 3,000 MHz rather than 2,700 to 2,900 MHz.

The radar will be able to operate at any designated frequency in the above range. The frequency used at any particular site will be chosen to minimize interference received from and delivered to other systems, including other NEXRAD radars. The choice of frequency is not simple because approximately 630 radars are now operating in the 2,700-to 2,900-MHz band; perhaps 300 additional radars operate in the 2,900-to 3,000-MHz band. Some existing weather radars operate at frequencies near 6,000 MHz.

A NEXRAD unit will be a combination of one RDA, one RPG, one or more directly connected PUPs, and the necessary communication systems. These components may all be located at one site, or they may be distributed between one radar site and one or more principal user sites. The RDA will generate data at a very high rate. Because transmission of high-speed data over extended distances is expensive, in many cases the RPG will be located within a few hundred feet of the RDA. For some locations, the radar antenna may be placed at a considerable distance from the user location, necessitating a remote communications link. Electric power will be drawn from the local system, generally from a commercial utility either directly or indirectly. Backup power equipment will be installed for routine use when severe weather approaches as well as for when normal power is unexpectedly interrupted.

A number of functional configurations will be possible for each NEXRAD unit. The configuration installed at a particular site will depend on the specific requirements and conditions at that site. Figure 2-4 illustrates three possible configurations. The sites are distinct geographic locations. Thus, RDA 1, RPG 1, and PUP 2A are collocated at Site A--i.e., in this example, all the equipment needed to perform their

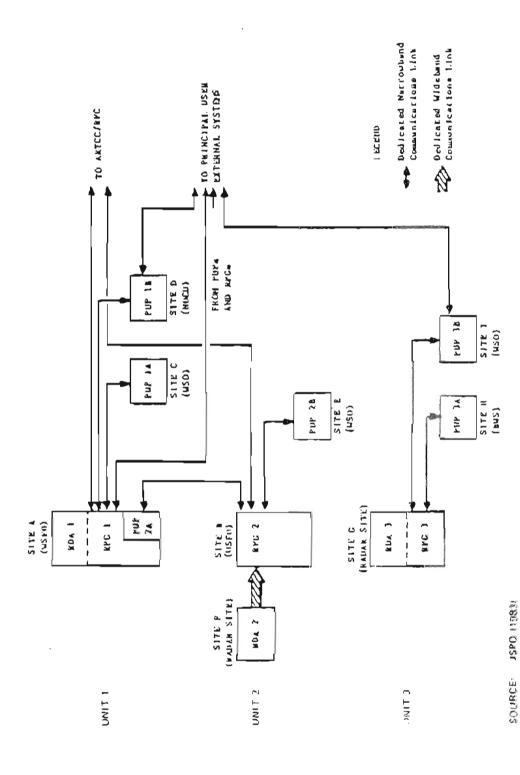


FIGURE 2-4 EXAMPLE LEXRAD CONFIGURATIONS

functions is located at one WSFO. Sites C and D, although both having PUPs associated with Unit 1, are not collocated with any other equipment of Unit 1. Similarly, although PUP 2A is associated with Unit 2, it is collocated with Unit 1 equipment at the WSFO (Site A), providing an example of a principal user site receiving data from two different radar sites. In the configuration of Unit 2, the radar site is not collocated with equipment needed to perform RPG functions. The configuration of Unit 3 shows the RDA and RPG collocated at a radar site without a collocated PUP. (In this case, the RPG control capability would be at one of the associated PUPs.)

Physically, the installation of a NEXRAD unit will depend greatly on the site being used. Figure 2-5 shows a conceptual site layout for a new site where the RDA is collocated with a user facility. It shows an antenna tower, an equipment building to house the transmitter and receiver, and utility lines. The tower, building, and adjacent equipment is surrounded by a 7-ft high chain-link security fence. The radar antenna is enclosed in a nearly spherical radome about 10 m (35 ft) in diameter mounted on a tower, which may be as tall as 30 m, depending on the local terrain and man-made obstructions. The location of the tower sets the basis for the layout of the remaining facilities. A new site will typically require a land area of approximately 0.5 acres (excluding access roads and utility corridors). If both wells and on-site wastewater disposal are required, a minimum of 1 acre will probably be required.

In this concept, all functions are contained within the site. Hany NEXRAD units will be installed at locations where weather radars already exist. In these cases, existing equipment and buildings will be used to the extent feasible. However, the NEXRAD antenna and its tower will entail new construction; existing towers and radomes will not be used. Further, wherever possible, to avoid interrupting operations, the new radar and tower will not be constructed in the same location as the existing tower.

The antenna of the RDA will consist of a dish-shaped circular parabolic reflector with a microwave feed assembly at its focal point. The assembly will be supported on a two-axis (altazimuthal) mount. Rotation about the vertical axis will provide azimuthal scanning; rotation about the horizontal axis will provide vertical scanning. The flexibility of the NEXRAD hardware and software will permit a wide range of scanning programs, only two of which have been defined to date. In all of the scanning sequences, the azimuth will be scanned at a rate between one-half and 5 revolutions per minute, and the elevation will be raised progressively in specified increments from the horizontal to a maximum of 20 deg and then returned to the horizontal. (The antenna will be capable of operating at any elevation angle up to 60 deg, but the higher elevation angles will be used infrequently.) To improve clutter suppression, at least the 0 deg elevation will be scanned twice.

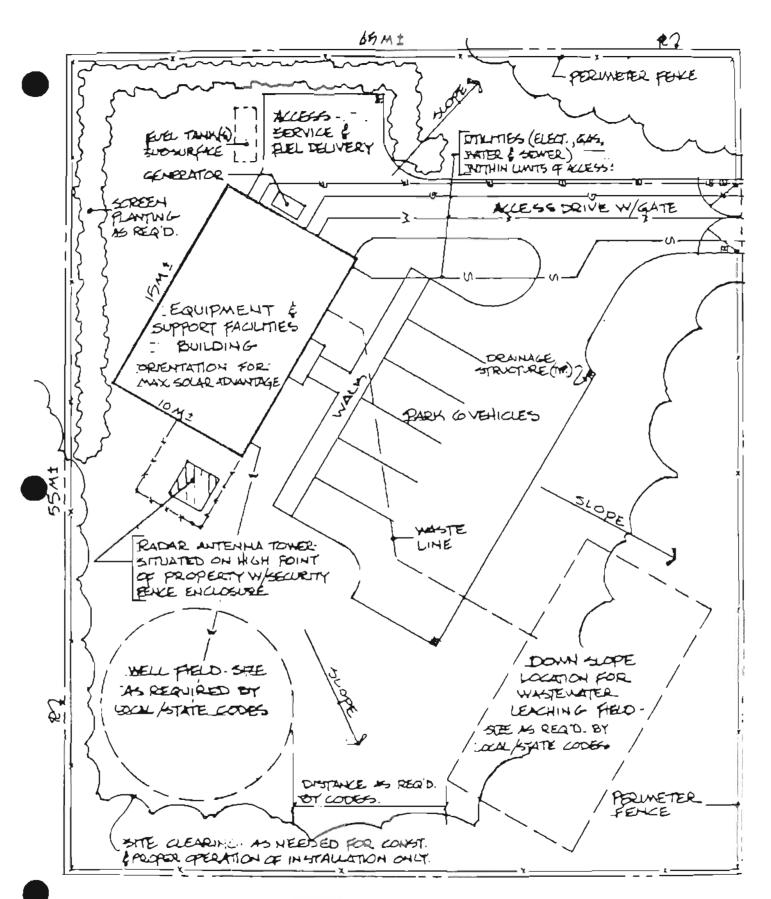


FIGURE 2-5 CONCEPTUAL NEXRAD SITE DEVELOPMENT 1:250)

The peak power radiated by the radar will be 1 MW (10⁶ W). The duration of each pulse may be varied from 0.7 to 4 µs, and pulses may be repeated at any rate between 250 and 1,200 pulses per second (pps). The combination will be chosen so that the average radiated power will be about 2 kW. The input power requirement for the entire NEXRAD unit is estimated not to exceed 75 kW.

Power from the transmitter will be delivered to the feed horn located at the focal point of the reflector; it will be formed by the reflector into a narrow pencil beam (see Figure 2-5). The diameter of the antenna is expected to be between 24 and 28 ft to produce the desired beam, which is not to exceed 1 deg between points where the power density falls to one-half its maximum value. In the far field (beyond about 550 ft), about 70% of the radiated power will be concentrated in the main beam. The remainder will be sent in other directions and form a series of sidelobes and backlobes. The first few sidelobes will form a well-defined symmetric pattern centered on the main beam; others will be more or less random in nature and are best described in statistical terms. The power density in the first sidelobe will nowhere be greater than 0.0032 of that in the main beam. The second through fifth sidelobes will be still weaker. At angles greater than 10 deg from the axis of the main beam, the power density will be nowhere greater than 0.0004 of that in the main beam.

More information on the operation of the RDA and the formation and characteristics of the radiated beam is supplied in Appendices A and B.

Current plans call for the NEXRAD system to operate continuously for 20 years. Construction is scheduled to begin in 1986 and continue for about 5 years.

Based on estimates provided by the contractors at the end of the system definition phase studies, the per-unit cost, including logistics and training support, is currently estimated at \$2.0 to \$2.5 million. Increases in that estimate are expected to be equal to or less than the average cost of inflation experienced for this class of electronic equipment. The NEXRAD unit costs include: (1) the radar; (2) data communication between the radar, data processing, and display subsystems and interfacing hardware associated with narrow-band communication to remote users; and (3) support for initial spares and support equipment, radar site preparation, packaging and shipping, installation and checkout, documentation, manuals, initial training, backup power, diagnostic test equipment, and equipment warranty.

The principal user facility of each NEXRAD unit will be staffed, on average, by 16 people (1 manager, 10 meteorologists, 5 technicians), all of whom will be civilians currently employed by the federal government. The operating staff will work around the clock in three shifts (3-4 people per shift), while management and maintenance will be primarily day-shift functions. This staffing is approximately the same as at existing NWS offices. The principal user facility at Air Force sites

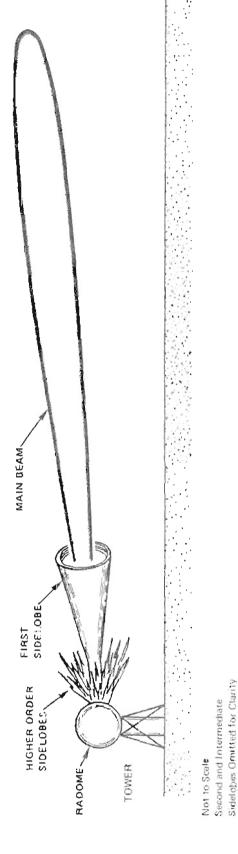


FIGURE 2-6 ARTIST'S SKETCH OF NEXRAD RFR PATTERN

will be staffed by an average of 16 people (1 commander, 11 forecasters/observers, 3 maintenance technicians, and 1 clerk). No change in Air Force staffing is planned, nor will new facilities be built. Thus, no significant change in staffing is expected when a NEXRAD unit is installed. Further, because no new user facilities are expected to be built, personnel will be added to an area only if a user facility is relocated to a new site.

2.3 Candidate Sites

2.3.1 Introduction

An elaborate site selection process (described in Section 2.3.4) will be employed to determine the extent to which the condidate sites in an area meet the diverse requirements of the principal user agencies for the NEXRAD system.

Meeting tadar coverage requirements is a primary consideration. In general, the meteorological site selection criteria call for locating radars where climatological records show that there is a significant threat of hazardous meteorological conditions and where the radars have a clear view in the directions from which most damaging weather approaches.

Existing weather radar sites are prime candidates. In most cases, they are at good locations for tracking weather conditions, the sites are available for government use, and the needed utilities, access, and compatible features exist. Generally, all existing user facilities and installations, including weather radar installations, Weather Service Offices (WSOs), WSFOs, airports, military bases, and other government property in a given area will be assessed and will be given first consideration because of their prospective availability. Notwithstanding the likely suitability of these sites as a whole, when specific geographic areas are studied, existing sites will be scrutinized to determine their adequacy (e.g., availability of space and power) and the degree to which they meet user requirements.

2.3.2 Site Selection Criteria

General site selection criteria have been defined for the identification of candidate sites:

- Sites on government-owned land, especially federal land, are preferred. Private land will be considered if other land is unavailable or affords inadequate coverage.
- If practical, each NWS radar site will be located within 100 m of an existing user facility. Although the radars will be designed to be unattended, efforts will be made to keep radar and user facilities close enough to allow data transmission by

cable. (Fiber-optic cable may be considered for this application if it is found to be practical and cost-effective. Should locating the antenna and office within practical cable distance be impossible, microwave relay will be considered. However, a cost analysis of the alternative communication links will be performed prior to a recommendation.) If an existing user site is unsuitable for a new NEXRAD radar, alternative sites will be surveyed to identify an adequate area for the user facilities as well. On the other hand, the AWS radars will frequently be located 5-10 km from the user facility.

- Existing NWS radar sites will be used where possible, but the AWS will not always use its FPS-77 sites. Many of them are in acceptable locations. Relocation of the radar to a new site would require preparation of the new site and construction of new facilities, and, in most NWS cases, would also require moving the user's facilities. This alternative is more expensive than locating a new NEXRAD radar at an existing NWS site. Therefore, strong consideration will be given to using existing sites, possibly even at the expense of somewhat superior radar coverage that would be possible at an alternative site.
- Considerable attention must be paid to achieving optimum coverage in areas where radar surveillance is especially important, for example, for providing populated areas with tornado warnings. General site elevation, the antenna height, and its exact location on the site must be selected to give unobstructed coverage with minimum ground clutter effects.
- Consideration will be given to electromagnetic interference (EMI) in the initial selection of candidate sites for the radar. However, EMI generally will be a secondary siting factor because, in most cases, measures can be taken to alleviate EMI between radars in the same frequency band. Only in a few areas, e.g., Los Angeles, is this factor likely to be a significant consideration.
- Sites must be accessible year-round. Radars located on high terrain can sometimes provide better radar coverage, but access to such sites can be difficult during adverse weather.
- Overall cost is a primary consideration. Costs will be estimated for site preparation, facility construction or renovation, roads, utilities, and the like. Significant cost variations can be expected among candidate sites. In many cases, the final decision is expected to be a trade-off between cost and radar coverage.
- If alternative commercial power sources exist at the site, an attempt will be made to determine which is the most stable.

2.3.3 Initial Candidate Sites

The JSPO has prepared a working list of locations as a starting point for the identification and evaluation of candidate radar sites (see Table 2-1 and Figure 2-7). The locations are grouped into four geographic regions: northeast, tornado, mountain, and coastal. The sequence of regions reflects the relative priority in which they will be surveyed. No priority is implied by the order in which the locations are listed within each region. Table 2-2 lists additional candidate sites located outside the lower 48 states. Table 2-3 lists military bases that AWS has identified as requiring weather radar coverage. Specific sites at or near these bases will be selected after the NWS and FAA sites have been chosen. At that time, it is expected that about 25 additional NEXRAD radars will be required to ensure coverage of military bases not adequately covered by the NWS and FAA sites.

The status of the sites listed in Table 2-1 varies considerably. In some cases, an existing site is known to be satisfactory and almost certainly will be chosen for a NEXRAD radar. At the other extreme, a requirement for radar coverage in an area may exist, but neither an existing site nor a specific plot of land has been identified as a candidate site, only an area as much as many miles square in which the radar needs to be sited. In these cases, candidate sites will be identified during the site selection process.

The sites listed in Table 2-1 can be characterized only in general terms, as shown for the NWS and FAA sites in Table 2-4. Weather redars now exist at slightly more than half (57%) of the listed sites. The lowest proportion (40%) occurs in the mountain region; it is about 50% in the coastal region and higher in the northeast and tornado regions (67% and 70%, respectively).

Becuase they have not yet been selected, the AWS sites cannot be similarly characterized. However, AWS criteria for site selection indicate that the NEXRAD sites serving these bases will be located within about 35 nmi of the base.

In about 80% of the Table 2-1 cases in which a radar exists, the radar is at an airport, with a high proportion generally true for all regions except coastal, where the proportion is about 50%. Where a radar does not exist, about 40% of the candidate sites identified to date are at airports. Thus, overall, about 62% of the identified sites are at airports. However, in many of the areas in which a new site is being sought, the preferred locale is at or very near an airport. Consequently, the proportion of new sites at airports may turn out to be somewhat greater than 80%, raising the overall proportion to a similar number. These figures suggest that the number of new sites that will not be located at an airport may be between 20 and 30.

Table 2-1
INITIAL CANDIDATE SITES

Name	<u>State</u>	Radar	Density	Land Use
Northeast Region				
Washington	DC	_	ts	1,2
Des Moines	IA	A	\$	1,8
Chicago	IL	-	U	1,2
Moline	IL	A	R	5,6
Indianapolis	IN	A	S	1,2
Ft. Wayne	IN	A	R	6
Boston (Chatham)	MA	E	R	8
Caribou	ME	_	R	6
Portland	ME	_	8	1,2
Alpena	MI	Α	R	8
Ann Arbor	MI	_	U	4
Marquette	MI	٨	R	8
Duluth	MIN	A	R	1
Minneapolis	MIN	A	U	8
Kansas City	MO	A	R	6
Kansas City	MO	-	N/A	N/A
St. Louis	MO	E	S	2
Atlantic City	NJ	A	S	1
Albany	NY	A	8	1
Binghamton	NY	A	R	N/A
Buffalo	NY	A	S	1,2
New York (Islip)	NY	_	N/A	N/A
New York (NYC)	NY	Е	N/A	N/A
Cincinnatí	ОН	Α	N/A	N/A
Cleveland	он	A	U	1,2
Harrisburg	PA	E	R	6
Philadelphia	PA	_	U	1,2
Pittsburgh	PA	E	N/A	N/A
Burlington	VT	A	Ŕ	6
Green Bay	WI	-	N/A	N/A
La Crosse	WI	_	ប	2
Milwaukee	WI	_	S	1
Charleston	wv	E	N/A	N/A

Table 2-1 (continued)

Name	State	Radar	Density	Land Use
Tornado Region				
Birmingham	AL	_	N/A	N/A
Mobile	AL	A	R	1,6
Little Rock	AR	A	R	1
Dodge City	KS	_	R	6
Goodland	KS	A	R	6
Wichita	KS	A	S	2,8
Louisville	KY	A	Ü	1,2
Paducah	ΚY	~	R	6
Lake Charles	LA	A	8	6
Shreveport	LA	A	S	1,2
Slidell	LA	Ε	S	1,2
Springfield	HO	-	R	7
Jackson	M S	Α	R	6
Grand Island	NE	A	R	6
North Platte	NE	A	R	6
Omaha	NE	A	R	6
Norman	OK	_	N/A	N/A
Oklahoma City	OK	A	R	1
Oklahoma City	OK	V	N/A	N/A
Tulsa	OK	A	វ	1.8
Amarillo	TΧ	A	R	6
Brownsville	TX	A	R	7
Corpus Christi	XT	A	R	6
Pt. Worth	TX	_	R	6
Houston	TX	_	æ	6
Lubbock	TX	A	8	6
San Antonio	TX	_	S	1,2
San Angelo	TX	A	N/A	N/A
Memphis	TN	~	R	6
Nashville	TN	e	R	8
Mountain Region				
Flagstaff	AZ	Λ	R	5
Phoenix	AZ	Α	บ	1,2,3
Tucson	AZ	A	R	7
Yuma	AZ	Ų	Ŗ	7
Denver	CO	_	บ	1,2
Grand Junction	CO	_	R	7,6
Pueblo	CO	_	R	6
				-

Table 2-1 (continued)

Name	<u>इ</u> ध्या <u>ं ङ</u>	Reder	<u> Pensity</u>	Land Use
Mountain Region (cont.)				
Boise	ID	ħ	S	3
Pocatello	aı	V	R	6
Billings	MT	A	S	1,2,7
Glasgow	MT	A	R	6
Greet Palls	MT	v	S	1,3
Missoula	MI	A	R	5
Bismarck	ND	A	Я	6
Pargo	מא	A	S	1,2
Albuguerque	MM	V	U	1,2
Roswell	МИ	V	R	6
Las Vegas	VK	A	R	1,2
Reno	NV	V	Ü	1,2
Winnemucca	NA	V	N/A	N/A
Huron	SD	A	R	6
Rapid City	SD	A	Ŕ	6
Sioux Palls	SD	Ä	S	1,2
El Paso	TX	V	S	1.2
Cedar City	UT	_	R	6
Salt Lake City	UT	V	S	1,2,6
Cheyenne	ÜΥ	٨	S	1,2
Lander	WY	~	R	6
Coastel Region				
Eureka	CA	_	S	1,2,3
Presno	CA	V	S	1,2,7
Los Angeles	CA	E	Ü .	1,2
Sacramento	Cl	E	Ü	1,2
San Diego	C4	v	U	1,2
San Francisco	CA	_	Ü	1,2
Jacksonville	FL	V	N/A	N/A
Kennedy Space Center	FL	_	S	1,2,8
Key West	FL	A	S	1,2,8
Híami	FL	E	_	, - 1 -
Tallahassee	FL	V	8	5,8
Tampa	FL	Ž	Ŕ	7
Atlanta	GA	Ε	ប	1,2
Hatteras	NC	<u> </u>	N/A	N/A
Releigh	NC	Ā	R	8
Wilmington	NC	Å	N/A	N/A
Medford	OR	A.	17/ A	N/A
Pendleton	OR	v	R	5

Table 2-1 (concluded)

Name	State	Radar	Density	Land Use
Coastal Region (cont.)				
Portland	OR	A	U	1,2,3
Charleston	SC	A	2	1,2,3
Columbia	SC	A	S	4
Bristol	TN	С	R	5
Norfolk	VA	_	U	1,2
Roanoke	VA	~	ប	1,2
Seattle	WA	_	U	1,2
Spokane	WA	v	N/A	N/A

Key:

N/A - Not available

Radar

A - Radar exists at airport E - Radar exists, not at airport V - No radar - site at airport - No radar - site not at airport

Density

U - Urban S - Suburban & - Rural

Land Use

l - Residential	3 - Industrial	S - Forest	7 -	Agricultural
2 - Commercial	4 - Educational	6 - Open Lands	8 -	Recreational

FIGURE 2-7 INVITIAL CANDIDATE SITES

Table 2-2

INITIAL CANDIDATE SITES OUTSIDE LOWER 48 STATES

Anchorage,	AL
Anett Island,	AL
Cold Bay,	AL
Pairbanks,	ΛĹ
Juneau,	AL
King Salmon,	AL
Valdez,	ΥĽ
Georgetown,	BH
Grand Turk,	BWI
San Juan,	28
Xamuela,	BI
Molokai,	ΗI
So. Kauai,	ні

Note: BH = Balamas

BWI = British West Indies

Overall, about half the candidate sites are in rural (i.e., low-density) settings. The remainder are about evenly distributed between urban and suburban (high and medium-density) settings. Tornado region sites are predominantly rural (nearly 80%), while almost half the coastal sites are urban. Mountain sites tend to be in areas of somewhat lower density and the northeast sites somewhat higher density than the national distribution.

The list of candidate sites is expected to change somewhat as the site selection process progresses. The areas for which weather radar coverage are required will be the same but the sites finally chosen may be different from the current candidates. Consequently, the character of the sites is also likely to shift.

2.3.4 Site Selection Process

The selection of sites for the installation of NEXRAD radars is being carried out in a three-step, iterative process in which progressively more detailed information is gathered and analyses are performed. First is the initial site assessment, the purpose of which is to gather data and other information about one or more prospective candidate sites for comparison with radar coverage and other requirements. One or more

Table 2-3

AWS SITES (MILITARY BASES)

Altus, OK Langley. VA Andrews, MD Laughlin, TX Barksdale, LA Little Rock. AR Bergstrom, TX ME Loring, Blytheville, AR ΑZ Luke, Cannon, NM MacDill, FL Cape Canaveral, FL Malstrom. MT Carswell. TX Maxwell, AL Charleston, SÇ McConnell. KS Columbus. MS McGuire. NJ D. Monthan, AZ Minot. ND Dobbins. GA Moody, GA Dover. DE Mountain Home, ID Dyess, ŢХ Myrtle Beach, SC Eglin, FL Nellis, NV Ellsworth, SD Offutt. NE England, LA Pease. NH Fairchild, WA Peterson. CO Ft. Campbell, ΚY Plattsburg, NΥ Ft. Hood, TX NC Pope. Ft. Riley, KS Randolph, XT Ft. Rucker, AL Reese, ΤX Ft. Si11, OΚ Robins, GA Ft. Benning, GA Scott, IL Grand Forks, ND Selfridge, MI Griffis, NY Seymour, NC Grissom, IN Shaw, SC Hill, UT TX Sheppard, Holloman. NM Tinker, OK Homestead. FL Tyndall, FL Hunter, GA Vance, OK Hurlburt, ۴L Vandenberg, CA Keesler, MS W. Patterson, ОН Kelly, TX Whiteman. MD Ki Sawyer. MI Williams, ΑZ

Wurtsmith,

IĦ

NM

Kirtland,

Table 2-4

CHARACTERISTICS OF INITIAL CANDIDATE SITES*

Density	Site	Existing Radar	No Existing Radar
Urban	At airport	6	3
	Not at airport	3	10
Suburban	At airport Not et airport	14 2	5 5
Rural	At airport	28	7
	Not it airport	4	11
Unknown	At airport	4	4
	Not at airport	5	4

^{*}NWS and FAA sites in 48 conterminous states.

sites in a geographic region under study will be recommended for further investigation. Second, in the preliminary site survey, a survey team will visit each site to gather a variety of information, including that pertinent to potential environmental impacts. Based on its findings, the survey team will recommend which sites should receive an in-depth site survey. The objectives of the third step—the in-depth site survey—are to confirm the selection of the site and obtain detailed information on radar coverage, electromagnetic interference and compatibility, site access, and, if an environmental assessment is to be prepared, environmental impact.

If an existing radar site offers satisfactory coverage and other features, site surveys will be conducted only for the existing location; no additional site surveys will be carried out in that geographic area. If an existing site is not satisfactory, or in areas where no radar not exists, more than one candidate site will probably be surveyed. Site selection will then become essentially a process of elimination. The objective will be to eliminate those sites with serious problems or deficiencies as early as possible. It is expected that any site subjected to an in-depth site survey will almost certainly be among those at which NEXRAD radars are constructed.

Table 2-5 presents an overview of the site evaluation process in which five general subject areas will be analyzed during each of the three successively more detailed surveys:

- Radar coverage analysis--how well the radar can meet the users' airspace coverage requirements for the site.
- Geographic suitability analysis—difficulty of constructing the necessary facilities at the site and the suitability of existing facilities to accept NEXRAD equipment.
- Roads and utilities analysis--availability and adequacy of access roads and utilities, including power, water, sewer, and communications.
- Operational environment analysis--potential adverse effects of the surrounding environment on the site, including EMI, corrosive pollutants, dust, and other deleterious factors.
- Environmental impact analysis--potential adverse effects on the surrounding environment of constructing and operating a NEXRAD radar on the site.

2.3.5 Environmental Impact Analysis

The objectives of this analysis are to determine the need for special environmental design considerations and to identify sites that may require the preparation of a site-specific environmental assessment. The initial site assessment will focus on the identification of environmental issues associated with each site. For new sites, the full range of possible issues will be considered. At existing sites, the possibility for many environmental issues has been precluded by prior development, and only certain possible issues, such as electromagnetic radiation hazards and aesthetics, may be significant.

The preliminary site survey will verify, by direct observation, the inferences made during the initial site assessment. A survey team will gather readily observable information about site features and environmental conditions that relates to possible environmental impacts. This information will be used to determine the need for an environmental assessment for the site.

Additional, more detailed environmental information will be gathered as part of the in-depth site survey if the preliminary site survey indicates the likelihood of significant adverse impacts. Data in hand will be expanded and updated through field observations and interviews. Environmental sampling and measurement will be carried out, if needed, to resolve environmental issues. Mitigating measures will be identified.

A wide range of possible issues, including biological impacts, air pollution, and use or discovery of hazardous materials and their possible effects, will be considered during the continuing environmental

Table 2-5

OVERVIEW OF THE SITE-SURVEY EVALUATION METHODOLOGY

In-Depth Site Survey	Prepare new radar coverage plots based on accurate measurements taken at the site	Prepare detailed estimates of site preparation costs	Prepare detailed planning and cost estimates	Make accurate EMI measure-ments at the site and generate special design requirements for adverse environmental effects	Gather detailed data for environmental assessments
Survey Evaluation Preliminary Site Survey	Update radar coverage plots from coarse visual sightings taken at the site	Make visual inspection of the site and prepare pre- liminary site layout	Estimate distances and routing to utilities during site visit	Inspect potential pollution problems. Verify list of emitters for location, frequency, and strength	Make preliminary inspection of site and continue data collection from local organizations
Initial Site Assessment	Prepare radar coverage plots from map data	Prepare initial assessment based on maps and other data	Prepare initial assessment based on maps and contact with utility companies	Study EMI data and review area maps	Inspect maps and data and contact local organizations
Area	Radar Coverage Analysis	Geographic Suitability Analysis	Roads and Utilities Analysis	Operational Environment Analysis	Environmental Impact Analysis

impact analysis. Explicit guidance on these issues will be provided to the site survey teams. Federal, state, and local environmental protection and resource conservation agencies will be consulted throughout the process. Information on required permits and other approvals will be gathered beginning with the preliminary site survey for each site. Complete requirements will be determined during the in-depth site survey.

2.4 Alternatives

In the course of developing the MEXRAD program, alternative methods of meeting agency requirements for weather radar information were investigated. Five alternative approaches, described below, to meeting agency requirements for improved weather radar information exist:

- Continue the existing system
- New non-Doppler system
- New coherent non-Doppler system
- Mixed system of new Doppler and non-Doppler radars
- Environmental satellite system.

A number of other possible variations in the technical design of the NEXRAD system have no bearing on environmental considerations and so are not included here. The proposed action is preferred to any of the alternatives because none could provide the advantages of an all-Doppler system. The alternatives of no action and postponement of action must also be considered for environmental review purposes. The environmental impacts of these alternatives are discussed in Section 4.4.

2.4.1 Continue the Existing System

Requirements for information about weather phenomena are being met in part today by data from several types of radars, some designed for weather purposes and some adapted for limited weather uses. In this alternative, the weather radars used by NWS and all DOD radars would be renovated and modernized. Such renovation and modernization would not meet the existing severe weather and aircraft safety requirements.

2.4.2 New Non-Doppler System

A new non-Doppler rader system would be purchased to replace the present system and meet some of the common agency requirements for weather radar information derivable from reflectivity data in the same manner as employed today. This alternative would result in a significant improvement in reliability and maintenance cost-effectiveness. However, the severe weather warning and aircraft safety improvements attainable with Doppler technology would not be realized.

2.4.3 New Coherent Non-Doppler System

Existing weather radars are "noncoherent," meaning that the energy pulses transmitted by the radar have random phase relationships. Coherent radars transmit pulses that have exactly the same phase relationship.

Coherent pulses help minimize the problems first of ground clutter, which often obscures weather echoes at short ranges, and second of the very weak reflected signals mixed with "noise" at long ranges, both of which make interpretation very difficult.

New coherent radars would replace existing radars in the same way and with the same basic benefits of reliability and maintenance cost-effectiveness as the preceding non-Doppler alternative. Doppler capability could be added at a later data by adding the necessary components and greatly expanding the data processing capability. Again, the advantages of Doppler technology would not be realized.

2.4.4 Mixed System of New Doppler and Non-Doppler Radars

The Doppler radar's principal advantages lie in making possible more accurate and timely warnings of thunderstorms and tornadoes and in providing information about turbulence in storms. An alternative national system would place non-Doppler radars in lower risk areas, i.e., in the western intermountain areas and in portions of the northeastern United States. The non-Doppler radar could be essentially the same device as the Doppler radar; the latter would have the special Doppler features and processing subsystems added. Development of a non-Doppler radar meeting Doppler performance requirements and the need to provide training, maintenance, documentation, and logistics support for a second type of operational radar would add both the initial system cost and recurring annual burdens to the life-cycle cost of the mixed system. Complications of a mixed system and loss of some capability may reduce the apparent value of this alternative.

2.4.5 Environmental Satellite System

Environmental satellites operated by the U.S. government view the earth's atmosphere periodically, day and night. These satellites carry sensors that create images in both visible and infrared portions of the spectrum. The visible images show clouds; the infrared images may be interpreted to obtain cloud top heights. However, the clouds beneath higher ones are hidden from view. Present and planned polar orbiting environmental satellites provide images of the United States four times daily while satellites in geosynchronous orbits provide near-continuous images. This alternative relies on the development of new sensors to provide the necessary spatial resolution and information on internal storm intensity and dynamics. Development of such sensors is not likely in the same time frame as the availability of Doppler technology.

3 AFFECTED ENVIRONMENT

Generally, the candidate sites may be classified by the:

- Existence of a radar
- Location of the candidate site at an airport, office location, or other.

Except for electromagnetic characteristics, the affected environment is described below for each combination of these dimensions. The description of the electromagnetic environment applies to all sites.

3.1 The Electromagnetic Environment

The electromagnetic environment at a particular location and time consists of all the electromagnetic fields that are arriving there from numerous sources, both man-made and natural. Some of these fields are used for communication or for radiolocation (radar). The electromagnetic spectrum in the area is a continuously usable renewable resource having the dimensions of amplitude, time, frequency, and space. In areas large enough to permit sufficient geographic separation of users, the spectrum will accommodate a number of users on the same frequency simultaneously. In smaller areas, the spectrum will accommodate a large number of simultaneous users only if they are sufficiently separated in frequency. A high-power signal can mask a low-power signal on the same frequency.

The electromagnetic environment at a point can change almost instantaneously and, at a given instant, it will not be the same at two points a few feet apart. Therefore, it is generally convenient to deal with averages over time and space. When there is sufficient incentive, certain features of the electromagnetic environment can be measured and documented. However, because of the cost, attempts are seldom, if ever, made to define the electromagnetic environment simultaneously over wide frequency ranges, large geographic areas, and long periods. Most attempts at defining the spectrum are of very limited scope, aimed only at providing answers to particular questions such as, "Is the channel-5 TV signal on this mountaintop above this remote community strong enough to permit the operation of a translator?" or "Is the man-made radio noise at this location low enough to successfully operate a sensitive HF receiving system?" or "Are the land-mobile radio bands in Chicago too crowded to accept additional users?" Some measurements have been made in the Los Angeles area of the particular portion of the electromagnetic spectrum to be most affected by the NEXRAD radar. The measurements showed that in some areas that part of the spectrum can be crowded with various other maders.

Some of the man-made contributions to the electromagnetic environment in the vicinity of each of the candidate NEXRAD radar sites are intentional, but others are accidental and incidental to some other activity. Radio (and radar) signals are intentional man-made contributions. The electromagnetic environment in any area consists in part of signals from various broadcast radio and TV stations, from local or transient amateur and CB operators, from air navigation aids, from passing aircraft, from satellites that provide cable TV programming, and so on. Because some signals can be reflected back to the earth at great distances by high-altitude ionospheric layers, part of the electromagnetic environment in any area consists of transmissions propagated by sky wave from stations thousands of miles away. Signals from the NEXRAD radar and others that use the same part of the spectrum do not propagate by sky wave and will generally not propagate very far beyond the horizon.

The unintentional human contributions to the electromagnetic environment are called man-made electromagnetic noise. Such noise is radiated by power lines, fluorescent lights, household lighting dimmer switches, household appliance motors, computers, hand-held calculators, and so on. A major contributor is the automobile ignition system, which radiates a pulse of energy over all the communication bands with each spark-plug firing. Although man-made electromagnetic noise is a major feature of some parts of the spectrum, it is not a concern in the portion of the spectrum to be used by the NEXRAD system.

Nature contributes only noise to the electromagnetic environment, but it can do so in a big way. Lightning strokes in storm centers in Africa and South America can cause "static" in radios in the United States thousands of miles away. Each lightning stroke acts as a powerful transmitter covering a wide frequency band. Its "signal" propagates by sky wave to regions thousands of miles away. This noise is an intermittent major feature of the part of the electromagnetic spectrum used by standard AM broadcast stations and by HF international broadcast stations. In the portion of the electromagnetic spectrum to be used by the NEXRAD radar, radio noise from the sun and from the stars (galactic noise) is, in the absence of signals from other radars, the predominant feature of the local electromagnetic environment.

Human beings are not generally capable of sensing the electromagnetic environment or changes in it. However, radio (and radar) receivers are designed precisely for this purpose. They sample portions of the spectrum to extract a small amount of energy, which they then amplify and convert to a signal meaningful to the receiver's operator. This signal might be in the form of a picture on TV channel 5, music from a local FM broadcast station, a long-distance telephone conversation, an air navigation signal, or a radar signal reflected from an airplane or a heavy rainstorm, for example.

For man to make use of some portion of the electromagnetic environment for communication, radiolocation, radionavigation, or other such purposes, usually the power of the signal must exceed the power of the

noise in that portion of the spectrum at the receiving location. (In some systems, complex signal processing schemes permit use of signals slightly weaker than the noise.) Unless the power in the desired signal is greater than the sum of the natural noise, the man-made noise, the receiver's own background noise, and any other interfering signals in the receiver's bandwidth, usually one cannot hear or otherwise make use of the desired station's signal. In the portion of the spectrum to be used by NEXRAD, natural and man-made electromagnetic noise is not significant relative to the radar receiver's internal noise level or to signals from other radars. Thus, the electromagnetic environment of present concern is affected mainly by the presence of man-made signals from other radars.

NEXRAD will share the frequency band between 2,700 MHz and 3,000 MHz with a large number of other currently operating radars, each radar using a small part of that band and contributing to the electromagnetic environment there. The upper adjacent band, extending from 2,900 MHz to 3,100 MHz, is occupied by other radar systems. In the United States, no transmissions are permitted in the lower adjacent band, from 2,690 MHz to 2,700 MHz. That band is set aside for radioastronomy measurements, with the intent that the electromagnetic environment there be left in its natural state—affected as little as possible by radars.

Signals in the spectrum between 2,700 MHz and 3,000 MHz do not usually travel far beyond the horizon, so the contributions to the environment at any particular location will be limited to those from radars within, at most, 100 or 200 miles. At some locations, very few other radars will be that close; at other locations, such as near large metropolitan areas, many radars will contribute to the electromagnetic environment in that part of the spectrum.

3.2 Biophysical Environment

3.2.1 Existing Radar

3.2.1.1 Airports

Many of the NEXRAD facilities are expected to be sited at airports where a radar and user facility already exist. However, existing radar towers or radomes will not be used, nor will the new radar tower be constructed in the same location as the old one unless absolutely necessary. Rather, the new tower and equipment will be placed as close as practical to the old tower and, if possible, no more than 1.5 miles from the user facility, assuming the latter can accommodate the necessary NEXRAD equipment.

Airports can range from small facilities with a single building and landing strip to those with an extensive network of runways and taxiways, many aircraft hangers, numerous equipment warehouses, and huge parking lots. Substantial disturbance of the natural environment has already occurred in major portions of most larger, and even some smaller, air-

ports. For example, much of the vegetation has been removed to allow maximum clearance for landing; terrain features have also been eliminated to reduce hazards and to improve visibility. A large percentage of the land area within an airport is paved; therefore, minimal habitat is available for animal species. Aircraft activities routinely degrade air quality as take-offs and landings result in relatively high pollutant emissions. Water supply and sewage disposal services are generally in place at airports. In addition, other infrastructure components such as storm drainage systems are often installed to prevent flooding of the runways and adjacent fields. Access roads and connectors are common.

Example: The Minneapolis airport, which is located on the southern side of the metropolitan area, contains a 70-ft radar tower approximately 1,500 to 2,000 ft from the airport building that houses an NWS office.

Minnesota--particularly the northern part, but also the central, more inhabited portion where Minneapolis is located--is known for its widespread wetland habitat that is important to large waterfowl populations and other animals. The Minneapolis metropolitan area is surrounded primarily by oak savanna grassland/forest vegetation and also by maple-basswood forests. Both vegetation types are underlain by dark, humus soils that are most suited for agriculture.

In the vicinity of Minneapolis and St. Paul, air quality has deteriorated to the extent that levels of some pollutants exceed federal standards. Local air quality problems and such state and regional concerns as acid rain are expected to continue. In general, water supply for new facilities is not a problem in this area.

3.2.1.2 Office Locations

Some existing radars and associated user facilities are located in urban centers or suburban office parks. Such commercial areas are even more densely developed and have as many infrastructure services available as airports. Centers of commerce commonly contain a variety of business structures and building types, include multiple parking areas, and are within access of major transportation thoroughfares. Electric and communication links as well as water and sewage facilities are generally in place. The quality of the air in urban/suburban centers depends on the activities that take place there—light manufacturing and other processes generate more emissions than do the activities occurring in an office building. Although commercial areas may be well landscaped, the vegetation provides too little habitat for most animal species, and continuous human activity scares many small species. The only locations where important species may be present are fields and wetlands adjacent to suburban office parks that are at the outer edge of a metropolitan area.

Example: An existing weather radar is located on a 70-ft tower next to an NWS facility in a commercial section of St. Louis, Missouri. The NWS office is in a one-story building where space is limited. In fact, the site itself is small and expansion presents a problem because

of surrounding commercial development. A 60-kW generator supplies backup power to the radar.

3.2 1.3 Other Locations

Existing radars are also located in rural areas. Some are on ridgetops and others are on level terrain. Not all are collocated with the associated user facility. The natural environment at these other rural sites varies greatly depending on the local terrain and the region of the country. The more remote the site, the more environmentally sensitive it is likely to be. The most sensitive sites will be those surrounded by undisturbed habitat that can support a substantial wildlife population, with relatively clean air and water resources, without infrastructure elements in place, and accessible by unpaved roads.

Example: At Harrisburg, Pennsylvania, the radar is located on top of a mountain and is connected to the NWS office in the downtown area by a microwave communications link. The radar site does not have water or sewer facilities, the power supply has been unreliable, and access is unpredictable. The NWS office, on the eleventh floor of the federal building, is small with an unreliable power supply.

3.2.2 No Existing Radar

3.2.2.1 Airports

Some existing radar sites may be unsuitable for NEXRAD, making it necessary to install a NEXRAD facility at another location. In other cases, no radar may exist in the area requiring coverage. Thus, some NEXRAD sites may involve a new radar tower, radome, and user facility. Others, however, may involve collocating a new radar with an existing user facility. In a large number of cases, the user facility is at an airport. Therefore, depending on the location of the user facility, the tower might be sited either in the developed part or in a far corner of the airport. The same will be true if there is no user facility and all-new facilities are required.

At the periphery of airports, there are often unused and generally undisturbed areas that may be operationally suitable for NEXRAD. These undisturbed environments may also provide sufficient habitat for small mammals and reptile species. Services may or may not be available in these remote pockets of both urban and rural airports.

Example: AWS will install a NEXRAD radar and user facility at Chanute Air Force Base, near Rantoul, Illinois. A preliminary site survey led to the recommendation that the radar be located in a relatively isolated corner of the base. This site, which is about 1 2/3 miles from the user facility, is surrounded primarily by farmland, including occasional structures and trees. Most base activity is at least as far from the radar site as the user facility.

3.2.2.2 Office Locations

Another alternative is to locate a new NEXRAD radar adjacent to a user office (currently operating without its own radar) at a non-airport location in a commercial area. This does not appear likely because few locations of this type, which are probably in commercial zones, could satisfy all construction and operational requirements. Changing the sesthetics of an already developed area could also be problematic.

Example: In La Crosse, Wisconsin, a small NWS office is housed in the town's post office building.

3.2.2.3 Other Locations

If neither an airport site nor a commercial site is satisfactory from a technical or environmental standpoint for a NEXRAD radar, other more appropriate locations in relatively undeveloped rural areas may be considered. For operational reasons, sites surrounded by undeveloped areas are preferred over those in heavily congested urban areas or business districts, as long as future growth is not expected. These remote locations may be outside the boundary and in the vicinity of an airport, or they may be distant from population centers or commercial facilities. Many will not have all the necessary services provided (i.e., commercial power, communications, public water, and sewage disposal).

Example: Ann Arbor, Michigan, does not have a radar. An NWS office is located in the metropolitan area. However, because no site adjacent to the NWS facility is appropriate for a new radar, other locations in and on the periphery of the community will be evaluated for NEXRAD.

3.3 Socioeconomic Environment

3.3.1 Airports

Most airports being considered as sites for the NEXRAD facilities are located near communities with populations greater than 1,000; approximately one-third of the airport sites are near cities with more than 100,000 residents. Very few of the airport sites are located near communities with populations of less than 1,000.

Housing, schools, and other public services and facilities generally are available in urban areas. These services may, however, be limited in communities with less than 1,000 residents. Urban areas are characterized by a full range of land uses including residential, commercial, industrial, recreational, public, and open space. In smaller communities, residential and commercial land uses generally predominate. The surrounding land may be industrial or rural, with forests and agricultural or open land.

3.3.2 Office Locations

Some NEXRAD radars will be located near user facilities (both those with and without existing radar facilities). Non-airport NWS offices typically are situated in the commercial sections of urban or suburban areas. Housing and public services and facilities are available, and a full range of land uses exists in most urban and suburban locations.

3.3.3 Other Locations

Some NEXRAD radars are expected to be located in rural areas, either near existing user facilities or in areas without such facilities. Rural areas are characterized by forest, agricultural, recreational, or open land uses. One or more urban areas ranging in size from less than 1,000 residents to well over 100,000 residents are located within a 50-mile radius of most rural NEXRAD sites. Housing, public services, and facilities are generally available in urban areas. However, these services may be limited in communities with fewer than 1,000 residents and may be nonexistent in very remote rural locations.

4 ENVIRONMENTAL CONSEQUENCES

The scope of the analysis of potential impacts of the construction and operation of the NEXRAD system includes possible health effects of radiofrequency radiation (RFR), electromagnetic interference, and effects on the biophysical and socioeconomic environment.

4.1 Radiofrequency Radiation

The contribution of RFR to the environment depends primarily on the magnitude, nature, and distribution of the RFR. A detailed description of the NEXRAD radar system is given in Appendix A, and a comprehensive technical description of the resulting RFR is presented in Appendix B. Measurements made on existing radar systems that are similar to NEXRAD show that the field model is well founded and conservative.

The RFR power densities that will exist in the vicinity of a NEKRAD unit will depend on the minimum elevation angle of the antenna, the scan mode, and the characteristics of the local terrain. Because the main beam is quite slender and will be elevated during a large fraction of the time, it will strike the ground only occasionally and only in isolated locations that are higher than the general terrain. Time—averaged values of RFR will be quite low because the maximum average power is only 2 kW. The nature and magnitude of the RFR produced by the NEXRAD radar will not differ substantially from those produced by the radars that NEXRAD will replace. In all cases, the time-averaged power density to which the general public will be exposed will be at least one order of magnitude below the maximum permissible values recently adopted by the American National Standards Institute (AMSI).

4.1.1 RFR Fields

Time-averaged values of RFR are based on a 0.2% duty cycle, which is the maximum percentage of time that NEXRAD is designed to radiate. However, some specific effects related to electromagnetic interference depend on the pulse power density and other details of the individual pulses. For this reason, peak values of power density and electric field intensity are also given. Following common usage, all values of radiation intensity are expressed as power density in milliwatts per square centimeter (mW/cm^2) . Electric field intensities are given in volts per meter (V/m), the accepted unit for this parameter.

Most of the power radiated by the MEXRAD antenna will be concentrated in the main beam and a few adjacent sidelobes. Therefore, a distinction must be made between regions that are within or near the main beam and those that are remote from it. Because the beam requires

a substantial distance to merge into its final form, a distinction must also be made between regions close to the antenna and those that are further away. Values of RFR also depend on the scanning pattern, antenna height, and other details. All these parameters are discussed in Appendix B.

The properties of the NEXRAD antenna are such that the values of RFR can be expressed uniquely in terms of two variables: horizontal distance from the center of the antenna and vertical distance below the axis of the beam when the beam is at its lowest elevation angle. Curves of maximum pulse and average power density, based on this representation, are presented in Figures 4-1 and 4-2 (which duplicate Figures B-7 and B-8 from Appendix B).

4.1.2 Biological Effects

4.1.2.1 Human Health

In this section, which considers the effects of exposure to RFR on human health and on plants and animals, the term "RFR" is used generically to include other terms commonly found in the bioeffects literature, such as electromagnetic radiation (EMR), nonionizing electromagnetic radiation (NIEMR), microwave radiation, radiofrequency electromagnetic (RFEM) fields, electromagnetic fields (EMF), microwave fields, and others. The term applies to frequencies from 0 to 300 GHz, both modulated and unmodulated. The frequency band of the NEXRAD transmitter is 2,700 to 3,000 MHz. The time-averaged power densities used in considering possible health hazards are based on averaging the intensities over the worst-case 6-min interval used in U.S. exposure guidelines.

The basic RFR issue is whether brief or continual exposure of people to the RFR power densities produced by a NEXRAD transmitter is likely to affect their health adversely. A critical review of the present state of knowledge regarding biological effects of RFR, Report SAM-TR-83-1, entitled "Bioeffects of Radiofrequency Radiation: A Review Pertinent to Air Force Operations," by L. N. Heynick and P. Polson, serves as the primary reference for the human health aspects of this assessment of NEXRAD. The cited review (discussed in Appendix C) was prepared for the U.S. Air Force, but is useful for considering possible bioeffects of all kinds of radar systems. In Appendix C, research results considered most significant scientifically and pertinent to the operational characteristics of the NEXRAD radar and to the RFR power densities in the general vicinity of a hypothetical radar site were examined to determine whether the RFR from NEXRAD would have any significant effects on human health.

Attention is also directed to another recently completed critical review, "Biological Effects of Radiofrequency Radiation" (Elder and Cahill, 1983), which is the final draft of a report scheduled for publication by EPA in summer 1984. This report is similar in many respects to the SAM-TR-83-1 report, covering many of the same subject areas and specific scientific references.

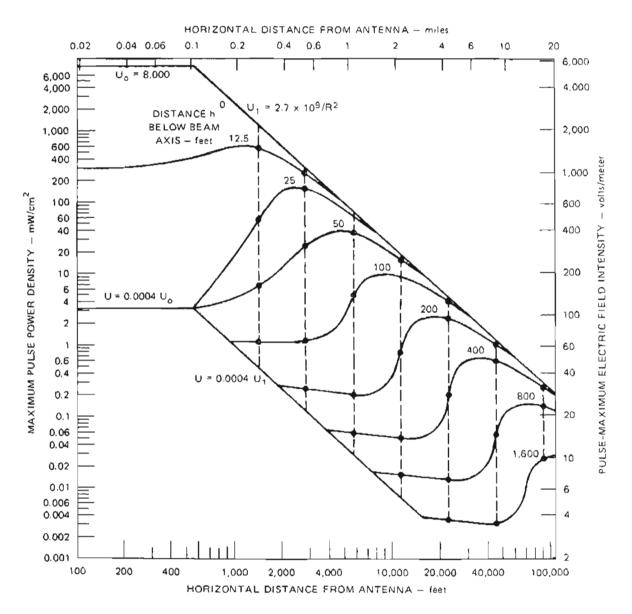
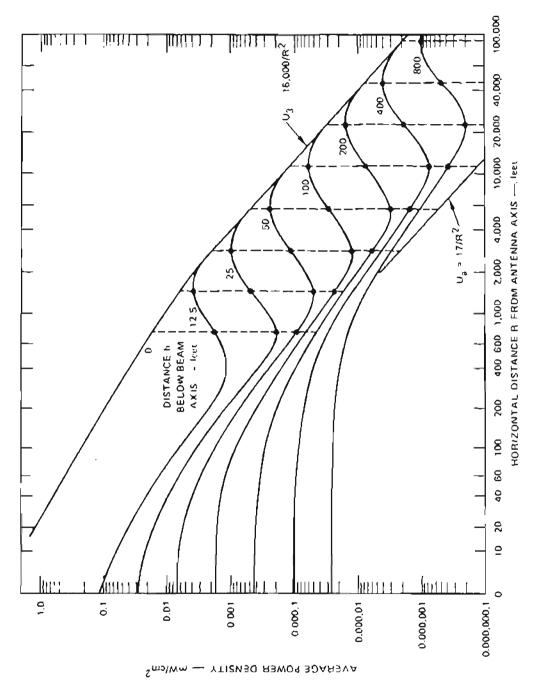


FIGURE 4-1 MAXIMUM PULSE POWER DENSITIES AND ELECTRIC FIELD INTENSITIES NEAR NEXRAD RADAR



AVERAGE POWER DENSITIES NEAR NEXRAD RADAR (Averaged Over 6 Minutes) FIGURE 4-2

Humans could be exposed to the RFR from a NEXRAD transmitter under two circumstances: first, people airborne near a radar could be exposed to the main beam; second, populations at ground level near a transmitter site could be exposed to low-intensity RFR at distances up to several miles from the antenna.

4.1.2.1.1 <u>Airborne Exposure</u>. Exposure of people in an airplane to the main beam is a possibility shared with many operational high-power radar systems. However, as far as is known, no case of harm to humans from any such incidental exposure has ever been reported, and there is no reason to believe that the NEXRAD situation would be different from that of other radar installations in this respect.

A phenomenon associated with RFR pulses per se is the perception of individual pulses as apparent sound. The threshold pulse power density for this effect is about 300 mW/cm². An airplane in the general vicinity of a NEXRAD antenna may be swept by the main beam for periods of about 0.5 ms per sweep. If so, calculations presented in Appendix B indicate that within about 550 ft of the antenna (the near-field region), the maximum pulse power density in the main beam may be as high as 8,000 mW/cm²; beyond that distance (in the far field), the pulse power density will diminish by the inverse-square law, and the 300-mW/cm² threshold will be at about 3,000 ft. Thus, people who are airborne and who are swept by the main beam within distances of less than 3,000 ft may "hear" the pulses. However, there is no experimental evidence that these people would be adversely affected by exposure to such levels of pulse power density.

The calculations in Appendix B also indicate that the time-averaged power density at an airplane swept by the main beam and all sidelobes will be only 0.23 mW/cm² at 100 ft, 0.035 mW/cm² at about 300 ft, and still lower at greater distances. Such levels are below prevailing standards for human exposure, and there is no evidence that exposure to such levels would be harmful. Moreover, the cited values do not include the potential shielding properties of metal aircraft.

4.1.2.1.2 Ground-Level Exposure. For a "worst-case" ground-level exposure situation in the near field, the ground near the antenna was assumed to be essentially flat out to a distance of about 3,000 ft, the main beam was assumed to be horizontal, and the bottom of the antenna rim was assumed to be 20 ft above ground. With the latter assumption, the center of an antenna 24 ft in diameter would be 32 ft above ground level, and the head of a person 6 ft tall would be 26 ft below the center of the main beam. For this situation, calculations presented in Appendix B indicate that at all distances from the antenna, the maximum pulse power density at such head heights will be considerably less than the 300-mW/cm² threshold for the auditory RFR effect discussed above. Thus, it is most unlikely that people anywhere at ground level will "hear" the NEXRAD pulses.

For this worst-case situation, the maximum time-averaged power density at heights of 6 ft or less above ground will nowhere exceed 0.03 mW/cm², and will be less than 0.001 mW/cm² for distances beyond about 200 ft. In the standard recently adopted by ANSI, the maximum permissible average power density for human exposure to RFR in the 2,700- to 3,000-MHz range is 5 mW/cm². The new USSR limit for chronic exposure of the general population is reported to be 0.01 mW/cm². Thus, the ground-level values of RFR within the near field of a NEXRAD antenna will be at least 50 times lower than the new ANSI standard, and the values in the far field will also be well below the new USSR standard.

Collectively, the results of the relatively few epidemiologic studies performed in the United States, the USSR, and other Eastern European countries do not present convincing evidence that environmental levels of RFR are likely to constitute a hazard to the general population.

Most U.S. experiments with animals that yielded recognizable and repeatable effects of exposure to RFR were performed at incident average power densities of more than about 1 mW/cm². Most such effects are thermal, in the sense that the RFR energy is absorbed by the organism as widely distributed heat that increases the whole-body temperature, or as internally localized heat that is biologically significant even with natural heat-exchange and thermoregulatory mechanisms operating.

The existence of threshold values of average power density has been experimentally demonstrated for some effects and postulated for others. Exposure to RFR at average power densities exceeding the threshold for a specific effect for a few minutes to a few hours (depending on the value), may or may not cause irreversible tissue alterations. The heat produced by indefinitely long or chronic exposure at power densities well below the threshold is not accumulated because its rate of production is readily compensated for by heat—exchange processes or thermo-regulation. However, it should be noted that there is some current controversy concerning the minimum threshold for thermal—physiologic effects. Nevertheless, the lowest threshold level suggested is well above those associated with human exposure to RFR from NEXRAD.

Most investigations involving chronic exposure of mammals yielded either no effects or reversible, noncumulative behavioral or physiological effects for average power densities exceeding about 1 mW/cm². In the few cases in which irreversible adverse effects of exposure were found, such effects were absent for average power densities below 1 mW/cm².

In a relatively small number of investigations, biological effects of RFR were reported at incident average power densities less than about 1 mW/cm². Such effects have been called "nonthermal" to distinguish them from those mentioned above. However, this usage of nonthermal is confusing and imprecise because the interaction mechanisms involved in

each such effect differ considerably from those for the other effects, and clear distinctions between thermal and nonthermal effects based on precise scientific definitions of these terms are difficult to discern in the interactions.

The previously mentioned detection of individual RFR pulses as apparent sound has been characterized as nosthermal, primarily on the basis that the average power density would be minuscule if the time intervals between consecutive pulses are large. However, the average power density is not relevant because the interactions that produce the effect depend primarily on the characteristics of individual pulses.

In sum, examination of the relevant literature on RFR bioeffects (Appendix C), including such subjects of concern as possible RFR-induced birth defects, cancer induction, decreased resistance to disease, effects on the heart, genetic alterations, and others, indicates that there is no reliable evidence to suggest that chronic exposure to the RFR from NEXRAD will be deleterious to the health of even the most susceptible members of the population, such as the unborn, infirm, or aged.

4.1.2.2 Plants and Animals

Significant effects on plants or animals are not expected to result from the RFR emitted during operation of NEXRAD. Temporary minor effects that may occur near a NEXRAD site will be due to the repulsion or attraction of species that are sensitive to noise and human disturbances other than RFR associated with radar operation.

4.1.2.2.1 Main Beam Exposure. The biota potentially affected by the main beam are airborne fauna, such as birds and possibly bats and insects. Of ecological interest are birds and the insects involved in pollenization. As discussed in Appendix C, the literature suggests that biological effects, not necessarily hazardous, are possible at everage power densities exceeding about 1 mW/cm². Calculations in Appendix B indicate that the time-averaged power densities at distances beyond about 10 ft from a NEKRAD antenna radome along the propagation direction will be less than 1 mW/cm². Thus, only the propagation column within about 10 ft from the radome would be of possible concern to airborne organisms. Trensient airborne organisms near an RDA, therefore, should not experience adverse effects from RFR exposure.

For local airborne biota, minor effects may occur in the near field. The RFR from NEXRAD might tend to cause birds to avoid the antenna site (see Tanner and Romero-Sierra, 1969). On the other hand, birds might learn to seek out the RFR for warmth during cold weather (Gandhi et al., 1978). On the basis of existing information, the probable effects, if any, on birds are unclear. Moreover, RFR-induced biological effects will vary among airborne biota because of species-dependent differences in physiology and in the rate of absorption of RFR energy.

Nonthermal effects on birds of low-level RFR have been claimed by a few researchers (Tanner, 1966; Tanner et al., 1967), but the methodology used in these experiments has been questioned (Eastwood, 1967; Krupp, 1976). Temperatures of the experimental subjects were not measured, and the effects may have been thermal. Irrespective of whether the effects were thermal or nonthermal, the experimental arrangements (caged birds in highly restricted areas with horn antennas mounted on the cages) bore little relationship to the habitats in which birds normally operate. Tanner and Romero-Sierra (1974) themselves have concluded that external environmental parameters such as temperature, humidity, and atmospheric pressure, as well as internal factors of the experimental subjects, should be considered when analyzing RFR effects on organisms.

The RFR fields from NEXRAD will be similar to those of existing military and civilian radar systems that have been in operation continuously for many years without any evident ecological damage. In addition, for more than a decade, animal behaviorists and ornithologists have considered radar a legitimate tool for studying animal migration, navigation, and homing (Eastwood, 1967; Krupp, 1976; Schmidt-Koenig and Keeton, 1978; Williams et al., 1977).

Gary and Westerdahl (1978) summarized reports in the literature on various effects of exposure of insects to RFR. The effects ranged from unrest to death, depending on the level and duration of the exposure and the species studied. In laboratory studies, abnormal development of beetle pupae was reported at power densities and exposure durations that produced significant heating (see Appendix C, Section C.6.3). In a recent study (Westerdahl and Gary, 1981), adult honeybees were exposed to continuous-wave (CW) 2.45-GHz RFR at power densities from 3 to 50 mW/cm² for durations of 0.5 to 24 hr, after which they were held in an incubator for 21 days to determine the consumption of sucrose syrup and to observe mortality. No significant differences were found between RFR-exposed and sham-exposed or control bees. In another study, Gary and Westerdahl (1981) found that foraging-experienced honeybees retained normal flight, orientation, and memory functions after exposure to such RFR at the same levels for 30 min.

Bem and Trzaska (1976) reported on a case in which a pair of sparrows built a nest within the antenna feedline for a 2-MW, 277-kHz transmitter. Calculations indicated that the electric field in the immediate vicinity of the nest was about 100 kV/m. Because of its location, the nest was watched virtually constantly by operating personnel, who reported that the eggs hatched normally and the baby sparrows remained within the nest until they became fledglings and flew off. No ill effects or deviant behavior were evident for the parents or their brood.

In summary, no significant biological effects from exposure to the main beam of NEXRAD are expected. At most, only a few sirborne individuals of fauna common to a NEXRAD transmitter site might be affected in a

small region outside the radome, but these effects are not likely to be hermful.

4.1.2.2.2 <u>Ground-Level Exposure</u>. The same considerations discussed for main-beam exposure indicate that plants and animals at or near ground levels near a NEXRAD antenna will not be affected adversely by chronic exposure to the power densities of the RFR emitted by it.

4.1.3 <u>Electromagnetic</u> <u>Environment</u>

4.1.3.1 The Addition to the Environment

An operating NEXRAD radar will change the electromagnetic environment within the physical space its energy reaches and over the frequency band (and the harmonic frequencies) of its operation. (Appendix B contains a detailed analysis of the change.) This change can be described in two ways: as an actual addition of electromagnetic energy to the electromagnetic environment, and as the way in which the change affects other systems and thus becomes perceptible to those using them.

Government use of the radio spectrum is under the control of the National Telecommunications and Information Administration (NTIA), formerly the Office of Telecommunications Policy (OTP). Because NEXRAD is a government system, a detailed application for spectrum "support" (i.e., authorization to use) has been made to the Interdepartment Radio Advisory Committee (IRAC) of NTIA, which has the power to authorize operation of the radar.

The NEXRAD transmitter will be built to transmit in the band from 2,700 MHz to 3,000 MHz. An important characteristic of radio (or radar) signals in this frequency band is that they propagate almost as if they were light waves, and so do not normally extend a long distance beyond the horizon. The band is shared with various other government radars used for airport surveillance, air traffic control, and weather surveillance. The 2,700- to 2,900-MHz part is shared with about 630 such radars in the continental United States.

The choice of operating frequency for each NEXRAD radar installation will take into account all other radars in the vicinity to minimize the likelihood of interference between the NEXRAD radar and the others. Local coordination of the operating frequencies of all the radars in the NEXRAD band is accomplished by regional FAA frequency controllers, who assure electromagnetic compatibility between the radars.

The NEXRAD antenna will usually rotate azimuthally, transmitting a beam of energy that propagates until it reaches precipitation, from which a portion of the energy is reflected back to the antenna over the same path. Not all the radar's power is focused in the main-beam direction. There are also (much smaller) concentrations of power in the antenna's sidelobes and backlobes (see Figure 2-6). Their maximum power density is no greater than about 1/300 the maximum power density of the

main beam. Signals will propagate from these minor lobes at a much lower Level than from the main beam.

The radar will emit signals on frequencies other than the intended one, but at a much lower power level. Great care will be taken in the design of the radar system to minimize them, as they are both a waste of transmitter power and a potential source of interference to other radars operating on nearby frequencies. Some of these unintended frequencies are integer multiples of the intended, or fundamental, frequency and are termed "harmonics." Others not directly related to the fundamental are called "spurious emissions."

When a radar or other transmitter radiates a modulated signal in its desired frequency band, it also transmits some energy in the directly adjacent portions of the spectrum, creating the possibility of adjacent-channel interference. (The strong possibility of adjacentchannel interference is the reason why adjacent TV channels, such as 9 and 10, are not used in the same community.) This out-of-band energy is close enough in frequency to propagate along with the desired signal. The modulation of the NEXRAD radar transmitter will be carefully designed to minimize the out-of-band energy. The NEXRAD emission spectrum must meet the current Radar Spectrum Engineering Criteria (RSEC) of the NTIA's Manual of Regulations and Procedures for Federal Frequency Management. Some NEXRAD radars will be required to operate in unusually crowded radar environments, such as near some large cities. Therefore, the NEXRAD design will include the capability to improve the emission spectrum of such radars greatly beyond the usual RSEC criteria simply by adding a waveguide filter or other device.

4.1.3.2 The Effects of NEXRAD on Systems

NEXRAD's contribution to the electromagnetic environment could affect both systems using the electromagnetic environment and systems not intended to receive electromagnetic energy. Other users of the spectrum include TV, radio, and other radars; systems or processes not intended to receive electromagnetic energy include cardiac pacemakers, electroexplosive devices (ERDs), and fuel handling operations.

Appendix D discusses interference between radar systems and the level of the HEXRAD signal relative to certain safe levels for the handling of EEDs and fueling of aircraft. No actual interference predictions have been made, as the complex calculations are highly dependent on the circumstances at each NEXRAD site. Interference with another radar depends on the type of the other radar, on the distance and terrain between the two, and on the separation between the two operating frequencies.

4.1.3.2.1 Effects on Telecommunication, Radionavigation, and Radiolocation Systems

- 4.1.3.2.1.1 <u>Services That Share the Band with NEXRAD</u>. Because the radar will operate in a band that is also used by other radars, mutual interference between the NEXRAD radar and the other radars is possible. In all cases, the operating frequencies, powers, and locations of the existing radars will be considered in selecting the frequency for the NEXRAD radar to avoid mutual interference.
- 4.1.3.2.1.2 <u>Services Adjacent to NEXRAD</u>. The lower adjacent band, from 2,690 to 2,700 MHz, is allocated for radioastronomy, and no U.S. radar stations are authorized to transmit there. Because interference to radioastronomy work would be a site-specific concern, no predictions have been made to determine whether any NEXRAD installation would interfere with any particular radioastronomy effort. The Radioastronomy Service can claim protection from interference from out-of-band signals only if the offending station is not operating in compliance with the technical standards or criteria applicable to the service in which that station operates. NEXRAD installations will be in full compliance.

The upper adjacent band, from 2,900 to 3,100 MHz, is also used for radars, with government and nongovernment maritime radionavigation the primary service, and with military aeronautical radionavigation the secondary service. The NEXRAD radar will be capable of operating in the lower helf of this band, so that its potentially usable frequency band will extend from 2,700 MHz to 3,000 MHz. Therefore, interference with this band will be avoided in the same manner as for the in-band radars. Interference specifically with maritime radiolocation systems will be avoided by not using frequencies in the 2,900- to 3,000-MHz range at sites near major ports.

- 4.1.3.2.1.3 <u>Services Harmonically Related to NEXRAD</u>. The harmonics of the NEXRAD signal could interfere with other systems but because the interference situations are site-specific, they can be considered in detail only when particular installations are of concern. The harmonics of the NEXRAD are integer multiples of the desired, or fundamental, frequency. The NEXRAD third harmonic could fall on a frequency used by the FAA for radar microwave links. These strictly local matters will be considered when individual NEXRAD installations are being planned so as to avoid mutual interference.
- 4.1.3.2.1.4 Other Radio Services. Like all the other radars currently operating in the 2,700- to 3,000-MHz band, each NEXRAD radar may cause some interference to the reception of broadcast TV and radio in its immediate vicinity. This is sometimes heard on the radio as a buzz at the radar's pulse repetition frequency (which will be between 250 and 1,200 pps for NEXRAD). The buzz is sometimes modulated as the radar antenna rotates; it becomes periodically more and less noticeable, sometimes disappearing entirely. Radar interference to television appears as patterns of dots on the screen.

The presence or absence of the interference depends on characteristics not only of the radar but also of the particular radio or TV receiver, and on the frequency and signal strength of the potentially interfered-with signal. However, no studies are known to specifically treat interference from such radars to broadcast TV and radio. In the NEXRAD site selection process, the existence of dwelling units within about 1 mile of each candidate site will be considered in the selection decision.

4.1.3.2.2 Effects on Pacemakers, Electroexplosive Devices, and Fuel Handling. Although no definitive information is available regarding the susceptibility of currently used cardiac pacemakers to fields in the NEXRAD radar's frequency range, radars such as NEXRAD are not considered to constitute a significant threat to pacemaker owners. A 1975 draft standard by the Association for the Advancement of Medical Instrumentation (AAMI) contained a design susceptibility threshold of 200 V/m (the electric field equivalent to a pulse power density of 10 mW/cm²) at about 450 MHz. Measurements had shown that implanted pacemakers were most susceptible to signals in that general frequency range. Further, a pacemaker is more likely to cease operating when exposed to a pulsed field at a low pulse rate than to a CW field. Most pacemakers sense naturally occurring electrical signals in the heart and send out a pacing pulse only when the heart's own pacing pulse seems to be missing; such a pacemaker could possibly confuse low-rate radar pulses with the natural cardiac signals that it is designed to sense.

However, implanted pacemakers are less susceptible to fields in the NEXRAD radar's frequency range than to those around 450 MHz and also less likely to react adversely to pulse rates as high as those used by radars in this band. (Pulse rates used by NEXRAD and similar search and surveillance radars are too high to be mistaken by a pacemaker for the heart's own signal.) If they were to produce any effect at all, it would be to cause the pacemaker to begin harmless fixed-rate pacing rather than to remain in the usual pulse-only-when-needed mode.

Air Force Technical Manual T.O. 31Z-10-4, concerning electromagnetic radiation hazards, instructs that fuel handling operations (e.g., fueling of aircraft) should not be undertaken in electromagnetic fields with pulse power densities greater than 5,000 mW/cm². Although such pulse power densities can be found within the main beam at distances closer than about 730 ft (225 m), at most sites they are not expected to pose a hazard to fuel handling. At that distance from the NEXRAD radar, the beam will usually be well in the air; it will not illuminate ground-based fueling operations within that potentially hazardous distance unless they are being carried out on nearby elevated terrain. As specific candidate sites are examined, this possibility will be checked and, if necessary, addressed in a site-specific environmental assessment.

The Air Force has a standard for determining safe separation distances between radars and areas where EEDs are stored, handled, or transported. Probably the most common EED is the electric blasting

cap. At the recommended safe separation distances, EEDs are considered definitely safe, which does not imply that the EEDs are definitely unsafe at slightly smaller distances.

Even considering direct main-beam illumination, NEXRAD presents no hazard to EEDs stored or being transported at distances beyond about 730 ft (225 m) from the antenna. This may be a problem for aircraft or where there is elevated terrain close by the site. At each NEXRAD installation, it will be determined whether EED-equipped military aircraft are likely to fly within 730 ft and whether the radar's main beam will sweep high ground within that same distance.

Again considering direct main-beam illumination, exposed EEDs, such as blasting caps being handled in preparation for some blasting operation, appear safe according to Air Force criteria at distances beyond about 1.300 ft (400 m). Civilian criteria suggest a minimum distance of 1,000 ft. Again, the main beam of the radar could illuminate EEDs at ground level only if they are on elevated terrain.

4.1.3.2.3 Effects on Other Electronic Systems. Various other electronic systems, such as high fidelity audio equipment and computers, have been found to be affected by some radar systems. Electronic equipment purchased by the military must be capable of operating in the presence of relatively strong electromagnetic fields without experiencing electromagnetic interference. Equipment made for the civilian market does not have that requirement. Actual thresholds of susceptibility are not known for either military or civilian systems, and so there is not sufficient information on which to base predictions as to which systems could be affected and at what distances from a NEXRAD radar.

4.2 Biophysical Environment

4.2.1 Plants and Animals

4.2.1,1 Plants

Construction of a NEXRAD site for both a radar and a user facility will result in the removal of trees, shrubs, and other vegetation that would interfere with site preparation, radar placement, and access. In addition to controlling the growth of vegetation inside the security fence and along connecting corridors during construction, tall trees that would adversely affect radar operation may be selectively cut or topped. Some screening, however, is considered advantageous. For example, in areas with flat terrain, obstructions that break up reflections of the radar beam are desirable. On the other hand, in heavily forested areas, the preferred radar location is above tree level where the view of the horizon is not obscured. Therefore, decisions regarding vegetation removal will be made case by case.

At some locations—namely, an airport site adjacent to existing facilities—a small amount of vegetation (i.e., less than one-half acre)

would probably have to be removed. This will be particularly true if the site is already partially developed (or has been cleared for other purposes) and if access routes are available. In a commercial area near an existing user facility, about half an acre of vegetation would most likely be disturbed if a building rooftop could not be used. If a proposed site is in an undeveloped area (for example, on the periphery of an airport or on a mountain top), if all functional components (RDA, RPG, and PUP) are to be installed, if a well and leachfield are planned, and if access and utility corridors must be established, then a larger amount of vegetation (probably between 1 and 5 acres) may be affected.

Because of the susceptibility of various soil types to wind and water erosion, additional vegetation losses could occur unless precautions are taken. As a mitigation measure, at the end of the construction period, each site will be landscaped to prevent soil erosion, preclude reflections from surrounding structures (such as the security fence), and improve the overall aesthetics.

To comply with the requirements of federal, state, and local environmental protection and resource conservation agencies, as part of the site evaluation procedure, these agencies will be consulted for assistance in identifying trees, shrubs, grasses and forbs, crops, and aguatic plants in the locations under consideration. Whether any rare or endangered plant species are present in the areas will also be determined. Such species might be found in distant, undisturbed corners of airports, in the vicinity of commercial developments, or in other locations that appear technically satisfactory for a NEXRAD radar. Any rare plant populations discovered will be avoided. In general, ecologically sensitive sites will be avoided if possible.

4.2.1.2 Animals

During construction of a new NEXRAD facility, removal of ground-cover and vegetation within the security area and along the access corridors could affect resident animal species. At airports, such species would likely be small mammals, reptiles, and birds. At less developed and more rural locations, affected wildlife could include other, larger animals such as deer. Although each site will have a unique combination of wildlife, the acreage disturbed will be relatively small, i.e., probably never more and usually much less than 5 acres, at each location. Assuming the existence of similar habitat in the vicinity, wildlife present when construction begins may adapt to being displaced during the S- to 12-month construction period. With the planting of new vegetation after construction, smaller species may reinhabit the site, but larger species may be prevented from doing so by fences and structures. Thus, some wildlife losses may occur.

During operation of the NEXRAD facilities, most enimals would not be disturbed by normal human activities. However, at some sites distant from populated areas, deliberate harrassment and use of off-road vehicles in undisturbed habitat could be damaging.

The radar tower may provide perching and nesting places for birds, but it is also a potential collision hazard. In addition, if above-ground electric distribution lines to the site are not properly designed, birds trying to perch on them could be electrocuted.

Federal, state, and local environmental protection and resource conservation agencies will be consulted when each candidate site and its surroundings are surveyed during the site selection process for assistance in characterizing resident birds, mammals, reptiles, and fish and other aquatic organisms. In evaluating sites, ecologically sensitive areas, such as critical habitat for endangered animal species, breeding grounds, migration corridors, and wetlands will be avoided if possible. This strategy will be especially important for remote locations in regions of the country known to contain fragile ecosystems with unusual wildlife species.

4.2.2. Air Quality

During construction of new NEXRAD facilities as well as modification of existing ones, air pollutants will be emitted by vehicles and equipment engaged in access road clearing and leveling, site preparation, and construction (or demolition) of towers and support buildings. Heavy-duty diesel-powered construction equipment generates relatively high levels of nitrogen oxide and carbon monoxide emissions. In addition, particulates (dust) would be created by all vehicle traffic in unpaved areas.

Construction workers commuting to the site will also create air emissions. The volume of commuter traffic, and thus incremental emissions, during this period will depend on the number of workers involved during peak activity and the distance they must travel to and from the construction site. Construction-related air emissions would likely be greatest at a location where there is no existing radar tower or user facility. If the rader and the user facility cannot be collocated and two separate sites must be prepared, emission levels would be higher than if the two were adjacent.

The radar itself will not be manned, but personnel will staff the user facility at all times. During normal NEXRAD operation, about 16 people will be assigned to the user facility. The facilities will be manned 24 hours (three shifts) per day. Vehicle exhaust emissions will not be significant.

Two independent sources of electric power will be required at each site to minimize such problems as brown-outs, single-phase losses, and transients. In some cases, arrangements may be made to obtain power from two separate commercial sources. However, at the majority of sites, a standby power plant will be used to ensure continuous operation and air conditioning of the radar and related equipment. This backup power facility will be the largest source of air pollutants during NEXRAD operation.

Generator use cannot be predicted, but is likely to be at least 1 hr/wk for testing and maintenance. At all sites, the facility will switch to the standby power source when severe weather approaches. Generators at the existing radar sites vary in size. A standby generator not exceeding 75 kg in size is expected to be sufficient to meet the power requirements at all NEXRAD sites. Anticipated annual emissions from testing a 75-kW diesel generator 1 hr/wk are 35 lb of carbon monoxide, 117 1b of hydrocarbons, 160 lb of nitrogen oxides, 12 lb of sulfur oxides, and 12 lb of particulates. Emission controls would reduce these amounts. Under federal law, all sources that generate "significant" omission rates -- i.e., in the range of 25 to 100 tons/yr of any pollutant -- are considered "major" sources and are subject to New Source Performence Standards (NSPS) and Prevention of Significant Deterioration (PSD) regulations. Thus, NEXRAD auxiliary power plants, without emission controls, would not qualify as a "major" emission source.

In the vicinity of areas already designated or currently being considered by the U.S. Forest Service and Bureau of Land Management for classification as "wilderness," siting may be controversial. New construction of various kinds within about a 20-mile radius of such areas has, in previous cases, been constrained for air quality or other reasons. However, this 20-mile radius is not fixed; the encircling zone or airshed in question varies according to the specific circumstances. Total emissions from NEXRAD facilities will be considerably less than those from other projects that have been contested.

Emissions related to NEXRAD construction are likely to represent only a very minor percentage increase above background pollutant levels. For instance, at an airport site, emissions during both construction and operation will be negligible compared to emissions from aircraft and airport-related automobile traffic. At an office park or other commercial location, these incremental emissions will also probably be small compared to existing traffic or power plant emissions. NEXRAD construction-related air pollutant emissions may be more noticeable at a rural location accessible, for example, only by unpaved road; if this location were also remote from populated areas and thus had relatively high air quality, such emissions might prove to be significant relative to ambient conditions. But even with the contribution of emissions from employee vehicles, local air quality is not likely to be significantly degraded.

4.2.3 Water and Water Quality

Many of the NEXRAD sites may require new drinking water and wastewater disposal arrangements for operations personnel. Approximately 1,100 gallons of water will be required daily at a site for potable and sanitary use. Although the radar and associated equipment do not require cooling water, small amounts may be needed for cooling the backup power plant, for a fire control system, or for maintaining the vegetative cover around the buildings. The total water requirement will probably not exceed I gallon per minute (gpm). Connections will be made to local water and sewer systems, if possible.

If connections cannot be made to municipal water or sanitary sewer systems, a well and septic tank or leachfield will be needed. Local hydrological conditions and soil characteristics are variable, so the implications of such development will differ from site to site. A well of the size required is relatively small, however, and would not likely have significant drawdown effects on the local water table.

Before selecting the final NEXRAD sites, local well drillers will estimate the probable depth to potable water. In addition, if a septic system is indeed required, the soil on the proposed site will be checked against local percolation requirements and a determination made of other pertinent local ordinances and design specifications with which to comply. Finally, NEXRAD facilities will not be sited in floodplains because they must be accessible at all times.

There are several ways that local water quality may be affected in the vicinity of a NEXRAD site. For instance, during the construction phase, oil and gasoline could leak from construction equipment, mix with surface runoff during a rainstorm, and flow into nearby drainage channels. Similar contamination could occur during radar operation if there were leaks or spills at the fuel handling and storage facilities for the power generator. However, measures can be taken by operations and maintenance personnel and contingency plans established to prevent or remedy the potentially harmful consequences of such occurrences.

Other potential impacts could result from the use of chemicals at the radar site. Chemical deicing and soil stabilization, fertilization, weed prevention, and insect control may lead to toxic and harmful materials flowing into surface water courses and ultimately into the groundwater supply. Adverse effects will be avoided by good storage, handling, and application procedures as well as by careful evaluation of the need for chemicals and by judicious selection of chemicals.

The only type of liquid waste generated at a site would be domestic waste. Yet the installation of subsurface disposal systems can result not only in hydraulic interference but also in adverse impacts on the quality of ground and surface waters. For this reason, water resource agencies in many states have specific site evaluation criteria and regulations for individual waste treatment and disposal facilities. As an example, to prevent health hazards or nuisance conditions from occurring, the California Water Quality Control Board requires: natural ground slope on all areas to be used for effluent disposal shall not be greater than 30%; minimum soil depth below the bottom of the leaching trench shall not be less than 5 ft; allowable minimum depth to groundwater below the bottom of the leaching trench shall depend on soil texture and percolation rate; and minimum setback distances from

streams, lakes, and reservoirs shall be specified depending on the type of treatment facility chosen. NEXRAD facilities will comply with all pertinent wastewater disposal regulations applicable at each site, making it unlikely that water sources in the vicinity of a NEXRAD site will be contaminated.

4.2.4 Earth Resources

4.2.4.1 Geology

Excavation of soils and perhaps bedrock may be required for the foundation of each NEXRAD tower. If rock underlies the site, blasting or drilling may be necessary. In addition, hook-up to commercial electrical power and telephone service at the site may require the installation of buried feeder lines and cables. Underground water and sewer pipe connections may also be required. Depending on the location of existing utility corridors in the vicinity of the sites, several trenches may need to be excavated.

The integrity of local geological conditions will be maintained as much as possible during site preparation, earth movement, and excavation for access routes, utility corridors, and parking and service areas. Access and parking areas as well as buildings will conform to the contours of the terrain at each radar location.

4.2.4.2 Soils

Preparation of a NEXRAD site is likely to involve leveling or grading to ensure adequate drainage around the radar equipment.

As part of the facility siting process, top soils and subsoils will be evaluated to ensure that they can support the weight of the radar tower. Site examination will also include identifying soil resistivity and moisture content, depth to the water table, deepest frost penetration, slope gradients, and surface/subsurface geology. Other processes will also be evaluated, including the potential occurrence of flooding, erosion, sedimentation, compaction, and settling. If site preparation activity takes all the above factors into account and if revegetation is accomplished, erosion and other soil damage should be well controlled at the majority of sites.

4.2.4.3 Minerals

Because it is undesirable to locate a NEXRAD radar near mining or quarry operations, NEXRAD facilities are not likely to be sited near any known mineral resources with potential for future development. During the in-depth site surveys, the potential for the presence of unknown mineral resources in the vicinity will be considered.

4.2.4.4 Solid Waste

No unusual or toxic solid waste will be generated at a NEXRAD site; only domestic waste (mostly paper and organic debris) will be created by operations personnel. Waste disposal practices will be consistent with local regulations.

4.3 Socioeconomic Environment

Some of the socioeconomic effects discussed below depend directly on the size of the NEXRAD facility staff. These effects will be largest at new sites or those to which a user facility is relocated. Where the user facility remains and a NEXRAD radar is installed, staff size is expected to remain about the same and the corresponding effects to be smallest—and nearly nonexistent. The discussion focuses on the "worst case" of a new facility. Even in this case, the impacts will be very small and insignificant except in areas of very low population density.

4.3.1 Employment

A portion of the construction and operating workforces for the NEXRAD installations will be hired locally, creating new jobs and thereby reducing the local rate of unemployment. New construction and operating personnel hired from outside the local area will infuse new income into the local economy as these individuals and their dependents purchase local goods and services and create additional employment opportunities. Local purchases of construction materials and the goods and services required to operate and maintain the radar installations will contribute further income to the local economy and, in so doing, create new jobs.

The approximate cost of each NEXRAD location will be \$2 to \$2.5 million. This figure includes hardware, facilities, site preparation, and construction. Construction is expected to require 5 to 12 months. Most of the construction workforce is likely to be hired locally, i.e., from the community in which the site is located or from other communities within commuting distance of the site. This will favorably affect the relatively high rates of unemployment in the construction industry that currently characterize most sections of the nation. Spending by the construction workers and local purchases of construction materials will create additional employment opportunities in the communities in which such spending occurs. Thus, local employment conditions should be favorably affected by construction of the NEXRAD facilities. The magnitude of this effect will depend on the extent of new construction, the spending patterns of the construction workers, and the amount and distribution of purchases of construction materials. Problems are likely to arise only in very remote rural areas and in urban areas with very low unemployment rates in the construction industry. In both cases, construction workers may be difficult and costly to hire.

On average, an estimated 16 people (1 manager, 10 meteorologists, 5 technicians) will be employed to operate and maintain each complete NEXRAD installation. Sites with an existing user facility are likely to require few new employees, as nearly all the personnel operating the existing radar are likely to continue with the NEXRAD facility. No increase in Air Force staffing is anticipated. Given the qualifications required for the NEXRAD personnel, it is unlikely that local residents (i.e., residents of the communities near the site) will be hired to fill these professional and technical positions. Thus, the direct effects on local employment are likely to be negligible.

Local purchases of goods and services by 16 NEXRAD personnel, whose average annual payroll will total about \$580,000, will induce the creation of additional jobs. For example, each employee will spend a portion of his salary on purchases of goods and services such as food, housing, transportation, and entertainment. The recipients of these dollars will, in turn, purchase goods and services. This process of respending continues until, eventually, the new dollars introduced to the local economy "leak" out of the area, and the round of expenditures comes to a halt. An employment multiplier that gives the ratio of secondary to primary employment can be used to estimate the impact of this spending. The ratio of the number of secondary jobs, such as jobs in retail and service sectors, that spending by the new NEXRAD personnel would create, to the number of primary jobs is determined by the new NEXRAD employees' propensities to consume goods and services and the proportion of these goods and services that are purchased in the local area. The extent of local pur hases depends on the price, quality, and availability of goods and services that can be purchased locally compared with those available in other relail centers. Experience shows that the value of the multiplier can vary significantly from place to place. It may range from 0 to 4 or greater, but multipliers will generally be lower in rural than in urban areas. Assuming that multipliers for NEXRAD situations range from 0.5 (typical of a small town in a rural area) to 2 (slightly below the 1970 average for U.S. counties) (Murphy/Williams, 1978), spending by the new NEXRAD personnel may create between 8 and 32 additional jobs in the communities surrounding each site.

Because the personnel to staff the 145 NEXRAD sites would already be employed, the NEXRAD system would result in a redistribution of personnel and the corresponding local economic effects discussed above, but would negligibly affect nationwide employment totals. There will be a short-term positive effect on employment in the construction and selected other industries resulting from expenditures on development, acquisition, and installation of the NEXRAD system.

4.3.2 Housing

Some of the construction workers hired from outside the local area will seek local lodging, thereby temporarily affecting local motel and hotel occupancy rates. Similarly, a proportion of the operating workers

hired nonlocally will also seek housing locally. Those without dependents are likely to rent housing, while those accompanied by their families will probably purchase homes. Correspondingly, rental vacancy rates will drop and home sales will quicken over the short term. If the desired types of housing are in short supply, the costs of such housing will increase over the short term. Over the long term, the local housing markets will adjust to the increased demand for housing through construction of new units (assuming financing is available).

Because the construction workers will in most cases be hired from the communities surrounding the sites, residential relocation will not be necessary. The effects of the construction workforce on local housing markets will accordingly be negligible. Exceptions could occur at sites in remote rural areas and in areas with very low construction sector unemployment rates where the construction workers must be hired from outside the local area. Because the construction period will be relatively short, the workers hired to construct the NEXRAD facilities are unlikely to relocate permanently to the site. Those workers will, however, require temporary housing such as hotel and motel accommodations. Short-term lodging should be obtainable in most urban areas, but will generally not be available in remote rural areas. In the latter case, temporary housing may have to be provided, either directly or by providing incentives for private sector participation.

NEXRAD operating personnel are likely to seek permanent housing for themselves and their dependents in communities within commuting distance of each NEXRAD site. Sufficient housing (i.e., adequate in type, quantity, and price) should be available in most urban and suburban areas to accommodate the 16 households associated with each NEXRAD installation. In communities of less than 1,000 people, the incoming NEXRAD households will probably be able to obtain housing but may have to accept housing of lesser quality or higher cost than they desire. Personnel assigned to remote rural NEXRAD sites may be forced to live in distant communities and commute long distances to work or to build their own homes near the site.

4.3.3 <u>Demographics</u>

Those construction and operating personnel not hired locally who choose to reside in the local area while employed at the NEXRAD radar installation will increase the local population. These new residents and the dependents who accompany them could affect other demographic characteristics of the local population as well if they differ significantly from the existing population in age, sex, marital status and average household size, ethnicity, and level of educational attainment. Such demographic differences could be a potential source of social tension.

Because the construction workers will, for the most part, be hired from the local workforce, the NEXRAD construction phase will not affect local demographic characteristics at most sites. If construction workers

are relocated to remote rural sites, they will affect the demographic characteristics of any small communities (i.e., those with populations under 1,000) in which they choose to reside. These effects would be temporary and are unlikely to be significant. Phasing of construction activities to moderate the peak size and fluctuations in size of the construction workforce could be used to mitigate any potentially adverse impacts on local demographics.

The 16 NEXRAD personnel and their families are likely to seek housing in communities surrounding the NEXRAD site. Based on the 1981 national average household size of 2.73, the communities located within commuting distance of each site would have to absorb a maximum of about 44 new residents. Communities generally can tolerate as much as a 10% to 20% change in population without experiencing significant demographic or social disruption. Therefore, adverse demographic effects are likely only in cases where the NEXRAD site is located in a rural area in which only one or a few very small communities are available as residential locations for the incoming NEXRAD personnel and their families.

4.3.4 Public Services and Facilities

Nonlocal hires and their dependents who choose to reside in the local community will create additional demands for public services and facilities such as education, police and fire protection, and sewage treatment. Operation of the radar installation may also create additional service demands, particularly for utilities. The significance of these impacts would depend on the capacity and utilization of the current and projected service systems.

As discussed above, construction workers are unlikely to relocate to the NEXRAD site area and therefore will in most cases impose very little additional demand for public services and facilities on the surrounding communities. Again, sites located in remote rural areas could be problematic because the public infrastructure (such as sewage treatment and disposal, utilities, roads, and the like) is likely to be limited or nonexistent.

The public service demands of the incoming NEXRAD operating and maintenance personnel and their families are unlikely to impose a burden on most urban areas. Again, only in very small communities may the capacity of the public service system and facilities be insufficient to accommodate the demand generated by these new residents.

The NBXRAD radar installation itself will have its own backup power but will depend on local utilities to supply primary power. The power requirement for each site is relatively small and should pose no problem to even a small electric utility.

4.3.5 Land Use

4.3.5.1 Potential Impacts

The NEXRAD radar may affect or be affected by activities or land uses adjacent to its site. The operation of the radar can be compromised by EMI and by screening and the creation of multiple reflections and clutter caused by buildings and traffic. Consequently, a number of criteria will be applied during the site selection process to avoid locations that may be detrimental to satisfactory operation of the radar.

From the opposite point of view, there are several ways in which operation of the radar may affect surrounding activities. The energy rediated by the radar will cause EMI or pose hazards to certain types of activities if they are close to the radar. Safe separation distances between the radar and objects or activities in the main beam of the radar are: fuel handling, 225 m; exposed EEDs, 400 m; and EEDs in storage or transport, 225 m. Nowever, as described in Section 4.1 and Appendix B, the geometry of the NEXRAD installation is such that the main beam will not strike the ground within these separation distances unless there is elevated terrain nearby. In that case, the RFR may pose a ground-level hazard outside the boundaries of the NEXRAD site and affect surrounding land uses. Such impacts would consist of limitations on fuel handling and the use of EEDs.

Another issue is the possibility of general incompatibility of a NEXRAD installation with surrounding land uses. Such incompatibility is best judged by land use regulations. Local (city and county) regulations frequently enumerate the types of land uses permitted in a specific area, site development criteria, sesthetic considerations, and construction standards. The goals of these regulations are to protect public health, safety, and welfare and to ensure that development is of a character desired by the community.

The types of uses (e.g., residential, industrial) permitted on a specific parcel are typically dictated by zoning ordinances. These ordinances often specify property line setbacks, maximum building height, site coverage, and similar attributes. Aesthetic criteria, such as building design and landscaping, are usually implemented by a design review process. Construction standards, particularly the type of construction and the use of certain materials, are commonly addressed by building codes.

Special state and federal land use criteria and approvals often apply in certain geographic areas such as coastlines or near inland waterways. State and federal regulations also apply to lands owned or managed by these governmental entities.

Other criteria affecting the use of a site may be invoked by covenants, codes, and restrictions (CC&Rs). These instruments are usually recorded with the deed of a parcel of property. CC&Rs are typically

created by the initial developer of a tract of land to ensure that the development and use of each parcel within the tract are compatible.

4.3.5.2 Mitigation and Avoidance

Most of the potential effects on, or caused by, a NEXRAD installation can be avoided by the proper selection of sites. This will be accomplished by the multilevel site selection process geared to identifying land uses that may adversely affect the radar and, conversely, land use incompatibilities created by the existence of the radar. The locational flexibility of the NEXRAD system will, in most cases, permit the selection of a site in an area that does not create incompatible land uses.

Potential land use conflicts will be identified during the site surveys. Zoning ordinances, master plans, and other tools to regulate land use and development will be reviewed to determine whether incompatible land uses exist or could occur near candidate sites. Where there is a potential problem, one of the following actions will be taken: the site will be eliminated from further consideration; a proposal to change applicable regulations will be made to the local government; or additional property or easements will be purchased. For example, easements, such as those used by the FAA, could be used to preclude certain types of development or structures taller than a prescribed height.

For sites on land owned by a government entity, a use permit is typically required by the administering agency. Such permits are usually issued with conditions that ensure that the facility and the manner in which it is developed are acceptable to the administering agency. Property owned by federal entities is not subject to local and state land use regulations. This includes zoning and other codes and ordinances that would typically apply to the development of radar and other structures at other locations. Therefore, those NEXRAD facilities that are located on federal land (e.g., owned by the NWS or the DOD) will be exempt from state and local regulations. However, the development or modification of facilities leased from private owners for the NEXRAD program will be subject to these regulations.

The intent of the regulations described above is to ensure a desired level of quality and to prevent discordant structures or uses. NEXRAD facilities will be designed to comply with the intent of land use and development regulations, and this compliance should ensure that NEXRAD facilities are compatible with adjacent land uses and with community goals.

4.3.5.3 Site Classes

Many NEXRAD radars will be located at airports. The clear zones required for aviation safety will also serve the setback criteria of the radar. NEXRAD will be subject to FAA height and clear zone restrictions. In addition, the radar sites will be located to avoid potential fuel

handling and EED problems. Ground and building space are likely to be leased at most locally (government or private) owned airports. The radar and its structure are less'likely to disrupt surrounding land uses than aviation activities and, therefore, will probably not be the source of land use conflicts.

NEXRAD facilities may also be located on mountain tops and ridges. Many of these areas are owned by government bodies. In the case of federal ownership, the prescribed permits for the primary and support facilities (e.g., access road) will be acquired. Depending on the agency and the circumstances, right-of-way, electronic-site use permits, easements, and the like may be required. The land use and development criteria of the agency administering the land are typically incorporated into any permit approvals. Thus, the mechanisms to help ensure that land use incompatibilities do not occur are in place.

In those cases where the site is controlled by local or state government, use of the NEXRAD site may also be secured by permit. Under a permit or easement arrangement, the permit issuer has the authority to stipulate land uses and development criteria. If land is purchased in fee for NEXRAD facilities, such authority will not normally exist (unless the sale is contingent on such conditions). In either case, the radar will be constructed and operated in a manner that will not disrupt surrounding land uses.

A few NEXRAD sites will be located at existing user facilities. Where these facilities are not government-owned, compliance with local regulations--including restrictions that affect tower height--will be required. Again, government-owned facilities are not subject to local regulation. However, local entities will be informed of plans and an effort made to develop the radar facilities in a manner acceptable to the local community. Thus, a NEXRAD radar in this situation will likely be in compliance with stated as well as unstated community goals.

4.3.6 Aesthetics

Aesthetic considerations are not likely to be an issue for proposed NEXRAD sites in most urban locations. Airports already contain air traffic control towers and other structures that protrude on the landscape. Business districts may have multistory buildings as high as the tallest radar towers anticipated, although the tower and radome obviously do not resemble a typical skyscraper. Some controversy may arise, however, when a radar tower is proposed for a commercial area where the existing buildings are predominantly one or two stories tall. And, in certain residential areas and rural locations (whether the terrain is flat, rolling, or mountainous) NEXRAD siting could be disputed for aesthetic reasons.

Before siting a NEXRAD facility, the effect of the radar tower on scenic views or vistas and on any unique physical features, if any exist in the vicinity, will be evaluated. The visual appearance of the radar

tower from wilderness and open space areas, parks, or national monuments will also be considered. To the extent operational requirements and site features permit, the tower will be built in the least obtrusive location on the site.

4.3.7 Cultural Resources

In urban areas, archaeologists or local altitact collectors are likely to have removed pottery remains and other recognizable material as construction has occurred. Past construction of airports, commercial complexes, utility corridors, and other built-up areas greatly disturbed the lands and often destroyed cultural resources. At newer facilities, it is more likely that archaeological surveys were completed prior to or during construction, and that any significant archaeological sites have been excavated. Only or rare occasions have intact archaeological sites been discovered beneath structures during renovation or redevelopment. In contrast, sparsely populated rural locations and distant ridgetops have greater potential for containing cultural resource sites that would require either excavation or protection during NEXRAD construction. Each location being considered for a NEXRAD site will be different and will be examined separately.

During the site selection process, the survey teams will be alert for field conditions that may indicate the presence of cultural resources. If such evidence is discovered or the prospective site is in a relatively undisturbed location, the state historic preservation office (SHPO) will be contacted for information. Advice on how to proceed and on mitigation measures will also be requested. The literature, files, land records, cadastral surveys, and other materials in local university libraries, museums, and historical commissions may be examined to determine whether cultural resources have been previously identified at the site in question. An initial reconnaissance survey (i.e., collection of surface material and shovel testing) may be conducted to discover if surface or subsurface artifacts are present. If artifacts are discovered, formal test excavations may be performed to gather enough information necessary to judge whether the archaeological site is eligible for the National Register of Historic Places. Should a site be considered worthy of inclusion on the National Register, two basic mitigation procedures are possible: alter construction plans to avoid and preserve the archaeological site; or excavate the site so that artifacts are recovered and preserved (and significant data are not destroyed during construction).

4.4 Long-Term Implications

If the proposed action is implemented, some environmental impacts will unavoidably result from both construction and operation of each NEXRAD radar and supporting facilities. Of course, construction of the facilities will unavoidably alter conditions at the site itself. However, other potential impacts can be limited to the site or its immediate vicinity and can be limited in significance.

The purpose of the NEXRAD system is to help reduce loss of life, injuries, property damage, and interruption of economic activity. These benefits will be realized nationally over the projected 20-year life time of the system. The potential adverse environmental impacts will generally be minor and local. Therefore, there will be a favorable balance between local uses of the environment and the maintenance and enhancement of long-term productivity.

The proposed construction of the NEXRAD system will require land, money, materials, and fuels. The commitments of money and fuels will be irreversible and irretrievable. This will also be true for most materials. Practically speaking, the land on which NEXRAD facilities will be constructed will be irreversibly and irretrievably committed because of the expense of removing buildings and other improvements. However, most NEXRAD radars and facilities will be located in places such as airports where the land has previously been committed to a specialized use.

4.5 Alternatives

Alternatives to the NEXRAD system as proposed were described in Section 2.4. They include:

- No action or postponement of action
- Continue the existing system
- New non-Doppler system
- New coherent non-Doppler system
- Mixed system of new Doppler and non-Doppler radars
- Environmental satellite system.

The following discussion focuses on the environmental implications of these alternatives. The practicality of the alternatives was addressed in Section 2.4.

Taking no action now or postponing execution of the proposed NEXRAD program would avoid or defer the potential impacts associated with constructing and operating the NEXRAD system. Deferral is usually considered when the possibility exists that some feature of the proposed action or the setting in which it will take place is likely to change favorably from the point of view of environmental impacts. On the one hand, no new developments are expected to occur over the next decade that would alter the needs to be met by the NEXRAD system or the technological manner in which it can be achieved. On the other hand, no fundamental change in the fashion in which the technology can be implemented (i.e., system of rader sites) is anticipated either. Consequently, although

deferred, there would very probably be no environmental gain realized by postponing the action.

Continuing with the existing system would avoid all potential impacts associated with constructing and operating the new sites in the NEXRAD system, as well as any effects arising from the modification of existing sites.

The alternatives involving various combinations of Doppler and non-Doppler radars are all essentially identical from an environmental impact point of view. This presumes that the coverage requirements are independent of the type of radar and that roughly the same number of radars would be needed to meet the requirements. The key question then is whether new sites would be a part of the specific alternative or whether only changes to existing sites would be made. All alternatives would evidently have the potential to produce impacts associated with modification of existing sites. Any alternative that incorporated the construction and operation of new sites would, of course, produce the impacts associated with those activities. These impacts would be expected to be essentially the same as those expected to arise from constructing and operating new NEXRAD sites.

The satellite alternative would result in somewhat different impacts than produced by the NEXRAD system. The need for new sites would probably be eliminated. If a backup or supplemental radar network were required, some new sites might be needed. Some existing sites might be maintained as well. Thus, probably no or very few instances of impacts from constructing and operating new sites would accompany this alternative. Reduction in the number of existing sites could be an environmental benefit in some locations, especially at isolated sites, if the sites were cleared and returned to conditions and uses consistent with their surroundings. In exchange for this reduction in impacts, new impacts would be created by the need to launch satellites into orbit. New launch facilities would probably not be required, but combustion gases would be released every time a launch vehicle was operated.

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Appendix A

NEXRAD RADAR AND ANTENNA CHARACTERISTICS

Appendix A

NEXRAD RADAR AND ANTENNA CHARACTERISTICS

A.1 Introduction

This appendix describes the principal characteristics of the NEXRAD radar system, which is very similar to systems that have been installed and are now being operated by the National Weather Service (NWS). Compared to these older systems, the principal differences are that both the diameter of the antenna and the peak power are roughly doubled, and the minimum time between successive pulses is roughly helved.

A radar operates by transmitting a pulse of electromagnetic energy and then waiting to receive energy reflected back to it from some object (target) illuminated by the pulse. The radar interprets the time interval between the transmission and the return as a measure of the distance from the radar to the target. To perform their basic functions, radar systems operate in very small units of time. The conventional unit—the microsecond (µs), or one-millionth of a second—is to be distinguished from the millisecond (ms), which is one thousand times longer.

Most radar systems are designed and operated to detect objects such as ships, airplanes, or missiles. In contrast, the purpose of the NEXRAD radar is to detect weather features such as rain or hail and storms such as hurricanes and tornadoes. This difference of purpose has a strong influence on the design of the signal-processing components of the receiver, but has little effect on the transmitter or on the antenna that radiates the transmitted pulses and receives echoes.

It is highly advantageous for a radar to concentrate its transmitted energy (and to limit its receiving capability) in a relatively
narrow beam. A narrow beam permits greater certainty regarding the
direction in which the energy was sent and from which it returned; it
conserves the available energy by concentrating most of it into a single
direction; and it permits reception of weaker returns from a particular
direction by discriminating against electromagnetic noise or extraneous,
interfering signals that may arrive from other directions.

Radar has long used parabolic reflectors, or dishes, to form beams in the same manner that the silvered reflector of an automobile head-light forms a beam from the light generated by the lamp's filament. To move the beam, the radar dish and the radiating element are typically rotated at a particular fixed rate to sweep the beam past a given azimuth

(radial direction) every few seconds. Rotation about a second axis permits scanning at various angles of elevation.

A.2 Pormation of the NEXRAD Beam

Power produced by a klystron amplifier tube is delivered by wave-guide to a tapered feed horn, which is located at the focal point of the circular parabolic reflector. The power radiates from the feed horn, reflects from the parabolic surface, and passes out through the radome (radar dome) to form the beam. The radome is a nearly spherical, mostly plastic enclosure whose function is to protect the antenna and associated parts from dirt, wind, and weather, while providing free passage for microwave power.

The primary function of NEXRAD is to detect weather conditions at distances up to almost 300 miles. To perform this function, the radar must radiate a very strong, well-focused beam of electromagnetic energy and must provide a corresponding sophistication in receiving any echoes that are returned. These considerations force the system designer to use a large antenna and provide strong motivation for refining the design so that most of the power is concentrated in the main beam. The NEXRAD antenna meets these criteria.

Figure A-1 provides a general idea of the beam-forming process.*

Near the antenna face, the energy moves forward in an almost circular column of roughly constant diameter. At a greater distance, the energy expands as a cone with an included angle of 2.5 deg, with its apex at the center of the antenna face. A slender conical beam of this kind is commonly referred to as a pencil beam. The intersection of the cone and cylinder occurs at a distance of about 550 ft. A more detailed description of the beam is provided in the following sections.

A.2.1 Beam Structure

The reflector forms the power radiated from the feed horn into a main beam with associated sidelobes, as indicated in the upper right-hand sketch in Figure A-1. The nulls of the main beam are separated by about 2.5 deg; the points at which the power density falls to half its maximum values are separated by no more than 1.0 deg. The sidelobes result from the inability of the reflector to concentrate all the energy into the main beam. The locations and relative intensities of the first few sidelobes are well known; their intensities are never greater than 0.0032 (-25 dB) that of the main beam. The large number of higher order (and very minor) sidelobes are distributed at various, almost random, angles. They have power densities no greater than 0.0004 (-34 dB) of that of the main beam and generally are smaller than 0.0001 (-40 dB) that of the main beam.

^{*}R.C. Hansen, Microwave Scanning Antennas, Vol. 1: Apertures (New York and London): Academic Press, 1964).

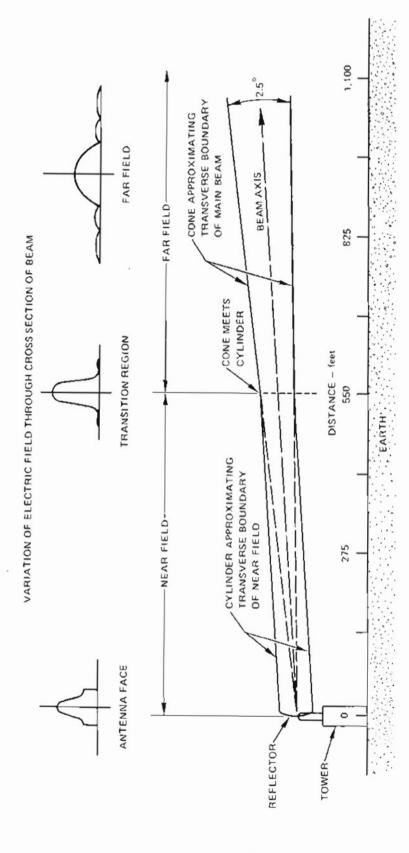


FIGURE A-1 FORMATION OF THE NEXRAD RADAR BEAM

A.2.2 Scanning Characteristics

To perform the surveillance function, the pencil beam formed by the antenna scans continuously. Both the NEXRAD hardware and the software that controls it are very flexible, and a wide range of scanning programs is possible. In all cases, the antenna will rotate continuously around the vertical axis as the elevation of the beam is held constant. Usually, the elevation of the beam will be changed at the end of each revolution.

The complete set of programs that will be used when the NEXRAD network becomes operational has not yet been defined. The following scanning program illustrates the general features of the scanning process and leads to maximum possible values of time-averaged power densities at and near ground level. In this program the antenna rotates at a constant rate of one-half revolution per minute at each of the following elevation angles in succession: 0, 4, 8, 12, 16, and 20 deg. Each revolution requires 2 min, and the 0 deg elevation is scanned twice to increase data and improve clutter suppression. Thus, the program has seven revolutions, and the time required to complete each cycle (the revisit time) is 14 min.

A.2.3 Scanning Limits

The NEXRAD antenna system is designed to prevent the transmitted beam from being directed below a minimum elevation angle of -1 deg or above a maximum elevation angle of 60 deg.

At each particular site, the limit switches that control the minimum elevation angle will be set in accordance with the tower height and local terrain. The system operator will be strongly motivated to choose this limit so that the full strength of the main beam never strikes the ground because such operation would produce strong clutter signals that would greatly interfere with the desired observations.

An interlock is provided so that transmission is prevented unless the antenna is moving.

A.3 Pulse Shape, Duration, and Repetition Frequency

A.3.1 Pulse Shape

Many radar systems use the simple trapezoidal pulse shape shown in Figure A-2a. In contrast, the NEXRAD radar will use a more complicated waveform such as that shown in Figure A-2b, in which all the corners are deliberately rounded. The purpose of using such a shaped pulse is to narrow the frequency band occupied by the radar, thereby reducing the potential for interference with other systems that use the 2,700- to 3,000-MHz frequency band. The waveforms of actual radars only approximate the idealized shapes shown in Figure A-2.

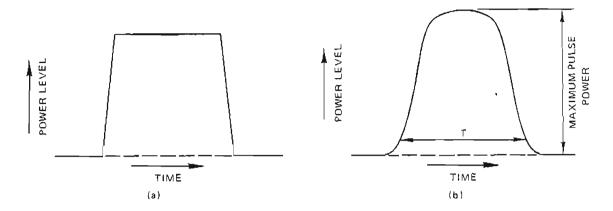


FIGURE A-2 TRAPEZOIDAL AND SHAPED PULSE WAVEFORMS

A.3.2 Pulse Duration

The pulse duration, T, indicated in Figure A-2b, will be in the 0.7- to $4.0-\mu s$ range. The choice at any time will depend on the range and nature of the weather feature that is of principal interest to the system users.

A.3.3 Pulse Repetition Frequency

The number of pulses transmitted per second is called the pulse repetition frequency (PRF). The value of PRF will be chosen in the range of 250 to 1,200 pulses per second (PPS). Long pulses will be associated with low values of PRF so that the average power level will never exceed 2 kW.

A.4 Frequencies

The NEXRAD system is designed to operate at any fixed frequency in the 2,700~ to 3,000-MHz range. The frequency to be used at any particular site will be chosen on the basis of frequencies used by other radars (including other NEXRAD units) located within about 300 miles of the site. Near major seaports, the frequency range of 2,900 to 3,000 MHz will be avoided. The purpose will be to minimize the risk of mutual interference. In regions having few radars, the selection will be relatively easy; in urban centers where many radars already use the same general frequency band, frequency selection may be difficult.

A.5 System Parameters

The characteristics of the NEXRAD radar are listed in Table A-1. The NEXRAD system is often called a Doppler radar because it takes advantage of the Doppler principle to discriminate between moving targets—such as raindrops—and fixed objects. A moving target changes the frequency of the returned signal, and this frequency change is used in the Doppler processing unit of the NEXRAD receiver.

Many details of the NEXRAD system, such as the diameter of the transmitting antenna, remain to be determined. Thus, the exact locations and relative power levels of the various sidelobes are not yet fixed. The diameter shown in Table A-1 is a reasonable estimate based on the 1-deg beamwidth and -25-dB first sidelobe designated in the system specification. The location of the various sidelobes and the relative intensities of the second, third, and fourth sidelobes are estimates based on other values given in the system specification.

Table A-1
CHARACTERISTICS OF THE NEXRAD RADAR SYSTEM

System Characteristic	Value	
Frequency (MHz)	2,700-3,000	
Wavelength ^a (ft)/(cm)	0.345/10.5	
Pulse power (max) ^b (MW)	1.0	
Maximum duty cycle (%)	0.2	
Average power (kW)	2.0	
Antenna diameter ^c (ft)/(cm)	24/730	
Antenna gain ^a compared to nondirectional		
antenna (ratio)/(dB)	32,000/45	
Beamwidth at half power density (deg)	1.0	
Main beam null (deg off-axis)	1.25	
First sidelobemax (deg off-axis)	1.75	
First sidelobe relative power densitymax (ratio)/(dB)	0.0032/-25	
First sidelobe null (deg off-axis)	2.25	
Second sidelobe relative power densitymax (ratio)/(dB)	0.0021/-27	
Second sidelobe null (deg off-axis)	3.25	
Third sidelobe relative power densitymax (ratio)/(dB)	0.00131/-29	
Third sidelobe null (deg off-axis)	4.25	
Other sidelobes maximum power densityrelative		
to main beam (ratio)/(dB)	0.0005/-34	
Azimuth scan rate, max (rev/min)	5	
Minimum elevation angle of beam (deg)	-1	
Maximum elevation angle of beam $(deg)^d$	+60	

Source: R.L. Hinkle, "Background Study on Efficient Use of the 2,700-2,900 MHz Band," National Telecommunication and Information Administration Report 83-117 (1983).

^aAt the midband frequency, 2,850 MHz.

bConsistent with other sections of this document, the root-mean-square (rms) value of the maximum value of the pulse is used when present.

^cThe actual diameter may be as large as 28 ft. The 24-ft value is used here and in Appendix B because it leads to maximum (i.e., worst case) values of RFR.

 $^{^{}m d}{
m In}$ normal scanning, the beam elevation will not exceed +20 deg.

Appendix B

CALCULATION OF RADIOFREQUENCY RADIATION INTENSITIES

Appendix B

CALCULATION OF RADIOFREQUENCY RADIATION INTENSITIES

B.1 Introduction

In this appendix, an analytic procedure for calculating the intensity of radiofrequency radiation (RFR) in the vicinity of a NEXRAD radar is developed. Data obtained from the NEXRAD Joint System Program Office (JSPO, 1983), Washington, DC, and the National Telecommunications and Information Administration (Hinkle, 1983) are combined with information available in textbooks and technical journals to develop mathematical expressions and graphical relationships that permit calculation of RFR intensity at specific locations. Because this document is general rather than specific to a particular site, the treatment is general. The results are presented in the form of analytic expressions and graphs, which make it easy to determine values for the peak electric field, maximum pulse power density, and average power density at selected points in the vicinity of the radar. Power densities at the center of the beam are also calculated to provide a basis for estimating their effect on the personnel and electronic systems in aircraft and on birds.

This analytic technique allows predictions that are quite accurate in free space; however, the results are affected by the presence of the ground and of objects such as trees, buildings, and power lines. In reality, the terrain is irregular, and objects such as trees, buildings, and other structures are randomly distributed. When they block the line of sight to the antenna, they tend to absorb, reflect, and scatter the beam. In such circumstances, the strength of the field is lower than it would be in free space. In other situations, the power reflected from the earth or other objects adds to that propagated directly, thus increasing the intensity of the radiation. Under circumstances relevant to NEXRAD, the electric field strength is rarely as much as doubled in this way. Field enhancement of this kind is much more important in calculations of maximum electric field strengths and power densities than of time averaged power densities.

8.2 Conditions and Assumptions

A large antenna that is many wavelengths in diameter produces a radiation field that is concentrated in a small volume of space and is commonly referred to as a narrow or pencil beam. The NEXRAD antenna falls into this class. The major characteristics of such a pencil beam (Hansen, 1976) are determined by the diameter of the antenna, the wavelength radiated, and the power distribution over the antenna surface.

The mathematical description of the complete field produced by large antennas is very complicated. Therefore, approximate expressions have been developed to facilitate calculation.

The following conditions and assumptions are applied:

- (1) The antenna has a specific height h above ground level, and all elevations are referred to the center of the antenna.
- (2) The antenna rotates at a fixed speed about its vertical axis and follows the fixed scan pattern described in Section A.2.2 of Appendix A. This pattern was used because it yields the highest (i.e., worst case) values of average power densities at and near ground level.
- (3) The main beam and its first five sidelobes have circular symmetry.
- (4) The intensity of the first sidelobe relative to the main beam is 0.0032 (-25 dB).
- (5) The transition between near-field and far-field conditions occurs at 550 ft, which is defined here as 0.33 D²/L, rather than the conventional 2D²/L (see Section B.2.1) where D is the antenna diameter and L is the radiation wavelength.
- (6) The maximum possible on-axis density in the near field is assumed to exist throughout the near-field column.
- (7) In most cases the greatest possible instantaneous field strength at any ground location will exist when the antenna main beam is at the azimuth of that location and has the minimum elevation angle of 0 deg. The results calculated on this basis are easily adjusted to accommodate other values of minimum elevation angle.
- (8) The duty cycle is taken as 0.2%, which is the maximum duty cycle for the system.
- (9) The calculation of RFR field strengths at any distance up to 20 miles from NEXRAD is based on direct line-of-sight propagation because all other modes of propagation, such as ducting due to temperature inversion, diffraction, or tropospheric scatter or reflection, are weaker (Kerr, 1951). Ground-level areas that are shadowed by intervening terrain will be illuminated by the diffraction mode of propagation. The RFR field strengths in such areas will be overestimated because the calculations are based on direct line-of-sight propagation. The attenuation caused by trees and underbrush, which can reduce RFR values by a factor of 10 or more, is not included.

(10) The calculations are intended to represent realistic estimates rather than precise scientific values. Many approximations are made; therefore it is expected that the field strength at any given location produced by operation of NEXRAD may be either larger or smaller by as much as a factor of 2 than the calculated value.

The electromagnetic field generated by the antenna is normally described by dividing it into two regions, the near field and the far field, to which different sets of analytical conditions apply. The boundary between the two regions is not sharply defined; rather, RFR field conditions gradually change with increasing distance from the face of the antenna. It is also necessary to distinguish between regions within or near the main beam and those at angles remote from it.

B.2.1 The Far-Field Region--Pulse Power*

The far field exists only at distances greater than 550 ft from the antenna; it is defined as a region over which the analytic conditions are constant and the fields vary inversely with distance (i.e., the power density varies inversely with the square of the distance). The conventional criterion for the distance from the antenna beyond which the far field exists is $2D^2L$. For the NEXRAD antenna at 2,850 MHz, this distance is 3,300 ft; however, far-field formulas give good approximations for all distances greater than a transition distance of 0.33 D^2/L , which is 550 ft in the present case.

B.2.1.1 The Main Beam

A well-known and generally applicable equation for the power density on the beam axis in the far-field region of any antenna is

$$U = PG/4\pi R^2 \tag{1}$$

where U is the power density, P is the radiated power, G is the antenna gain, and R is the distance; consistent units must be used. For NEXRAD, P = 1 MW and G = 32,000. To obtain results in the desired form of mW/cm^2 when the range is specified in feet, it is necessary to introduce suitable factors. To convert from megawatts to milliwatts and from square feet to square centimeters, one must miltiply by 10^9 and divide by $(30.48)^2 = 929$. Combination of these various terms leads to a key result: for the far field, the maximum pulse power in the center of the main beam is:

^{*}Here, and throughout this document, the term "pulse power" designates the maximum root-mean-square (rms) value of the pulse, when present.

$$U_1 = 2.7 \times 10^9 / R^2 \text{ mW/cm}^2 \tag{2}$$

where R is the distance in feet.*

The size of the main beam is limited by the system specification, which requires that the power density shall fall off to half its maximum value in not more than 0.5 deg from the axis (see Figure B-1). The position of the first null is not specified. The value 1.25 deg shown in Figure B-1 was chosen from data on similar antennas (Silver, 1949). The 1-deg interval between successive nulls was chosen on the same basis.

B.2.1.2 The Sidelobes

Both the main beam and the many sidelobes of the NEXRAD radar will sometimes strike the ground. Therefore, it is necessary to consider the distribution of power in the first and higher order sidelobes, as well as in the main beam.

System specifications require that the ratio of the power in the first sidelobe to the power in the main beam at the same distance be no greater than 0.0032 (-25 dB). The relative power densities in the first five sidelobes are controlled by the specification that the level shall decrease monotonically from -25 dB in the first sidelobe to 0.0001 (-40 dB) at 10 deg from the axis. The distribution shown in Figure B-1 is consistent with this statement.

Locations that sometimes fall in one of the nulls shown in Figure B-1 are at other times subject to the higher power density of the adjacent peak. Therefore, all calculations of peak sidelobe power use the envelope function shown in the heavy line in Figure B-1. The envelope function is extended to the right at the value 0.0004 (-34 dB) because the system specification allows a few isolated peaks of this magnitude. Use of this value with reference to Figure B-1 and Eq. (2) leads to the equation

$$U_2 = 0.0004U_1 = 1.08 \times 10^6 / R^2 \text{ mW/cm}^2$$
 (3)

which describes the maximum pulse power density at any location more than 6 deg from the axis of the main beam.

8.2.2 The Far-Field Region--Average Power

The main beam of NEXRAD is in constant motion, usually as a result of continuous rotation of the antenna around its vertical axis. This

^{*}This formula is correct for a beam pointed in any direction. For all cases of interest in this appendix, the beam is nearly horizontal, and no substantial error results from taking R as a horizontal distance, which simplifies the discussion.

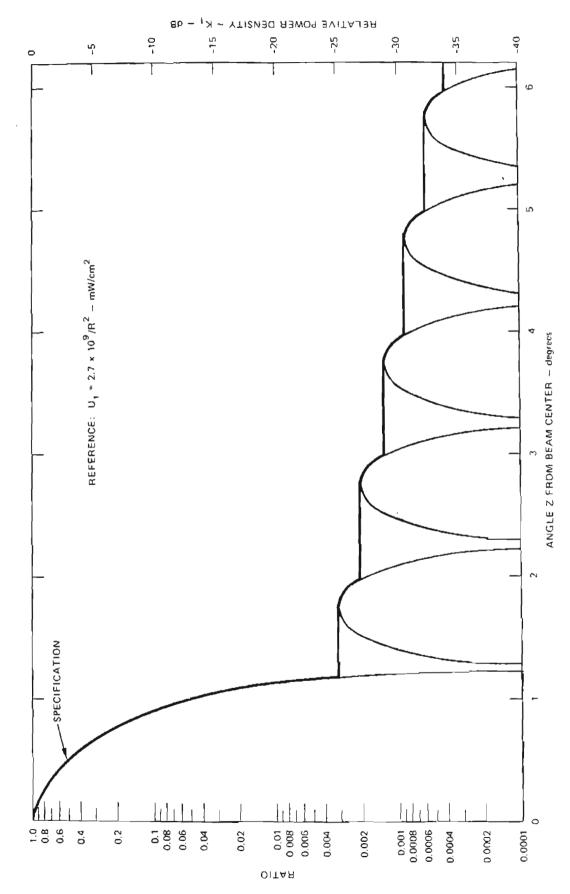


FIGURE 8-1 ANTENNA PATTERN FOR FAR-FIELD REGION OF NEXRAD BEAM

mobility has an averaging effect on the RFR power density. The result is to reduce the intensity of the main beam and near-in sidelobes and to fill in the nulls in the radiation pattern. The averaging factor will differ depending on whether the area is illuminated by the main beam or by some combination of sidelobes. The averaging factor becomes less important at close ranges, where the diameter of the radiation column is comparable to the distance through which it is swept.

B.2.2.1 Average Power at Beam Level

The NEXRAD radar is capable of operating in many modes, and it is impractical to make a detailed calculation for each possible mode. However, a large fraction of the time is likely to be devoted to scanning modes similar to those described in Section A.2.2 of Appendix A. This particular mode is chosen for analysis because it is typical and because it will produce maximum values of time-averaged power densities at locations on or near ground level.

Consider a location that is level with the radar antenna and separated from it by a distance R. (The following analysis applies to elevated beams if all heights are referred to the center line of the beam.) At one moment during the O-deg elevation scan, this point will be struck with the full power of the main beam with a maximum intensity of $U_1 = 2.7 \times 10^9/R^2$. At other instants it will be struck by all the sidelobes, as shown in Figure 8-2. The exact shape of the power density curve, as sketched at the top of Figure B-2, is not known; however, no great error will result from assuming that each lobe has the shape of a half sinusoid. On this basis the average value of each section of the lobe pattern is $2/\pi$ times the maximum value.

The technical specifications limit the maximum rotational speed of the antenna to 30 deg/s. Thus, even at the slowest pulse repetition frequency of 250 pulses per second (pps), the beam moves only 0.12 dag between successive pulses. Therefore, no significant error will result from treating the beam as continuous with a total power of 2 kW.

As noted in Section C.2.4, applicable exposure standards are stated in terms of averaging times not greater than 0.1 hr = 6 min. Therefore, as a worst case, we average over the 6-min interval in which the beam elevation has the values 0, 0, and 4 deg. To facilitate calculation, the relative power levels of the first five sidelobes of Figure B-1 are:

Sidelobe number 1 2 3 4 5
Relative level 0.0032 0.0021 0.0013 0.0009 0.0006

The width of each sidelobe is 1.0 deg; the half-width of the main lobe is 1.25 deg. Contributions due to the zero-level scan are listed in the first column of Table 8-1. Contributions associated with other elevation angles are listed in successive columns.

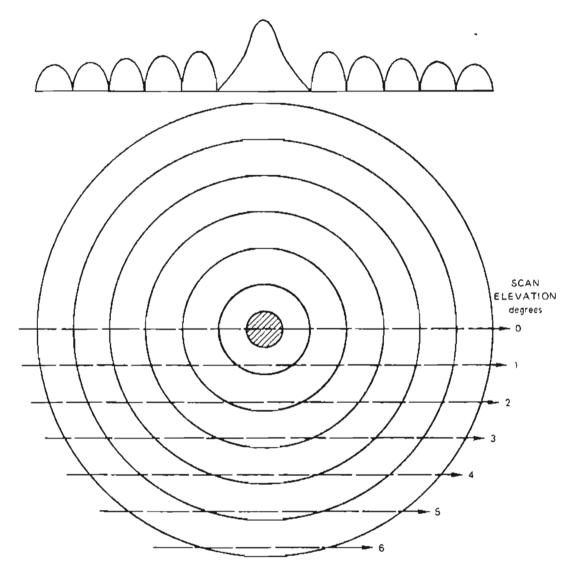


FIGURE B-2 EFFECT OF SCANNING BY MAIN BEAM AND FIRST FIVE SIDELOBES

Table 8-1 FACTORS FOR CALCULATION OF AVERAGE POWER DENSITY

Sidelobe	Elevation Angle (degrees)							
Number	0	1	2	3	4	5	6	
0	1.2500	0.0625	0	0	0	. 0	0	
1	0.0032	0.0032	0.0021	0	0	0	0	
2	0.0021	0.0021	0,0021	0.0013	0	0	0	
3	0.0013	0.0013	0.0013	0.0013	0.0009	0	0	
4	0.0009	0.0009	0.0009	0.0009	0.0009	0.0006	0	
5	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	
Total	1.2581	0.0706	0.0070	0.0041	0.0024	0.0012	0.0006	

The important conclusions to be drawn from Table B-1 are that the contribution of the main beam is much larger than the sum of the contributions of the first five sidelobes and that the power density decreases rapidly with increase of beam elevation angle. In particular, the contributions associated with a beam elevation angle of 4 deg are negligible.

The contributions of all the other sidelobes that radiate in all directions are addressed by noting that the system specification requires that throughout this region the antenna shall have a "median gain" not greater than -10 dB, i.e., 0.10. Median gain is defined as "that level over an angular region at which the probability is 50% that the observed or measured gain at any position of the antenna will be less than or equal to that level." This specification suggests, but is not fully equivalent to, a statement that the average gain over the entire region outside the main beam and first five sidelobes is 0.10 (-10 dB), which is equivalent to the statement that 90% of the available power is concentrated in the main beam and first five sidelobes and that only 10% remains to be distributed over all remaining directions in higher order sidelobes.

This 10% value is used to obtain the total time-averaged power density at the designated point. From Eq. (1) the average power density due to higher order sidelobes is

$$U_{a} = (0.002 \times 10^{9} \times 0.1)/(4\pi \times 929R^{2}) = 17/R^{2}$$
 (4)

Using the total of the first column of Table B-1 and introducing factors of 0.002 for the duty cycle, 2 for the repetition of the lowest scan, $2/\pi$ for averaging over a half sinusoid, 2 for the fact that each sidelobe is encountered twice, and $1/(3 \times 360) = 1/1,080$ for the total angle scanned in 6 min and referring to Eq. (2) gives

$$U_b = (1.26 \times 0.002 \times 8 \times 2.7 \times 10^9)/(1,080\pi R^2) = 16,000/R^2$$
 (5)

The value of U_B is negligible compared to $U_{\hat{D}}$. Therefore, the time-averaged power density is

$$U_3 = 16,000/R^2 \text{ mW/cm}^2$$
 (6)

This value applies to any point that is struck by the main beam only twice every 6 min. It is derived on the basis of far-field conditions and should not be used for values of R much below 2,000 ft.

B.2.2.2 Average Power at Other Levels

The procedure followed in the preceding section can be used to calculate average power densities at other locations. For example, consider a point that is located 1 deg below the main beam axis. Reference to Figure B-2 shows that Table B-1 still applies except that only figures in the second column should be used. On this basis, the revised value of power density becomes

$$U_{h} = (0.0706 \times 0.002 \times 8 \times 2.7 \times 10^{9})/(1,080\pi R^{2}) = 900/R^{2}$$
 (7)

When added to the (unchanged) value of Ug this yields

$$U_4 = 917/R^2 \text{ mW/cm}^2$$
 (8)

Repetition of this process for depression angles of 2, 3, 4, 5, and 6 deg yields as respective modified values of U_4 , 105, 69, 49, 33, and 25 (each divided by \mathbb{R}^2). The results of these calculations are presented in Figure B-3.

B.2.3 The Near-Field Region--Maximum Pulse Power

Hansen (1976) has studied the near-field region of antennas like that of the NEXRAD radar. Figure B-4, which is redrawn from one of his figures, shows that the power density on the axis of the beam is never higher than +15 dB, i.e. 32 times its values at the reference distance $2D^2/L$, which, as noted in Section B.2.1, is 3,300 ft. Thus, from Eq. (2), the maximum value of pulse power density on the beam axis in the near field is

$$U_0 = (2.7 \times 10^9 \times 32)/3,300^2 = 8,000 \text{ mW/cm}^2$$
 (9)

This value is used for all points within the circular column of the near field out to the distance of $0.17 \times 2D^2/L$, which corresponds very closely to the 550-ft value previously derived by a different method.

Additional information concerning power distributions in the pear field is provided by Figure B-5 based on work at the National Sureau of Standards (Hu. 1961). Out to distances greater than 1,100 ft the power remains strongly concentrated near the axis of the main beam.

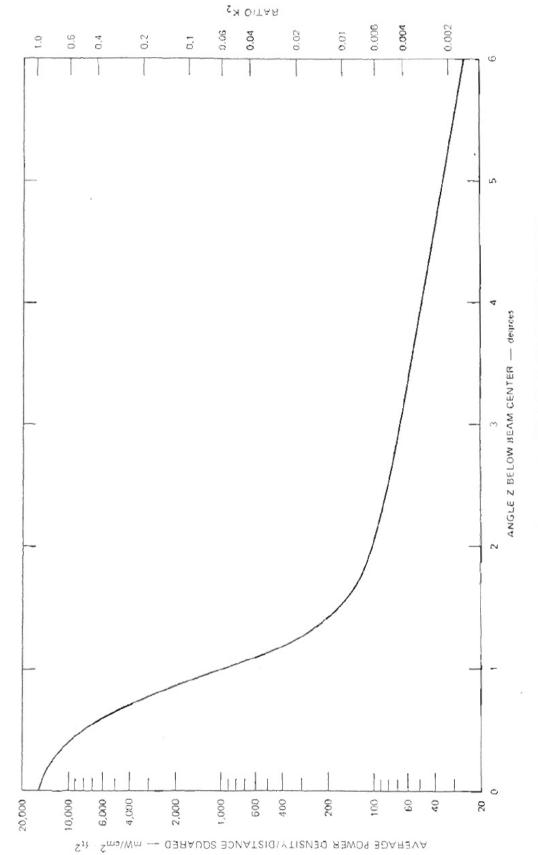


FIGURE B-3 ANGULAR VARIATION OF AVERAGE POWER DENSITY

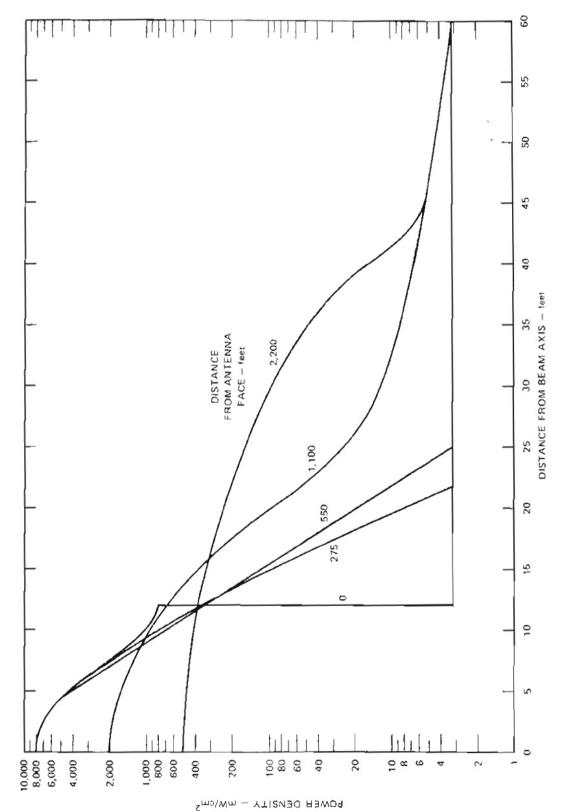


FIGURE B-5 OFF-AXIS POWER DENSITIES IN NEAR FIELD OF NEXRAD ANTENNA

In contrast to previous ones, this figure uses off-axis distances in feet rather than angles as the abscissa variable. This notation is preserved in subsequent figures because it is more convenient for calculations of power densities at various points of interest.

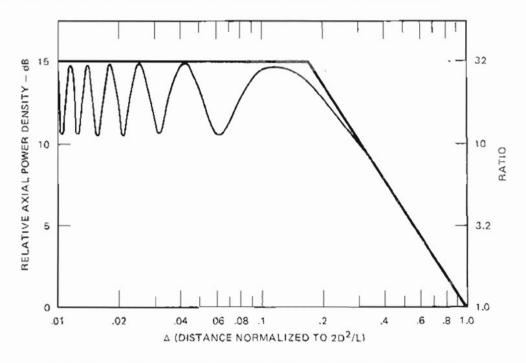


FIGURE B-4 RELATIVE POWER DENSITIES ON AXIS OF MAIN BEAM

B.2.3.1 The Near-Field Region -- Average Power

The average power density in the near field is calculated with reference to Figure B-6, which shows the axis about which the antenna rotates as well as the lowest and highest beam positions. In this region the beam is represented as a circular cylinder with a 24-ft diameter and a power density distribution of the form shown in Figure B-6.

Consider a (mathematical) cylindrical surface of radius R concentric with the antenna vertical axis. The zone that is illuminated by one or more scans of the beam has a height Y given by the equation

$$Y = 24 + R \tan 20 \deg = 24 + 0.36R$$
 (10)

The circumference of such a cylinder is 2mR and the total area A is

$$A = 2\pi RY = 151R + 2.26R^2 \tag{11}$$

The average power radiated is equal to or less than 2 kW; therefore, the average power density over the cylindrical surface cannot exceed the total power divided by the area.

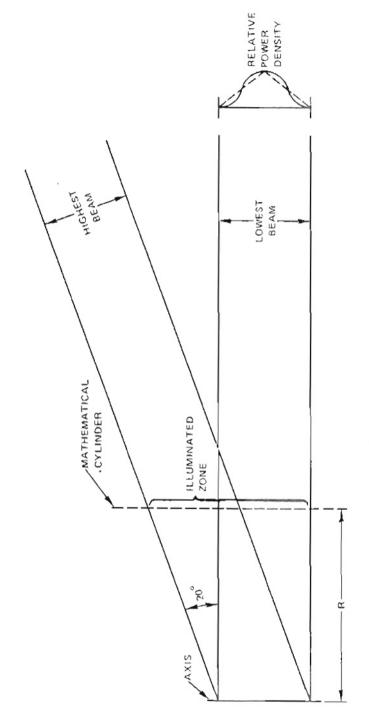


FIGURE B-6 EFFECT OF SCANNING BY NEAR-FIELD COLUMN

At the mid-height of this cylinder, the local power density will exceed the average value by a factor of two if the vertical power density distribution has either the sinusoidal form shown as a solid line or a triangular form shown in dashed lines. Introducing this factor, a factor of 10^6 to convert from kilowatts to milliwatts, and dividing by 929 to convert from square feet to square centimeters leads to the expression

$$U_5 = 2 \times 10^6 \times 2/(929)(151R + 2.26R^2) = 1.9 \times 10^2/(R^2 + 67R) \text{ mW/cm}^2$$
 (12)

which is accurate for values of R up to about 50 feet. For larger distances the repetition of the lowest beam calls for another doubling of the value of average power density, which leads to

$$U_6 = 3.8 \times 10^2 / (R^2 + 67R)$$
 (13)

This expression is used for distances from about 100 to 550 feet.

B.2.4 Electric Field Intensities

Electromagnetic waves such as those generated by NEXRAD are characterized by electric and magnetic fields, both of which are perpendicular to the direction of propagation. Of these, the electric field is of principal interest. Under all conditions relevant to the present calculations, the electric field strength (or intensity) E is related to the local power density U by the equation

$$E = (3.770 \text{ U})^{1/2} \tag{14}$$

where E is measured in volts per meter (V/m) and U is given in mW/cm^2 . The relationship is used only for pulse values of E and U.

B.3 Effect of Foliage and Scattering

B.3.1 Foliage

Microwave energy is absorbed and scattered by trees and underbrush. The effect of foliage on microwave propagation has been studied extensively (Trevor, 1940; Head, 1960; Doeppner et al., 1972; Tamir, 1977; Nelson, 1980). Waves that are forced to propagate directly through a forest are attenuated in an exponential manner. For typical woods the rate is about 0.15 dB/ft at NEXRAD frequencies; that is, the signal loses half its power (3 dB) in traveling a distance of about 20 ft. It is reduced to 1/10th its original strength in 60 ft and 1/100th its original strength in 120 ft.

Over extended distances, waves find easier paths that curve around or skim over the tops of the trees. Such paths usually reduce the power to a value no larger than 1/100th of that which would exist over a direct

free-space path. Waves that graze the treetops over a long distance behave somewhat like those that are guided over the surface of an imperfectly conducting earth, and the power density variation with distance includes a term of the form $1/R^4$.

In situations where vegetation provides shielding between the radar antenna and the location of interest, the levels of RFR (both peak and average power densities) are likely to be reduced by a factor ranging from 10 to 100. This factor is not included in this appendix; the purpose is to provide extremely conservative, i.e., overstated, estimates of RFR.

B.3.2 Diffraction and Scattering

From some locations of interest, the NEXRAD antenna is not visible. Under these circumstances it might be thought that no microwave power would reach such locations. While this ideal is closely approached, a small residue of power does propagate to such locations by diffraction around the edges of the land masses or buildings that block the view, and by scattering from trees, fences, and other objects that are struck by the main beam or its principal sidelobes.

It is impractical to make precise calculations of the RFR that results from such effects. A conservative upper bound is obtained by the principles of diffraction theory (ITT, 1977), which indicate that neither the peak nor the average power density within such regions will exceed 1/10th of that found in unshadowed regions at an equal distance from the radar.

B.3.3 Earth Curvature

Because the earth is nearly spherical, a horizontal beam of radiation is above the earth at all points. However, such a beam may be bent toward the earth by refraction in the atmosphere, which is caused by the decrease in atmospheric density associated with increase in altitude. The effect of such atmospheric refraction can be accounted for by using a fictitious earth radius that is 4/3 times the true radius. The result of such calculations leads to a simple formula for a beam launched horizontally from a particular point on the surface of the earth

$$h = R^2/2$$
 (15)

where R is the horizontal distance in (statute) miles and h is the beam elevation in feet. Thus, at a distance of 10 miles the beam clearance above the ground is increased by 50 ft as a result of earth curvature. This effect reduces the intensity of RFR at locations distant from the radar site.

B.4 Integration of Results

The preceding sections of this appendix have developed a set of formulas and graphs for calculating electric field strengths and power densities at various points relative to the NEXRAD radar. To facilitate calculations of RFR levels at specific locations of interest, these relationships are used to prepare two graphs that contain all the accumulated information.

B.4.1 Pulse Power Densities and Electric Field Intensities

Figure B-7 shows maximum pulse power densities and electric field intensities for all the distances and beam offset distances of probable interest. The straight line segments near the top of the graph represent an envelope of maximum values of pulse power densities that could be encountered by airborne objects. The horizontal line segment corresponds to points that are level with the antenna in the near-field zone. The sloping segment corresponds to the center of the beam in the farfield region. The transition occurs at SSO ft, the boundary between near-field and far-field conditions. These lines represent an upper bound on possible pulse power and electric field intensities. Parallel to these lines and separated from them by the factor 0.0004 (34 dB) are two more lines. These represent a floor above which occasional spikes will sometimes be observed. The intervening curves were obtained by graphical computation from Figures B-1 and B-5. The process was facilitated by use of Table B-2. The offset distances were arbitrarily chosen as convenient for this calculation and for subsequent use.

Table B-2
DISTANCES D FOR VARIOUS ANGLES AND OFFSET DISTANCES

(Feet)

Angle Z (degrees)			
1/2	1	2	4
	317	252	
1,432	/16	358	179
2,865	1,432	716	358
5,730	2,865	1,432	716
11,460	5,730	2,865	1,432
22,920	11,460	5,730	2,865
45,840	22,920	11,460	5,730
91,680	45,840	22,920	11,460
	91,680	45,840	22,920
0.50	0.050	0.0021	0.0009
0.50	0.060	0.0060	0.0030
	1,432 2,865 5,730 11,460 22,920 45,840 91,680	1/2 1 1,432 716 2,865 1,432 5,730 2,865 11,460 5,730 22,920 11,460 45,840 22,920 91,680 45,840 91,680 0.50 0.050	1/2 1 2 1,432 716 358 2,865 1,432 716 5,730 2,865 1,432 11,460 5,730 2,865 22,920 11,460 5,730 45,840 22,920 11,460 91,680 45,840 22,920 91,680 45,840 0.50 0.050 0.0021

The distances listed in Table B-2 appear as dashed vertical lines in Figure B-7. Properly applied to those lines, the values of K_1 taken from Figure B-1 yield the points needed for plotting the curves for far-field conditions. Some adjustments were necessary to fit near-field conditions, which were taken from Figure B-5. The electric field intensities shown in the right-hand margin were obtained by use of Eq. (14).

B.4.2 Average Power Densities

Figure 8-8, which is similar to Figure 8-7, was derived in the same general way; however, it differs in many important respects. In particular, the abscissa scale is unconventional in that it is nearly linear at the left margin, but fully logarithmic at the right. Use of this scale allows locations directly below the antenna rotational axis to be represented.

Values in the right half of the figure were obtained from Eqs. (4) and (6), together with values of K_2 derived from Figure 8-3 and listed in Table 8-2. The maximum value displayed is 1.5 mW/cm²; it occurs at R=15 and h=0, just outside the mid-height of the radome. Values along the R=0 axis were obtained from Eq. (4) by substitution of h for R. In the range h < R, the values were obtained by using $h^2 + R^2$ in the denominator. Smooth curves were used to connect these points to those calculated from far-field relationships.

Figures 8-7 and 8-8 are based on a continuous scan with a minimum elevation angle of 0 deg and the scan sequence described in Section A.2.2, which has a revisit time of 14 min. Actually, the restriction to zero elevation angle was removed by referring the beam offset distance h to the center of the lowest beam. With this interpretation, Figures 8-7 and 8-8 apply equally to any small elevation angle, positive or negative.

Values of maximum pulse power and electric field intensity are independent of duty cycle and scan pattern, depending only on distance and beam offset distance. Therefore, Figure B-7 is quite general. Values of average power density are proportional to the duty cycle and do depend on the scan pattern. Thus, Figure B-8 is subject to modification. No variation of the scan pattern within the capability of the NEXRAD hardware will increase these values by more than 50%.

B.5 References

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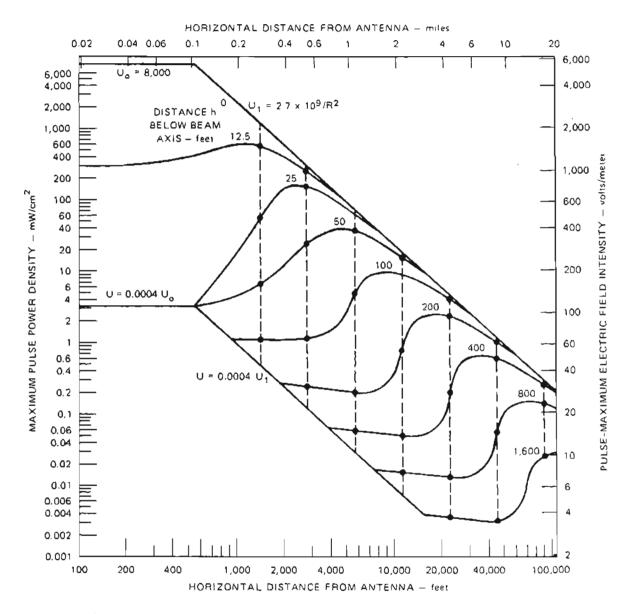
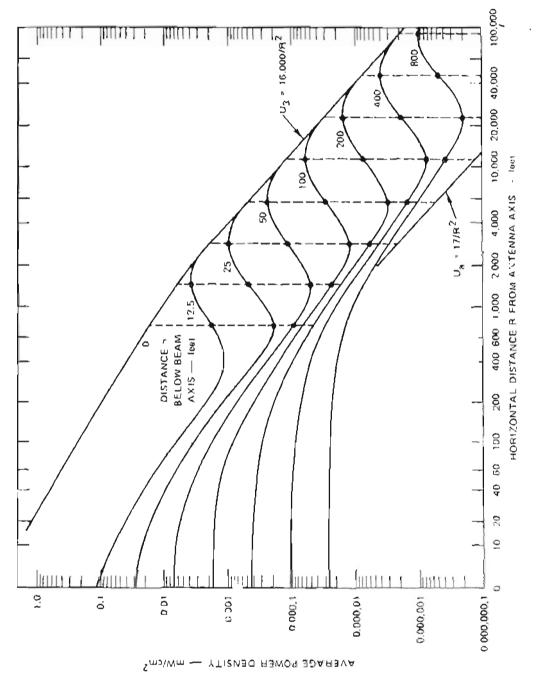


FIGURE B-7 MAXIMUM PULSE POWER DENSITIES AND ELECTRIC FIELD INTENSITIES NEAR NEXRAD RADAR



AVERAGE POWITS DENSITIES NEAR NEXRAD RADAR (Averaged Over 6 Winnes) FIGURE B-8

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Appendix C

HUMAN EXPOSURE TO RADIOFREQUENCY RADIATION

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Appendix C

HUMAN EXPOSURE TO RADIOFREQUENCY RADIATION

C.1 Human Health Effects -- Background

C.1.1 Definition of RFR

In the sections on the effects of exposure to radiofrequency radiation (RFR) on human health and on plants and animals, "RFR" is used as a generic term to include other terms commonly found in the bioeffects literature, such as electromagnetic radiation (EMR), non-ionizing electromagnetic radiation (NIEMR), microwave radiation, radiofrequency electromagnetic (RFEM) fields, electromagnetic fields (8MF), microwave fields, and others. In this document, the term "RFR" applies to frequencies from O to 300 GHz, both modulated and unmodulated. The frequency band of the NEXRAD transmitter is 2,700-3,000 MHz. The time-averaged power densities used in this appendix are based on averaging intensities over the worst-case 6 min interval, which is consistent with the current U.S. exposure standards.

C.1.2 The Problem

The basic issue addressed in this appendix on human health is whether brief or continual exposure of people to the power densities of RFR produced by a NEXRAD transmitter is likely to affect their health adversely. A critical review of the present state of knowledge regarding biological effects of RFR. Report SAM-TR-83-1, entitled "Bioeffects of Radiofrequency Radiation: A Review Pertinent to Air Force Operations," by L. N. Heynick and P. Polson, serves as the primary reference for the human health aspects of this assessment of NEXRAD. Although this review was prepared for the U.S. Air Force, it does not contain any systemspecific information and is useful for considering possible bioeffects of any radar of specified characteristics. The discussion and conclusions presented below regarding possible RFR-bioeffects of NEXRAD were derived by considering the research results that are most significant scientifically and pertinent to the operational characteristics of the NEXRAD radar and to the power densities of RFR in the general vicinity of a representative radar site.

Attention is also directed to another recently completed critical review, "Biological Effects of Radiofrequency Radiation," edited by J.A. Elder and D.F. Cahill, Health Effects Research Laboratory, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711, EPA-600/8-83-026A (Revised), which is the final draft of a report schoduled for publication in summer 1984. This report is similar in many

respects to the SAM-TR-83-1 report, covering many of the same subject areas and specific scientific references.

The subsections below, starting with C.2 "Present Climate and Context," are organized in parallel with the corresponding sections of the Air Force review. Also, where appropriate, parts of the review are reproduced below with the bibliographic references removed and with other minor changes. This parallel arrangement is to permit use of this assessment as a complete document without the need to refer to the review unless more detail and the reference citations are desired.

Humans could be exposed to the RFR from a NEXRAD transmitter under two circumstances. First, people sirborne in the vicinity may be exposed to the main beam. Second, populations in the geographic region around a transmitter site will be exposed to the low-intensity RFR near the ground for several miles from the antenna.

C.1.2.1 Airborne Exposure

Exposure of people in an airplane to the main beam is a possibility shared with many operational high-power radar systems. However, as far as is known, no case of harm to humans from any such incidental exposure has ever been reported, and there is no reason to believe that the NEXRAD situation would be significantly different from that of other radar installations in this respect.

A phenomenon associated with RFR pulses per se is the perception of individual pulses as apparent sound. The threshold pulse power density for this effect is about 300 mM/cm². An airplane in the general vicinity of a NEXRAD antenna may be swept by the main beam for periods of about 0.3s per sweep. If so, calculations presented in Appendix B (Figure B-7) indicate that within about 550 ft from the antenna (the near-field region), the maximum pulse power density in the main beam may be as high as 8,000 mW/cm²; beyond that distance (in the far field), the pulse power density will diminish by the inverse-square law, and the 300-mW/cm² threshold will be at about 3,000 ft. Thus, airborne persons swept by the main beam within distances less than 3,000 ft may "hear" the pulses. However, there is no experimental evidence that persons would be adversely affected by exposure to such levels of pulse power density, at least for exposures of a few minutes.

The calculations in Appendix B also indicate (Figure B-8) that the time-averaged power density at an airplane swept by the main beam and all sidelobes will be only 0.23 mW/cm² at 100 ft, 0.035 mW/cm² at 300 ft, and still lower at greater distances. Such levels are below prevailing standards for human exposure, and there is no evidence that exposure to such levels for several minutes would be harmful.

Because of these considerations, possible exposures of persons in sircraft to the main beam of NEXRAD are not given futher attention in this biological assessment.

C.1.2.2 Ground-Level Exposure

To estimate the maximum ground-level exposure in the near field, the ground near the antenna was assumed to be essentially flat out to a distance of about 3,000 ft, the main beam was assumed to be horizontal, and the bottom of the antenna rim was assumed to be 20 ft above ground. With the latter assumption, the center of an antenna 24 ft in diameter would be 32 ft above ground level and the head of a person 6 ft tall would be 26 ft below the center of the main beam. For this situation, Figure 8-7 indicates that at all distances from the antenna, the maximum pulse power density at such head heights will be considerably less than the 300-mW/cm² threshold for the auditory-RFR effect discussed above. Thus, it is most unlikely that persons anywhere at ground level will "hear" the NEXRAD pulses.

For the assumed situation, the meximum time-averaged power density at heights of 6 ft or less above ground will nowhere exceed 0.03 mW/cm², and will be less than 0.001 mW/cm² for distances beyond about 200 ft. In the standard recently adopted by the American National Standards Institute (ANSI), the maximum permissible average power density for human exposure to RFR in the 2,700- to 3,000-MHz range is 5 mW/cm², and the new USSR limit for chronic exposure of the general population is reported to be 0.01 mW/cm². Thus, the ground-level values of RFR within the near field of a NEXRAD antenna will be at least 50 times lower than the new ANSI standard and the values in the far field will be at or below the new USSR standard.

C.1.3 Data Base and Literature Selection

The criteria used in selecting articles for inclusion in the bioeffects review are described therein.

C.1.4 Eastern European Bioeffects Literature

Probably the most controversial aspects of research on the biological effects of RFR are the large discrepancies between results, at low levels of RFR, reported in the Eastern European literature and those obtained in Western countries such as the United States, and the basic differences in philosophy between the two groups of countries in prescribing safety standards or guidelines for the protection of humans against possible hazards from exposure to RFR.

From the end of World War II to about the late 1960s, few of the scientific reports on bioeffects research in the USSR (or other Eastern European countries) were amenable to critical review because they lacked essential information. In the early 1970s, starting essentially with an international conference on the bioeffects of RFR in Warsaw in 1973 under the joint sponsorship of the World Health Organization (WHO), the U.S. Department of Health, Education, and Welfare (HEW), and the Scientific Council to the Minister of Health and Social Welfare of Poland, international interchanges of information increased materially, and translations of Eastern European articles became easier to obtain. Because

most Eastern European documents published before 1973 (and many since then) are merely abstracts that contain no details of the experimental method, number of subjects, or analytical approach used in the study, evaluating them was difficult. More recent Eastern European studies contain more detail, and some of them have been cited and analyzed in the review.

C.2 Present Climate and Context

C.2.1 Proliferation of RFR Emitters

Public use of RFR-generating devices and acceptance of their benefits have been growing almost exponentially over a number of years. Public television and radio broadcasting stations, ham radio transmitters, citizen bend radios, ground-level and satellite communication systems, civil and military aircraft navigation systems, airport traffic control systems, medical diathermy units, defense tracking systems, remote garage-door opening devices, microwave ovens, and a variety of units for industrial heating and processing of materials contribute to the expansion of RFR use in this country.

All of these devices are regulated by the federal government, mainly the Pederal Communications Commission (PCC), and all are restricted to specific frequency bands. The power levels that most devices may emit are also restricted. Still, as the number of such devices increases, the background level of RFR in this country, particularly in urban and industrial centers, is bound to increase as well. It is therefore appropriate to ask whether this increasing level of RFR will be deleterious to human health.

Various agencies of the federal government have established programs to deal with the question of effects of RFR on human health. The U.S. Air Force has taken an active role for more than 10 years to advance the state of knowledge of RFR bioeffects in the interest of personnel safety. The Environmental Protection Agency (EPA) is conducting a study of environmental levels of RFR. The Bureau of Radiological Health (BRH) has promulgated a performance standard for permissible microwave oven leakage (21 CFR 1010, "Performance Standards for Electronic Products"). The National Institute for Occupational Safety and Health (NIOSH) is investigating the use of industrial microwave devices. The Air Force, together with the Army, Navy, and other government agencies, maintains research programs on the biological effects of RFR, with the objective of assessing effects on human health. The results of these programs indicate that the biological effects of RFR are largely confined to average power densities exceeding about 1 mW/cm².

In summary, the benefits of RFR devices for communications, radar, personal and home use, and industrial processes are widely accepted. On the other hand, many people are concerned that the proliferation of the use of RFR devices, including various military radar and communications

systems, may be associated with some as-yet-undefined hazardous biological effects. The purpose of this document is to address such concerns as they pertain to NEXRAD.

C.2.2 <u>Measurements of Environmental Levels of RFR in Selected V.S.</u> Cities

EPA has measured the environmental field intensities at selected locations in various U.S. cities. Recent reports discuss the results for the 15 cities (a total of 486 sites) studied so far. The sites in each city were selected to permit estimations of cumulative fractions of the total population being exposed at or below various average power densities, based on the population figures for the 1970 census enumeration districts.

The measured field strengths at each site were integrated over the frequency bands from 54 to 890 MHz included in the analyses and converted into equivalent average power densities. The site values in each city were then used with the population figures in the various census enumeration districts in a statistical model designed to estimate the population-weighted median exposure value for that city and to calculate other statistics of interest. These median values range from 0.000002 mW/cm² (for Chicago and San Francisco) to 0.000020 mW/cm² (for Portland, Oregon). The population-weighted median for all 15 cities is 0.0000048 mW/cm². Also, the percentage of the population of each city exposed to less than 0.001 mW/cm² ranges from 97.2% (for Washington, D.C.) to 99.99% (for Houston, Texas), with a mean value for all 15 cities of 99.4%. The major contributions to these exposure values are from the FM-radio and TV broadcast stations.

EPA also measured RFR levels at sites close to single or multiple RFR emitters, e.g., at the bases of transmitter towers and at the upper stories (including the roof) of tall buildings or hospital complexes close to transmitter towers. At the base of an FM tower on Mt. Wilson, California, for example, the fields ranged from 1 to 7 mW/cm², but such values are believed to be uncommon. Most measurements in tall buildings close to FM and TV transmitters yielded values well below 0.01 mW/cm², but a few values were close to or slightly exceeded 0.2 mW/cm² (e.g., 0.23 mW/cm² on the roof of the Sears Building, Chicago).

C.2.3 Problems of Risk Assessment

Assessing risk to human health and setting standards to protect health are extremely complex problems. In addition to purely technical and scientific questions, there are problems, still only vaguely recognized, of philosophy, law, administration, and feasibility of programs. Although dealing with these subjects in detail is beyond the scope of this document, it is important that they be mentioned.

One distinction between RFR and ionizing radiation is the considerable experimental evidence for the existence of exposure thresholds for various RFR effects. In the review of RFR bioeffects, threshold levels are considered on a case-by-case basis, with due regard for the physiological mechanisms of effect.

C.2.4 Exposure Standards

The term "exposure standards" is generally applied to specifications or guidelines for permissible occupational and/or nonoccupational exposure of humans to electromagnetic fields. The standards are expressed as maximum power densities or field intensities in specific frequency ranges and for indicated exposure durations.

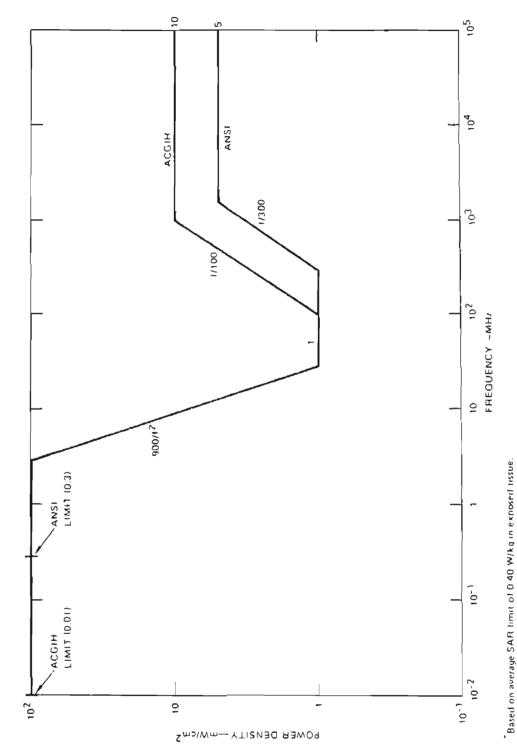
The ANSI Subcommittee C95.4 has adopted a frequency-dependent standard for both occupational and general-public exposure to RFR, to replace the ANSI Radiation Protection Guide, published in 1974, of 10 mW/cm². The new ANSI standard, shown in Table C-1 and graphically in Figure C-1, was derived from analyses of many representative recent experimental and theoretical results selected by a subcommittee of ANSI C95.4. It covers the frequency range from 300 kHz to 100 GHz and is based on a mean whole-body specific-absorption rate (SAR) limit of 0.4 W/kg instead of a constant incident power density. SAR is defined as the rate at which radiofrequency electromagnetic energy is imparted to an element of mass of a biological body (see Section C.5.1.2 for a more detailed discussion of SAR). The lowest limit, 1 mW/cm², is for the range from 30 to 300 MHz, within which RFR absorption by the human body as a resonant entity is highest. The value 0.4 W/kg includes a safety factor of 10, and the specified limits are not to be exceeded for exposures averaged over any 0.1-hr period.

Table C-1

NEW ANSI RADIOFREQUENCY RADIATION PROTECTION GUIDES

(1) Frequency Range (MHz)	(2) E ² (v ² /m ²)	(3) H ² (A ² /m ²)	(4) Power Density (mW/cm ²)
0.3 - 3	400,000	2.5	100
3 - 30	4,000 (900/f ²)	0.25 (900/f ²)	900/f ²
30 - 300	4,000	0.025	1.0
300 - 1,500	4,000 (f/300)	0.025 (f/300)	f/300
1,500 - 100,000	20,000	0.125	5.0

Note: f is the frequency in MHz.



ANSI AND ACGIH SAFETY GUIDES FOR WHOLE-BODY EXPOSURE OF HUMANS FIGURE C-1

In the far field of an RFR source, the governing maximum values are the power densities shown in column 4 of Table C-1, and the corresponding squares of the electric- and magnetic-field amplitudes (82 and 82) in columns 2 and 3 are approximate "free-space" equivalents.

In the near field of an RFR source, the governing maxima are the values of E^2 and N^2 but can be expressed in terms of corresponding power densities as is done in Figure C-1.

The ANSI power density limit for the NEXRAD 2,700- to 3,000-MHz range is S mW/cm².

The American Conference of Governmental Industrial Hygieniats (ACGIH) has proposed (in a notice of intent) a new standard also based on 0.4 W/kg, but for occupational exposures only. The ACGIH threshold limit values are displayed graphically in Figure C-1 for comparison with the ANS1 values. The major difference is that the 1 mW/cm² value extends only from 30 to 100 MHz and rises from the latter with a slope f/100 to 10 mW/cm² at 1 GHz, thus yielding the latter value as the standard for the NEXRAD band. This difference is based on the premise that children, who have higher whole body resonant frequencies than adults (see Section C.5.1.2), are not likely to be occupationally exposed to RFR. Another difference is that the lower frequency limit for the ACGIH standard is at 10 kHz instead of 300 kHz.

The currently applicable Air Force permissible exposure limits (PELs) are given in AFOSH Standard 161-9. For exposures averaged over any 0.1-hr period to frequencies between 10 MHz and 300 GHz, the PEL is 10 mW/cm², and from 10 MHz down to 10 kHz, the PEL is 50 mW/cm². For exposure within any 0.1-hr period, the product of the power density and the exposure duration shall not exceed 3.600 mW-s/cm² for frequencies between 10 MHz and 300 GHz, or 18,000 mW-s/cm² for frequencies between 10 kHz and 10 MHz. This standard is being revised: currently proposed PELs for exposure, during any 0.1-hr period, of adults of normal size (55 in. or more in height) are the new ACGIH values, and the PELs for exposure of humans of small size (less than 55 in. tall) are the new ANSI values, but extended down to the ACGIH lower frequency limit of 10 kHz. For the 2,700- to 3,000-MHz range, the new PELs are 10 mW/cm² for humans of normal size and 5 mW/cm² for humans of small size.

An exposure standard for the general (nonoccupational) population is also under consideration by the EPA.

For general interest, the standards of Canada and Sweden and standards adopted or proposed by several state, county, and municipal governments in the United States are discussed in the RFR-bioeffects review. Exposure limits in the USSR are considerably lower than those of Western countries, especially the limits for general population exposure. We surmise that such standards are based on the philosophy that exposure to power density levels that cause relatively small changes from normal mean values is potentially harmful. Until recently, the maximum level for 24-hr exposure of the general population was 0.005 mW/cm², and the occupational standard was as summarized in Table C-2. This table specifies higher maximum levels than those for the general population. For example, for rotating antennas emitting in the 2,700- to 3,000-MHz range, it permits exposures to 0.1 mW/cm² for a full working day or 1 mW/cm² for 2 hr. The Soviet military services and establishments were specifically exempted from such standards.

Table C-2

USSR MAXIMUM PERMISSIBLE LEVELS FOR OCCUPATIONAL EXPOSURE

Frequency (GHz)	Exposure <u>Duration</u>	Exposure Limit	Remarks
0.01 to 0.03	Working day	20 V/m	
0.03 to 0.05	Working day	10 V/m 0.3 A/m	
0.05 to 0.3	Working day	5 V/m 0.15 A/m	
0.3 to 300	Working day	0.01 mW/cm ²	Stationary antennas
	Working day	0.1 mW/cm ²	Rotating antennas
	2 hr	0.1 mW/cm ²	Stationary antennas
	2 hr	1 mW/cm ²	Rotating antennas
	20 min	1 mW/cm ²	Stationary antennas

Recent U.S. visitors to the USSR have reported pending and/or adopted revisions to the standards above (Microwave News, November 1982). For 24-hr exposure of the general population, the maximum level has been increased from 0.005 to 0.010 mW/cm². Also, the USSR appears to be developing standards for specific types of RFR emitters. As examples, for a specific radar that emits 1-µs pulses of 10-cm (3-GHz) RFR at 3 pps, the exposure limit is 0.015 mW/cm² (average power density), and for microwave ovens, the maximum value at a distance of 50 cm is 0.010 mW/cm². Regarding occupational exposure, for the frequency range from 0.3 to 30 GHz and exposures of 0.2 hr or longer, the product of the average power density and the

exposure duration should not exceed 0.2 mW-hr/cm². Thus, the exposure limit for an 8-hr working day has been increased from 0.010 to 0.025 mW/cm², the limit for 2-hr exposure is 0.1 mW/cm² (no change), and the 1 mW/cm² limit is for exposures of less than 12 (instead of 20) min. Though not stated, by implication these changes are applicable to RFR from stationary antennas; no information regarding rotating antennas was obtained. The limits for the frequency ranges 0.03 to 0.05 GHz and 0.05 to 0.3 GHz are unchanged.

The exposure limits in Poland and Czechoslovakia are higher than those of the USSR but lower than those of the Western countries.

Even ignoring any attenuation due to foliage, the ground-level time-averaged power densities for chronic exposure to the near field of a NEXRAD antenna will nowhere exceed 0.1 mW/cm² and in the far field (beyond about 550 ft) will be less than the new USSR safety standard of 0.010 mW/cm² for continuous (24-hr) exposure of the general population.

Thus, the controversy regarding the large differences in the U.S. and USSR standards is not really relevant to whether the RFR from NEXRAD will be hazardous to human health.

C.3 Assessment of Scientific Information

In an assessment of the potential biological effects of RFR from a specific system, it is necessary to consider certain quantitative relationships among (1) the physical parameters of the RFR such as frequency, power density, and polarization; (2) the mechanisms of absorption and distribution of energy within the biological organism; and (3) the resulting biological effects as measured by some functional or anatomic alteration. Like all scientific theory, the body of biophysical theory that links these three factors has been synthesized from a variety of experimental evidence. The theory is subject to refinement or revision as valid new evidence accumulates that is inconsistent with the theory. Nevertheless, it furnishes the context in which new experimental evidence is considered.

The most directly applicable experimental evidence concerning possible bioeffects of any specific system would come from experiments in which humans were exposed to its specific frequency range and likely power density values. Furthermore, the best evidence would come from quantitative evaluation of a large number of biological endpoints. Such data, however, do not exist. The relatively small amount of data on human exposure to RFR was derived primarily from epidemiologic studies conducted after exposure. Such studies are rarely adequate because the numerical values of the exposure parameters for most epidemiologic studies are not known in detail, and the unexposed control group of people selected for comparison may differ significantly from the exposed population in factors other than exposure to RFR. Most available information is indirect because it is derived primarily from experiments with

animals and requires at least some extrapolation of species, field characteristics, duration of exposure, and biological effects.

Regardless of the particular line of evidence being considered, certain concepts and constraints affect the interpretation. In particular, scientists disagree over whether an effect, especially one that is reversible or compensable, constitutes a hazard. Furthermore, only rarely is any particular study subjected to confirmation by the performance of an identical experiment by another investigator. More often, an analogous—but not identical—experiment is conducted with the objective of clarifying or expanding the results of the initial experiment. The second experiment ideally provides a better means of incorporating the findings into the theory that underlies the body of knowledge in a particular field of investigation, but it does not necessarily confirm the results of the first investigation.

Still another consideration is also important: scientific findings are probabilistic in nature, in that facts are known only to some level of probability for a given population; the applicability of those facts to a particular individual may be constrained. For example, the term "median effective dose" for a certain agent refers to the dose that will elicit the response characteristic of that agent in one half of the exposed individuals. Before the dose is administered, however, one cannot predict whether any specific individual will respond, although the prediction that an individual will have a 50% chance of showing the response is valid. In effect, the probabilistic nature of scientific evidence means that no amount of scientific data can guarantee the absolute safety of any agent for any individual or group of individuals. Analysts disagree over whether the conventional scientific approach, whereby an investigator finds or fails to find a statistically significant (very low probability of chance occurrence) difference between experimental and control groups, is appropriate to considering potential hazards to humans. The scientist's statement that no statistically significant differences between the groups are discernible is not equivalent to the absolute statement that there is no difference between the groups.

Conceivably, agents may have effects that are biologically real but so small in magnitude that the difference in mean response between experimental and control populations may not be discernible within the scattering of values for both populations if the sample sizes are small. Biological studies to detect such small differences and to show that they are statistically significant (to a prespecified probability that they are not due to chance) would require the use of large numbers of animals and, in some cases, long exposure times. The expenditures in time and money necessary to perform such studies may be so large that sponsoring institutions with limited budgets often decide that such studies are not cost-effective in terms of the sponsor's overall objectives. A frequent alternative is to predict effects at very low levels by extrapolation from findings at higher levels, on the basis of assumptions about the mathematical relationship between the level (or dose)

of the agent and the degree of the effect. Such assumptions are open to challenge, however, and this approach may lead to disagreement over the possible existence of a threshold dose or dose rate below which the agent has no effects.

It must also be remembered that scientists have personal values, goals, and attitudes. It has been said that there is no such thing as an unbiased expert because becoming an accepted authority involves a personal commitment over a period of time that leads to emphasis of certain viewpoints. Thus, like probabilistic scientific findings, objectivity may well be characteristic of scientists as a group without necessarily being characteristic of any individual scientist. Personal bias can consciously or unconsciously affect how the experiment is designed, how the data are interpreted, and particularly, how the results are applied to decision making. The last is especially important when the decision to be made is in an area outside the scientist's field of expertise.

Finally, scientific experiments are usually restricted to the evaluation of only one factor. In the real world, however, interactions are far more complex. The effect of combinations of factors is illustrated in the incidence of lung cancer in uranium miners, which is higher than in the general population, presumably as a result of the inhalation of radioactive material. The extent of the increased incidence in nonsmoking miners is marginal, but miners who smoke cigarettes have a much higher incidence of lung cancer than either nonsmoking miners or the general population. Thus, scientific evidence can only supply probabilistic information that is relatively narrow in its application to the real world.

C.4 Other Reviews

Representative general reviews of the literature on RFR bioeffects, including several papers by Eastern European authors, are described in Section 1.2 of the RFR-bioeffects review, primarily as background material. Although the conclusions of the authors of those reviews were exemined carefully, it is important to note that the conclusions presented below regarding the consequences of human exposure to the RFR from NEXRAD were derived independently.

C.5 Present State of Knowledge Regarding Physical Effects

C.5.1 Interactions of RFR with Biological Entities

Interactions of electromagnetic fields with biological entities are often loosely characterized in the bioeffects literature as "thermal" or "nonthermal," a usage that has led to confusion and controversy. Therefore, it is appropriate at this point to introduce working definitions of these terms, with the recognition that the boundary between these types of interaction is not sharp.

The interaction of an agent (e.g., RFR) with an entity (biological or nonbiological) can be characterized as thermal if the energy absorbed by the entity is transformed at the absorption site into heat. Heat absorption, in turn, is defined in classical thermodynamics as either an increase in the mean random speed (or kinetic energy) of the molecules at the site (a local increase in temperature), or as an increase in the disorder or randomness of the molecular motion without an increase in mean random speed (a first-order phase change, such as the process involved in ice melting at 0 deg C), or both.

An entity can also absorb energy at specific discrete frequencies in the form of energy packets or quanta, each of which has an energy proportional to one of the discrete frequencies. Although large numbers of molecules can be involved, quantum absorption is essentially a microscopic phenomenon in that the constituents and configurations of the various molecular species comprising the entity determine the specific frequencies or characteristic spectra at which such absorption can occur. The kinds of interactions involved are numerous and of varying degrees of complexity. They include alterations of molecular orien—tations and configurations that do not change the basic identities of the molecules, disruption of intermolecular or intramolecular bonds, and excitation of atoms or molecules to higher electron states (including ionization). Such interactions can be characterized as "short-range" processes.

It is theorized that cooperative interactions also occur among subunits of molecules within biological cells, in cell membranes, and in extracellular fluids. Cooperative interactions are often characterized as "long-range" because absorption of energy at one specific site in a structure (e.g., in a membrane or in a biological macromolecule) can affect a process elsewhere in the structure, or a function of the structure as a whole can be triggered by the release of energy stored in the structure, thereby producing biological amplification.

Conceptually, all such quantum interactions can be characterized as "nonthermal." However, if most of the energy thus absorbed is subsequently transformed locally into heat (as defined above), the distinction between nonthermal and thermal is blurred. Pragmatically, therefore, characterization of an interaction of RFR with a biological entity as nonthermal requires that the interaction give rise to a frequency-specific effect that is experimentally distinguishable from heating effects caused by thermalization of the absorbed RFR energy.

C.5.1.1 Thermal Interactions

Consider now the effects of continuous wave (CW) RFR on a human or an animal. The relative magnetic permeability of most organic constituents is about unity. Therefore, thermal interactions (as defined above) can be described in terms of the dielectric, electrically conductive, and thermal properties of the body organs, tissues, fluids, and so forth, as well as the characteristics of the RFR (frequency, power

density, polarization). Measurements of these properties have been made for various mammalian tissues, blood, cellular suspensions, protein molecules, and bacteria over the frequency range from about 10 Hz to 20 GHz. In the subrange from about 300 MHz to about 10 GHz, the dielectric constant of such constituents as skin, muscle, and blood vary little with frequency; the differences in values among such constituents are largely due to differences in water content. In addition, electrical conductivity increases slowly with frequency in this subrange.

Because the index of refraction of any material is related to its dielectric constant, RFR is reflected and refracted at boundaries between regions of differing dielectric properties, such as at the surface of a body (whether organic or inorganic), for the same physical reasons as for light at a glass-air interface. Thus, RPR at normal incidence to a relatively thick planar specimen is partially reflected at the surface, and the fraction of the power density entering the specimen suffers progressive attenuation with depth because of energy absorption. The concept of "penetration depth" is often used. For homogeneous specimens, the penetration depth is defined as the distance at which the electric-field strength is about 37% of its value or the power density is about 14% of its value just within the surface, and the numerical values depend on the electrical properties of the material. Both the reflection ratlo and penetration depth vary inversely with frequency. At 3 GHz, about 56% of the incident power density is reflected at the air-skin interface, and the penetration depths for skin, muscle, and blood are about 1.7 cm (0.67 in.) and about tenfold larger for fat. Therefore, the 44% entering the body passes through the skin and its underlying fat layer into the muscular tissue with relatively little attenuation. At 100 kHz, the penetration depths of all constitutents are quite large, but the reflection ratio is essentially 1. On the other hand, at approximately 10 GHz and higher, a somewhat smaller fraction of the incident power density than at 3 GHz is reflected, but penetration is largely confined to the skin.

C.5.1.2 Dose-Rate Considerations

In the literature on bioeffects of RFR, thermal energy absorption from an electromagnetic field is usually characterized by the SAR, which is defined as the rate of energy absorption per unit volume in a small volume at any locale within an entity, divided by the mean density of the constituents in that volume. SAR is expressed in terms of W/kg or mW/g (1 mW/g = 1 W/kg). The numerical value of SAR in any small region within a biological entity depends on the cheracteristics of the incident field (power density, frequency, polarization), as well as on the properties of the entity and the location of the region. For biological entities that have complex shapes and internal distributions of constituents, spatial distributions of local SAR are difficult to determine by experiment or by calculation. Thus, the concept of "whole-body SAR," which represents the spatial average value for the body per unit of incident power density, is useful because it is a quantity that can be

measured experimentally--e.g., by calorimetry--without information on the internal SAR distribution.

Many investigators have calculated or measured SAR for relatively simple geometric models, including homogeneous and multilayered spheroids, ellipsoids, and cylinders that have weights and dimensions approximately representative of various species, including humans. An important result of this work is that the largest value of whole-body SAR is obtained when the longest dimension of each kind of model is parallel to the electric component of a linearly polarized plane-wave field and when the wavelength of the incident RPR is about 2.5 times the longest dimension. The adjective "resonant" is often applied to the frequency corresponding to this wavelength. The resonant value of whole-body SAR for each model is also inversely dependent on the dimension perpendicular to the polarization direction (and propagation direction) of the field; i.e., the model has characteristics somewhat similar to those of a lossy dipole antenna in free space. Resonances would also occur for circularly polarized RFR. Such RFR can be resolved into two mutually perpendicular components, each having half the total power density. Therefore, an entity exposed to circularly polarized RFR would have lower resonant SAR values than it would have if exposed to linearly polarized RFR.

Based on prolate-spheroidal models (and linearly polarized RFR), the resonant frequency for an "average" man, approximately S ft 9 in. tall (1.75 m) and weighing about 154 lb (70 kg) is about 70 MHz; at this frequency the mean SAR is about 0.2 W/kg for 1 mW/cm² incident power density, or about 1/6 of his resting metabolic rate, or about 1/21 to 1/90 of his metabolic rate when performing exercise ranging from walking to sprinting. An alternative interpretation of this mean SAR value is that exposure to 1 mW/cm² for, say, 1 hr would produce a mean temperature rise of about 0.2 deg C in the absence of any heat-removal mechanisms. However, actual temperature increases would be lower or even zero because physical heat-exchange mechanisms (conduction, convection, radiation) are always present, and for manumals (and other warm-blooded species) these mechanisms are controlled by thermo-regulatory systems.

Similarly, the resonant frequency for an "average" woman about 5 ft 3 in. tall is about 80 MHz, and her mean SAR is about the same as for the average man. The resonant frequency of a 10-year-old is about 95 MHz; for a 5-year-old, about 110 MHz; and for a 1-year-old, about 190 MHz. The mean resonant SAR values for such children are about 0.3 W/kg for 1 mW/cm².

If a model human were to be standing on a wet surface or near other electrically conductive surfaces (reflectors), the resonant frequency would be lower and the mean SAR (at the lower resonant frequency) would be higher. However, because the values of incident power density from NEXRAD at ground level are much lower than 1 mW/cm² and its operational frequencies are considerably higher than the resonant frequencies

in either the absence or presence of nearby reflecting surfaces, no changes in body temperature would be expected.

The foregoing discussion of mean SAR also largely applies to pulsed RFR (and other types of modulated RFR) at corresponding carrier frequencies and time-averaged incident power densities. (However, as discussed in the next section, interactions of CW and pulsed RFR with biological entities differ in several ways.)

An early, very significant finding for spherical models of the isolated head assumed to be exposed to plane-wave RFR was the discovery of local regions of relative maximum SAR values. The locations of such regions depend on the size of the head, the electromagnetic characteristics of its layers, and the wavelength of the incident field. These regions have been conveniently dubbed "hot spots," even for combinations of incident power density and exposure duration that would produce biologically insignificant temperature increases at such spots. Pertinent hot-spot data are given in the RFR-bioeffects review.

Results of theoretical analyses of SARs have been verified experimentally. Physical models of simple geometry or in human- or animal-figurine shape were constructed from synthetic biological materials that have approximately the same electromagnetic characteristics as their corresponding biological constituents; the models were then exposed to sufficient power densities to obtain readily measurable temperature increases, which were measured immediately after irradiation.

Among the qualitative results of general interest obtained with human figurines are that, at frequencies near resonance, the local fields can be much higher for certain regions such as the neck and groin than for other body locations, and that field distributions for nonprimates differ greatly from those for primates. The latter point should be given proper consideration when one endeavors to extrapolate experimental bioeffects findings on any laboratory animal species to humans or to compare experimental results on one laboratory species with those on another species. However, the NEXRAD frequencies are much higher than the human resonance values (e.g., 70 MHz for the model average man) and the corresponding mean SAR values (per mW/cm²) are considerably lower than the resonance values (e.g., about 0.03 W/kg at 3 GHz versus 0.2 W/kg at 70 MHz). Consequently, local temperature rises in body regions such as the neck and groin would be negligible.

C.5.1.3 Quantum Interactions and Nonthermal Effects

For short-range quantum interactions (as defined in Section C.5.1) of CW RFR, the discrete frequencies are in the infrared range from about 19,000 to 2,400,000 GHz, and the lower end of this range is about 6,000 times higher than a quantum of RFR at 3 GHz. Conversely, the quantum energy of 3-GHz radiation is too low (by the same factor or more) for such interactions. Therefore, the existence of nonthermal biological

effects of CW RFR ascribable to such short-range molecular interaction mechanisms is extremely doubtful.

It has been logically postulated that cooperative or long-range quantum processes in biological entities (or the functions resulting therefrom) could be altered by exposure of the entity to external fields of magnitudes that do not produce heat as the primary or initial product. Much research has been done with models of cellular membranes. In general, the results indicate that cooperative processes have activation energies or exhibit resonant frequencies that can be much lower than those for short-range interactions.

The mean thermal energy corresponding to the physiological temperature 98.6 deg F (37 deg C) is about 0.027 eV, with a classical spectral distribution around a maximum at 6,500 GHz and encompassing the frequency range for cooperative processes. Therefore, as a counter-argument to the manifestation of such nonthermal effects, a question has been raised whether these effects would be distinguishable from those that are spontaneously induced thermally in vivo. Alternatively, separation of such RFR interactions from those thermally induced may require that the rates of occurrence of the former exceed the rates for the latter. This requirement implies that for manifestation of such effects of RFR, the intensity of the incident field must exceed minimum values or thresholds related to the specific processes.

Because predictions from various theoretical models and related considerations conflict to a significant extent, the issue of whether weak external fields at frequencies well below the infrared range (i.e., RFR) can alter biological processes is not yet resolved. However, increases and decreases of calcium-ion binding to cell membranes due to weak external RFR, a phenomenon called "calcium efflux," has been ascribed to alterations of cooperative processes by such fields. This phenomenon is discussed in Section C.6.5.2.

C.S.1.4 Interactions of Modulated RFR

Precise usage of the term "CW RFR" implies the presence of only a single frequency (and unvarying incident power density). Because of the time variations of power density and/or frequency in modulated RFR, possible biological effects ascribable to the modulation characteristics per se rather than to the time-averaged power density must also be considered, such as the calcium-efflux phenomenon, which was reported for 50-MHz, 147-MHz, and 450-MHz RFR modulated at sub-ELF (extremely low frequencies) but not for unmodulated RFR at these carrier frequencies.

Periodically pulsed RFR constitutes a particular type of amplitude-modulated RFR in which the pulse repetition rates are the primary modulation frequencies. Biological effects ascribable to modulation frequencies per se (as distinguished from those due to individual pulses) have been postulated.

C.5.1.5 Interactions of RFR Pulses

The interactions of individual RFR pulses with an entity (biological or nonbiological) are analogous to those of mechanical impulses, an impulse being defined as the sudden application of a force to an entity for a brief time interval, resulting in an abrupt increase in momentum. The total energy imparted to the entity depends on the magnitude of the force and the duration of its application. The interaction can be characterized as nonthermal or thermal, depending on the properties of the entity that determine the disposition of the energy. The impact of a piano hammer on a string, which excites the string into vibration at its discrete resonant frequencies (the fundamental frequency and integer-multiples thereof or harmonics), is an example of an essentially nonthermal interaction as defined previously; most of the energy is transformed into sound, which is converted into heat elsewhere.

A sudden blow to an entity such as a block of material having a set of resonant frequencies that are not necessarily harmonically related to one another will excite many of these frequencies; this illustrates the principle that an impulse contains a broad spectrum of frequencies. The results of an impact on a church bell can be characterized as nonthermal for the same reason as that given for the piano string. By contrast, the effects of a blow to a block of lead or asphalt are essentially thermal; even though some sound is produced, most of the energy is converted into heat on the surface of impact.

The temperature increase of any given region within a biological entity due to the arrival of a single RFR pulse would be small, because of the relatively large thermal time constants of biological materials and the operation of heat-exchange mechanisms. However, if the region contains a boundary between layers of widely different dielectric properties, then the temperature gradient (rate of temperature change with distance) can be large at such a boundary even though the mean temperature increase in the region is small.

One single-pulse effect known to occur in humans is the phenomenon of "microwave hearing" discussed in Section C.6.5.1, or the perception of single or repetitive short pulses of RFR as apparently audible clicks. The interaction mechanisms involved are not yet completely understood. However, most of the experimental results tend to support the theory that pulse perception occurs because the electromagnetic energy is transduced into sound pressure waves in the head at a boundary between layers having widely different dielectric properties (e.g., at the boundary between the skull and the skin or the cerebrospinal fluid). The energy in a pulse arriving at such a boundary is converted into an abrupt increase in momentum that is locally thermalized, producing a negligible volumetric temperature increase but a large temperature gradient across the boundary. Under such conditions, rapid local differential expansion would occur and create a pressure (sound) wave that is detected by the auditory apparatus. This effect is often characterized as nonthermal because the power density averaged over two or more pulses can be minuscule. Specifically, the time-averaged power density for two successive pulses is inversely proportional to the time interval between the arrival of the pulses at the perceiver, and this interval can be indefinitely long without affecting the perception of each pulse. Therefore, the time-averaged power density has no relevance to perception. Irrespective of how the RFR-hearing phenomenon is characterized, the significant point is that the preponderance of experimental evidence indicates that the pulses are converted into actual sound in the head, rather than perceived by direct RFR stimulation of the auditory nerves or the brain.

As discussed in Sections C.6.5.3 and C.6.6, pulsed RFR has been reported to produce other effects, such as alterations of the blood-brain barrier and behavioral changes.

C.5.2 Exposure Systems and Instrumentation for RFR Bioeffects Research

Much of the early laboratory research on RFR bioeffects suffered from lack of adequate systems for exposing the biological entities under study and lack of accurate techniques and instrumentation for measuring incident fields and/or determining energy absorption rates within such entities. The environmental characteristics of the exposure systems were often inadequately characterized or controlled. In addition, the instrumentation was frequently incorrectly used, or was the source of significant errors in numerical values or of spurious biological findings (artifacts) traceable to perturbations introduced by the presence of the sensors. For these reasons, many of the early results should be viewed as questionable, at least from a quantitative standpoint. During recent years, however, major advances have been made in specialized exposure systems and in instrumentation for determining incident-field intensities for biological research and for determining energy-absorption rates within biological entities. These developments are discussed in Sections 5.2.1 and 5.2.2 of the RFR-bioeffects review.

C.6 Present State of Knowledge Regarding Biological Effects

C.6.1 Epidemiology

Epidemiology, as used in the context of this document, refers to studies of whether one or more health-related conditions can be associated statistically with purported or actual exposure of humans to RFR (in contrast with assessments based on extrapolation from data on animals to humans). Epidemiologic results tend to be based on imprecise estimates of exposure characteristics (frequency, power density, and duration). The extent to which the control group matches the exposed group is sometimes open to question. Because matching of all relevant factors except exposure is the basis for concluding that any observed differences between groups are related to the RFR exposure, selection of an appropriate control group is critical. Despite these limitations, such studies do provide almost the only information available on possible effects of actual RFR exposure in humans.

A group of reports was selected for review from the literature in the United States, Poland, Czechoslovakia, and the USSR. These reports provide a representative sample of the kinds of information currently available.

The U.S. Embassy in Moscow was subjected to RFR from 1953, the year after the United States moved its chancery to Chekovsky Street, until Pebruary 1977. Within rooms having the highest RFR levels (rooms with windows or doors in outside walls toward the irradiation sources), the average power densities were typically about 0.004 mW/cm² within 2 ft of a door or window, and 0.0025 mW/cm² elsewhere in the room. The highest power density reported was 0.024 mW/cm², which occurred in one room during a 2-hr period of unusual signal strength on 24 January 1976.

A study was made of the health of U.S. personnel assigned to the Moscow embassy during the period from 1953 to 1976, compared with the health of those assigned to other U.S. Eastern European embassies. The investigators noted several limitations of the study but were able to conclude that there were no discernible differences between the Moscow and control groups in total mortality or mortality from specific causes, nor were there differences in mortality between the Moscow and control groups of dependent children or adults.

In a study published in 1965 of the causes of mongolism in U.S. children, an apparent correlation was found between this inherited condition and exposure of the fathers of affected children to RFR before their conception. However, in a later study (1977) in which the original study of 216 children was expanded to 344 children with mongolism, each matched with a normal child of the same sex born at about the same time and whose mother was about the same age, no such correlation was found. Thus, the earlier conclusion, based on a smaller sample, that exposure to RFR contributed to mongolism in offspring, was not confirmed. No quantitative assessment of the extent of the fathers' exposures was possible.

The causes of mortality in personnel who had served in the U.S. Navy during the Korean War were monitored in an attempt to establish whether exposure to RFR is associated with causes of death or with life expectancies. By 1977, the records of about 20,000 deceased veterans whose military occupational titles indicated more probable exposure to RFR had been compared with the records of an approximately equal number of less-exposed veterans. No quantitative exposure data were available. No differences between groups emerged in overall mortality rates or in the rates for about 20 specific categories of cause of death. However, death rates differed significantly for two categories: death rates from arteriosclerotic heart disease were lower and those from trauma were higher in the RFR-exposed group. The trauma category included military aircraft accidents, and a higher proportion of the exposed group had become fliers. It therefore appeared unreasonable to attribute the higher trauma death rate to greater previous RFR exposure. Overall death rates for both groups were lower than those for the general U.S. population of the same age.

The incidences of fetal anomalies and fetal death rates reported in birth records for white children born in the vicinity of the Army Aviation Center at Fort Rucker, Alabama, between 1969 and 1972 were evaluated in a series of three reports. Fort Rucker is of interest because of the concentration of radar units on or near the base. Taken together, these reports identify unusually high incidences of certain fetal anomalies and high fetal death rates in the two counties adjacent to Fort Rucker as compared with the corresponding statewide Alabama statistics, and at the Lyater General Hospital (Port Rucker) as compared with other military and civilian hospitals. A high incidence of fetal death at the Eglin AFB Hospital is also reported, but no further mention is made of the Eglin data in the remainder of the report. However, there was also evidence that these high rates for fort Rucker could not be attributed specifically to the unquantified radar exposures at or near Fort Rucker on the basis of the birth record data: Coffee and Dale counties ranked only sixth and eighth for anomaly incidence among the 67 Alabama counties; Lyster Nospital's anomaly and fetal death cates were not significantly higher than several other comparable "non radar" hospitals in Alabama and were in the range of values predicted from carefully controlled studies done in other states. The residences of mothers bearing anomalous infants were not clustered near radar sites, but many of the anomalies reported at Lyster occurred over a small time period, indicating a high anomaly-reporting rate for one or two physicians on the Lyster staff.

In 1971, a report was published on the results of a battery of medical evaluations carried out on 58 employees of Czech television transmitter stations. Exposure frequencies were estimated to range from 48.5 to 230 MHz at field intensities equivalent to 0 to 0.022 mW/cm², with a mean exposure duration of 7.2 years (10.6 hr/workday). Electrocardiograms, heart and lung X-rays, standard blood tests, urinalyses, and liver function tests were conducted, as well as ophthalmologic, neurologic, gynecologic, psychiatric, and psychological examinations. The only statistically significant finding was that the mean plasma protein levels were higher than "normal" values taken from the literature, a finding that the author describes as whexplainable. The appropriateness of the use of literature control values is highly questionable.

In a later study (1974) by the same investigators, the effects of RFR on blood protein levels were reexamined. The authors indicated that the only difference between exposed and control groups was that the members of the exposed groups had worked irregular shifts, whereas more than half of the control group had worked only morning shifts. The results for both groups showed that the individual levels of blood proteins and their fractions were within normal physiologic limits, but statistically significant differences were found between mean values for the exposed and control groups.

In our opinion, the absence in either study of a control group that had received virtually no RFR exposure renders questionable an interpretation that any differences found were due to RFR exposure. It is likely that the altered values of blood proteins (which were within normal limits) were caused by other factors.

A 1974 report by another investigator in Czechoslovakia was an assessment of workers exposed to RFR at 1-150 MHz, 300-800 MHz, or 3-30 GHz, with power densities, where specified, of 0.1 to 3.3 mW/cm², depending on their particular occupations. Changes were reported in brain wave patterns and in blood sugar, proteins, and cholesterol levels, as compared with those in administrative (nonexposed) personnel.

The authors of a 1974 paper from Poland compared the health status and fitness for work of 507 persons occupationally exposed to pulsed RFR exceeding 0.2 mW/cm² average power density (other RFR characteristics not specified) with a group of 334 workers at the same installations exposed to less than 0.2 mW/cm². Clinical tests included ophthal-moscopic and neurologic examinations, supplemented by psychological tests and electroencephalograms (EEGs). No statistically significant differences between the two groups were found. In our opinion, the lack of more definitive RFR exposure data vitiates, but does not invalidate, the negative findings of this study; i.e., the results provide no evidence for RFR-induced effects on the health status of either group.

In a USSR paper published in 1974, the authors reported that their clinical examinations of a group of specialists working with RFR generators in the 40- to 200-MHz range for 1 to 9 years showed occurrences of functional changes in the central nervous system, described as vegetative dysfunction accompanied by neurasthenic symptoms. No organic lesions were found, but among the many specific changes reported were deviations in the physiochemical and functional properties of erythrocytes and leukocytes (red and white blood cells). The authors also conducted experiments with human volunteers and reported functional changes in the thermoregulatory and hemodynamic systems and in the thermal, optical, and auditory "analyzers." However, no RFR intensity values were given for either the specialists or the volunteers; most of the findings were presented in narrative form, with no actual data; and the nature of the control group studied was not described. Consequently, this paper provides little basis for affirming or denying the occurrence of possible adverse effects of occupational exposure to RFR.

Another Soviet investigator presented clinical observations on the health status of two groups of USSR RFR workers. Those in the first group (1,000) were exposed to up to a few mW/cm², whereas those in the second (180) were exposed to values rarely exceeding several hundredths of a mW/cm², both at unspecified "microwave" frequencies. A group of 200 people of comparable backgrounds but presumably not exposed to RFR served as controls. Sixteen kinds of symptoms were reported, including fatigue, irritability, sleepiness, partial loss of memory, lower heartbeat rates, hypertension, hypotension, cardiac pain, and systolic murmur. In the higher-power-density group, the indices for 5 of the 16 symptoms

were higher than those in the lower-power-density group; they were lower for 9 symptoms and about the same for the remaining 2. Incidences in the control group were lower than those in either exposed group for 15 of the 16 symptoms.

Several epidemiologic studies have been performed in the United States to ascertain whether chronic exposure to RFR could cause cateracts. As reported in 1961, eye defects were sought in a group of 475 persons who were believed to have been exposed to RFR at 11 military and nonmilitary establishments; a group of 359 persons served as controls. The investigators found a slight but statistically significant difference in defect scores between the two groups, but they expressed some doubt regarding the full validity of the scoring method used.

A 1965 report by several of the same investigators discusses the examination of Veterans Administration Hospital records of 2,946 Army and Air Force veterans of World War II and the Korean War who had been treated for cataracts. A control sample of 2,164 veterans was selected. On the basis of military occupational specialties, they classified each individual as a radar worker, a nonradar worker, or one whose specialty could not be discerned. In the radar group, they found 19 individuals with cataracts and 2,625 individuals without cataracts; in the nonradar group, 21 individuals had cataracts and 1,935 did not. (The remaining 510 subjects were in the unspecified occupational category.) These differences between the radar and nonradar groups are not statistically significant.

In 1966, these investigators reported on statistical analysis of the records of 736 microwave workers and 559 controls for minor lens changes, using a scoring range from 0 to 3. They reported that the defect scores increased with age for persons in both groups, but that the average score for the microwave group was significantly higher than for the control group. They suggested that this finding is an indication that exposure to RFR may have an aging effect on the lens. However, no cateracts or decreases in visual aculty were found.

In a study published in 1973, which covered a period of 5 years, military personnel identified as having been occupationally exposed to RFR from radar and communications systems were matched as closely as possible in age and sex with other military personnel on the same bases who had not been occupationally exposed. Several ophthalmologists independently examined exposed and control personnel (without knowledge of the group to which each individual belonged) for opacities, vacuoles, and posterior subcapsular indescence, taken as diagnostic precursors of cataracts. Each precursor was scored as either present or absent in each individual, and the binary data thus obtained were used for statistical analyses by age group and numbers of persons per age group. The results indicated that more people in older age groups exhibited these precursors, but the pooled data from several Army installations

showed no statistically significant differences between exposed and control groups.

As in other epidemiologic studies, the accuracy and detail of the exposure histories (frequencies, intensities, durations, and so on) taken for either the exposed or the control groups in these three ocular studies are difficult to determine. However, the exposed groups quite likely did receive more RFR exposure than the control groups.

In summary, none of these U.S., Polish, and Czechoslovakian epide miologic studies offers clear evidence of detrimental effects associated with exposure of the general population to RFR. However, the Soviet findings, which are consistent with the voluminous, early Soviet literature, suggest that occupational exposure to RFR at average power densities less than 1 mW/cm² does result in various symptoms, particularly those associated with disorders of the central nervous system (CNS). Because the USSR symptomatology has not been reported in Western studies and because of the marked differences between Soviet and Western publications in the procedures used for reporting data, any prediction of possible RFR hazards based on the USSR epidemiologic studies would require acceptance of these Soviet findings at face value. We conclude that, taking all of the epidemiologic studies together, the results do not provide evidence that the RFR from the NEXRAD system will be hazardous to the general population.

C.6.2 Mutagenesis and Cancer Induction

One frequently expressed concern about RFR is that it may cause mutations. Mutagenesis and concer induction are considered to be related, and indeed many chemicals are screened for potential cancercausing properties by using bacterial mutation tests. Several studies for mutagenic effects have been carried out on bacteria, yeast, and fruit flies (standard test systems for mutagenesis). All of these studies failed to demonstrate a mutagenic effect. No mutations attributable to RFR exposure were found.

Another standard test system for mutagenesis is the so-called dominant lethal assay in which mutations result in the death of the embryo. Two studies in mice (both done by the same investigator at approximately the same time) gave marginal positive evidence of mutation. Certain aspects render these findings dubious, however. First, there was a large difference in the incidence of naturally occurring mutations between the two studies. By comparison, exposure produced very small increases in the incidence of mutations. If the value given for the natural incidence shows large variability from one study to the next, it is likely that an uncontrolled factor rather than RFR caused the observed mutations. Second, the mice used were anesthetized during exposure. Anesthesia in mice blocks the normal mechanisms for control of body temperature. Temperature rise in the testes of exposed mice might have been higher than if they were unanesthetized. Because heat

is known to be mutagenic in such tests, any true mutations may have resulted from overheating of the testes.

Another study of dominant lethal mutations, in unanesthetized rats, failed to find evidence of mutagenic effects. However, temporary sterility, as indexed by fewer pregnancies, was seen at power densities of 28 mW/cm² but not at lower power densities. The 28-mW/cm² level caused a significant increase in rectal and intratesticular temperatures.

Studies have been carried out on the effects of RFR exposure on the structure of chromosomes in cells. The occurrence of chromosomal aberrations is considered as indicating the possibility of genetic effects but not as absolute proof of such effects. In one study on garlic root tips, chromosomal aberrations were found, but the description of the exposure conditions was only sketchy. Power density could have ranged as high as 600 mW/cm2. Another study involved Chinese hamster cells and human amnion cells. Exposure to RFR did not induce aberrations. In another study, effects were seen in human lymphocyte cells, but only at power densities of 20 mW/cm2. In still enother study, effects were seen in Chinese hamster cells reportedly exposed to 200 and 500 mW/cm2, but these power densities likely were incorrect, casting doubt on the conclusions of the study. Two other studies investigated effects of RFR on sister chromatid exchange in Chinese hamster ovary cells and bone marrow cells of mice. Production of sister chromatid exchange was not related to RFR exposure.

Two papers reported studies on the effects of RFR on mechanisms involved in the repair of cellular deoxyribonucleic acid (DNA). After ultraviolet was used to damage DNA of normal human fibroblasts, RFR caused no alteration in the DNA repair process. Similarly, when mice were treated with streptozocin, a mutagenic/carcinogenic agent known to damage the DNA in rodent liver cells, exposure to RFR did not alter the level of DNA repair.

One paper has claimed an association between RFR exposure and cancer incidence. The study involved chronic daily exposure of mice to brief, high-power-density RFR. An increase in leukemia was claimed. Reexamination of the study indicates that it was improbable that the leucosis (an increase in the number of white blood cells) observed was actually leukemia.

Two other studies of chronic irradiation of mice and rats showed no effects of the exposure on a variety of general indications of health or on the occurrence of cancer.

In summary, all of the studies on mutagenic and cytogenetic effects of RFR exposure reviewed here indicate that the effects found are probably related to heating. Ground-level power densities from NEXRAD are incapable of producing significant heating. There is no evidence that such low power densities are likely to cause mutagenic effects. In

addition, a report claiming that RFR exposure has increased the incidence of cancer does not stand up to critical review: it does not provide evidence that exposure to RFR is likely to cause cancer. Other studies have failed to find an effect of RFR exposure on the general health of the exposed animals or on the occurrence of cancer.

C.6.3 Studies on Teratogenesis and Developmental Abnormalities

Teratogenesis in humans is the production of malformed infants by processes affecting their development in the womb. The term "developmental abnormalities" as used here refers to processes affecting the development of infants after birth. Teratogenic and developmental abnormalities occur naturally at a low rate in most animal species, and relatively little is known about their cause. In a few cases, however, specific agents have been shown to cause significant teratogenic effects; hence, the possibility of teratogenic effects from RFR is an appropriate matter of public concern.

Teratogenic studies with RFR have used a variety of animal models. One set of studies was performed on pupae of the darkling beetle, Tenebrio molitor. Several reports from different laboratories stated that relatively low levels of RFR would produce developmental abnormatities in the pupae. A follow-up study in one of the laboratories, however, reported that the number of developmental anomalies depended on such factors as the source of the larvae and the diet fed to them before they entered the pupal stage. This study also reported that production of developmental anomalies under worst conditions required exposure for 2 hr at a mean SAR of 54 W/kg (approximately equivalent to 192 mW/cm²).

Japanese quail eggs were exposed to 2.45-GHz CW RFR at 5 mW/cm2 (SAR of about 4 W/kg) for 24 hr/day during the first 12 days of development. The investigators found no gross deformities in the quail when euthanized and examined 24-36 hr after hatching, and no significant differences in total body weight or the weights of the heart, liver, gizzard, adrenals, and pancreas between RFR- and sham-exposed groups. Blood tests showed statistically significant higher hemoglobin (contained in red blood cells and important in oxygen transport) and lower monocyte (a form of white blood cell) counts in the RFR-exposed birds, but no differences in the other blood parameters. The differences in mean temperature from egg to egg in the RFR-exposed arrays were as much as 0.5 deg C, rendering it difficult to associate these positive findings with RFR per se. In another study by the same investigators, groups of eggs were similarly exposed and the birds were reared for 5 weeks after hatching. No significant differences in mortality or mean body weights at 4 and 5 weeks were found between RFR- and sham-exposed groups.

Teratogenic effects of RFR have been reported in several studies in mice and rats. In an early major study, pregnant mice were exposed on day 8 of pregnancy (gestation) to 2.45 GHz RFR at 123 mW/cm² for 2 to 5 min, corresponding to doses in the range 3-8 cal/g. On gestational day 18, the litters were examined for resorptions, and for dead, stunted,

malformed, and apparently normal fetuses. No abnormalities were reported at doses less than 3 cal/g, which correspond to about 25 to 30% of the lethal dose for these animals. At doses above 3 cal/g, some abnormalities were obtained, notably exencephaly, a disorder in which the skull does not close and the brain is exposed ("brain hernia").

In another investigation, pregnant mice were exposed to 2.45-GHz RFR for 100 min daily on gestational days 1 through 17 at 3.4 to 14.0 mW cm², or on gestational days 6 through 15 at 28 mW cm². Control mice were sham-exposed similarly. All mice were euthanized on day 18 and their uteri were examined for the number of resorbed and dead conceptuses and live fetuses. The live fetuses were examined for gross structural alterations and weighed. Ten types of anomalies were tabulated by the numbers of litters affected. A total of 27 of the 318 RFR-exposed litters, irrespective of power density, had one or more live abnormal fetuses, versus 12 of the 336 sham-exposed litters. For most of the individual anomalies, the numbers of litters affected were either too small for statistical treatment or no RFR-related pattern was apparent. The mean live fetal weights of the litters exposed at power densities of 14 mW/cm² or lower were not significantly different from those of the corresponding sham-exposed litters. The latter finding was confirmed in a subsequent study by these investigators. In addition, some of the mice exposed at 28 mW/cm² were permitted to come to term, and the mean weight of their offspring at 7 days of age was found to be about 10% less than that of control mice. However, there were no differences in survival rate between RFR-exposed and control offspring.

Other studies with pregnant mice at sublethal exposure levels yielded both comparable and conflicting results, presumably because of differences in experimental apparatus and procedures, but no evidence that doses less than 3 cal/g or power densities less than 1 mW/cm^2 are teratogenic.

Several similar studies were conducted with pregnant rats. In a representative recent study, 70 rats were exposed to 2.45-GHz CW RFR for 100 min daily on gestational days 6 through 15 at 28 mW/cm² (estimated SAR of 4.2 W/kg). The mean colonic temperature at the end of each exposure period was 104.5 deg F (40.3 deg C). A group of 67 rats was similarly sham-exposed. No significant differences between groups were found in: pregnancy rates; numbers of live, dead, or total fetuses; incidences of external, visceral, or skeletal anomalies or variations; or body weight of live fetuses. The investigators surmised that this lack of an effect may hold true at any exposure level less than that which will kill a significant number of the dams by hyperthermia (colonic temperature greater than 40 deg C).

In an investigation under way, 10 rats were exposed essentially continuously for 16 days to 2.4S-GHz pulsed RFR with a pulse duration of 10 μs and 830 pps. The average power SAR was held constant at 0.4 W/kg. Ten other rats were sham-exposed. In the two series of exposures performed thus far, none of the rats was allowed to come to

term. Instead, their uteri were removed and examined. In a preliminary analysis of the data, no gross visual or histological abnormalities or differences in number of offspring between the RFR and sham-exposed groups were evident.

In a study designed primarily for seeking possible effects of chronic RFR exposure on mother-offspring behavioral patterns and the EEG, 33 female squirrel monkeys were exposed near the beginning of the second trimester of pregnancy to 2.45-GHz RFR at whole-body SARs of 0.034, 0.34, or 3.4 W/kg (the last value equivalent to about 10 mW/cm² of plane-wave RFR) for 3 hr/day, 5 days/week, until parturition. Eight pregnant monkeys were sham-exposed for the same periods. After parturition, 18 of the RFR-exposed dams and their offspring were exposed to RFR for an additional 6 months; then the offspring were exposed without the dams for another 6 months. No differences were found between RFR- and sham-exposed dams in the numbers of live births or in the growth rates of the offspring. The major difference between RFR- and sham-exposed offspring was that four of the five exposed at 3.4 W/kg both prenatally and after birth unexpectedly died before 6 months of age, but the mortality values were too small to place much confidence in statistical inferences. A follow-up study of mortality per se, which involved sufficient numbers of squirrel monkeys for adequate statistical treatment, did not confirm the RFR-induced offspring mortality results.

In summary, the studies showing demonstrable teratogenic effects following exposure to RFR have involved power density levels that are capable of producing a significant heat load in the animals. In general, the results indicate that a threshold of heat induction or temperature increase must be exceeded before teratogenic effects are produced. Because the heat-load increase in humans from RFR exposure at the average power densities of NEXRAD will be very small relative to the normal metabolic rate of about 1 to 2 W/kg, teratogenesis in humans from such exposure is not likely to occur.

C.6.4 Ocular Effects

The fear that RFR can cause cataracts is a recurring theme in newspapers and other popular media. Indeed, based on many investigations with animals by various researchers, it is undoubtedly true that if a person's eyes were exposed to intensities high enough to elevate the temperature of the lens by about 5 deg C (9 deg F) or more, the lens would quickly suffer damage. The lens is the region of the eye most vulnerable to RFR because other regions have more effective means of heat removal, such as greater blood circulation, evidenced by much smaller temperature elevations in these regions than in the lens at the same incident power density. Therefore, the basic controversy regarding ocular effects is centered on whether exposure to much lower intensities (i.e., to power-density levels that would produce much smaller lens temperature elevations) for long periods of time, either continuously or intermittently, can cause eye damage. Implicit in this controversy is

the issue of whether effects (if any) of long-term, low-level exposure in the eye are cumulative.

C.6.4.1 Humans

Some cases of ocular damage in humans ascribed to occupational exposure to RFR were reported during the 25 years after World War II. Although the exposure histories of these individuals could not be ascertained with any degree of certitude, their actual or incipient vision impairment probably resulted from exposure to average power densities substantially greater than the threshold found in animal studies (about 150 mW/cm²).

The occurrence of cataracts in two editors with the New York Times was ascribed, in newspaper accounts during 1977 and 1978, to their exposure to supposed RFK from the cathode ray tubes in video-display terminals used by them. Cases of RFR induced birth defects and abortions were also linked, in other newspaper stories, to exposure to video terminals. The New York Times arranged for measurement surveys of the terminals in question. These surveys yielded negative results; the only measurable radiations emitted by the terminals were well above the RFR spectrum. Independent surveys of the same terminals by personnel from NIOSH confirmed these findings.

Epidemiologic studies have been conducted to determine whether prolonged exposure to RFR is cataractogenic. These studies were discussed in Section C.6.1.

C.6.4.2 Animals

During the past 30 years, various investigations have been conducted on the effects of RFR exposure on the eyes of live experimental animals. Hany of the results indicate that intraocular temperature increases of about 5 deg C or more are necessary for eye damage. Also, lens opacifications caused by RFR exposure alone were not produced at the same average power density when the eye was cooled during exposure.

Many of the results of RFR exposure indicate the inverse relationship between everage power density and exposure duration for cataract formation and the existence of a threshold average power density of about 150 mW/cm² for single or multiple exposures for tens of minutes or more.

Several investigators compared the ocular effects of pulsed and CW RFR at equivalent average power densities. In representative investigations, the average power densities were greater than 100 mW/cm² and the exposures were for about 1 hr/day for several weeks. No significant differences between the effects of pulsed and CW RFR were found.

The existence of a cataractogenesis threshold implies that single or multiple exposure for indefinitely long durations at average power densities well below the threshold would not cause eye damage to humans or any other species.

In summary, based on the experimental results with animals indicaling the existence of a threshold power density of 150 mW/cm² and on the finding of no statistically significant differences between exposed and control groups of humans on military bases, there is no evidence that prolonged exposure of humans to the ground-level RFR from NEXRAD is likely to cause eye damage.

C.6.5 Studies of the Nervous System

Several types of studies have been conducted on effects of RFR on the nervous system of animals. These studies are considered particularly important in the USSR, where RFR is believed to stimulate the nervous system directly and thereby cause a variety of physiological effects. U.S. scientists tend to doubt that RFR interacts directly with the nervous system except, possibly, under special circumstances (to be discussed later in this section); they consider most effects of RFR on the nervous system to be indirect results of other physiological interactions.

C.6.5.1 RFR Hearing Effect

Humans in the vicinity of some types of pulsed radar systems have perceived individual pulses of RFR as audible clicks (without the use of any electronic receptors). This phenomenon has attracted much interest -especially in the United States--because it has often been cited as evidence that nonthermal effects can occur and because an initial hypothesis was that one possible mechanism for perception is direct stimulation of the central nervous system by RFR. Various theoretical and experimental studies, the latter with both human volunteers and laboratory animals, have been conducted to determine the conditions under which pulsed RFR is audible and to investigate the interaction mechanisms involved. Many of the results support the hypothesis that an RFR pulse having the requisite pulse power density and duration can produce a transient thermal gradient large enough to generate an elastic shock wave at some boundary between regions of dissimilar dielectric properties in the head, and that this shock wave is transmitted to the middle ear, where it is perceived as a click. Persons with impaired hearing are unable to hear such clicks, and experimental animals in which the cochlea (the inner ear) has been destroyed do not exhibit brainstem-evoked responses.

Investigators used 3.0-GHz RFR to study the auditory effect in two cats, two chinchillas, one beagle, and eight human volunteers. For the animals, surface or brainstem-implanted electrodes were used to measure the responses to RFR pulses and the responses evoked by audio clicks from a speaker. They found that perception of 10-us pulses required

pulse power densities of at least 1.3 W/cm^2 for both cats, 1 and $2 W/cm^2$ for the two chinchillas, and 300 mW/cm^2 for the beagle.

The eight humans were given standard audiograms. Because such audiograms do not test hearing above 8 kHz, binaural hearing thresholds were also determined for seven of the subjects for frequencies in the range from 1 to 20 kHz. Five of the subjects could detect 15-µs pulses as clicks; the other three required a pulse duration of 200 µs for perception. No correlation between the results and the audiograms was apparent; however, there was a strong correlation between RFR perception and hearing ability above 8 kHz as determined from the binaural thresholds. The average threshold pulse power density for 15-µs pulses was about 700 mW/cm²; however, three of the subjects were able to perceive 15-µs pulses at a pulse power density of 300 mW/cm², a value taken hercin as representative for humans.

Thus, humans at ground level near a NEXRAD antenna would not likely "hear" the RFR pulses. However, airborne people in the main beam may hear the pulses if they approach closer than about 3,000 ft. Within this range, the pulse power density in the main beam will not exceed about 8,000 mW/cm². It should be noted that these investigators exposed the human volunteers to pulse power densities as high as 2,000 mW/cm² without apparent ill effects.

C.6.5.2 Calcium Efflux

Exposure of brain-tissue samples from newly hatched (neonatal) chicks to RFR amplitude-modulated at low frequency has been reported to increase the rate of exchange of calcium ions between the tissue and the fluid bathing it. This effect has been demonstrated by two groups of investigators for modulated carrier frequencies of 50, 147, and 450 MHz, as well as for exposure to the modulation signal (16 Hz) alone, but not for unmodulated 50-, 147-, or 450-MHz RFR. Incident power densities that are effective in altering the rate of calcium exchange lie between approximately 0.1 and 3.6 mW/cm2. However, within this range, not all power densities are effective. There appear to be narrow, effective power-density "windows." Calculations of internal field intensity appear to indicate that this factor is important in predicting effectiveness. The mechanisms whereby modulation effects are mediated are speculative. Of additional interest is a report that 16-Hz amplitude modulated 147-MHz RFR at 2.0 mW/cm² increases calcium efflux from pancreatic tissue slices to approximately the same extent as that from neonate chick brain tissue incubated and exposed under similar conditions. An attempt to obtain alterations in calcium efflux from rat brain tissue by use of pulse-modulated 1-GHz RFR was unsuccessful. It is uncertein whether these negative findings were a result of differences in brain tissue, exposure parameters, carrier frequency, or type of modulation.

All of the above studies were carried out on isolated tissues maintained in physiological solutions. A recent study has reported that similar alterations in calcium ion exchange occur for exposed brains of

paralyzed live cats irradiated at 3 mW/cm² with 450-MHz RFR sinusoidally amplitude modulated at 16 Hz.

The effect is scientifically interesting in that it represents a rare instance where RFR may be producing a biological effect by processes other than thermal mechanisms. Interpreting these results with regard to human health and safety is difficult. First, the phenomenon is subtle. Large numbers of samples have to be processed to show a statistically significant effect. Second, the observations are highly variable and difficult to reproduce. Third, the circumstances of the experimental methodology are such that the observations of changes of calcium exchange appear to apply to the surface region of the brain rather than to the brain as a whole. Finally, the phenomenon depends on the amplitude modulation of the RFR in a narrow frequency band around 16 Hz and occurs only for narrow ranges of average power densities (windows) between 0.1 and 3.6 mW/cm². Nevertheless, because this range is above the levels of general public exposure from NEXRAD, the occurrence of this effect in humans is unlikely.

C.6.5.3 Blood-Brain Barrier Effects

In most organs and tissues of the body, molecules in the blood can freely diffuse into the tissue around the capillaries. However, presumably to protect the brain from invasion by various blood-borne microorganisms and toxic substances, large molecules such as proteins or polypeptides exhibit little or no movement from the blood into the surrounding brain tissue in most regions of the brain. The exact manner by which the movement is prevented is still conjectural, but the process is referred to as the "blood-brain barrier" (8BB). The BBB can be "opened" by certain agents (e.g., ionizing radiation, heat) or chemical substances (e.g., DMSO). Studies have been conducted to examine whether RFR also can alter the BBB permeability of animals to various large molecules.

Four studies by two separate research groups have reported gross permeability increases in the rat 8BB when the brain temperature was raised significantly (e.g., several degrees) by RFR heating, or, equivalently, the local SAR was several hundred watts per kilogram. Other researchers found scattered regions in the brain displaying permeability changes for 2-hr exposure at 10 mW/cm². Twenty percent of the shamexposed animals also showed these changes, which were reversible. The 10-mW/cm² value may represent the lower limit at which local regions of the brain are heated.

One study reported alterations in BBB permeability to fluorescein by use of pulsed RFR at average power densities as low as 0.2 mW/cm^2 . These findings could not be repeated by three other groups using fluorescein and similar experimental procedures.

Another study reported increased BBB permeability to radiotracer-labeled molecules at average power densities less than 3 mW/cm², with pulsed RFR more effective than CW RFR. Three other research groups could not repeat these findings. Subsequently, the researchers first reporting the effect used a higher average power density (15 mW/cm²) and different techniques, and showed that their original findings could be explained as an increase in local cerebral blood flow rather than as an increase in BBB permeability. (Local cerebral blood flow can be altered in humans by mental activity in the absence of external physical stimuli.)

In summary, RFR can alter BBB permeability at exposure levels sufficient to cause heating of the brain. Exposure to levels considered insufficient to cause heating (below several mW/cm²) have also been reported to alter BBB permeability, but these results have not been confirmed, despite several independent attempts to do so. In one case, the original findings may have arisen as a consequence of the experimental techniques used. On the basis of the evidence available, it is very unlikely that exposure of people to the levels of RFR from NEXRAD at ground level would have any effect on the permeability of the BBB.

C.6.5.4 Histopathology and Histochemistry of the Central Nervous System

Histopathology is defined as the study of diseased or damaged tissues, and histochemistry as the study of the chemical composition of various tissues. Studies of histopathological effects of RFR on the brain have been conducted in both the United States and the USSR. Studies in the USSR have covered a wide range of frequencies, but the dosimetry and methods were inadequately reported in many instances. Exposure of animals (predominantly rats) to RFR between 500 MHz and 1 GHz (no additional information on frequency) at 10 mW/cm2 for 1 br/day for 10 months resulted in various changes from the normal appearance of nerve cells of the brain, as detected by delicate elective neurohistological methods (not otherwise specified). The authors reported that the power density did not raise body temperature, but current knowledge indicates that the method of exposing the animals was such that the SAR must have varied considerably among the animals. reported changes in appearance were similar to those found in other experiments of a frankly thermal nature (20 to 240 mW/cm²), and it is most probable that the reported effects in the chronic exposure experiments were also of thermal origin.

In the United States, a study of the histopathological effects of RFR on the brain was performed on hamsters exposed to 2.45-GHz RFR at power densities between 10 and 50 mW/cm² for periods between 30 min and 24 hr. Chronic exposures were also carried out at similar power densities over a period of 22 days. In this study, pathological changes were found only in the hypothalamus and subthalamus, two regions near the center and base of the brain. Comments after oral presentation of this study noted that the nature of RFR absorption inside the skull of such a small animal at the frequency used could lead to regions in the

brain where the SAR would be tens of times higher than that expected from the nominal power density and that rectal temperature measurements in the animals would not reflect such a condition. The observed pathological effects seem likely to have resulted from thermal processes. Quantitative studies on the effects of RFR at relatively high levels (10 to 46 mW/cm², SAR approximately 2 W/kg) on ret Purkinje cells of the cerebellum (a distinctive cell type in this region of the brain) showed that RFR exposure pre- and post natally caused a significant decrease in numbers of these cells. However, a similar study using squirrel monkeys did not show such an effect. Size differences between the heads and brains of the rat and squircel monkey may have resulted in high local SAR in regions of the rat brain, but not in similar regions of the squirrel monkey brain, again indicating that the observed effects seem likely to have resulted from thermal processes.

Two studies were reviewed that examined effects of RFR on brain neurochemistry. One showed no effects on specific neurotransmitters of mouse brain at 19 MHz for near-field exposure conditions of 6 kV/m (E field) or of 41 A/m (H field) for 10 min. The other showed a sequence of small (5 to 10%) changes of biochemical activity in subcellular components associated with tissue respiration at exposure levels of 5 and 13.8 mW/cm². The significance of these latter findings is unclear, but they are unlikely to be indicative of a hazard because of the wide range of tissue respiration values possible under various environmental and activity situations.

In summary, RFR can cause observable histopathological changes in the central nervous system (CNS) of animals, but these changes appear to be thermal in nature. Under special conditions of frequency and skull size, a focusing effect can be obtained in small rodents, causing local SARs tens of times higher than would normally be expected from whole-body SAR measurements. Such conditions do not occur for the adult human skull. One study has reported small changes in brain-tissue respiratory chain function at a power density of 5 mW/cm². It is unlikely that such effects would be detectable at the ground-level power densities of NEXRAD. These studies provide no evidence that exposure to such power densities are likely to be hazardous.

C.6.5.5 EEG Studies

Studies have been conducted to ascertain the effects of RFR on the ERG or other related electrophysiological properties of the CNS. For ERG measurements made after RFR exposure, the time consumed in placing and attaching the electrodes and the variability of placement introduce problems of interpretation. Additionally, if the effects are transient, they may stop then exposure ceases. For studies attempting to measure EEG changes during application of the RFR, the electrodes and leads used to pick up EEG signals also pick up electrical signals directly from the fields, causing artifacts that render the recordings difficult to interpret. In addition, indwelling or chronically attached electrodes will perturb the electric fields in their vicinity and

produce great enhancement of energy absorption, thereby creating still another artifact in the biological data. To meet these problems, specially designed indwelling electrodes of high-resistivity materials that do not cause field perturbation have been constructed and used in a few of the more recent studies.

Two groups of researchers, using implanted metallic electrodes. reported changes in EEG patterns after acute or chronic exposure of rabbits to RFR. Another group, using implented electrodes made of carbon instead of metal (an attempt to avoid the field distortion artifact), reported no significant differences in EEG between irradiated and control rabbits after 3 months of RFR exposure (1.5 mW/cm2, 2 hr/day). Another study, using electrodes externally placed after exposure rather than indwelling ones, reported no differences in EEG pattern between control and RFR-exposed monkeys after more than 12 months of exposure. A study of rats exposed to RFR from before birth to age 92 days (indwelling electrodes again not used) showed no differences from control animals when both groups were tested at 140 days of age. Lastly, the EEGs of rabbits having indwelling carbon-loaded Teflon (high resistance) electrodes were examined before and during exposure to 2.45-GHz RFR at 100 mW/cm2 (SAR of about 25 W/kg at the electrodes), and no obvious differences were found.

In summary, the use of indwelling metallic electrodes in studies of the effects of RFR on the EEG or on evoked potentials of the CNS may be questioned as a procedure likely to introduce artifactual effects in the preparation under study, as well as in the recordings themselves. These artifacts may be minimized by use of electrodes appropriately designed from high resistivity materials. Experiments in which such specially constructed electrodes were used, or in which electrodes were applied after exposure, show no evidence of statistically significant differences in EEGs or in evoked responses between control and RFR-exposed animals. There is no evidence that ground-level RFR from NEXRAD is likely to cause any effects on the EEG or evoked potentials of humans.

C.6.6 Effects on Behavior

Many experimental studies have been conducted on the effects of RFR on animal behavior. The results of such studies are considered particularly important in the USSR, where they are often considered to be evidence for direct effects of RFR on the CNS. Scientists in the United States do not always agree that behavioral effects necessarily imply direct effects on the CNS. However, behavioral effects are very sensitive indicators of biological function and hence receive appropriate attention in both Eastern European and Western countries. The papers described in the RFR-bioeffects review were selected as representative of the types of behavioral studies that have been conducted. These include studies of effects on reflex activity, RFR-perception studies, evaluations of effects of RFR on learning and on performance of trained tasks, studies of interactive effects of RFR and drugs on behavior, and

investigations of behavioral thermoregulation. Studies have been conducted on mice, rats, rabbits, squirrel monkeys, rhesus monkeys, and humans.

Soviet studies have claimed that exposure of rats to RFR at power densities as low as 0.01 mW/cm² for 10 days or more have resulted in disturbance of many inborn forms of behavior, including conditioned reflex activity. The validity of these claims is difficult to assess, however, because the reports of the experiments lack details. Attempts were made to repeat the studies in the United States, but using higher power densities. No effects on reflex development were seen at power densities up to 10 mW/cm² for durations up to 92 days. Soviet reports of effects at low (equal to or less than 0.5 mW/cm²) power densities under long-term exposure conditions and the absence of similar effects in the same or higher power-density range in the studies of U.S. researchers have appeared frequently in the RFR-bioeffects literature.

The RFR hearing effect is, by definition, perception of pulsed RFR. Other studies with CW or modulated RFR have been conducted to determine whether perception can serve as a behavioral cue, and some studies have indicated that rats modify their behavior in response to pulsed RFR at average power densities as low as 0.2 mW/cm². As discussed in Section C.6.5.1, however, average power densities are meaningless in the perception of pulsed RFR. Pulse power density is the meaningful parameter, and humans appear to be able to perceive pulse power densities of about 300 mW/cm² and higher. By contrast, CW RFR is an extremely feeble perceptual cue, with tens of milliwatts per square centimeter (average power density) necessary to modify behavior, unless the RFR is accompanied by other perceptual cues such as light or sound. This is borne out in studies on humans, where the threshold for perception of warming of the skin is 27 mW/cm².

Acute exposure to RFR will suppress performance of learned tasks and the learning of new tasks in rats, squirrel monkeys, and rhesus monkeys at sufficiently high power densities (generally 5 mW/cm² and up). The effect depends on duration of exposure, animal species, frequency of RFR, power density, and demand characteristics of the behavior. A reasonable conclusion is that suppression of learned behavior tasks depends on the amount and distribution of energy absorbed by the animal. Chronic exposure produces similar results, but with a slight reduction in minimum power density required (1 mW/cm² and up).

Studies on the interaction of RFR and drugs in rats that affect the CNS have yielded interesting results. Pulsed 2.45-GHz RFR at an average power density of 1 mW/cm² (SAR of 0.2 W/kg) was found to enhance the effects of dextroamphetamine, a CNS stimulant, and chlordiszepoxide and pentobarbital, CNS depressants. By contrast, pulsed 2.8-GHz RFR at 1 mW/cm² did not produce any alterations in the behavioral dose-effect functions of chlorpromazine or diszepam, two other commonly prescribed CNS depressant drugs. Mechanisms of this synergism between RFR and certain drugs, but not others, are unclear at present.

Studies specifically designed to examine thermoregulatory behavior in rats and squirrel monkeys, using 2.45-GHz RFR, have shown alterations in behavior at power densities from 5 to 20 mW/cm² in the rat and at 6 to 8 mW/cm² in the squirrel monkey. In addition, mice have been shown to orient themselves to reduce the percentage of RFR energy absorbed where they might otherwise have become overheated. Behavioral thermoregulation depends on the existing environmental situation. The 5-mW/cm² level appears to be the threshold value necessary to elicit a behavioral thermoregulatory response.

In summary, RFR is capable of producing alterations in a wide variety of behaviors of various species of animals. Except for pulsed RFR, average power densities required to modify behavior are almost all at levels of approximately 5 mW/cm² and above, and most appear to be in the thermal range. Perception of pulsed RFR as sound is a peak-power phenomenon, not one of average power. It is difficult to relate most of the behavioral studies in animals to humans. All behavioral studies are directly relevant to the nature of the species being studied, and the conclusions of a given study do not readily transfer to other species. Because of the power densities needed to cause reported effects, however, these studies provide no evidence that exposure to ground-levels of RFR from NEXRAD is likely to have adverse effects on human behavior.

C.6.7 Endocrinological Effects

Exposure of animals to RFR has produced somewhat inconsistent effects on the hormone-secreting (endocrine) system of manmals. In general, the effects produced appear to be related to either the heat load associated with the RFR or the stress induced in the animals by the RFR and, possibly, other experimental circumstances. Some effects also appear to be related to alteration of the circadian rhythm by RFR. There do not appear to be any effects clearly demonstrated to be associated with nonthermogenic stimulation of the endocrine system or the associated parts of the CNS.

Because of the known sensitivity of the testes to heat, several investigations of the effects of RFR on gonadal function have been conducted. In one early study, mice were exposed to 9.27-GHz RFR at 100 mW/cm² for 4.5 min/day (which increased mean body temperatures by 3.3 deg C) for 5 days/week over 59 weeks. Testicular degeneration was found in 40% of the RFR-exposed and in 8% of the control mice that had died during the course of the experiment. Recently, other investigators reported that exposure of mice to 2.45-GHz RFR at 20 to 32 mW/cm² for 16 hr/day for 4 days had no effect on sperm count or percentages of abnormal sperm.

In another recent investigation, the rear halves of anesthetized mature male mice were exposed to 2.45-GHz RFR for 30 min at half-body SARs ranging from 18 to 75 W/kg, which produced elevated rectal temperatures. For comparison, the rear halves of other anesthetized mice

were immersed for 30 min in a well, heated to yield comparable rectal temperatures. Extensive degeneration of the sperm-generating cells was evident for RFR exposure at 75 W/kg and for well heating to 45 deg C. At SARs of 37 W/kg or lower or a well temperature of 37 deg C, no effects were seen. Measurements of testicular temperature indicated the existence of a threshold of about 39 deg C for depletion of spermatocytes and of about 41 deg C for 50% cell death after 6 days of RPR exposure or direct heating. The corresponding SARs for these two thresholds were 20 and 30 W/kg.

Men occupationally exposed to RFR in the 3.6- to 10-GHz range at power densities of tenths to hundredths of a mW/cm² for 1 to 17 years (a mean of 8 years) were reported to show slightly reduced sperm counts, but normal plasma levels of hormones that control the functioning of the gonads.

Stimulatory effects on the thyroid glands of dogs were obtained from local exposure of one of the two thyroids to 2.45-GHz RFR for 2 hr at 72, 162, or 236 mW/cm². The SARs in the exposed gland were 58, 121, and 190 W/kg, respectively, and the corresponding temperatures were about 102, 106, and 113 deg F. In response, the exposed glands increased their output of thyroxine (a hormone that controls the metabolic rate in other cells) by factors of 1.5, 3.5, and 10, an effect attributed to the temperature rise. At the ground levels of RFR from NEXRAD, no temperature rise would occur; therefore, this effect would be absent.

The necessity for minimizing stresses induced in rats by factors other than RFR by allowing them to become accustomed to the experimental situation ("gentling" them) before RFR exposure was demonstrated in several investigations. With the use of such a procedure, endocrinological effects ascribable to RFR exposure can be more readily discerned from those due to non-RFR stresses, but the latter are difficult to eliminate entirely. In a recent study, gentled rats were exposed to 2.45-GHz RFR at power densities ranging from 1 to 70 mW/cm2 (equivalent SARs of 0.21 to 14.7 W/kg) for periods ranging from 1 to 8 hr at an environmental temperature maintained at 24 deg C. Sham-exposed rats were used as controls. After treatment, the rats were decapitated, colonic temperatures were taken, and blood was collected for assays of thyroxine, thyrotropin (a hormone secreted by the pituitary gland), growth hormone (also secreted by the pituitary), and corticosterone (secreted by the adrenal gland). For exposures of 1 hr, colonic temperatures increased with power density at 20 mW/cm2 and higher, but consistent elevation of serum corticosterone did not occur below 50 mW/cm2. Lower serum thyrotropin and growth hormone levels also occurred at this and higher power densities. For sham exposures and exposures at 1-20 mW/cm2 for longer durations (2-8 hr), the results were rather equivocal, presumably because such exposures encompassed significant portions of the circadian cycle.

Exposure of warm-blooded animals to RFR has been found to affect their involuntary thermoregulatory mechanisms. In a recent study, squirrel monkeys were exposed to 2.45-GHz CW RFR for 10 min or 90 min in relatively cool ambient temperatures of 59, 68, or 77 deg F. The power densities ranged from 2.5 to 10 mW/cm² (SARs from 0.4 to 1.5 W/kg). The metabolic heat production was calculated from the oxygen deficit in the expired air of each monkey. At all three ambient temperatures, 10-min exposures of two monkeys to a threshold power density of 4 mW/cm² and one monkey to 6 mW/cm² reliably initiated a reduction of their metabolic heat production, and the magnitudes of the reduction were linear functions of the power density above the threshold values.

This investigator also exposed squirrel monkeys to RFR in ambient temperatures ranging from about 90 to 95 deg F. After an initial 90-min or longer equilibration period, each monkey was exposed for 10-min periods to power densities in an increasing sequence from 2.5 to 20 mW/cm², with sufficient time between exposures for reequilibration. The results indicate that at ambient temperatures below about 97 deg F, at which sweating in a sedentary monkey may occur spontaneously, the threshold power density (or SAR) for initiating thermoregulatory sweating decreased with decreasing ambient temperature.

In summery, although some of the effects of RFR exposure on the endocrine system appear to be relatively straightforward and predictable from physiological considerations, other, more subtle effects require further study, notably those related to the interactions among the pituitary, adrenal, thyroid, and hypothalamus glands and/or their secretions. Part of the problem in interpreting results appears to arise from uncertainties regarding stress mechanisms and accommodations thereto. Animals placed in novel situations are much more prone to exhibit stress responses than animals that have been adapted to the situation. However, there may be large variations in adaptation among animals in a given situation or among experimental situations in different laboratories.

In conclusion, because the reported effects of RFR on the endocrine systems of animals are largely ascribable to increased thermal burdens or stresses engendered by the experimental situation, or both, there is no evidence that such effects would occur in humans exposed to the RFR from NEXRAD.

C.6.8 Immunological Effects

Various reports indicate that RFR has definite effects on the immune system of mammals. Most of the reported effects were detected after exposure at power density levels of about 10 mW/cm² and higher; a few were detected following exposure to power densities as low as about 0.5 mW/cm²; and in some cases, effects obtainable with the higher power-density range were not found at lower power densities. In most studies, the mechanisms for the effects seen were not investigated, and the various reports are somewhat inconsistent. Because of the complexity

of the immune system and the variety of test procedures used, the representative studies discussed in this subsection are grouped into appropriate categories.

C.6.8.1 In Vitro Studies

An important question is whether human or animal lymphocytes (a type of white blood cell of key importance in the immune system) can be stimulated by RFR exposure to transform into lymphoblasts (mitotically active form of lymphocytes) and undergo cell division (mitosis). In vitro studies directed toward this question are those in which lymphocytes are removed from the body, cultured, exposed to RFR (or exposed, then cultured), and examined for RFR-induced effects. Usually such cells are cultured in the presence of a mitogen (an agent, usually chemical) that stimulates blastic transformation (i.e., lymphocyte to lymphoblast) and cell division.

One of the early investigators cultured specimens of human lymphocytes, added the mitogen phytohemagglutinin (PHA) to one set of specimens, and exposed groups from both sets to 2.95-GHz pulsed RPR at an average power density of either 7 or 20 mW/cm² for various durations. The results for the PHA-stimulated cultures showed no significant changes in percentages of blastoid forms, but there were significant decreases in percentages of lymphocytes and increases in the mitotic index correlated with exposure duration. However, another investigator endeavored to repeat these experiments with human lymphocytes, but encountered difficulties in obtaining reproducible results. He implicated uncontrolled temperature increases in the specimens (which were not cooled during exposure) as the problem.

In a representative recent study, bone marrow cells from mice were prepared and exposed at constant temperature to 2.45-GHz RFR for 15 min at 30 to 1,000 mW/cm² (SARs of 60 to 2,000 W/kg). Similar specimens were sham-exposed. Cell samples were then treated with a colony-stimulating factor, permitted to grow in an appropriate medium, and examined on days 5-7 and 12-14 following exposure. No significant differences were found at either time between the number of colonies from sham-exposed samples and from the samples exposed at 30 mW/cm² (SAR of 60 W/kg). However, at higher power densities, the ratio of the number of colonies from RFR-exposed to sham-exposed samples was found to decrease with increasing power density.

In another investigation, bone-marrow specimens from children with acute leukemia in remission or other disorders were similarly exposed. Again, no significant differences between RFR- and sham-exposed specimens were obtained at 31 and 62 mW/cm² (SARs of 62 and 124 W/kg). Thus, negative results are obtained when the temperature of the cell suspension is held constant (at 37 deg C) during RFR exposure.

C.6.8.2 In Vivo Studies: Acute Exposures

In most <u>in vivo</u> investigations involving acute (i.e., short-duration) exposures, live animals were exposed one time for a period typically ranging from a few minutes to an hour at power densities high enough to produce substantial temperature increases in various tissues or organs or of the body as a whole. In general, the effects of such acute RFR exposure on the immune system appear to be stimulatory. The number of circulating lymphocytes in the blood increases, as does the ability of the immune system to manufacture antibodies to foreign substances. The number of cells involved in production of immune complement (a complicated series of interacting chemicals in he blood) also increases. The mechanisms of those effects are not completely understood, but in some cases they may be a secondary result of the stress induced in the animals by the RFR-produced heat or by other stresses, such as from handling.

In a study selected to illustrate the complexity of this topic, mice were exposed to 2.45-GHz RFR for 30 min/day at 5 to 15 mW/cm2 (SARs of 3.7 to 11 W/kg) for 1 to 17 days, after which the spleens were removed and cells therefrom were cultured for 72 hr with or without one of several mitogens. Tritiated thymidine, a radioactively labeled substance whose uptake is an indication of the DNA synthesis involved in cell proliferation, was added 4 hr before the end of the culturing period. The cells were then harvested and assayed for thymidine uptake. Plots of uptake versus exposure duration showed biphasic or cyclical responses for cells from both mitogen-stimulated and nonstimulated cultures from the RFR-exposed mice. The investigators suggested that such cyclical fluctuations could account for the differences in results from various laboratories. However, similar plots for the sham-exposed mice also showed cyclical fluctuations. evidently resulting from factors other than RFR, such as circadian rhythms and estrus cycle changes in female mice; therefore, it was impossible to ascertain the proliferative effects of RFR per se. In another part of the study, RFR exposure at 15 mW/cm2 for 5 days (30 min/day) did not diminish the effectiveness of lymphocytes against leukemic cells injected after, or concurrently with, the last exposure.

In a series of investigations, exposure of mice to thermogenic levels of RFR produced increases in the numbers of splenic B-lymphocytes (one of several subclasses). There is also experimental evidence for the existence of a threshold energy absorption (about 10 J/g) for this effect and for the dependence of the effect on genetic factors.

C.6.8.3 In Vivo Studies: Effects of Chronic Exposures on Immunological Parameters

In many investigations involving chronic (long-term) exposures of animals to RFR, changes in various components of the immune systems of usually healthy animals are sought, under the often tacit assumption that such changes could be detrimental (or perhaps beneficial) to the subjects exposed. Investigations of this kind are discussed next. Other in vivo investigations are directed toward determining whether chronic exposure to RFR actually alters the incidence or severity of diseases imparted to the subjects. Studies of the latter kind are described in the next section.

In a representative early study, exposure of mice to pulsed 2.95-GHz RFR at an average power density of 0.5 mW/cm² for 2 hr/day, 6 days/week over 6 weeks was reported to cause general stimulation of the immune system. This effect diminished when the exposure was extended to 12 weeks, suggesting that the mice were adapting to the RFR.

Most of the recent investigations involving chronic exposure showed no significant alterations of the immune system. In one such study, pregnant mice were exposed to 100-MHz CW RFR for 4 hr daily from day 6 of pregnancy to parturition. On birth, several male pups were exposed similarly until age 20-22 days, others until 40-42 days, and the remainder until 97 days. The SARs varied with body mass, ranging from a mean of about 2 W/kg for the pregnant dams to about 3 W/kg for the newborn rats. No significant differences in counts of red blood cells, counts of the various types of white blood cells, or the other standard blood tests were found between blood samples of RFR- and sham-exposed rats taken at ages 22 and 42 days. In addition, stimulation by mitogens produced no significant differences in lymphocyte response. The pups removed at age 22 days were immunized with purified pneumococcal polysaccharide. Blood samples taken 5 days later showed no significant differences in antibody levels of RFR and sham-exposed rats.

In a current study, rats are being exposed for 22 hr/day over their entire lifetimes to circularly polarized, pulse-modulated 2.4S-GHz RfR at peak and average power densities of 12S and 0.5 mW/cm², respectively. These exposure values were selected to simulate, by scaling considerations, chronic exposure of humans to 4SO-MHz RfR at an average power density of 1 mW/cm². The latest results (through the 21st month) indicate no significant differences between RfR- and sham-exposed rats in immunological parameters.

C.6.8.4 <u>In Vivo Studies: Effects of Chronic Exposures on Health and</u> Disease

Relatively few studies have been conducted to determine whether chronic exposure to RFR elters the resistance to, or the severity of, diseases accidentally acquired or purposely given to animals. Such studies have been difficult to conduct, and reliable, consistent results have been hard to achieve.

In an early study, the investigators observed that mice exposed to 9.3-GHz pulsed RFR at $100~mW/cm^2$ average power density for 4.5~min/day over 59 weeks appeared to have more resistance than controls to a pneumonia infection accidentally introduced into the colony; however,

this was an incidental observation, not the results of a planned experiment.

Subsequent studies yielded mixed results, some indicating that RFR exposure is beneficial and others that it is detrimental to the animal challenged with specific pathogens. However, the results of both kinds indicate that the effects were essentially due to the heat produced by the RFR.

In a recent study, groups of mice were immunized against Streptococcus pneumoniae and then sham-exposed or exposed 2 hr/day for S successive days to 9-GHz pulsed RFR at an average power density of 10 mW/cm² (calculated SAR of 3.3-4.7 W/kg). Another group injected with saline but not exposed served as controls. On day 6 after immuni zation (the day after exposure), blood samples were taken for various tests, the mice were challenged with a dose of virulent streptococcus that is normally fatal to 50% of the mice, and the number of deaths per day were noted for 10 days after challenge. The RFR-exposed mice had significantly higher levels of circulating antibodies (about 28%) than the sham-exposed mice, but there were no significant differences between the groups in red and white blood cell counts or other standard blood tests. No antibodies were detected in the saline-injected mice. Ten days after challenge, 25 of the 53 RFR-exposed mice and 27 of the 54 sham-exposed mice had died, a nonsignificant difference. However, the greatest number of deaths in one day in the RFR-exposed group (10) occurred on day 6, whereas 14 of the deaths in the sham-exposed group occurred on day 3. The authors suggest that the RPR caused a greater initial neutralization of the pathogens, but not enough to produce complete recovery. No saline-injected mice survived the challenge.

C.6.8.5 Summary of Immunological Effects

RFR does appear to have effects on the immune system of mammals. Some of the reported effects were obtained at low power-density levels, but most of the studies were performed at relatively high power densities; in some cases, effects obtained at high power densities were not found at lower power densities, suggesting the possibility that power density thresholds exist. Some of the results indicate immunosuppressive effects; some indicate immunostimulative effects; and others, both kinds of effects. Also, results from various laboratories obtained under apparently comparable conditions are sometimes contradictory, an indication of the probable presence of uncontrolled factors or subtle differences in the experimental protocols. Based on current findings, it appears that in vivo RFR-induced effects on the immune system are dependent to varying degrees on the ages of the experimental subjects, the frequency and average power density of the RFR (or the whole-body SAR resulting therefrom), the exposure duration and perhaps the time of day when the exposures are given, the 'tind of exposure system used (which affects the internal SAR distributions within the animals), and the kind of endpoint analyses undertaken and when they are performed relative to the completion of exposures.

Reported in vivo effects on the immune systems of animals from chronic exposure to RFR at average power densities below 1 mW/cm² are unlikely to be linked simply to temperature increases, but such results have not yet been replicated elsewhere. In most other in vivo investigations, such as those discussed herein, the exposures were at average power densities exceeding 1 mW/cm². The existing evidence indicates that some of the immune-system effects are probably mediated through the effect of RFR on the endocrine system, involving the general syndrome of adaptation to stress. The mechanisms and significance of such effects are not yet understood, nor have individual findings been independently verified. There is currently no evidence that reported RFR effects on the immune systems of animals would occur in humans chronically exposed to the levels of RFR from NEXRAD, or that such effects would be hazardous to human health.

C.6.9 Biochemical and Physiological Effects

The literature on biochemical and physiological effects associated with RFR is extensive. Many of the reported effects are associated with other events (e.g., changes in hormonal levels or stress adaptation), some are questionable for various reasons, and others do not have a clear medical significance.

C.6.9.1 In Vivo Exposure of Intact Animals

In the first of four studies with rhesus mankeys, 12 mankeys were exposed to 10.5- or 26.6-MHz pulsed RFR for 1 hr at average power densities of 200 or 105 mW/cm², respectively, or to 19.3-MHz RFR for 14 days, 4 hr/day, at 115 mW/cm². Hematologic and blood-chemistry analyses indicated no statistically significant differences between exposed and control mankeys that could be ascribed to RFR. In another part of this study, exposure at increasing power densities up to 600 mW/cm² yielded no obvious indications of thermal stress, increases of heart rate, or other influences on the electrical events of the heart cycle due to the RFR.

In the second study, male rhesus monkeys were exposed to 26-MHz CW RFR at 500, 750, or 1,000 mW/cm² for 6 hr. Measurements of skin and rectal temperatures indicated that even at the highest power density, the monkeys were in thermal equilibrium; i.e., they were able to dissipate the additional heat induced by the RFR, and their thermoregulatory mechanisms were quite efficient in doing so. Calculations by the investigators show that exposure of a 3.6-kg (about 7-1b) monkey to 26-MHz RFR at 1,000 mW/cm² is approximately equivalent to exposing a human 1.8 m (5 ft 11 in.) tall to this frequency at 400 mW/cm². The third study, performed at 15 and 20 MHz and power densities ranging from 760 to 1,270 mW/cm², yielded similar results.

The fourth was a follow-up study of 18 rhesus monkeys that had been exposed 1 to 2 years previously to 15-, 20-, or 26-MHz RFR for up to 6 hr on at least two occasions at power densities in the 500- to 1,270-mW/cm² range. Hematological and biochemical blood parameters were measured, and physical (including ophthalmologic) examinations were performed. No variations from normal values or conditions that could be attributed to RFR exposure were found.

In another primate study, the thermoregulatory system of the squirrel monkey, when stimulated by exposure to increasing levels of 2.45-GHz RFR, was shown to be quite effective in adjusting to the additional thermal burden or to decreases in environmental temperature.

Numerous studies have been performed on the physiological and biochemical effects of RFR in mice, rats, and rabbits. Among the effects reported were increases in oxygen-consumption rate, reduced food intake and blood glucose level, and other changes in blood chemistry indicative of thermal stress. In addition, stress-induced behavioral changes were observed.

In a representative study, mice were exposed to 2.45-GHz RFR under controlled environmental conditions for 30 min, during which the oxygen-consumption rate (a measure of the specific metabolic rate, SMR) and the SAR were determined at S-min intervals. At the highest power used, the mean SAR decreased, during exposure, from 56 to 39 W/kg while the mean SMR decreased from 17.5 to 14 W/kg, thereby decreasing the mean total thermal burden from about 74 to 54 W/kg. Apparently, the mice endeavored to decrease their thermal burdens by altering their body configurations to minimize their RFR absorption rates.

In another investigation, rats were exposed to 918-MHz CW RFR at 10 mW/cm² (mean SAR of 3.6 W/kg) for 10 hr/day over 3 weeks. Physiological and behavioral comparisons between RFR- and sham-exposed rats showed no significant differences in fluid intake, body weight, rectal temperature, and corticosterone levels. However, food intake and blood glucose level were lower for the RFR-exposed animals, and their behavioral repertoires were altered, apparently to cope with the additional thermal burden imposed by the RFR. Two other similar investigations confirmed these findings, which indicate the existence of an SAR threshold between 0.9 and 3.6 W/kg for such effects. In consonance with this threshold are the results of another investigation in which mice were exposed to 148-MHz RFR at 0.5 mW/cm² (mean SAR of 0.013 W/kg) for 1 hr/day, 5 days/week for 10 weeks. Blood samples drawn at ages 28 through 600 days showed that the formed elements in the blood were not affected.

Another physiological effect reported was bradycardia (lower heart rate) in rats exposed to 2.45-GHz RFR for 30 min at relatively high SARs. Specifically, statistically insignificant bradycardia was observed in rats exposed at 4.5 W/kg; mild but statistically significant bradycardia developed within 20 min for those at 6.5 W/kg, with recovery within about 2 hr; and pronounced bradycardia developed abruptly for those exposed at 11.1 W/kg, after which heart rates increased to values well above those of controls (tachycardia) and persisted at these levels

to the end of the test period. These effects were evidently due to the excessive heat from the RFR.

None of these effects in intact live animals would be likely to occur in humans exposed to the RFR levels from NEXRAD.

C.6.9.2 In Vivo and In-Vitro Exposure of Specific Tissues

Studies have been conducted to determine the physiological effects of RFR on various tissues either excised completely and kept alive artificially or accessed surgically and locally exposed in the live animal, with mixed and sometimes contradictory results.

One group of investigators reported that the contraction rate of excised segments of rat gut could be altered by exposure to 960-MHz RFR for 10 min at SARs of 1.5 to 5.5 W/kg. However, a similar study by another group did not confirm this finding.

Alterations of heart beat rate in excised turtle and frog hearts by exposure to RFR were observed by several investigators, but at either measurable heart temperature increases (e.g., 0.2 deg C) or heart SARs of 1.5 W/kg and higher. Another group of investigators surgically induced myocardial ischemia (inadequate blood flow rate to the heart) in the live cat and exposed the heart to 2.45-GHz CW RFR for 5 hr at an SAR of 30 W/kg. Although physiological differences between ischemic and nonischemic cats were evident, RFR exposure produced no significant changes in either group in mean arterial blood pressure, cardiac output. heart rate, EKG, or several subsequent heart tissue assays. These results indicate that local exposure of either the undamaged or ischemic heart to CW RFR in vivo at SARs as high as 30 W/kg has no effect on the myocardium or its neural components. These investigators also exposed isolated atria of spontaneously beating rat hearts for 30 min to 2.45-GHz CW RFR at 2 or 10 W/kg. Heasurements of contractile force and beat rate showed no significant differences between RFR- and sham-exposed specimens. All of these findings are at variance with those obtained from isolated turtle and frog hearts.

In 1968, exposure of isolated frog hearts to 1.425-GHz RFR pulses triggered synchronously with the EKG (200 ms after the peak of the R wave) was reported to produce significant tachycardia. However, in two subsequent studies by other investigators, this effect was not reproduced.

C.6.9.3 In Vitro Cellular Effects

The principal technical problems in studying effects of RFR on cells in various media arise because such investigations are often conducted using conventional apparatus designed for cell studies—flasks, dishes, holders, agitators, water baths, incubators, and the like—and various elements of the apparatus may distort the field in such a way that the SARs of the cell cultures may be severalfold higher

or lower than field measurements indicate. Thus, the results of many investigations on RFR-induced effects on cell and tissue cultures are questionable. However, progress has been made in designing exposure apparatus for cell cultures that provide for accurate measurements of SAR in such cultures.

In 1974, researchers reported increases in membrane permeability of rabbit erythrocytes (red blood cells) and granulocytes (a type of blood cell that contains granules in its cytoplasm) during in vitro exposure for up to 3 hr to 1-GHz RFR at power densities of 1 to 10 mW/cm². Other investigators subsequently showed that membrane permeability increases from RFR exposure were thermally induced. For example, suspensions of rabbit, human, and dog erythrocytes were exposed for 3 hr to 2.45-, 3.0-, or 3.95-GHz RFR at various SARs; the resulting suspension temperatures ranged from 25 to 44 deg C. The investigators also heated such cell suspensions in a water bath to comparable temperatures. As a representative result, they found no significant differences in membrane permeability between RFR-exposed suspensions and those heated to the same temperature. Researchers also found no significant differences in the sequence and time course of mouse fibroblast cells heated to 43 deg C by RFR or water bath.

Exposure of <u>Escherichia coli</u> <u>B</u> bacterial cells in aqueous suspension to 2.6- to 4.0-GHz RFR for 10 hr at an SAR of 20 W/kg had no significant effect on their colony-forming ability or molecular structure.

C.6.9.4 Conclusions Regarding Biochemical and Physiological Effects

The thermal basis for most of the reported physiological and biochemical effects of in vivo exposure of intact animals to RFR is evident. Most significant with respect to possible hazards of human exposure to RFR are the investigations with nonhuman primates because their anatomies and physiological characteristics are closer to those of humans than are those of other experimental animals. The results with rhesus monkeys showed that exposure to RFR at frequencies in the HF range at average power densities of the order of 100 mW/cm² were well within the thermoregulatory capabilities of this species. Also noteworthy were the negative findings of the blood-chemistry assays performed on rhesus monkeys 1-2 yr after exposures to such high power densities and the observations that the thermoregulatory system of the squirrel monkey is quite effective in compensating for RFR exposure.

The investigations involving exposure of intact, smaller species of mammals to RFR have yielded a variety of positive and negative results. Some of the positive findings are also clearly due to the additional thermal burden imposed by the RFR. Other results, such as those on decreased food intake and lower blood glucose levels in rats, indicate the existence of an SAR threshold of about 1 W/kg or higher for such effects.

One physiological aspect of concern is whether exposure of humans to RFR can affect their heart function. In early work on this subject with excised turtle, frog, or rat hearts, various investigators reported RFR-induced bradycardia, tachycardia, or both (depending on average power densities, with bradycardia for the lower range of power densities used). The lowest SAR at which bradycardia was observed in the isolated turtle heart was 1.5 W/kg. Hore recently, no RFR-induced changes were found in beat rate or contractile force in isolated atria of rat hearts exposed to 2.45-GHz CW RFR at 2 or 10 W/kg.

The possibility that pulsed RFR at pulse rates that are synchronous with various periodic characteristics of the EKG may alter the heart rate was also investigated. Significant tachycardia in isolated frog hearts induced by pulsed RFR was reported in 1968. However, subsequent investigators were unable to reproduce this effect.

SAR-dependent changes in heart beat rate in intact animals were also reported. The results indicate the existence of a threshold between 4.5 and 6.5 W/kg.

Investigators found no significant changes in the mean arterial blood pressure, heart rate, and colonic temperature of unanesthetized rats exposed to CW RFR at 10 mW/cm² and no differences in various blood-chemistry parameters. These investigators also compared the results of in situ RFR exposure of the cat hearts with and without myocardial ischemia, and found no significant differences ascribable to the RFR, an indication that RFR at the levels used does not affect the functioning of already damaged hearts.

The preponderance of results indicates that pulsed RFR synchronized with elements of the EKG does not alter the heart beat rate. Some of the results indicate that CW RFR does not alter heart function, and others that it does. However, most of the results, both positive and negative, support the conclusion that the effects occur at relatively high average power densities (above 1 mW/cm²) or SAR values (above 1 W/kg). The same conclusion is applicable to the in vitro cellular effects discussed in the previous section, which were obtained at much higher SARs than those in the tissue preparations. Thus, the occurrence of physiological or biochemical effects from exposure to the RFR from NEXARD is very improbable.

C.7 Misconceptions

Several misconceptions regarding the bioeffects of RFR continue to be expressed in popular accounts outside peer-reviewed scientific publications on the subject. Those accounts tend to be sources of some confusion for the nonspecialist. The following are representative exemples.

The distinction between RFR and ionizing radiation is often not made; consequently, the known hazards of ionizing radiation are

linked--by implication--with exposure to RFR. In essence, ionizing radiation (which includes ultraviolet light, X-rays, and the emissions from radioactive materials) has sufficient quantum energy (see Section C.5.1) to expel an electron from a molecule, leaving the molecule positively charged and thereby strongly affecting its interactions with neighboring molecules. Ionization can alter the functions of biological molecules fundamentally and often irreversibly.

By contrast, the quantum energies of RFR are so much smaller that their primary effect is to agitate molecules rather than to ionize them. (The possibility of long-range quantum interactions, discussed in Section C.S.1.3, is not excluded; however, evidence of their occurrence in live animals is sparse as yet, and there is no evidence that such effects would be harmful if they do occur.) Also, RFR-induced agitation ceases as soon as exposure to RFR is halted. At low RFR intensities, the heat that such agitation represents is well accommodated by the normal thermoregulatory capabilities of the biological entity exposed, and therefore such effects are generally reversible. At high RFR intensities, the thermoregulatory capabilities may be inadequate to compensate for such effects, and exposure at such intensities may lead to thermal distress or even irreversible thermal damage. In short, a single quantum of ionizing radiation that is absorbed by a molecule alters the properties of that molecule, and exposure to such radiation may thereby profoundly affect the function of the biological constituent involved, whereas the concurrent absorption of many quanta of RFR is necessary to cause biologically significant effects.

Even if an effect is produced by RFR, that effect may not necessarily be deleterious to the entity involved. As an example of a nonhazardous biological effect, the eyes must absorb light (a form of electromagnetic radiation having quantum energies above those of RFR but below those of the ionizing radiations mentioned previously) for vision. Light is also absorbed by the skin and at normal levels is converted into harmless heat. One of the reasons that the levels of allowable human exposure to RFR are generally lower in Eastern European countries than they are in the West is the philosophically based assumption that even small RFR-induced effects are potentially harmful—a view not generally shared in Western countries.

Concerned people often ask whether guarantees can be offered that chronic exposure to low levels of an agent such as RFR will have no deleterious effects many years in the future. It is scientifically impossible to obtain data on which a guarantee of absolute safety can be based. However, the large body of experimental data on the bioeffects of RFR indicates that, unlike the ingestion of certain substances in small quantities that can accumulate into a potentially harmful dose, RFR energy continually absorbed at low incident power densities (dose rates) is readily dissipated and does not accumulate in the body toward the equivalent of RFR energy absorbed at high incident power densities. This is one of the basic reasons for the existence of threshold power densities for the various RFR bioeffects.

C.8 Unresolved Issues

The potential biological effects of RFR have been assessed from existing studies at frequencies up to 300 GHz. Based on the studies evaluated, with recognition that the negative findings reported in some studies may have been obtained because the experiments had been poorly conducted, there is no reliable evidence to indicate that chronic exposure to RFR at incident average power densities below 1 mW/cm² or at SARs below 0.4 W/kg is likely to be hazardous to human health. However, certain gaps remain in our knowledge of the biological effects of RFR. These gaps may be identified as follows:

- (1) Epidemiologic Studies. Epidemiologic studies of effects of human exposure to RFR in which the actual frequencies, levels, and durations of exposure are accurately known and quantified, are lacking. Existing epidemiologic studies, while extensive and reasonably well done, are subject to inherent defects, such as unavailability of complete sets of medical records, death certificates, or health questionnaires, or imprecise classification of the individuals with regard to RFR exposure.
- Extrapolation of Findings on Animals to Humans. The most directly applicable experimental evidence relative to possible bioeffects of exposure to the RFR from any specific system such as NEXRAD would be from studies in which humans were exposed to the frequencies and waveform characteristics of that kind of system for appropriate durations at the pulse and average power densities likely to be encountered. Further, quantitative evaluation of many biological endpoints would be necessary. Such data, of course, do not exist. Instead, data are obtained from laboratory animals (mostly small rodents) used as surrogates for humans, a standard practice for investigating the effects of other agents. Because of the biological differences among species, a basic uncertainty in this practice is its degree of validity, which depends in part on the species used, the nature of the agent and its quantitative aspects, and the biological endpoints studied. In investigations of RFR bioeffects, much progress has been achieved in quantifying exposures in terms of whole-body SARs and internal SAR distributions in animal carcasses and in physical and mathematical models of various species (including humans).

For example, such data can be used to determine what the whole-body SARs would be in humans at a frequency in the 2.7- to 3.0-GHz range, if, say, laboratory rats are exposed to 2.45-GHz RFR at prespecified power densities. Nevertheless, there are significant gaps in knowledge regarding internal SAR distributions in humans. Moreover, most such interspecies calculations do not endeavor to account for the roles of blood flow and other factors in determining heat flow patterns or of

thermoregulatory mechanisms in mammals that maintain constant body temperatures.

- (3) Thresholds and Long-Term, Low-Level Studies. Most experimental data indicating the existence of threshold power densities for various RFR bioeffects were obtained from exposures for relatively short durations. Although it is difficult to conceive of mechanisms whereby RFR exposures at well below threshold values over a long time could result in cumulative effects deleterious to health, there have been very few investigations involving exposure of animals to low-level RFR over a large fraction of their lifetime.
- (4) Differential Bioeffects of Pulsed Versus CW RFR. Questions of quantitative and/or qualitative differences in bioeffects induced by pulsed versus CW RFR at equivalent average power densities cannot be resolved fully from current knowledge (i.e., some investigators have found no significant differences, whereas others have). Also, it should be noted that although the permissible average power densities in most current and proposed safety guidelines are applicable to both pulsed and CW RFR, these guidelines do not include maximum allowable pulse power densities per se.

In the light of these gaps, the possibility that new information would reveal a significant hazard from chronic exposure to low levels of RFR cannot be dismissed, but is judged to be relatively low.

C.9 Conclusions

Collectively, the results of the relatively few epidemiologic studies performed in the United States, the USSR, and other Eastern European countries do not present convincing evidence that environmental levels of RFR are likely to constitute a hazard to the general population.

Most U.S. experiments with animals that yielded recognizable and repeatable effects of exposure to RFR were performed at incident average power densities of more than about 1 mW/cm². Most such effects are thermal in the sense that the RFR energy is absorbed by the organism as widely distributed heat that increases the whole-body temperature or as internally localized heat that is biologically significant even with natural heat-exchange and thermoregulatory mechanisms operating. The existence of threshold average power densities has been experimentally demonstrated for some effects and postulated for the others. Exposure to RFR at average power densities exceeding the threshold for a specific effect for a few minutes to a few hours (depending on the value) can cause irreversible tissue alterations. The heat produced by indefinitely long or chronic exposures at power densities well below the threshold is not accumulated because its rate of production is readily compensated for by heat-exchange processes or thermoregulation. However, it should

be noted that there is some current controversy concerning the minimum threshold for thermal-physiologic effects. Nevertheless, the lowest threshold level suggested is well above those associated with human exposure to RFR from NEXRAD.

Most investigations involving chronic exposures of mammals yielded either no effects or reversible, noncumulative behavioral or physiological effects for average power densities exceeding 1 mW/cm². In the few cases in which irreversible adverse effects of exposure were found, such effects were absent for average power densities below 1 mW/cm².

In a relatively small number of investigations, biological effects of RFR were reported at incident average power densities less than about 1 mW/cm². Such effects have been called "nonthermal," to distinguish them from those considered above. However, this usage of "nonthermal" is confusing and imprecise because the interaction mechanisms involved in each such effect differ considerably from those for the other effects, and clear distinctions between "thermal" and "nonthermal" based on precise scientific definitions of these terms are difficult to discern in the interactions.

Alterations of the blood-brain barrier that permit entry of normally blocked substances into brain tissue from its blood vessels have been reported for pulsed and CW RFR at average power densities as low as 0.03 mW/cm², but the effects at such low levels appear to be artifactual. Results of a subsequent study at 15 mW/cm² indicate that the technique used does not permit discrimination between changes in local cerebral blood flow and small alterations of the blood-brain barrier. Most experimental results indicate that significant localized heating of brain tissue is necessary to produce the effect.

The calcium-efflux phenomenon in brain-tissue preparations exposed to VHF or UHF RFR modulated at sub-ELF frequencies has been ascribed to complex, long-range quantum interactions, and such interactions are basically nonthermal. Most of the experiments to date were performed in vitro, with mixed results. Some of these results indicate that the phenomenon may occur in narrow amplitude "windows" for specific modulation frequencies, which may account in part for contradictory findings. However, very few experiments have been performed in vivo thus far.

One pulse power effect known to occur in humans is the detection of individual RFR pulses as apparent sound. This phenomenon has been characterized as nonthermal, primarily on the basis that the average power density would be minuscule if the time intervals between consecutive pulses were large. However, the average power density is not relevant, because the interactions that produce the effect are dependent primarily on the characteristics of individual pulses. For perception, a pulse-power-density threshold of about 300 mW/cm² must be exceeded. No ill effects from this phenomenon have been reported, and human volunteers have been exposed to pulse power densities as high as 2,000 mW/cm² (i.e., well above the 600 mW/cm² maximum pulse power density for the basic and growth systems) without apparent harm.

In summary, the review of the relevant literature indicates that there is no reliable scientific evidence to suggest that chronic exposure to the RFR from NEXRAD is likely to be deleterious to the health of even the most susceptible members of the population, such as the unborn, infirm, or aged.

C.10 Other Viewpoints

Some general concerns expressed on occasion were as follows: first, data on which to base an assessment of potential hazard to human health are insufficient; second, research on the effects of long-term, low-level exposures is only in its infancy; third, because little is currently known about the details of mechanisms of interaction of RFR with biological tissues, potentially hazardous effects that may occur have not been more precisely targeted for study; fourth, certain studies report effects at average power densities less than 0.1 mW/cm²; fifth, even though some studies report negative findings (i.e., no effects as a result of RFR exposure), such negative findings can possibly be attributed to faulty experimental design or procedures; sixth, epidemiologic studies from the Soviet Union have reported various symptoms in persons exposed for many years to RFR at levels in the range from tenths to hundredths of a mW/cm^2 --symptoms that when taken together are called the "microwave radiation syndrome" - but such symptoms are not recognized in Western epidemiologic studies; seventh, although we know much more today than we did 10 years ago, we will know even more 10 years from now and it is therefore likely that with this additional knowledge will come recognition of new, hazardous effects of long-term, low-level exposure to RFR; eighth, safe power thresholds for RFR exposure of the general population have not been established, and, further, safety standards vary from country to country; and ninth, research on possible alterations of genetic material and carcinogenic effects of long-term, lowlevel exposure to RFR has been insufficient.

Commenters have presented the following documentary evidence as reasons for these concerns: the studies by Bawin and Adey on calcium efflux changes; the studies by Frey on blood-brain barrier permeability changes and modifications of behavior; the studies by Shandala on changes in the immune system; the studies by Oscar and Hawkins on changes in permeability of the blood-brain barrier to certain radiotracer-labeled molecules. The studies by these investigators and others on the same topics are summarized herein and are referenced and discussed in more detail in the RFR-bioeffects review. They do not alter the conclusion that there is no reliable evidence that the low levels of exposure to RFR from NEXRAD will be hazardous to the general public.

Appendix D

ELECTROMAGNETIC INTERFERENCE AND HAZARDS TO SYSTEMS

Appendix D

ELECTROMAGNETIC INTERFERENCE AND HAZARDS TO SYSTEMS

D.1 Introduction

This appendix presents a discussion of the potential electromagnetic effects of the operation of a NEXRAD radar on other systems and activities. The other systems considered include some that use the electromagnetic spectrum, as well as others that are not designed to be users of the electromagnetic spectrum but may nevertheless be susceptible to the energy radiated by the radar. The first group includes telecommunication and radionavigation systems, which are designed to sense electromagnetic energy. The second group includes cardiac pacemakers, fuel handling, and electroexplosive devices (EEDs), which may inadvertently be subjected to the radar energy.

Appendix A describes the frequency and time behavior of the radar, and Appendix B describes the levels of the electromagnetic fields. Information on the characteristics of the emission is basic to an analysis of the effects of any emitter of electromagnetic fields. A NEXRAD radar is a complicated system, in some cases remotely operated by means of data requests from the users who may be many miles away. Unlike a search radar, the NEXRAD will not simply display a screen of blips representing returns from solid targets such as aircraft. Instead, it will utilize computers and complex signal-processing schemes to extract air—and rainfall-movement information from the returned signal. Its antenna, protected from the weather by a radome, generally will scan through 360 deg of azimuth at various elevation angles. The scanning operation will be tailored to the requirements at each site and cannot be predicted in detail now.

Section D.2 describes the NEXRAD signal in terms of its frequency band, its operating frequency, its emission spectrum, and the propagation of its signal. Section D.3 analyzes incidental electromagnetic effects of NEXRAD on broadcast radio and TV and on other radars with which it will share the band. Section D.4 discusses potential bazard effects to three inadvertent receivers of electromagnetic energy.

D.1.1 Background

To determine the likelihood that an emitter of electromagnetic fields will cause electromagnetic interference (EMI) to some other system, some knowledge is required of the operating characteristics of both systems and of the means by which the electromagnetic energy is propagated from one to the other. It is common to speak of the thresh-old of susceptibility for a system that is subject to interference. It

is the lowest level of undesired signal that will cause some perceptible effect on the susceptible system (or activity). The systems include other radar systems, communication systems, and cardiac pacemakers; activities include the handling of volatile fuels and EBDs.

Typically, the threshold of susceptibility must be determined separately for each pair of interfering and potentially interfered-with systems, primarily because the threshold of susceptibility depends not only on the power density of the undesired signal at the potentially susceptible system (and therefore on the distance between them), but also on the frequency of the undesired signal and the characteristics of its modulation. Theory is useful in predicting likely modes of interference, and it can go far in helping to predict thresholds of susceptibility. Measurements, however, are often needed, either when theory is insufficient or to confirm theoretical results; each new situation is usually unique in some way, and susceptibility thresholds applicable to that situation are generally not available.

Definitive statements are rarely possible regarding distances from the radar beyond which a given system will not be affected. Susceptibility levels are either educated judgments or are based on measurements of only a very few units, generally selected in the hope that they are representative or typical. However, they could be either more or less susceptible than the entire population of units of that type. The variation in the susceptibility levels of all the units of a type (taken as a group) may be quite large, but it is generally unknown. Also, circuit designs change, and the susceptibilities of the systems change with them. The nature of radio-wave propagation over irregular terrain is such that the level of the interfering signal will not be the same at all locations at the same distance from the source. At a given location, the level varies with time, and so dealing with expected, or median, values is common. That is also true of the desired signals, when they are applicable.

In some situations, it is not necessary to determine actual susceptibility; standards for maximum fields have been established so that the devices or systems are said to be safe if that field is not exceeded. Such is the case for EEDs and fuel handling.

D.1.2 Scope

This appendix discusses general effects and is not specific to any particular planned NEXRAD location. Each NEXRAD site will differ from the others in terms of the numbers, types, locations, and operating frequencies of other nearby potentially affected radar systems. The operating frequency of each NEXRAD installation will be selected so as to reduce the likelihood of mutual interference between it and the other users of the radio spectrum. Some installations may require detailed studies of specific potential EMI problems, and some site-specific environmental assessments may have to be prepared.

At some NEXRAD locations, the radar data acquisition (RDA) and the radar product generation (RPG) function will not be collocated, and information will have to be passed between them using a wideband communication link. This is a site-specific matter not treated in this document.

D.2 The NEXRAD Signal

D.2.1 The Available Frequency Band and Its Occupants

The NEXRAD radars will operate at frequencies within the band between 2,700 MHz and 3,000 MHz, and between 2,700 MHz and 2,900 MHz whenever possible. In the United States, the 2,700- to 2,900-MHz band is allocated for exclusive use by federal government radars--for the Aeronautical Radionavigation Service (air traffic control radars) and the Meteorological Aids Service (weather radars) as primary users, and for the Radiolocation Service by the military as a secondary user. Some nongovernment use is also permitted in the band on a secondary basis, but this is limited principally to the development of radar systems for government agencies. The secondary users of the band are required to coordinate their operations with the primary users to avoid interference with them.

The lower adjacent band, from 2,690 to 2,700 MHz, is allocated for radioastronomy, and no U.S. radar stations are authorized to transmit there. The Radioastronomy Service can claim protection from interference from out-of-band signals only if the offending station is not operating in compliance with the applicable technical standards or criteria.

The upper adjacent band, from 2,900 to 3,100 MHz, is also used for radars, with government and nongovernment Maritime Radionavigation the primary service, and military Aeronautical Radionavigation the secondary service. The NEXRAD radar will be built to operate in the lower half of this band so that its potentially usable frequency band will extend from 2,700 MHz to 3,000 MHz (JSPO, 1984). Indications are that shipboard radars generally do not use this lower half (Katz and Harper, 1981), and measurements in the Los Angeles area showed maritime radar signals on frequencies above 3,000 MHz but not below (Matheson et al., 1981). The JSPO will request that operation of the Meteorological Aids Service be permitted in the 2,900- to 3,000-MHz band on a secondary basis to make additional frequencies available in congested areas.

The NEXRAD radar transmission will not be significantly different (either more powerful or with different pulse characteristics) from the hundreds of other radars currently occupying portions of the 2,700- to 3,000-MHz band. The major difference between NEXRAD and the others is not in its emissions, but rather in the complex signal processing schemes at the RDA and the associated RPG, and in the networking of the radar's processed (or partially processed) data to the various users. Certain characteristics of the NEXRAD signal are at the discretion of the radar designers working within the constraints of the NEXRAD

Technical Requirements and are not yet firmly established. The existing radars in the band use pulse widths in the 0.7- to 4.0- μ s range; NEXRAD's will be within that range. The existing radars use pulse repetition frequencies (PRFs) from 500 to 1,200 pulses per second (pps); NEXRAD will have at least three PRFs within the 250-1,200 pps range.

Hinkle (1983) examined the Government Master File (GMF) of frequency allocations and equipment characteristics and also obtained information from the frequency management offices of the various government agencies to determine the current and projected use of the 2,700- to 2,900-MHz band. As of October 1983, 627 radars were authorized to operate in the band. The Air Force and the FAA each has about 35% of them; the Navy and the Department of Commerce each has about 11%; the remaining few belong to the Army, NASA, and others. More than 60% of the radars are FAA Airport Surveillance Radars (ASRs) and military Ground Control Approach (GCA) radars; about 11% are operating weather radars; about 10% are experimental radars of one sort or another; the remainder are in the secondary radiolocation service.

Despite the addition of about 145 NEXRAD radar systems by 1990, the total number of radars is expected to remain about the same, as certain older radar systems are replaced by NEXRAD and other newer radars. Some of the new radars, including the FAA's new ASR-9 (but not NEXRAD), will be dual-channel radars, however, operating simultaneously on two frequencies, so that the total number of occupied radar channels may increase significantly. The number of radar channels in the bend is expected to increase by about 22% by 1989 and by more than that by the end of 1990, when an additional 50 or so NEXRADs and ASR-9s are to be activated.

D.2.2 Power Transmitted at Various Frequencies

The power emitted by a radio transmitter is never confined completely to the intended bandwidth of operation. A transmitter will typically emit some power within the spectrum adjacent to the operating band. It may also emit some power on frequencies that are integer multiples of the operating, or fundamental, frequency; these frequencies are called harmonics. Further, there may be noise and spurious signals generated within portions of the transmitter system that are amplified, and radiated by the antenna system.

D.2.2.1 The Transmitted Spectrum in and Near the Operating Band

The emission spectrum of a pulse radar is determined by the modulating pulse shape and width, transmitter RF tube, and RF output tube load. To aid in achieving compatibility among the radars using the same band, an upper bound on a radar's permissible emissions is mandated by the Government's Radar Spectrum Engineering Criteria (RSEC) of the Manual of Regulations and Procedures for Federal Radio Frequency Management (NTIA, 1984). JSPO (1984, Section 3.7.1.4) states that RSEC Criteria D (Subsection 5.3.3) is applicable to the NEXRAD system design. In addition, the radar is to be built to permit certain in-the-field modifications to further enhance electromagnetic compatibility (EMC) where

needed. The top curve of Figure D-1 shows the RSEC emission spectrum bounds, based on a pulse width of 1.5 µs, and a pulse risetime of 0.4 µs. These NEXRAD pulse characteristics provide a ~40-dB bandwidth of 8 MHz, and the emission spectrum drops at a rate of 40 dB per frequency decade to a floor level 80 dB below the level of the signal at the operating frequency.

The NTR requires that NEXRAD's add-on EMC-enhancement capability (waveguide filter, etc.) be able to achieve a fall-off rate (beyond the -40-dB bandwidth) of up to 80 dB per decade to a floor level 80 dB below the level at the operating frequency. This is shown as the lower of the two curves on Figure D-1.

Hinkle (1983) points out that three transmitter output tube types-conventional magnetrons, coaxial magnetrons, and klystrons--are used in radars in the 2.700- to 2,900-HHz band. Of the three, the klystron has the narrowest emission spectrum (i.e., keeps more of its energy closer to the intended operating frequency) and is therefore less likely to interfere with other radars. The ASR-9, a currently planned radar considered to be most similar to the eventual NEXRAD radar, will use a Varian VA-87EN klystron, as does the ASR-8. The NEXRAD emission spectrum will be quite similar to the spectra of those raders. Figures D-2 and D-3, taken from Minkle, show ASR-8 emission spectra (for one of its two channels) measured with and without a waveguide filter, for comparison with the normal RSEC criteria and with the enhanced EMC criteria. The plots strongly suggest that NEXRAD emissions will be well under the KSEC bounds, so that its compatibility with other radars will be much better than would be indicated by simply meeting the RSEC criteria. In fact, the unfiltered ASR-8 comes very close to meeting the enhanced-EMC criteria. The filtered ASR-8 is well within the enhanced-EMC criteria; 40-50 MHz away from the center frequency, its emissions are more than 115 dB below the power level at the fundamental. Emission spectrum levels much more stringent than the present RSEC criteria, or even the enhanced-EMC criteria, can be achieved by the use of klystrons with bandpass waveguide filters.

D.2.2.2 Harmonics

A transmitter may radiate some power on frequencies, called harmonics, that are integer multiples of its fundamental frequency. (The second harmonic of a radar operating at, say, 2,800 MHz would fall at 5,600 MHz and could potentially interfere with some other radar operating at 5,600 MHz.) For that reason, some care will be taken when selecting the operating frequency of each NEXRAD RDA to note whether any local systems operate on the NEXRAD harmonics and whether NEXRAD would operate on the harmonics of other local systems. As an example, the NEXRAD third harmonic could fall on a frequency used by the FAA for radar microwave links (RMLs). Katz et al. (1982) point out that interactions between the RML and the NEXRAD may occur if the NEXRAD frequency's third harmonic is the same as the operating frequency of an RML facility located in the immediate vicinity.

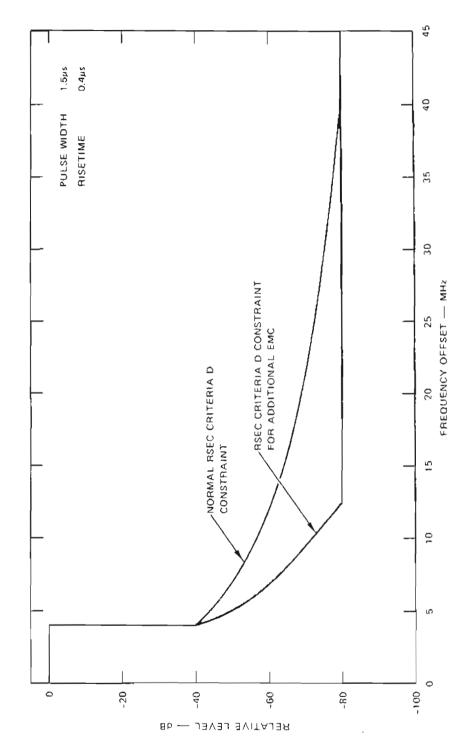


FIGURE D-1 NEXRAD EMISSION LIMITS

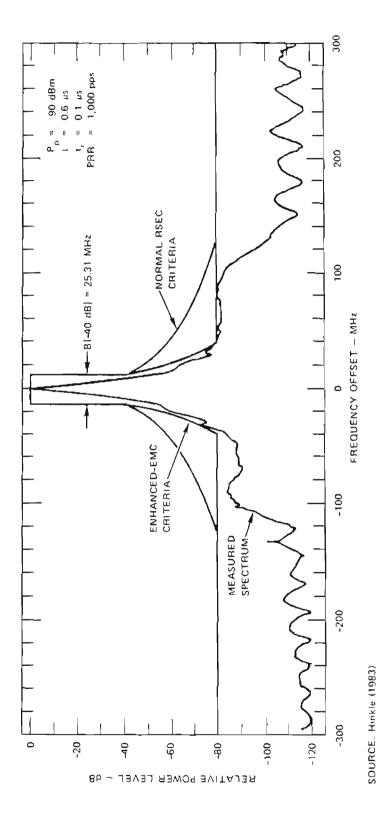


FIGURE D-2 MEASURED ASR-B EMISSION SPECTRUM, CHANNEL A (Klystron without Waveguide Filter)

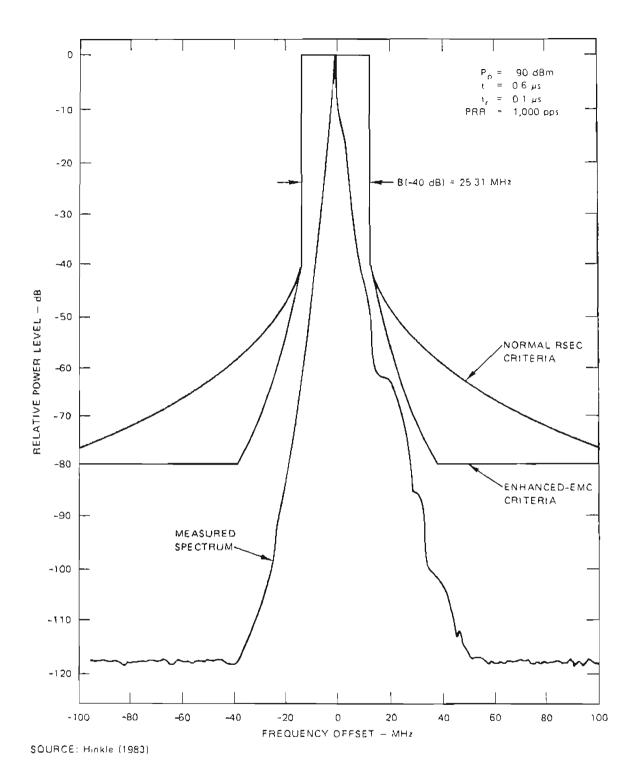


FIGURE D-3 MEASURED ASR-8 EMISSION SPECTRUM -- CHANNEL A (Klystron with Waveguide Filter)

D.2.2.3 Noise and Spurious Outputs

Transmitting systems can radiate noise and spurious signals that are generated somewhere within the transmitter and are far from the operating frequency. These will be at a very low level relative to the intended signal. Figure D-2 indicates that they will be at least 80 dB (a factor of 100,000,000) below NEXRAD's intended signal, whether or not the enhanced-EMC modification is made, and could be as far as 115 dB (a factor of 300,000,000,000).

D.2.3 Propagation of the NEXRAD Signal

Radio and rader signals such as NEXRAD's travel in straight lines in free space, but are slightly bent or refracted downward within the earth's atmosphere. This bending is caused by normal variation in the index of refraction in the atmosphere. One result of this refraction is to extend the effective range of a radar beyond the horizon. This is accounted for by assuming that the signal propagates in a straight line but that the earth's radius is 4/3 its actual size

Certain weather conditions cause irregular variations of the refractive index in the atmosphere, making the refraction of a radar beam not as predictable. In these circumstances, a phenomenon known as supercefraction, anomalous propagation, or ducting constrains the movement of electromagnetic energy and causes the signal to propagate much farther than normal.

Ducting is a fairly common phenomenon in some seasons in some parts of the country, and is often the normal condition over the ocean. Ducting has received considerable study because it can complicate the problem of EMC between radar systems (Dougherty and Dutton, 1981). When ducting occurs, potentially interfering signals can arrive at a radar site from other radars that are normally considerably beyond the horizon. Sometimes the level of these signals is greater than would be expected from normal free-space propagation. According to Hinkle (1983), in several of the radar-crowded parts of the country, ducting occurs more than 30% of the time. Frequency managers, including the PAA, take ducting into consideration in coordinating radar frequency assignments.

D.3 Interference with Other Redio and Radar Systems

D.3.1 Broadcast Radio and Television

Like all the other radars currently operating in the 2,700- to 3,000-MHz band, each NEXRAD radar may interfere with the reception of broadcast TV and radio in its immediate vicinity. This is sometimes heard on the radio as a buzz at the radar's PRF (somewhere between 250 and 1,200 pps for NEXRAD). As the radar antenna rotates, its beam is scanned past the victim receiver, and, due to the pattern's lobing structure, the buzz becomes periodically more and less noticeable, sometimes disappearing entirely. Radar interference to television appears as dots on the screen.

The presence or absence of the interference depends not only on characteristics of the radar, but also on the characteristics of the particular radio or TV receiver, and on the frequency and signal strength of the potentially interfered-with signal. No studies are known to specifically treat interference from NEXRAD radars to broadcast TV and radio. The existence of dwelling units within about 1 mile of each candidate NEXRAD site will be considered in the site selection process.

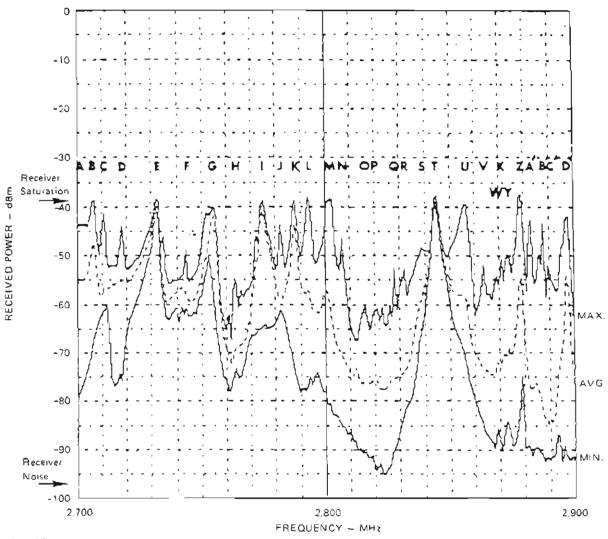
D.3.2 Interference with Other Radar Systems

D.3.2.1 Identification of the Other Radars

The approximately 145 NEXRAD radars will be sharing the band between 2,700 MHz and 2,900 MHz with more than 600 other radars in the United States operated by the FAA, the military, and the National Weather Service (NWS). Some will be replaced by NEXRAD installations, so the total number in service will remain about the same through the 1980s.

These radar systems are used for airport surveillance, airport ground-controlled approach, tracking weather features, and the like. Although it is common to say that a radar uses a particular frequency, that is only the radar's center frequency; each radar actually uses a portion of the spectrum extending both above and below its center frequency. Figure D-2 shows the emission spectrum of an ASR-8 airport surveillance radar, demonstrating that although this radar's energy extends, at low levels, at least as far as 100 MHz above and below the radar's center frequency, the energy there is less than 1/100,000,000 as great as at the center frequency. The possibility of mutual interference denies only part of that particular 200-MHz portion to use by other radars in its vicinity, as can be seen in Figure 0-4, where more than 20 radars are operating in the band extending 100 MHz each side of 2,800 MHz. (Two of those radars--identified as "K" and "T"--are ASR-8s.) Moreover, because radar signals do not generally propagate far beyond the optical horizon, a given frequency can be used by another radar if the two radars are physically far enough apart. Thus, two radars separated by a very great distance will not interfere with each other.

Although the radars are scattered throughout the country, there are some areas in which radars are more highly concentrated than in others. Pigure D-4 shows a measurement of the power density in the 2,700~ to 2,900-MHz band in the Los Angeles area, one of these heavily used areas. Each of the peaks on the plot is a part of a radar emission spectrum, as in Pigure D-3; the letters identify the signals of particular radars. The three traces show the maximum, minimum, and average powers received in a S-s dwell time at each of 200 1-MHz-wide sampling bandwidths. The receiving system used an omnidirectional antenna, so that the signal-level fluctuations on any given frequency are due to changes in the propagation path, changes in the transmitting antenna's effective gain as it rotates, and other effects.



SOURCE Matheson et al. (1981).

FIGURE D-4 RADAR POWER RECEIVED IN THE 2,700- TO 2,900-MHz BAND IN THE LOS ANGELES AREA

D.3.2.2 Selection of the Operating Frequency

The operating frequencies of the approximately 145 NEXRAD radars will be selected within the 2,700- to 3,000-MHz band to minimize mutual interference between each NEXRAD and the other radars already operating in its vicinity, as well as between adjacent NEXRADs. To prevent interference, a radar can be isolated from another radar by being separated sufficiently either in operating frequency or in geographical distance, or by an adequate combination of both. (An intervening mountain range will provide much better isolation than will an equal distance over flat terrain.) Thus, each installation will present a somewhat similar, but unique, situation. Where the available combinations of frequency and geographical separation are not adequate, special filtering will be required.

The physical location of the NEXRAD radar will probably be dictated by requirements for the coverage of certain areas such as airports. In such instances, the geographic isolation is not a variable parameter for the system designer, who will have to find an unoccupied portion of the spectrum. There will probably even be portions of the country where the selection of the NEXRAD frequencies depends not only on the existing radars, but also on the frequencies selected by adjacent NEXRADs, which, in turn, are constrained by the existing radars in their immediate vicinities.

Selection and coordination of radar frequencies in the 2,700- to 2,900-MHz band is accomplished locally in eight frequency management regions in the contiguous United States under the authority of each region's FAA Frequency Manager (Hinkle, 1983), and according to procedures set forth in the NTIA Manual of Regulations and Procedures for Radio Frequency Management (NTIA, 1984). The FAA has identified 19 heavily used areas within the United States where, due to already crowded conditions, it may be difficult to accommodate additional radars in the 2,700- to 2,900-MHz band. The Navy, FAA, Commerce Department, and Air Force, respectively, have 45%, 35%, 30%, and 25% of their radars in these areas. Detailed EMC studies may be required to determine how the NEXRAD and ASR-9 radars can be deployed in them. The identified heavily used areas include four covering the east-coast megalopolis (from Boston to Washington), two covering the west-coast areas of San Francisco and Los Angeles/San Diego, and three around the Great Lakes. Others include the vicinities of Cincinnati, Memphis, Oklahoma City, St. Louis, Miami, Jacksonville, Pensacola, Millington (Tennessee), Norfolk, and Phoenix.

D.4 Potential Hazard Effects

This section discusses the potential effects of NEXRAD electromagnetic fields on equipment other than other radars and telecommunication systems. They are termed "hazard effects," because they describe three potentially dangerous situations that high-amplitude radio-frequency (RF) fields can cause under certain circumstances: (1) accidental detonation

of EEDs, (2) ignition of liquid fuels as they are being handled, and (3) interference with the normal operation of implanted cardiac pace-makers. Besides pacemakers, there are other implanted or attachable medical prosthetic devices, but they are principally in the developmental or prototype stage so there is little information on their susceptibility to interference. The implantable devices are to have the same resistance to interference as modern pacemakers (Toler, 1982).

D.4.1 Electroexplosive Devices

D.4.1.1 Introduction

Electroexplosive devices are commonly found at military air bases. EEDs are used to activate secondary explosive charges, to ignite propellant systems, and to actuate electroexplosive switches. EEDs are used in some military aircraft to jettison flares and wing tanks while in flight, to release externally carried missiles, and to activate ejection seats. There are still other applications, and the use of EEDs on modern military aircraft is common. EEDs are by no means limited to aircraft applications; a common electric blasting cap is an EED.

All EEDs are ignited electrically and hence are subject to accidental ignition from the following causes:

- Lightning discharge—lightning-protective systems normally preclude the inadvertent ignition of EEDs by direct lightning strikes.
- Static electricity discharge—this is a hazard mainly for ground operations.
- Stray energy, such as transients and other forms of induced conducted energy, from nearby electrical equipment.
- Radiated fields from RF emitters--if the RF field is strong enough, it can induce currents that will cause the EED to fire.

Although EEDs are susceptible to ignition by exposure to radiated fields, the degree of susceptibility depends on many variables: the sensitivity of the EED; the ability of the EED leads to capture RF energy; the frequency and power density of the RF energy; and the condition of exposure of the EED--whether contained in a shielded canister, mounted inside an aircraft with shielding provided by the skin of the aircraft, or exposed to the environment with no shielding present.

D.4.1.2 Air Force Safe Exposure Criteria

Air Force safe exposure criteria are specified by the new draft of AF Regulation 127-100(C1), Explosives Safety Standards, (U.S.A.F. 1982). The safety criteria are based on a worst-case situation: the most sensitive EED currently in inventory, unshielded, and having leads or circuitry that could inadvertently be formed into a resonant antenna. The criteria apply generally to critical areas involving explosives assembly, disassembly, testing, loading, and unloading operations, and are based on the safe, no-fire threshold of the EED. This is intended to be a very conservative safety threshold, and exceeding it does not imply that the EED will fire. The actual firing threshold of the EED may be several orders of magnitude above the safe no-fire threshold.

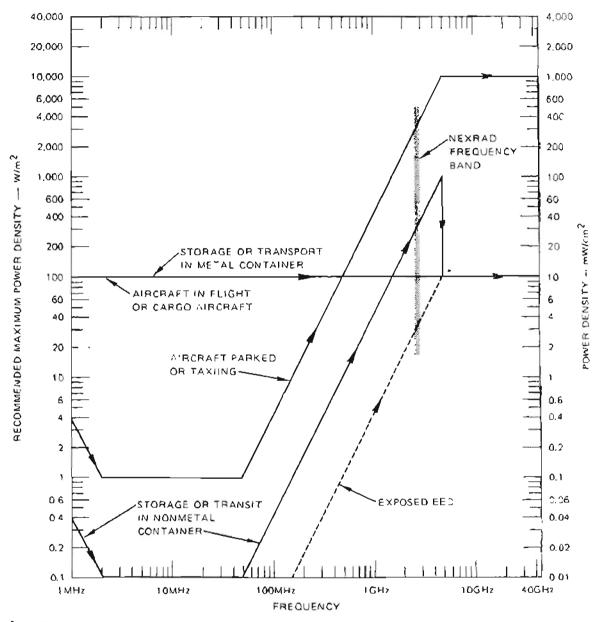
The criterion for safe exposure in a certain situation is expressed either as a recommended maximum power density or as a corresponding safe separation distance beyond which the EEDs are guaranteed safe. (The terminology would perhaps be clearer if this were called a "safe approach distance.") The calculations for the safe separation distance use powerdensity equations that are strictly applicable only in the far field of the source and are made with the assumption of direct main-beam illumination by the emitter in question. Therefore, adherence to such calculated safe separation distances will provide more than adequate protection -- for two reasons. First, the safe separation distance is based on direct main-beam illumination, which is a conservative approach since the assumption of main-beam illumination may not always be appropriste. If main-beam illumination can occur, the EEDs are safe as close as that distance; if main-beam illumination of BEDs cannot occur, they will be safe even much closer. Second, if the far-field power-density equation (Eq. [1] of Appendix B) is applied in the near-field regions, it will overstate the power density; therefore, if a recommended maximum power density is sought, the far-field equation will yield a conservative safe separation distance.

The Air Force standard indicates that for certain situations or locations, the measured average power density can be compared with the recommended maximum average power density, with the possibility of finding that the location is "safe" despite being closer than the nominal safe separation distance.

Figure D-5 was obtained by plotting the Air Force's formulas (Table 6-1 of AFR-127-100[C1]) for the recommended maximum power densities as a function of frequency for EEDs in several exposure situations.

Table D-1 shows recommended maximum power densities at the NEXRAD frequency band, as well as the corresponding safe separation distances. Some of the recommended maximum power densities in the table are more conservative (i.e., lower) than indicated by Figure D-5. This is discussed in Section D.4.1.2.2.

D.4.1.2.1 Exposed EEDs. The most hazardous exposure situation is the handling of exposed EEDs, such as electric blasting caps, when setting up a blasting operation; this situation, then, rates the lowest recommended maximum power density and therefore the greatest safe separation distance. Figure D-5 shows that the recommended maximum power density



The lines for all exposure condutions except aircraft parked or taxting coincide at 10 mW/cm 2 above 5 GHz.

FIGURE D-5 RECOMMENDED MAXIMUM POWER DENSITY FOR EEDS

Table D-1

RECOMMENDED MAXIMUM POWER DENSITIES FOR EEDs
AT NEXRAD FREQUENCIES AND SAFE SEPARATION DISTANCES
FOR NEXRAD MAIN-BEAM EXPOSURE

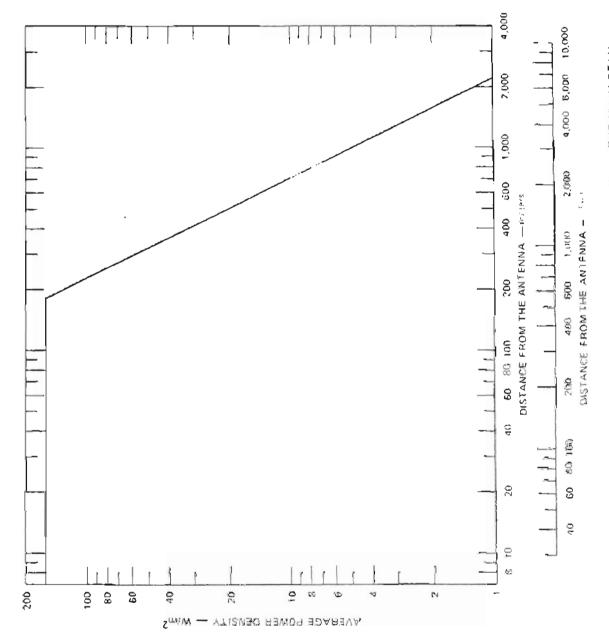
Exposure or Storage	Maximum Power Density	Safe Separation Distance			
Condition	(W/m ²)	(feet)	(meters)		
EEDs in exposed condition	31	1,300	400		
EEDs in storage or transport, in metal containers, leads shorted	100	730	225		
BEDs in storage or transport, in nonmetallic containers, leads shorted	100	730	225		
Aircraft parked or taxiing with externally loaded weapons	100	730	225		
Aircraft in flight with externelly loaded weapons, or shipment of EEDs inside cargo aircraft	100	730	225		

Source: (USAF, 1982).

for exposed EEDs at 2.7 GHz, the lower edge of the NEXRAD band, is about 31 W/m^2 .

Section 3.2.12 of the Siting Handbook (JSPO, 1983) states that "hazards to exposed Electro-Explosive devices exist out to 285 m along the main beam axis." That number was obtained by inserting the 31-W/m^2 recommended maximum average power density, and the radar transmitter power and antenna gain, into the far-field power density equation and solving for the distance. However, an average transmitter power of 1 kW was used in that calculation, and it now appears that the average transmitter power will be 2 kW.

Figure D-6 shows an upper bound on the short-term everage power density in the main beam, derived from Figure B-4 of Appendix B, and based on our assumptions for the NEXRAD transmitter power and the main-beam gain of the antenna. This is not the long-term average discussed in Section B.2.2.1, but an average during the brief duration of main-beam illumination. The sloping part of the curve is from the far-field



DPPER ROUND ON THE AVERAGE POWER DENSITY IN THE MAIN BEAM FIGURE 0-6

equation; it is exact beyond about 1,000 m (where the conventional far field begins, assuming the antenna has a 24-ft diameter) and is only slightly high from there in to about 280 m. The curve indicates that the recommended maximum short-term average power density of 31 W/m² will not be exceeded beyond about 400 m in the radar's main beam. Thus, 400 m (about 1,300 ft) is a conservative safe separation (or safe approach) distance for handling EEDs, even in a location that can be exposed to direct main-beam illumination.

D.4.1.2.2 <u>BEDs in Other Situations</u>. Logical inconsistencies will result if all the recommended maximum power densities are obtained by simply applying the formulas of Table 6-1 of AFR-127-100(C1) (USAF, 1982) at the NEXRAD frequencies. However, by plotting the curves of recommended maximum power density as a function of frequency in Figure D-5, we can see the nature of the inconsistencies and can resolve them in a conservative manner—that is, by recommending smaller (and safer) power densities.

D.4.1.2.2.1 Storage and Transport of EEDs. Two storage and transport conditions for EEDs are treated in the USAF standard, and equations for the maximum power density are provided for each condition. In one, the EEDs are assumed to be in a metal container and "normally would be safe in almost any military electromagnetic environment." In the other condition, the EEDs are considered to be in a nonmetal container, which is not assumed to provide any shielding from electromagnetic fields. Although the standard covers the frequency range from 63 kHz to 45 GHz, the recommended maximum power density for EEDs in metal containers is not a function of frequency; it remains at 100 W/m².

Over most of the standard's frequency range, the recommended maximum power density for EEDs in nonmetal containers is considerably lower than for those in a shielding metal container. This is as one would expect; EEDs in nonmetal containers are not as well shielded and so they should not be exposed to fields as great as EEDs that are shielded. Note, in Figure D-5 how the standard's recommended maximum power density for these EEDs increases in the frequency range 48.5 MHz to 4.85 GHz. At 4.85 GHz, there is an abrupt discontinuity and the recommended maximum power density drops from 1,000 W/m2 to 100 W/m2. where it remains as the frequency increases to 45 GHz. Thus, in the relatively narrow frequency range from about 1.5 GHz to 4.85 GHz, which includes the NEXRAD band, the standard permits unshielded EEDs to be exposed to stronger fields from a radar than it does EEDs shielded in metal containers. We resolve this apparent problem by recommending that EEDs in storage or transport in nonmetal containers be exposed to fields no stronger than those permitted for EEDs in metal containers. That is, none should be exposed to more than 100 W/m2 at the frequencies in the NEXEAD band.

Reference to Figure D-6 shows that the NEXRAD radar will produce a short-term average power density of 100 W/m² in the main beam at a distance of about 225 m (about 730 ft). Although this is, then, the

safe separation distance (or safe approach distance) for the storage or transport of EEDs, the beam is usually well in the air at this distance and cannot be steered downward far enough to illuminate the ground so close to the radar unless some part of the surrounding terrain is elevated. Only in this circumstance would the radar pose a hazard to the storage and transport of EEDs in its vicinity. This possibility will be investigated for each candidate NEXRAD site.

D.4.1.2.2.2 EEDs in or on Aircraft. An inconsistency similar to that just described also exists for the recommended maximum power density for aircraft. Two situations are covered by the standard. The first applies to EEDs or EED subsystems being carried in cargo planes and to (military) "aircraft in flight with externally loaded weapons." The recommended maximum power density for this situation is not a function of frequency and is the same as for E2Ds in metal containers--100 W/m2. The second aircraft situation is for parked or taxiing (military) aircraft with externally loaded weapons. Such planes, with their landing gear doors open, are presumably not as well shielded as is an aircraft in flight and are thus more susceptible. Over most of the standard's frequency range, the recommended maximum power density is, then, lower for these planes than for planes in flight. That is, they should remain farther away. Note, on Figure D-5, though, that the curve for the recommended maximum power density for parked or taxiing aircraft increases above that for aircraft in flight and is about 3,000 W/m2 in the NEXRAD band. It is more reasonable to recommend that any parked or taxiing aircraft corrying such armament -- and presumably more susceptible than the same aircraft when all the doors are closed -- be exposed to power density no greater than should an aircraft in flight. The 100-W/m² power density, then, would be the limit for any military aircraft carrying EEDs or equipped with "externally loaded weapons."

Again, Figure D-6 shows that the NEXRAD radar can produce a short-term average power density of $100~\text{W/m}^2$ only within the main beam at distances within about 225 m (about 730 ft). As was stated before, the radar's main beam cannot be directed downward far enough to illuminate the ground this close to the radar, and so parked or taxiing aircraft with EEDs are not in a hazardous situation anywhere near the radar. However, any airborne EED-equipped aircraft flying within about 225 m of the radar would be within a region where they could be illuminated by the main beam with a power density greater than $100~\text{W/m}^2$. This potentially hazardous region would be defined by the 225-m radius about the antenna and by the limits of the beam's elevation angle (-1 deg to +60 deg). Each NEXRAD installation will have to be considered individually to note whether EED-equipped aircraft are likely to enter this region.

D.4.1.3 Electric Blasting Caps and Civilian Criteria

The use and handling of electric blasting caps are specifically addressed in a publication by the Institute of Makers of Explosives (IME, 1981), which might be more familiar or available to civilian users

of blasting caps than the Air Force standard. The publication, which has been approved as a guide by American National Standards Committee C95 on Radio-Frequency Radiation Hazards, does not provide safe exposure limits in terms of power densities. Rather, it recommends safe distances from common emitters of RFR; in some cases the distance is given as a function of transmitter power or effective radiated power (the product of the transmitter power and the antenna gain). The data in this document regarding radars are quite sparse and deal mainly with maritime radionavigation radar. The publication's best advice is. "In cases where an uncertainty exists as to the nature of the radar signal as well as ground scatter and reflection of the radar signal, a recommended minimum distance of 1,000 feet [about 300 m] should be maintained from the radar antenna." Although this is closer than the distance obtained from the Air Force standard, it is reasonably similar. Again the NEXRAD radar will not be directed downward far enough to illuminate operations that close at ground level.

A document by Maine's Department of Public Safety (Maine, 1976) states that although "The Institute of Makers of Explosives have not found it possible to detonate a commercial electric blasting cap by means of radar; nevertheless, it is advisable to keep them out of a radar beam."

D.4.2 Fuel Handling

Strong electromagnetic fields can induce currents in conductive objects and may produce open sparks when contact between conductive objects is made or broken. For that reason, there is concern about the handling of liquid fuel (such as when fueling aircraft) in the presence of strong electromagnetic fields. The Air Force, in T.O. 31Z-10-4, considers areas where the peak power is greater than 5 W/cm² to be hazardous for refueling operations, regardless of the source of the RF energy (USAF, 1971).

Because some NEXRAD radars will be situated at airports, the possibility that aircraft or vehicles being fueled would be subjected to unsafe power densities from the radar alone or from the concerted action of NEXRAD and any other operating radars was considered. Based on the assumed characteristics of the NEXRAD radar, by itself it appears to present no hezard to fueling operations even if they are very close. If the actual NEXRAD characteristics differ greatly from these assumptions, the matter should be reconsidered.

Section 3.2.12 of the Siting Handbook (JSPO, 1983) states that "fuel hazards exist out to 224 m along the main beam axis." That figure can be obtained by inserting the Air Force's maximum permissible peak power density, the radar power, and the antenna gain into the far-field power density equation (Eq. [1] of Appendix B) and solving for the distance. Assuming a 24-ft dish antenna, the far field, as conventionally defined, begins at about 1,000 m, and although using the far-field equation at a near-field distance of 224 m is not strictly appropriate, the result is not far off and is on the conservative side.

Figure D-7 shows an upper bound on the main-beam pulse power density in the near-field region--that is, within about 1,000 m of the antenna- and slightly beyond. In the far field (beyond about 1,000 m), the power density decreases with distance at the 20-dB/decade slope of the latter part of the plot, and is determined by the familiar far-field equation. Use of the far-field power-density equation in the region between about 0.2 and 1 times the far-field distance (i.e., from about 200 m to about 1,000 m) will slightly overstate the power density. Using it in closer than that will greatly overstate the power density, which is never more than about 15 dB (a factor of 31.6) greater than at the point where the conventional far field begins. The pulse power density at that distance is 0.25 W/cm², and so the maximum pulse power density, even quite close to the radar, will not be greater than about 31.6 x 0.25 = 7.9 W/cm².

Thus, even though close-in direct main-beam exposure will indeed produce a power density as high as that which the Air Force considers hazardous for fuel handling, the NEXRAD radar by itself presents no hazard. The radar's beam generally points up, and it cannot be pointed downward at an angle great enough to illuminate any ground-based fueling operations within the potentially hazardous distance unless they are located on nearby elevated terrain.

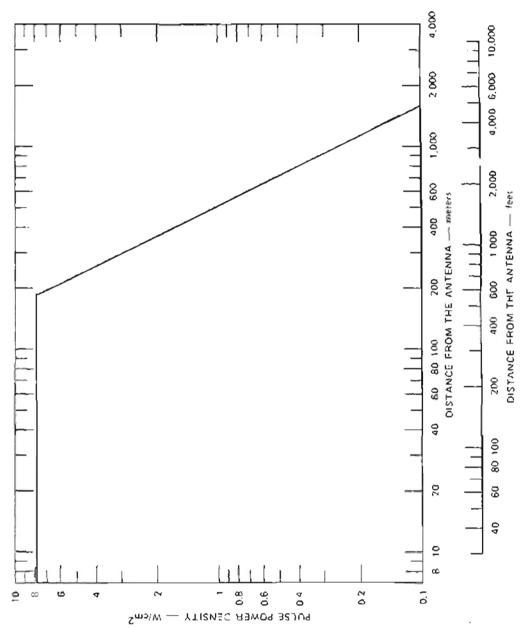
D.4.3 Cardiac Pacemakers

Cardiac pacemakers are potentially subject to electromagnetic interference, leading to the concern that the NEXRAD radar could affect pacemaker wearers in the air or on the ground in its vicinity. Whether NEXRAD would affect pacemakers depends on the susceptibility of the individual device and on the level of the NEXRAD signal that reaches it. Although no directly applicable susceptibility data from which to make exact predictions of any hazardous regions for a pacemaker owner are available, the data that do exist suggest that the possibility of harmful interference is remote.

D.4.3.1 Background

The heart can be considered to be an electrically operated pump. It is a set of muscles that contracts rhythmically in response to a periodic electrical impulse that originates naturally in a certain portion of the cardiac tissue. Some people who suffer impaired operation of that natural pacemaker or of the conducting paths in the cardiac tissue rely on an artificial pacemaker, which supplies the electrical signal to make the heart beat when it should. Hundreds of thousands of people in the United States have pacemakers.

Four general types of cardiac pacemakers are employed, but by far the most common (80% to 90% of the pacemakers in use) is the R-wave inhibited type. The R-wave inhibited (synchronous) pacemaker supplies a pulse only on demand (i.e., when the heart requires it) and is often called a demand pacemaker. It senses the electrical signal of the main



UPPER BOUND ON THE PULSE POWER DENSITY IN THE MAIN BEAM FIGURE D-7

pumping action of the heart. If that signal fails to occur when it should, the pacemaker supplies the signal to trigger the heart's action. Although R-wave inhibited pacemakers are generally more susceptible to EMI than are other types, great progress has been made in recent years in reducing that susceptibility.

Pacemakers do not fail permanently when exposed to strong RF fields; instead, if the field is sufficiently intense, they may exhibit one of four types of dysfunction, of which the most common (for a synchronous pacemaker) is termed "reversion." This means that the pacemaker reverts to a benign fixed rate; it is designed to respond to RF by becoming, for the time being, an asynchronous pacemaker. Reversion is not always even considered a form of dysfunction. In fact, for purposes of monitoring the pacemaker's fixed rate (and thus the condition of its battery), a pacemaker owner frequently will deliberately cause his pacemaker to revert to fixed-rate pacing.

D.4.3.2 Susceptibility to RF Fields

The preponderance of the available data on the susceptibility of pacemakers was developed 5 or 6 years ago at radio frequencies around 450 MHz or at the AC power frequencies of SO Hz, 60 Hz, and 400 Hz. A few measurements were made at frequencies around 3,000 MHz. The AC power frequencies were chosen for experiments because exposure to them is virtually unavoidable; everyone, in day-to-day living, is exposed to fields or to physical contact with devices radiating at these power frequencies. For standardized testing, a pulse-modulated 450-MHz signal "was selected as a compromise frequency that represents good body penetration and has been used by expert personnel in the field" (AAMI, 1975). Some measurements were made at 3,000-MHz frequencies, chosen because so many high-powered radars operate using them. Between 400 Hz and 450 MHz, and between 450 MHz and 3,000 MHz, are very large frequency ranges in which there are very few published data; what little testing is done is typically done for special purposes, such as when the safety of pacemaker owners in the vicinity of some specific device or system is of concern.

The modulation of the RF field dictates, in large part, whether and how a field will affect a pacemaker. Pulse modulation is the form of modulation most likely to affect a pacemaker, since the pacemaker is designed to sense electrical pulses, and a threshold of field intensity exists above which a given pacemaker will react to external RF pulses. According to Denny et al. (1977), at low PRFs (less than 10 pps) an R-wave inhibited pacemaker is likely to misinterpret such pulses as the heart's normal electrical activity and to become inhibited (i.e., to "feel" that it should not supply any pulses). At higher PRFs, it is more likely to revert to asynchronous operation. Long-term inhibition (for durations greater than about five normal heartbeats) may constitute a health hazard for some owners, whereas reversion to fixed-rate pacing is less serious.

Although, in the mid- and late 1970s, considerable research was conducted and many papers were published on pacemaker susceptibility to electromagnetic fields, this activity has since greatly decreased. The principal reasons are that a pacemakor susceptibility standard was developed in 1975 by the Association for the Advancement of Medical Instrumentation (AAMI, 1975), and in accordance with that standard, the pacemakers now being marketed are capable of unaffected operation in 450-MHz pulsed field-strengths in excess of 200 V/m. (Because the body penetration of 3,000-MHz fields would be less, this suggests that these pacemakers would very likely also be capable of unaffected operation in a 3,000-MHz field of 200 V/m.) That 1975 draft standard also requires that the pacemaker be unaffected by (unmodulated) continuous wave (CW) power-frequency signals directly coupled to the pacer at a 100-mV level. Susceptibility testing has now become routine, with the Biomedical Research Division of the Engineering Experiment Station of Georgia Institute of Technology conducting that work for all but one of the major U.S. manufacturers, as well as for many of the major foreign manufacturers (Toler, 1982). The latest (November 1981) draft version of the AAMI pacemaker standard (AAMI, 1981) describes various performance tests. but has dropped all reference to EMI susceptibility testing. According to a co-chairman of the AAMI pacemaker committee, this was done for several reasons. One was to make the U.S. standard more similar to an international standard so as to facilitate trade. Another was that the committee felt that a rigid EMC standard could encourage manufacturers to produce pacemakers with EMI susceptibility no better than the minimum requirements of the standard (Flink, 1982). He agrees that the modern pacemakers are almost invulnerable to electromagnetic interference.

Susceptibility levels based on pulsed 3,200-MHz tests in 1975 were published by Mitchell and Hurt (1976). They used a pulse rate of 10 pps, and found that although some of the the pacemakers tested reacted to pulse widths as long as 1 ms, none reacted to pulse widths of 2 μ s, even when the field strength was increased to 1,200 V/m, the maximum field strength available from their equipment. (NEXRAD pulse widths will range between 0.7 and 4 us.) That report states that the levels reported therein "are believed most representative of the current state of technology" (for 1975). The report also states that "if pacemakers were designed and tested to be compatible with the minimum E-field level, viz 200 V/m, associated with the unrestricted 10 mW/cm2 personnel exposure level, potential EMI situations would be substantially reduced or effectively eliminated." Such a 200-V/m testing level, described in the 1975 draft standard prepared by the AAMI for the Food and Drug Administration, is now in use by independent university testing labs working under contract for manufacturers.

Both Mitchell (1978) and Denny (1978) suggested that the manufacturers were them probably meeting the 450-MHz, 200-V/m level in their newer models. The 1975 measurements reported by Mitchell and Hurt in 1976 indicated that none that they measured were susceptible to 3,200-MHz pulsed signals at levels as high as 1,200 V/m. Denny stated in 1978 that the 450-MHz threshold for most of the newly released pacemakers was

above 300 V/m. Toler stated in 1982 that none of the pacemakers even then being released were susceptible to pulsed 450-MHz fields of 200 V/m.

Hanufacturers contacted in an informal 1978 survey for the BIS for the PAVE PAWS (420- to 450-MHz) radar at Beale AFB stated that their newer pacemakers met the 1975 AAMI draft standard, and one manufacturer said that the manual for a particular model stated that it had been tested (at 450 MHz) to 295 V/m.

By now (1984), few if any of the older pacemakers described in the literature of 6 or 7 years ago would still be functioning, so the susceptibility thresholds of the pacemakers currently in use are probably quite high. The ceason for the rapid replacement of the older pacemakers with the newer ones is that an entirely new pacemaker must be implanted in an individual when the battery becomes exhausted; thus, the physician has an opportunity to implant a pacemaker less susceptible to EMI. When the mercury cell was the only type of battery used, pacemaker replacement was necessary about every 2 to 3 years; lithium iodide batteries last 6 to 8 years or more and are now essentially the only type used.

D.4.3.3 Susceptibility to NEXRAD

Pacemakers are apparently not particularly susceptible to signals in the frequency range of about 3,000 MHz; also, the fact that the pulse repetition rate of the NEXRAD radar is so much beyond that of a normal cardisc signal means that the pacemaker does not confuse it with the naturally occurring electrical signals that the pacemaker is designed to sense. (If the pacemaker were to react at all, it would most likely revert to fixed-rate pacing.) Although, of course, no measurements have been made to elicit information about the effects of NEXRAD specifically on modern pacemakers, Mitchell and Hurt (1976) conducted tests, using older, probably more susceptible pacemakers in the neighborhood of various types of radar. They stated that NEXRAD-like search radars operating in the frequency range 2,400-2,900 MHz "did not produce any significant pacemaker interference...primarily because such systems were located on a 50-75 ft tower and their operating frequency is significently attenuated by the implant." They also noted that although air route surveillance radars might "cause many pacemakers to miss single beats as the radar beam scans past," this would be "an effect most likely unnoticed" by the pacemaker owner.

Thus, although there is no directly applicable data on reactions of pacemakers exposed to NEXRAD signals, the available evidence strongly suggests that if there were to be any reactions, they would not be likely to be harmful to the pacemaker owner.

D.5 Susceptibility of Other Electronic Equipment

Electronic equipment such as computers and word processors purchased by agencies within the Department of Defense (DoD) must conform to certain requirements regarding the equipment's susceptibility to interference from emitters of electromagnetic energy. Details of the requirements are contained in MIL-STD-461B "Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference." When tested by being subjected to specified radiated field strengths, the equipment is not to "exhibit any malfunction, degradation of performance, or deviation from specified indications beyond the tolerances indicated in the individual equipment or subsystem specification."

The specified electric field level for testing equipment to be used aboard nonmetallic aircraft or mounted on metallic aircraft is 200 V/m. For equipment at ground-based fixed and mobile facilities, the Army and Air Porce require that the equipment not react at a level of 5 V/m, while the Navy requires a level of 1 V/m for receiver sites and 40 V/m for all other sites.

Figure D-8 shows the main-beam and the first-sidelobe field strengths as a function of distance from the NEXRAD radar. It indicates that the 200-V/m testing level for some aircraft equipment would be exceeded within the NEXRAD main beam at distances within about 5 km (3 miles) of the radar. Also, the radar's first sidelobe will sweep the ground whenever the main beam's elevation angle is less than about 2 deg. At that time, the 5-V/m testing level for ground-based equipment would be exceeded within about 600 m (0.35 miles) of the radar.

Thus, although various military electronic equipment may have been designed for compliance with the MIL-STD-461B electromagnetic interference susceptibility levels, the NEXRAD radar may subject them to higher levels of field strength. Whether this exposure will result in malfunctions of such equipment is not known.

There is no comparable susceptibility requirement for nonmilitary electronic equipment, and the field-strength levels that can cause them to malfunction and/or degrade in performance are, in general, unknown. Manufacturers of a piece of equipment may or may not consider the need for its protection against electromagnetic interference from radio and radar transmitters, and they can incorporate whatever degree of protection they feel to be adequate. Although some radars have caused interference to high fidelity audio equipment and to computer equipment, there is not sufficient information with which to predict which systems could be affected and at what distances from a radar.

D.6 References

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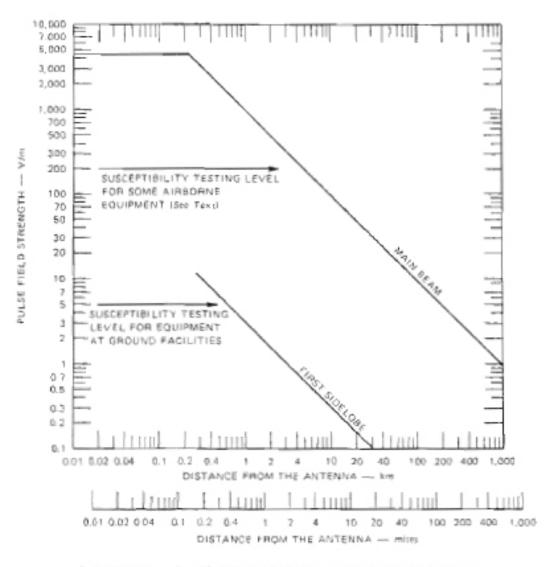


FIGURE D-8 PULSE FIELD STRENGTH IN THE NEXRAD BEAM

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- USAF (1971). "Electromagnetic Radiation Hazards," Air Force Communications Service (E-1 Standard), Technical Manual T.O. 31Z-10-4, 1 August 1966 (Change 2, 1 June 1971).
- USAF (1982). "Explosives Safety Standards," AF Regulation 127-100(Cl), 31 March 1978 (Change 1, 18 June 1979), (revised draft obtained 27 July, 1982).
- U.S. Department of Defense, "Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference," Military Standard MIL-STD-461B, 1 April 1980.

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Appendix E SAMPLE ENVIRONMENTAL IMPACT WORKSHEET

Table E-1

SAMPLE ENVIRONMENTAL IMPACT WORKSHEFT

Site Name:

Location:

	Comments																		
User Sites:	Data Items	General Environmental Considerations	Surrounding Land Use	Radar Site Military Base	Airport Other Government	Industrial Commercial	Residential Agriculture	Forest	Other Open Resource Extraction	Distance to Populated Areas	Environmental Characteristics	Earth	Mineral Resources	Construction Materials	Soils	Land Form	Force Fields and Background Radiation	Unique Physical Features	

Table E-1 (continued)

Data Irems	Comments
Water	
Surface Oughty	17.7
Underground	
Atmospheric Quality Processes	
Flooding	
Erosion -	
Sedimentation	
Compaction and Settling	
Flora	
rees	
Shrubs	
Grasses and Forbs	
Crops	
Microttora	
Aquatic Plants	
Endangered Species	
Fauna	
Birds	
Land Animals Including Repules	
Fish and Shellfish	
Benthic Organisms	
Endangered Species	
Corridors	

Table E-1 (continued)

Data Items	Comments
Recreation	
Hunting	
Fishing	
Other Sports	
Picnick ing	
Camping	
Resorts	
Radio/TV	
Aexthetics	
Scenic Views and Vistas	
Wilderness Ouglities	
Open Space Qualities	
Landscape Design	
Unique Physical Features	
Parks and Reserves	
Monuments	
Historical or Archaeological Sites and Objects	
Cultural Status	
Life Style	
Employment	
Health and Salety	

Table E-1 (continued)

Data Items	Comments
Man-Made Facilities and Activities	
Transportation Networks	
Utility Networks	
Fivel Storage and Handling	
Communication Networks	
Public Services	
Fire Protection	
Police Protection	
Maintenance of Public Facilities Including Roads	
Environmentally-Sensitive Areas	
Radiation Mazard	
Number of Homes Within 224 meters	
ID TV Interference	
Number of Homes Within 1600 meters	

Table E-1 (concluded)

Status			-							
Data Reguned		1	*							
Address										
Agency										
Outstanding Data Requests	-	2	n	4	ĸ	9	۲	&	ō	10

David A. Leone, "Site Survey Plan, Site Surveying and Facility and Support Planning for the Next Generation Whather Radar (NEXRAD) Program," SRI International, Prepared for the NEXRAD Joint System Program Office (January 1984). SOURCE:

Appendix F

COMMENT LETTERS

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Appendix F

COMMENT LETTERS

Many letters commenting on the NEXRAD program were received subsequent to the issuance of the Draft Programmatic EIS. Those letters that required response or that provided information to augment the Draft PEIS are reprinted here. Responses to questions raised in these letters appear in Appendix G. The comments for which responses have been prepared are numbered in the right margin of the letters. Letters that did not require responses are identified below but not reprinted.

Letters Reprinted

- Gordon F. Snow, Assistant Secretary for Resources, California Resources Agency, May 22, 1984.
- Tony Miller, Commissioner, Department for Facilities Management, Kentucky Finance and Administration Cabinet, May 15, 1984.
- 3. Robert A. Chandler, Executive Director, Lower Rio Grande Valley (Texas) Development Council, May 17, 1984.
- 4. Sheila M. Prindiville, Administrator, Virginia Council on the Environment, May 25, 1984.
- 5. Howard S. Druckenmiller, Director, Bureau of Environmental Analysis and Review, Wisconsin Department of Natural Resources, May 24, 1984.
- Herbert P. Benner, National Weather Service Western Region, May 24, 1984.
- Stuart G. Bigler, National Weather Service Alaska Region, May 15, 1984.
- 8. Paul M. Wolff, National Ocean Service, May 14, 1984.
- David W. Cain, Manager, Program and Planning Branch, Federal Aviation Administration, Northwest Mountain Region, May 22, 1984.
- Gary D. Vest, Deputy for Environment and Safety, Deputy Assistant Secretary of the Air Force (Installations, Environment and Safety), May 29, 1984.
- 11. Col. John C. Tait, USAF, Director, Operational Requirements and Tests, DCS/Plans, May 31, 1984.

- Bruce Blanchard, Director, Environmental Project Review, U.S. Department of the Interior, June 8, 1984.
- Allan Hirsch, Director, Office of Federal Activities, U.S. Environmental Protection Agency, May 29, 1984.

Letters Not Reprinted

- Kenneth C. Arndt, Planning Administrator, Northern Maine Regional Planning Commission, May 1, 1984.
- Guy W. Hager, Director, State Clearinghouse for Intergovernmental Assistance, Maryland Department of State Planning, May 24, 1984.
- Robert Kerrey, Governor, State of Nebraska, May 14, 1984.
- Mrs. Chrys Baggett, Clearinghouse Director, North Carolina Department of Administration, May 30, 1984.
- John M. Gosdin, Coordinator, Natural Resources, Water and Environment, Texas Office of the Governor, June 8, 1984.
- Robert R. Weaver, Executive Director, Concho Valley (Texas) Council
 of Governments, May 16, 1984.
- LaVerne Herrington, Deputy State Historic Preservation Officer, Texas Historical Commission, May 11, 1984.
- Jerry D. Casstevens, Executive Director, South Plains (Texas)
 Association of Governments, May 10, 1984.
- Thomas Serrano, Director, Community and Economic Development, West Texas Council of Governments, May 15, 1984.
- Mike Hightower, Director, Coastal Division Land Hanagement, Texas General Land Office, May 24, 1984.
- Charles D. Travis, Executive Director, Texas Parks and Wildlife Department, May 17, 1984.
- James M. Hoore, Engineer, Texas State Soil and Water Conservation Board, May 29, 1984.
- Michael B. Zuhl, Director, Utah Office of Planning and Budget, May 22, 1984.
- Bruce J. Larson, Review and Compliance Coordinator, Virginia Research Center for Archaeology, May 7, 1984.

- Assistant Commissioner, Office of Health Protection and Environmental Management, Virginia Department of Health, May 8, 1984.
- Arthur L. Collins, Executive Director/Secretary, Southeastern Virginia Planning District Commission, May 22, 1984.
- Allen Kerner, National Weather Service Eastern Region, May 8, 1984.
- 18. Richard H. Hagemeyer, National Weather Service Pacific Region, May 8, 1984.
- Edward J. Phillips, Manager, Airway Facilities Division, Federal Aviation Administration, May 10, 1984.
- Robert H. Tracy, Director, Watershed and Air Management, U.S. Forest Service, May 29, 1984.
- 21. William R. Snell, Director, Central Region Planning and Programming, Alaska Department of Transportation and Public Facilities, June 1, 1984.
- 22. Richard J. Pastor, Director, Secretary's Office of Policy, Pennsylvania Department of Environmental Resources, July 3, 1984.
- 23. Walter O. Kolb, Sr. Governmental Analyst, Florida Office of the Governor, August 8, 1984.
- 24. Lynn F. Griffin, Environmental Specialist, Intergovernmental Programs Review Section, Florida Department of Environmental Regulation, April 19, 1984.
- 25. Dale Adams, Administrative Assistant, Division of Resource Management, Florida Department of Natural Resources, May 7, 1984.
- 26. Ed McNeely, Administrator, Surface Transit Planning, Florida Department of Transportation, April 27, 1984.

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Resources Building 1416 Ninth Street 95814

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partment of Conservation
Department of Fish and Game
Department of Forestry
Department of Boating and Waterways
Department of Parks and Recreation
Department of Water Resources

GEORGE DEUKMEJIAN GOVERNOR OF CALIFORNIA



THE RESOURCES AGENCY OF CALIFORNIA SACRAMENTO, CALIFORNIA

Air Resources Board California Coastal Commission California Conservation Corps Colorado River Board Energy Resources Conservation and Development Commission Regional Water Quality Control Boards San Francisco Bay Conservation and Development Commission Solid Waste Management Board State Coastal Conservancy State Lands Commission State Reclamation Board State Water Resources Control Roard

Mr. John Porter NEXRAD-JSPO WX7 11420 Rockville Pike Rockville, MD 20852

May 22, 1984

Dear Mr. Porter:

The State has reviewed the draft programmatic EIS, Next Generation Weather Radar (NEXRAD) Systems, submitted through the Office of Planning and Research in accordance with the National Environmental Policy Act of 1969. Review was coordinated with the Water Resources Control Board and Departments of Fish and Game, Health Services, Parks and Recreation, and Transportation.

The Department of Parks and Recreation, Office of Historic Preservation, has submitted the following comment:

- 1. Sections on cultural resources are essentially programmatic discussions of steps usually taken to identify, evaluate, and manage cultural resources potentially subject to effects of the project. The draft EIS refers to the fact that the National Historic Preservation Act is applicable to this project.
- 2. The Department believes it inappropriate to suggest that surface collection and shovel testing are advisable actions to take during a field reconnaissance. The need for such actions may not be apparent in all cases, at least in California. Appropriate field actions should be determined on a case-by-case basis.

The Office of Historic Preservation looks forward to the consultation process that NOAA will initiate for all prospective NEXRAD sites in California. It is suggested that this process begin as soon as is possible. Questions regarding these comments may be directed to Hans J. Kreutzberg, 1050 20th Street, Sacramento 95814.

Thank you for providing an opportunity to review this report.

for Gordon F. Snow, Ph.D

Sincerely,

Assistant Secretary for Resources

cc: Office of Planning and Research (SCH 83081510)

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DIVISION OF ENCINEERING CONTRACTING & ADM TELECOMMUNICATIONS PHYSICAL PLANT REAL PROPERTIES

FINANCE AND ADMINISTRATION CABINET DEPARTMENT FOR FACILITIES MANAGEMENT

NEW CAPITOL ANNEX FRANKFORT, KENTUCKY 40601 TONY MILLER COMMISSIONER

May 15, 1984

Mr. John Porter Wx7, NEXRAD JSPO National Weather Service Room 323, 11420 Rockville Pike Rockville, Maryland 20852

Public Hearing on Next Generation Weather Radar.

Dear Mr. Porter:

This office has received notification of the May 22, 1984, public hearing at the Berbert Hoover Building in Washington, D.C., relative to the proposed Next Generation Weather Radar (NEXRAD). In the event there are no witnesses representing the Commonwealth of Kentucky at the public hearing, I would like to file this letter as a comment on the proceedings.

The Kentucky Emergency Warning System (KEWS) is a highly survivable and redundant state-owned and operated microwave communications system that was built expressly for the purpose of notifying the people of Kentucky of imminent danger from natural and man-made phenomena. In 1976, the Commonwealth of Kentucky entered into a cooperative agreement with the National Weather Service for the operation and maintenance of NOAA Weather Radio in Kentucky integrated with KEWS. The agreement served as a model for the development of similar cooperative agreements with several other states.

Today, through KEWS and the Division of Disaster and Emergency Services, Kentucky continues its cooperation with the National Weather Service. Additional projects include the IFLOWS Flood Warning System, and distribution of weather rader through the KEWS microwave. Kentucky is proud of the leadership it has shown in providing this cooperation with the National Weather Service.

We applaud the development of the next generation radar. It is our hope that the deployment of the total system will provide complete coverage of Kentucky's geography and its people. In addition, we would hope that KEWS could continue to be utilized to distribute the output of the radar to all parts of the Commonwealth providing the greatest advance notification period possible. We feel that Kentucky should be placed in a high service priority due, at least in

Mr. John Porter National Weather Service May 15, 1984 Page 2

part, to the cooperation and service to the National Weather Service we continue to exemplify. Should Kentucky be at all limited in the number of NEXRAD installations, we would encourage installations at least in Paducah, cont'd Louisville and Jackson.

We welcome the opportunity to assist in the development, testing and deployment of the new weather radar and hope you will call upon this office for whatever assistance we might contribute.

Sincerely.

Tony Miller Commissioner

Department for Facilities Management

cc: Governor Martha Layne Collins Secretary Lester M. Thompson J. Paul Warnecke



Lower Rio Grande Valley Development Council

Mayor Emilio A. Hernander Judge Bull Rapp Judge Santos Saldana Mayor Sam Lazano Commissioner Tony Gutierrez Robert A. Chandler

President
Ist Vice President
2nd Vice President
Treasurer
Secretary
Executive Director

May 17, 1984

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Mr. Robert A. McPherson Governor's Planning Director Regional Planning/TRACS Section P. O. Box 13561 Austin, Texas 78711

RE: PROGRAMMATIC EIS NEXT GENERATION WEATHER RADAR (NEXRAD) SYSTEM -SAI# TX40521004

Dear Mr. McPherson:

The statement outlining the environmental impact of the Next Generation Weather Radar (NEXRAD) has been reviewed by the Lower Rio Grande Valley Development Council staff. The NEXRAD environmental impact statement exhibits extensive demonstration on the impact of the proposed radar equipment, and concludes that no substantial adverse effects on the environment and on human health will result.

Under the directions of the Texas Review and Comments System, the drafted Programmatic EIS NEXRAD is officially cleared by the LRGVDC with the following comments:

- The key operational goals and objectives of the NEXRAD System (as proposed) will provide necessary data at critical periods making the per unit cost of \$2.0-\$2.5 million seem well invested.
- I disagree with the deactivation of the existing radars, but rather suggest that they be maintained, not as the major data gathering source, but as a back-up to the NEXRAD units; if not to supplement them.
- In this Tornado Region, it is strongly encouraged that the weather radar site at the City of Brownsville be selected as a NEXRAD site due to its existence at the airport, plus its rural density and agricultural land use classification. (Identified by the Joint System Program Office)
- During the site preparation/construction phase, NEXRAD encouragement to hire the local unemployed is concurred herewith.

Cont'd...

Mr. Robert A. McPherson May 17, 1984 Page 2

Should there be any further environmental evaluations or supplemental statements regarding the proposed radar system(s), please notify us so we may be kept abreast of NEXRAD.

Thank you for letting the LRGVDC review and comment on your EIS.

Sincerely,

Robert A. Chandler Executive Director

RAC:SZ:1c



COMMONWEALTH of VIRGINIA

SHE LA M. PRINOIVILLE
ADMINISTRATOR

Council on the Environment

May 25, 1984

POD NINTH STREET OFFICE BUILDING
RICHWOND 22219
BOL-186-4500

Mr. John Porter
Chief, Facilities
NEXRAD Joint System Program Office
National Weather Service
National Oceanic and Atmospheric
Administration
11420 Rockville Pike
Rockville, Maryland 20852

Dear Mr. Porter:

The Commonwealth of Virginia has completed its review of the Draft Programmatic Environmental Impact Statement for the Next Generation Weather Radar (NEXRAD) System. The Council on the Environment is responsible for coordinating Virginia's review of federal environmental documents and responding to appropriate federal officials on behalf of the Commonwealth. The following agencies have joined in this review:

Department of Conservation and Economic Development Department of Health State Air Pollution Control Board Office of Emergency and Energy Services Virginia Research Center for Archaeology Fifth Planning District Commission Southeastern Virginia Planning District Commission.

The Commonwealth of Virginia would not object if a Virginia site were proposed for this project. We agree that archaeological surveys and necessary mitigation measures should be undertaken at sites for the facility prior to construction (pages 4-25, 4-26). Appropriate state or local approvals for potable water sources and wastewater disposal plans will be required. Site selection criteria should address the potential for chemical spills and their impacts on downstream water supply intakes.

Inasmuch is the State Office of Emergency and Energy Services depends on the Richmond National Weather Service Forecast Office for weather warnings and information during hazardous weather conditions or emergencies, we recommend that the Richmond Office be added to the list of potential sites for the NEXRAD project (page 2-22). The Southeastern Virginia Planning District Commission has indicated its willingness to assist you in site selection in the event the Hampton Roads area is chosen.

Mr. John Porter Page 2

We will be interested in reviewing supplements to the Draft Programmatic EIS in the event any Virginia sites are chosen for further evaluation for the NEXRAD system.

Thank you for the opportunity to review this document. Agency comments are attached.

Sincerely,

Kuth Butteman (for Sheila M. Prindiville)

Attachments

cc: The Honorable Betty J. Diener, Secretary of Commerce and Resources

Mr. Bruce J. Larson, Virginia Research Center for Archaeology

Dr. Robert B. Stroube, Department of Health

Mr. Henry G. Allard, Office of Emergency and Energy Services

Mr. Arthur L. Collins, Southeastern Virginia Planning District Commission

Mr. Wayne G. Strickland, Fifth Planning District Commission



State of Wisconsin

DEPARTMENT OF NATURAL RESOURCES

Carroll D. Besadny Secretary

BOX 7921 MADISON, WISCONSIN 53707

May 24, 1984

File Ref. 1650-2

Mr. John Porter NEXRAD-JSPO Wx7 Room 323 11420 Rockville Pike Rockville, MD 20852

Dear Mr. Porter:

The State of Wisconsin Department of Natural Resources recently completed our review of the Draft Programmatic Environmental Impact Statement for Next Generation Weather Radar (NEXRAD) System dated April, 1984.

The document appears to be very complete and addresses alternatives and possible impacts adequately based on current knowledge. We are concerned, however, with the potential effects on birds due to their possible attraction to the antennas. We are also aware that although no known adverse effects, other than thermal, from non-ionizing radiation at this end of the spectrum are known at this time further study by organizations such as the National Academy of Sciences may be advisable.

We would like to request that several items be included as recommendations in the Record of Decision for this proposal as follows:

- Mitigation measures for potential impacts should be developed. If mitigation is developed, monitoring of possible effects of NEXRAD and the mitigative measures should be conducted in accordance with section 1505.2(c) of the Council of Environmental Quality Regulations implementing NEPA.
- The state natural resource agency and the U. S. Fish and Wildlife Service should be coordinated with as sites are planned and subsequently constructed or modified.

We appreciate the opportunity to comment on this document.

Sincerely,

Bureau of Environmental Analysis and Review

Howard S. Druckenmiller

Director

cc: Bob Bartlett - Governor's Office

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U.S. DEPARTMENT OF COMMERCE National Oceanic and Atmospheric Administration National Weather Service Western Region P.O. Box 11188 Federal Building Salt Lake City, Utah 84147

Dace May 24, 1984

Reply to Aten. of W/WR1x5

Tο W/Wx7 - John Porcer

Subject.

NEXRAC Programmatic Environmental Impact Statement (PEIS)

Our MSD, DATAC, and Engineering Divisions have reviewed the draft PEIS for NEXRAD and find it to be comprehensive with no major deficiencies.

Plenne

The following minor points should be made:

On page 2-11, backup power equipment is discussed. This should include 10 mention of an uninterruptible power system to protect equipment when power is switched to the backup source.

Section D.2.3, p. D-9. The explanation of refraction is not correct. A standard or "well mixed" lower atmosphere causes refraction of the beam and illumination of targets beyond the optical horizon, not straight line propagation. This is due to a lapse of refractive index with height even in a well-mixed atmosphere.

cc:

W/WR7 W/WR4





U.S. DEPARTMENT OF COMMERCE National Oceanic and Atmospheric Administration NATIONAL WEATHER SERVICE FLASKA REGION 701 C Street, Box 23, Anchorage, AK 99513

May 15, 1984

W/AR72/ECH:mm

TO:

Wx7 - John R. Porter

FROM:

W/AR - Stuart G. Bigler Strant Circle

SUBJECT: Comments on NEXRAD Programmatic Environmental Impact Statement

Per the request of Janet Springsteen, we have reviewed the Programmatic Environmental Impact Statement Next Generation Weather (NEXRAD) System and have the following general comments:

- Page S-1, Description of Action, paragraph 5 Should you consider easements on adjoining land such as limiting height of new construction or maintaining cable and power rights-of-way?
- Page S-2, Radiofrequency Radiation and Human Health Do your calculations consider the antenna in an elevation scan mode and/or helicopter operations at the airport.
- 3. Page S-2, Environmental Effects Should you not mention in your text how you handle your subsurface (site) fuel tanks for emergency power or the facility heating plant, if oil?
- 4. Page 2-13, Figure 2-5 CONCEPTUAL NEXRAD SITE DEVELOPMENT The building appears very large for people on stift and equipment based on 15 the President's recent order of 135 square feet per person. The parking area is too small to handle your day shift.
- Page 2-17, 2.3.2, Site Selection Criteria, 1st paragraph, sentences 1 and 2 -- If the FPS-77 sites are in acceptable locations, why is AWS not planning to use those sites? This sentence, perhaps, should be moved to the end of the paragraph.
- 6. We understand NEXRAD is scheduled for Alaska and Hawaii by DOT 17 or DOD. Do you want to include these sites in your Table 2-1 on pages 2-21 or 2-22?

For the most part this seems to be a very complete document and we found Appendix A through D very informative. Thank you for allowing us to comment.







UNITED STATES DEPARTMENT OF COMMERCE National Oceanic and Atmospheric Administration NATIONAL OCEAN SERVICE Washington, D.C. 20230

MAY | 4 232

N/MB21:VLS

PP2 - Joyce M. Wood

FROM:

TO:

N - Pat: M. V

SUSTECT:

DEIS 8404.05 /- Next Generation Weather Radar (NEXRAD) System

(Department of Commerce)

The subject statement has been reviewed within the areas of the National Ocean Service's (NOS) responsibility and expertise, and in terms of the impact of the proposed action on NOS activities and projects.

Geodetic control survey monuments may be located in the proposed project area. If there is any planned activity which will disturb or destroy these monuments, NOS requires not less than 90 days' notification in advance of such activity in order to plan for their relocation. We recommend that funding for this project includes the cost of any relocation required for NOS monuments. For further information about these monuments, please contact Mr. John Spencer, Chief, National Geodetic Information Branch (N/CG17), or Mr. Charles Novak, Chief, Network Maintenance Section (N/CG162), at 6001 Executive Boulevard, Rockville, Maryland 20852.





Administration

Northwest Mountain Region Colorado Idaho Montana Oregon, Utah Washington, Wyomina 17900 Pacific Highway South C-88966 Seattle Washington 98168

MAY 2 2 1984

Mr. John Porter NEXRAD-JSPO WX-7 Room 23 11420 Rockville Pike Rockville, Maryland 20852

Dear Mr. Porter:

We have reviewed the draft programmatic environmental impact statement of the Next Generation Weather Radar (NEXRAD) Systems and offer the following comments:

a. Par 2.3.2

"Sites should be on government owned land, preferably Federally owned. Private land will be considered only as a last resort."

Comment: It would be imprudent to sacrifice significant operational characteristics for "real estate" reasons. Considering the total long-term cost of the facility, skimping on site acquisition costs, and accepting a consequent performance penalty does not make sense.

b. Sec 2.3.3, 4th Par

Comment: Many airports are poor locations for a long-range weather radar. For example, both Portland, Oregon, and Salt Lake City, Utah, airports are surrounded by hills or mountains which will obscure distant weather because of high horizon elevation angles. It is unclear why airports are favored as a site for weather radars.

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c. Chapt 4

Comment: There is no analysis or mention of interference to high fidelity audio equipment or computer equipment in homes and offices near the site. Granted that such interference usually results from poor design of the vulnerable equipment, such interference has been a major problem near some urban FAA sites and at FAA Academy sites.

21

Thank you for this opportunity.

Sincerely,

David W. Cain

Manager, Program & Planning Branch

DEPARTMENT OF THE AIR FORCE

DIFCE OF THE ASSISTANT SECRETARY

May 29, 1984

Mr. John Porter NEXRAN-JSPO Wx7 Room 323 11420 Rockville Pike Rockville, Maryland 20852

Dear Mr. Porter:

We have reviewed the draft Programmatic Environmental Impact Statement of the Next Generation Radar. Attached are review comments from the Air Force offices most interested in the NEXRAD.

We appreciate the opportunity to review and comment on the program. Please contact us if there are any questions.

Sincerely,

GARY D. VEST

Deputy for Environment & Safety
Deputy Assistant Secretary of the Air Force

(Installations, Environment and Safety)

1 Atch
Comments on Draft Programmatic
LIS, NEXRAD

cc: Ms. Joyce M. T. Wood Chief, Ecology and Conservation Division National Oceanic and Atmospheric Administration Washington, D.C. 20230

1. The programmatic EIS needs to address the required topics in the areas of Threatened and Endangered Species, Prime and Unique Farmlands, Wilderness Areas, and Floodplains and Wetlands. A 22 short discussion of these topics should discharge the federal requirements in those areas. 2. The issue of frequency interference with other radars (for example, Air Traffic Control) is a concern. In preliminary planning, Air Force Communications Command has discovered areas, such 23 as California and Washington, DC, where interference of NEXRAD on other radar systems will be a major problem. Resolving this issue is a critical item to successful deployment of the system. 3. Recommend worst case situations be used in lieu of average when discussing radio frequency radiation (RFR). The antenna 24 will be capable of a -1 degree tilt and assumptions of essentially flat terrain out to 3000 feet will be difficult to find whether near an airport or metropolitan area. 4. Page 2-17. DoD will have electromagnetic interference problems when attempting to site on existing government real estate and in close proximity to GPN-20, FPN-47 and GPN-12 ASRs. 5. Page 4-11, Paragraph 4.1.3.2.1.4. and Page D-10, paragraph D.3.2. Recommend including a reference to potential interference to digital processing equipment. 6. Page A-4, paragraph A.2.3. The system engineer for AFCC is 27 unaware of an interlock so that transmission cannot occur when the antenna is not moving. Recommend this be clarified. 7. Page B-8, last paragraph. Equation "1/(13x360)" should be 28 changed to "1/(3x360)." 8. Page S-2 and Page C-6, Paragraph C.2.4. The maximum allow-29 able E-field, 100K volts/meter, should be included. (Reference AFOSH-STD-161-9). 9. The biophysical discussion should address, or defer to site-

specific environmental analysis, the potential effects of uncovering hazardous waste, use of asbestos (or removal in old struc-

tures), cathodic protection of POL tanks, and use of hazardous chemicals either in construction or operation of the radar.



DEPARTMENT OF THE AIR FORCE MERECURPTERS MILITARY AND RECOMMEND SCITT AIR FORCE BASE WINCH 4 GEZ LS

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.mc= NEXRAD Programmatic Environmental Impact Statement (PEIS)

-a HO USAF/RDSL

- We have reviewed the NEXRAD PELS and offer the 'u'lowing comments:
- a. Page 2-10, first para, line 7. Change ". . . Station and to ARTCC via telephone lines." to " . . . Station, Automated Weather Distribution System, 31 Air Force Global Weather Central, and the European and Korean Forecast Offices via telephone lines."
- b. Page 2-10, first para, line 8. Change " . . . ARTCC." to 32 . . . ARTCC via telephone line."
- c. Page 2-16, first para, line 7. Add following sentences after " . . . NWS offices.": "The principal user facility at Air Force sites will be staffed by an average of 16 people (1 commander, 11 forecasters/observers, 33 3 maintenance technicians, and 1 clerk). No change in Air Force staffing is planned nor will new facilities be built."
- d. Page 2-17, first para, next to the last line. Change " . . . AWS requires that the radar be located . . . " to " . . . AWS radars will fre-34 quently be located
- e. Page 2-17, second para, line 2. Change " . . . AWS is not planning to 35 use . . . " to " . . . AWS will not always use . . . "
- f. Page 2-17, second para, line 5. Change " . . . in most c:ses . . to " . . . in most NWS cases "
- g. Page 2-17, second para, line 7. Change " . . . existing site . . . to " . . . existing NWS site . . . " . . . existing NWS site
- h. Page 2-18, first para. AWS has forwarded a siting list and map to the 38 JSPO. These sites should be included in Table 2-1 and Figure 2-7.
- Page 2-18, third para. AWS sites can be characterized because a list has been forwarded.
- j. Page 4-19, second para, line 5. Add following sentence after 40 " . . . NEXRAD facility.": "No increase in Air Force staffing is anticipated."
- k. Page A-4, first para. Which scan strategy has these characteristics (0.5 rpm, elevation angle change of 4 degrees, and scan time of 12 minutes)?
 - Page B-2, para (7). When will we scan at 0 degrees? 42

- m. Page 8-6, fourth para. Why not use the slow speed of 3 degrees/ second? Isn't this the worst case?
- n. Page 8-13, first para. A 4-degree elevation angle change is not the 44 worst case.
- 2. Our comments clarify the differences in NWS and AWS siting needs and staffing plans. Please contact us if further clarification is required.

CONTRACT COTONET, USAF Dir Opn7 Romts & Tests

DCS/Flans

cc: AWS/LGL

NEXRAD JSPO

43

HO AFCC/EPE



United States Department of the Interior

OFFICE OF THE SECRETARY WASHINGTON, D.C. 20246

In Reply Refer To: ER-84/472 JUN 8 1984

Mr. John Porter NEXRAD-JSPO Wx7 Room 323 11420 Rockville Pike Rockville, Maryland 20852

Dear Mr. Porter:

This letter responds to your request for the Department of the Interior's (DOI) review of the Draft Programmatic Environmental Impact Statement (DEIS) for the Next Generation Weather Radar (NEXRAD) System. We have reviewed the DEIS and have the following comments.

General Comments

Although it is not discussed in this program document, we are assuming a site specific environmental assessment (EA) or environmental impact statement (EIS), as necessary, will be prepared for each facility in accordance with the National Environmental Policy Act.

In regard to the site selection process, close coordination is suggested with the Department's Fish and Wildlife Service (FWS) and the Bureau of Land Management (BLM). For sites likely to impact fish and wildlife resources, early coordination with the FWS should eliminate or reduce most problems. Of particular concern are:

- Lands managed by the FWS.
- Lands used by federally listed or candidate threatened or endangered species.
- State-managed lands acquired with FWS Federal Aid to Fish and Wildlife Restoration Acts funds.
- Sensitive aquatic resources, especially wetland and riparian habitat.
- Lands that coincide with bird migration routes, especially waterfowl flyways.

Initial consultation is suggested with the Director, FWS, Washington, D.C. 20240.

As the initial BLM coordinating office for the identification of States and Resource Areas involved in NEXRAD site selections, it is suggested that you contact the Director, Bureau of Land Management (330), Washington, D.C. 20240. Information on land use authorizations, rights-of-way, and a list of BLM field offices to be contacted can also be provided. In addition, BLM would like to be a cooperating agency in those instances

Mr. John Porter 2

where EA's or EIS's will be prepared for public lands under BLM management. This would permit BLM to adopt these documents in lieu of preparing their own and consequently would hasten the decision-making process.

It should be noted that close coordination is already occurring between DOI and the National Oceanic and Atmospheric Administration (NOAA) through an interagency agreement with the Federal Aviation Administration (FAA). Under this agreement, the Bureau of Reclamation's (BR) Division of Atmospheric Resources Research is conducting joint weather studies in support of the NEXRAD Program. These studies include aircraft measurements in clouds of various atmospheric and cloud physics parameters, operation of a weather radar at FAA-selected sites, and analysis of data. The findings may be used in developing siting criteria and radar operating procedures.

The FEIS should analyze the impacts of the radar's electromagnetic waves on migratory and/or resident bird populations more fully and include mitigation measures as necessary. Since birds cannot be excluded from the site or from the effects of the radar by fencing, the following issues should be discussed in more detail in the final EIS:

- Chronic exposure effects on birds and wildlife within the fenced transmitter sites.
- Effects of the radiation and electromagnetic field on nesting birds and eggs.

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- Effects of the NEXRAD System on birds migrating through the radar field.
- 4. Bird strikes and kills related to powerlines, towers, and guy wires.
- Potential for bird electrocutions.

To support additional analysis, a list of references not already cited in the document has been provided.

Specific Comments

Page 2-16, Section 2.3.2. Site Selection Criteria. This section of the final EIS should indicate that all units of the National Park System will be excluded from consideration as sites for proposed radar installations and that radar sites will not be within the visible range of any National Park Service area. Such protection is alluded to in Sections 4.3.6 and 4.3.7, but needs to be made a part of site selection criteria in Section 2.3.2.

Page 3-4, Paragraph 1, Section 3.2. Biophysical Environment. It should not be assumed that wildlife, especially birds, are absent from existing airport sites. The undeveloped open spaces buffering airport facilities often attract birds and other wildlife.

Page 4-7, Section 4.1.2.2. Plants and Animals. The determination that significant effects on plants and animals are not expected to result from the system is not fully established by discussion in the DEIS.

A limited literature review leads us to the conclusion that the potential exists for the NEXRAD System to adversely affect wildlife resources. Orientation of birds migrating in the axis of the main beam may be affected. Studies show some birds will turn and change altitude, while others may be attracted and strike the radar facility. Additional information is needed on the effects of this system on bird migration. Many of the proposed candidate sites lie within the major flyway routes of waterfowl. It is suggested that a bird monitoring program be developed as part of the operation of the system.

49 cont'd

Page 4-13, Section 4.2.1.1. Plants.

Paragraph 1. When removing "tall trees" during site preparation, the potential value of the trees for the conservation of eagles and other threatened and endangered species should be considered.

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Paragraph 3. Vegetative cover that does not attract birds should be used when revegetating disturbed areas to minimize erosion.

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Paragraph 4. This paragraph describes measures to be taken to comply with State and local environmental protection and conservation. Mention of the need for compliance with Federal fish and wildlife resource protection laws or regulations should also be included. A discussion of such compliance is necessary to inform the reader that the authors are familiar with federally mandated resource protection. For example, Federal requirements in regard to the Endangered Species Act must be complied with when considering federally listed or candidate threatened and endangered plan species. For assistance in dealing with such species, the Fish and Wildlife Service's Office of Endangered Species, Washington, D.C. 20240 should be contacted.

52

Page 4-14, Section 4.2.1.2. Animals.

Paragraph 1. Here, as well as on page 3-4, reference is made to the temporary displacement of wildlife at the constructed antenna sites. Displaced animals will seek shelter and food elsewhere, but will be forced to compete with organisms already residing in those areas. Competition for essential life requirements will most likely result in a permanent loss, not a temporary displacement.

53

Last Sentence. Caution should be exercised not to plant new vegetation that would attract wildlife.

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Paragraph 3. The discussion of potential adverse effects to birds from radar towers, powerline/poles, and guidewires should be expanded to include mitigation measures to minimize losses.

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Page 4-17, Paragraph 1, Section 4.2.3. Water and Water Quality. There is no discussion of the potential impacts to fish and wildlife from the use of chemicals at radar sites. These impacts, if applicable, as well as measures to mitigate potential contamination of surface and ground water, should be discussed in the final EIS.

Mr. John Porter 4

In regard to sites requiring dredging, filling, or construction in U.S. waters, a U.S. Army Corps of Engineers' Section 10/404 permit may be required. The Department's Fish and Wildlife Service provides input to the Corps concerning these permit applications in accordance with the Fish and Wildlife Coordination Act.

We appreciate the opportunity to review this document and anticipate future involvement with the site specific environmental documents.

Sincerely,

Jacuce M. Martur

Bruce Blanchard, Director
Environmental Project Review

Enclosure

cc: Ms. Joyce M. T. Wood

Additional References

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY WASHINGTON, D.C. 20460

MAY 2 9 1984

OFFICE OF EXTERNAL AFFAIRS

Mr. John Porter NEXRAD JSPO National Weather Service 11420 Rockville Pike Rockville, Maryland 20852

Dear Mr. Porter:

In accordance with our responsibilities under the National Environmental Policy Act (NEPA) and Section 309 of the Clean Air Act, the Environmental Protection Agency (EPA) has reviewed the Draft Programmatic Environmental Impact Statement (EIS) for Next Generation Weather Radar (NEXRAD) System. Our general comments follow and detailed comments are enclosed.

Overall we believe that the draft EIS provides a good foundation for environmental review of the proposed action. We note that this programmatic EIS will be supplemented by site specific environmental assessments where needed, based on the results of site specific surveys. Such surveys will employ an environmental impact worksheet. We suggest that additional items be added to this worksheet to reflect required permits and special regulated resources such as wetlands and sole source aquifers.

57

While the analytical models used to estimate radiofrequency (RF) radiation exposure intensities and potential health effects differ in some cases from EPA's approach, we are in general agreement with the conclusions reached in the EIS. On the basis of current knowledge of the effects of RF radiation exposure, there should be no adverse environmental or health impact from the time-averaged radiation exposure which would result from the proposed operation of the NEXRAD system. However, we suggest that the discussion of the health effects should be refined and that an expanded discussion of current scientific uncertainties be included. To assist in this assessment we have enclosed a prepublication copy of Biological Effects of Radiofrequency Radiation. This document was prepared by EPA and recently transmitted

to Administrator Ruckelshaus by the Chairman of EPA's Science Advisory Board as a "scientifically defensible basis for the Agency's development of radiation protection guidance for use by Federal agencies to limit exposure of the general public to radiofrequency radiation." The Science Advisory Board is a congressionally mandated committee of scientists and engineers outside of Government that advises the EPA Administrator. The report will be published later this summer.

EPA has rated this draft EIS LO-1 (lack of objections/adequate information). This rating reflects our basic conclusions that the impacts of the proposed program will be minor. We do, however, suggest that additional discussion of the data limitations associated with potential health effects of RF radiation be provided in the final EIS for completeness and to assist the decisionmaker.

58 cont'd

Thank you for the opportunity to comment. Should you have any questions concerning our comments please contact Margaret Schneider (382-5070) of my staff.

Sincerely

Allan Hirsch

Director

Office of Federal Activities

Enclosure

Environmental Protection Agency's

Detailed Comments on the DEIS for the NEXRAD System

I. RF Radiation Intensities and Potential Health Effects

General

- o The analytical approach used is reasonable and proper in that it models the actual exposure situation. While we may differ with specific definitions (such as near field extent) and numerical values of calculated time-averaged power densities that may exist at specific distances from the antenna and at given off-axis distances, the values calculated (in the EIS) for the near-field on-axis time-averaged power density and the corresponding value at the onset of the far-field generally agree (within about a factor of 2) with our calculated values.
- o We agree with the conclusions that the maximum time—averaged exposure power density will not exceed 100 uW/cm² at heights of 6 feet above ground (even in the near-field) and will be less than 0.4 uW/cm² at a distance of 550 feet from the antenna at a height of 6 feet above ground (an off-axis distance of approximately one antenna diameter). However, since this DEIS is not system or site-specific, we would encourage calculations be made for the specific system to be used at a site if the perimeter fence falls in the near field. We would assume that the perimeter fence could be adjusted if necessary at the actual site design stage.

Pages 4 - 2 through 4 - 7

o This section should provide a more detailed discussion of the health impacts and make use of specific references beyond the Air Force Report, (Report SAM-TR-83-1). The authors should refer to EPA's recent health assessment document, Biological Effects of Radiofrequency Radiation. Publication is scheduled for July; a copy of the final is enclosed.

59

Page 4-2, first paragraph of Section 4.1.2.1.

o The last sentence states that time-average power densities are "... consistent with the current U.S. exposure standards." This statement may be misleading to the reader. By inference, one might assume this means Federal or governmental standards, but there are no Federal population exposure standards and only a few State standards. The statement primarily refers to the American National Standards Institute's (ANSI) voluntary standard. The ANSI standard should be viewed as an occupational exposure standard and, at most, only on upper limit for general population exposure:

61

Because of the limitations of the biological effects data base, these guides are offered as upper limits of exposure, particularly for the population at large. [ANSI C95.1-1982, page 11.]

The paragraph should state explicitly what standard is being referenced.

Page 5, second paragraph of Section 4.1.2.1.1, Airborne Exposure

o first, greater detail and citations are needed when discussing a threshold pulse power density for the RF hearing effect, since certain studies have reported different values. The RF hearing phenomenon is discussed in the enclosed EPA report, and that write-up might be helpful. Second, as stated in the last sentence, it is true that there is no experimental evidence of harm to people exposed to such levels of pulse power density. This is because consequences of such exposure and of RF hearing have not been adequately studied:

62

Because a very low average power density can cause an acoustic response in the head and there is the potential for exposure of the public to pulsed fields that induce the effect, an unresolved issue is the need to assess the psychological effects of RF hearing, particularly in populations that may have no knowledge as to the origin of the RF sounds in the head. (EPA, Biological Effects of RF page 5-277.)

In the last sentence we suggest that "... that these..." be changed to "... on which to conclude whether..." It is recognized, however, that people in airplanes are unlikely to 'hear' NEXRAD pulses.

Page 4 - 6, second paragraph

 Why epidemiological studies are not regarded as evidence should be discussed.

Page 4 - 6, third paragraph, second sentence concerning effects at or above 2 mW/cm²

o It would be better to say "most such effects are thermal . . . " since, in some studies, a clear linkage with temperature changes has not been made.

Page 4 ~ 6, fourth paragraph, last sentence, "The heat produced by . . . processes or thermoregulation."

o This statement might be true for healthy young men but may not be true for the population at large. Sensitive subgroups, e.g., the young, elderly, ill, or pregnant women, may not be as adaptive and can have compromised thermoregulatory systems. Effects in such subgroups, in general, and under adverse environmental conditions (high temperature and humidity and in combination with other pollutants), have not yet been thoroughly evaluated. In addition, one must generally assume, as ANSI did, the following:

Because of the paucity of reliable data on chronic exposure . . . the assumption is that reversible disruption during an acute exposure is tantamount to irreversible injury during chronic exposure. (ANSI c95.1-1982, page 13).

Chronic effects and long-term exposures are, thus, not well understood. Thermal physiology vis-a-vis RF radiation is a controversial subject, and should not be oversimplified.

Also, it is not clear whether or not the threshold value being discussed is 2 mW/cm^2 .

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Page 4 ~ 6, fifth paragraph

o At what level(s) did irreversible adverse effects occur? It would be helpful to include a discussion of effects below 2mW/cm² and to comment on relative adversity and problems, if any, with that data.

66

Page 4 - 7, first paragraph

o It would be helpful to discuss why RF hearing has been characterized as nonthermal, for example, the temperature change can be so slight (about 10-6 °C per pulse) so as to be nondetectable.

67

Page 4 - 7, second paragraph

We believe that the conclusion is overstated. The scientific data base is much more uncertain than implied here for both the health effects and the population subgroups listed. It creates the misimpression that "no reliable evidence" means negative studies/no effects when actually, many issues have not been evaluated or the available research data are limited in some fashion. Effects of modulation are also not yet clear:

68

It was recognized by the subcommittee that the specific absorption rate (SAR), which provides that basis for limiting power densities, does not contain all the factors that could be of importance in establishing safe limits of exposure. First, other characteristics of an incident field such as modulation frequency and peak intensity may pose a risk to health. Again, the data base does not provide the evidence of adversity by which to recommend special provisions for modulated fields. There was an intuitive concern by some members of the subcommittee that caution should be exercised when individuals are exposed to a pulse-modulated field of high peak but low averaged density, or to a sinusoidally-modulated field, when either field has a recurrence rate in the range of bioelectric rhythms. A supportable way of expressing this concern, which would be applicable to all exposed populations, could not be reached. (ANSI C95.1-1982, page 14.)

This paragraph should be rewritten and include more thorough discussion of uncertainties and limits of the available health effects data.

68 cont'd

II. Worksheet (Appendix E)

o A heading for permits required should be added. Applicable statutes might include: Clean Water Act, Clean Air Act, Safe Drinking Water Act, Resources Conservation and Recovery Act, etc.

69

- o A specific heading should be added for special resource areas such as wetlands and sole source aguifers.
- We note that the initial list of candiate sites for NEXRAD radars includes the existing Boston (Chatham), Massachusetts, weather radar site, a site located within the recharge zone of the Cape Code sole source aquifer. (See enclosed notice) The Programmatic EIS should acknowledge that the construction and operation of a NEXRAD installation on Cape Code will be subject to an EPA review pursuant to Section 1424(e) of the Safe Drinking Water Act. We recommend that the NEXRAD Joint System Program Office contact the appropriate EPA Regional Drinking Water Branch during preliminary site surveys to discuss the information needed to be included in the site specific environmental assessments/programmatic EIS supplements for EPA's sole source regiew.

70

pipeline (Continental Divide Pipeline Company), which is the subject of an application before the Federal Energy Regulatory Commission, will be jointly owned by subsidiaries of Transwestern and Northwest.

The Agreement provides that the price Transwestern will pay ProGas for the imported natural gas will be the authorized international order price, currently U.S. \$4.94 per MMBtu.

Transwestern also states that on April 2, 1982, ProGas filed an application with the National Energy Board of Canada (NEB) to export the gas for sale to Transwestern. The NEB has not yet approved ProGas' proposed export to Transwestern.

Transwestern is obligated under the Agreement to take or otherwise pay for a minimum annual quantity of gas equal to 75 percent of the maximum daily contract quantity times the number of days in the particular contract year, less the difference between the daily volumes requested by Transwestern and the actual amounts delivered. The price that Transwestern will be required to pay for the gas under the take-or-pay provisions is the prevailing Canadian border price.

In any contract year after it has met its minimum annual purchase obligation. Transwestern may recover any gas paid for but not previously taken (prepaid

The Agreement also provides a mechanism for reducing Transwestern's volume of prepaid gas if ProGas' contractual obligations to take gas from the Alberta producers which supply it are less than the total volume of prepaid gas of all of ProGas' customers. in that case, Transwestern's prepaid gas will be adjusted by its pro rata share of the difference (obtained by mulitplying ProGas' prepaid volume by Transwestern's prepaid volume and dividing by the total prepaid volume).

In support of its application
Transwestern asserts that it is
experiencing a decline in its supply of
natural gas from present sources and
that it is making extensive efforts to
secure replacement gas by various
means in order to meet, in future years,
its existing contractual supply
commitments to its customers.
Transwestern states the proposed
import is one of several sources it
intends to pursue to offset this decine,
and that the import is in the public
interest of the United States.

Transwestern requests that the processing of this application be expedited.

OTHER INFORMATION: Any person wishing to become a party to the

proceeding, and thus to participate in any conference or hearing which might be convened, must file a petition to intervene. Any person may file a protest with respect to this application. The filing of a protest will not serve to make the protestant a party to the proceeding. Protests will be considered in determining the appropriate action to be taken on the application.

All protests and petitions to intervene must meet the requirements specified in 18 CFR 1.8 and 1.10. They should be filed with the Natural Gas Branch, Economic Regulatory Administration, Room 6144, RG-631, 12th & Pennsylvania Avenue NW., Washington, D.C. 20461. All protests and petitions to intervene must be filed no later than 4:30 p.m., August 12, 1982.

A hearing will not be held unless a motion for a hearing is made by a party or person seeking intervention and granted by ERA, or if ERA on its own motion believes that a hearing is necessary or required. A person filing a motion for hearing must demonstrate how a hearing will advance the proceedings. If a hearing is scheduled, ERA will provide notice to all parties and persons whose petitions to intervene are pending.

A copy of Transwestern's application is available for inspection and copying in the Natural Gas Branch Docket Room, located in Room 6144, 12th & Pennsylvania Avenue NW., Washington, D.C., between the hours of 8:00 a.m. and 4:30 p.m., Monday through Friday, except Federal holidays.

Issued in Washington D.C. on July 6, 1982 James W. Workman,

Director, Office of Fuels Programs, Economic Regulatory Administration.

[FR Doc. 82-18782 Filed 7-11-62: 5-65 a.m] BILLING CODE 6459-61-82

Office of Energy Research

Solar Panel Energy Research Advisory Board; Meeting

Notice is hereby given of the following meeting:

Name: Solar Panel of the Energy Research Advisory Board (ERAB). ERAB is a: Committee constituted under the Federal Advisory Committee Act (Public Law 92– 463. 86 Stat. 770)

Date and time: August 2 and 3. 1982, 9 a.m. to 5 p.m.

Place: Room 4A-110, Forrestal Building, 1000 Independence Avenue SW', Weshington, D.C. 20585

Contact: William Woodard, Energy Research, Advisory Board, Department of Energy, Forrestal Building, ER-6, 1000 Independence Avenue SW., Washington, DC 20585, Telephone: 202/252-8933. Purpose of the parent board: To advise the Department of Energy on the overall research and development conducted in DOE and to provide long-range guidance in these areas to the Department.

Tentative agenda:

Meet and discuss with solar lechnology and engineering and development community, including individuals from universities, industry, and the National Laboratories the draft report of the Solar R&D Panel.

Review draft of the Solar R&D Panel's report and obtain public comments

thereon.

Public participation: The meeting is open to the public. Written statements may be filed with the Panel either before or after the meeting. Members of the public who wish to make oral statements pertaining to agenda items should contact the Energy Research Advisory Board at the address or telephone number listed above. Requests must be received five days prior to the meeting and reasonable provision will be made to include the presentation on the agenda. The Chairperson of the Panel is empowered to conduct the meeting in a fashion that will facilitate the orderly conduct of business.

Transcripts: Available for public review and copying at the Freedom of Information Public Reading Room, 1E-190, Formatial Building, 1000 Independence Avenue, SW. Washington, DC. between 8:30 a.m. and 4 p.m. Monday through Friday, except

Federal bolidays.

Issued at Washington, DC, on July 7, 1982. Irs M. Adler,

Acting Director for Management, Office of Energy Research

FR Doc. 82-18781 Filed 7-12-82: 8:45 am] BILLING CODE 6450-01-M

ENVIRONMENTAL PROTECTION AGENCY.

(W-1-FAL 2133-6)

Cape Cod Aquiter Determination

AGENCY: U.S. Environmental Protection Agency.

ACTION: Final determination.

SUMMARY: Pursuant to Section 1424(e) of the Safe Drinking Water Act the Administrator of the U.S. Environmental Protection Agency (EPA) has determined that the Cape Cod aquifer is the sole or principal source of drinking water for Cape Cod, Massachusetts, and that the Cape Cod aquifer, if contaminated, would create a significant hazard to public health. As a result of this action. Federal financially assisted projects constructed anywhere on Cape Cod will be subject to EPA review to ensure that these projects are designed and constructed so that they do not

create a significant hazard to public

ADDRESSES: The data on which these findings are based are available to the public and may be inspected during normal business hours at the U.S. Environmental Protection Agency. Region I, Drinking Water Branch, LF. Kennedy Federal Building, Boston. Massachuseits, 02203. FOR FURTHER INFORMATION CONTACT: Steven J. Koorse, Drinking Water Branch, Environmental Protection Agency, Region I, at (617) 223-6688. SUPPLEMENTARY INFORMATION: Notice is hereby given that pursuant to Section 1424[e] of the Safe Drinking Water Act (42 U.S.C. 300h-3(e), Pub. L. 93-523) the Administrator of the U.S. Environmental Protection Agency (EPA) has determined that the Cape Cod aquifer is the sole or principal source of drinking water for Cape Cod, Massachusetts. Pursuant to Section 1424(e), Federal financially assisted projects constructed anywhere on Cape Cod will be subject to EPA review.

Background

Section 1424(e) of the Safe Drinking Water Act states:

If the Administrator determines, on his own initiative or upon petition, that an area has on aguiler which is the sole or principal drinking water source for the area and which. If consuminated, would create a significant hazard to public health, he shall publish notice of that letermination in the Federal Register. After the publication of any such notice, no commitment for Federal financial assistance (through a grant, contract, loan guarentee, or otherwise) may be entered into for any project which the Administrator determines may contaminate such aquifer through a racharge zone no as to create a significant hazard to public health, but a commitment for Federal financial assistance may, if authorized under another provision of law, be entered into to plan or design the project to easure that it will not so contaminate the aquifer.

On March 4, 1981. EPA received a petition from the Cepe Cod Planning and Economic Development Commission requesting EPA to designate the Cape Cod aquifer as a sole source aquifer. In response to this petition. EPA published a notice in the Federal Register on November 18, 1981 (46 Fed. Reg. \$6232), announcing a public comment period and setting a public hearing date. A public hearing was conducted on January 4, 1982, and the public was allowed to submit comments on the petition until February 12, 1982.

II. Basis for Determination

Among the factors to be considered by the Administrator in connection with the designation of an area under Section 1424(e) are: (1) Whether the aquifer is the area's sole or principal source of drinking water, and (2) whether contamination of the equifer would create a significant hazard to public health.

On the basis of information available to this Agency, the Administrator has made the following findings, which are the bases for the determination noted above:

 The Cape Cod agulfer is a single continuous aquifer which currently serves as the "sole source" of drinking water for the approximately 147,725 permanent residents and 424,445 peak seasonal residents of Cape Cod.

 There is no existing alternative drinking water source, or combination of sources, which provides fifty percent or more of the drinking water to the designated area, nor is there any reasonably available alternative future source capable of supplying Cape Cod's drinking water demands.

3. The Cape Cod aquifer is glacial in origin and is composed of unconsolidated sand, gravel, silt and clay deposits. As a result of its highly permeable soil characteristics, the Cape Code aquifer is susceptible to contamination through its recharge zone from a number of sources, including but not limited to, chemical spills, highway runoff, septic tanks, leaking storage tanks, and leaching from open dumps. There is present evidence of localized contamination of the aquifer from chemical spills, individual disposal systems, leaking fuel tanks, and wastewater treatment systems. Since ground water contamination can be difficult or impossible to reverse, and since this equifer is relied on for drinking water purposes by the general population, contamination of the equifer would pose a significent hazard to public health.

III. Description of the Cape Cod Aquifer and Its Recharge Zone

Cape Cod. located within Barnstable County in southeastern Massachusetts, is a peninsula that extends 40 miles into the Atlantic Ocean. It is 440 square miles in area and is separated from the mainland by Cape Cod Canal. The area in which Federal financially assisted projects will be subject to review is the area that includes the Cape Cod aquifer, its streamflow source zone, and its recharge zone, which are one and the same.

For purposes of this designation, the Cape God aquifer is considered a single continuous aquifer, with the Cape God Canal, Cape God Bay, the Atlantic Ocean, Nantucket Sound and Buzzards Bay its latera! boundaries Similarly, the 'echarge zone boundaries of the aquifer will be regarded as coterminous with the lateral boundaries of the equife:

IV. Information Utilized in Determination

The information utilized in this determination includes the petition. written and verbal comments submitted by the public, U.S. Environmental Protection Agency technical publications, and a ground water resources study conducted by the U.S. Geological Survey (Cape Cod Aquifer, Water-Resources Investigation 80-571). The above data is available to the public and may be inspected during normal business hours at the Environmental Protection Agency. Region I, Drinking Water Branch, I. F. Kennedy Federal Building, Boston, Massachusetts.

V. Project Review

EPA Region I is working with the Federal agencies that may in the future provide financial assistance to projects in the area of concern. Interagency procedures are being developed in which EPA will be notified of proposed. commitments by Federal agencies for projects which could contaminate the Cape Cod aquifer. EPA will evaluate such projects and, where necessary conduct an in-depth review, including soliciting public comments where appropriate. Should the Administrator determine that a project may contaminate the aquifer through its recharge zone so as to create a significant hazard to public health, no commitment for Federal financial assistance may be entered into. However, a commitment for Federal financial assistance may, if authorized under another provision of law, be entered into to plan or design the project to assure that it will not so conteminate the aquifer.

Although the project review process cannot be delegated, the U.S. Environmental Protection Agency will rely to the maximum extent possible on any existing or future State and local control mechanisms in protecting the ground water quality of the Cape Cod aquifer. Included in the review of any Federal financially essisted project will be coordination with the State and local agencies. Their comments will be given full consideration and the Federal review process will attempt to complement and support State and local ground water protection mechanisms.

VI. Summary and Discussion of Public Comments

Most of the comments received from Federal, State and local government agencies and from the public were strongly in favor of designation. Only three commenters expressed any reservations regarding the designation.

One commenter felt that EPA currently has sufficient ground water protection mechanisms, which together with State and local mechanisms, render a sole source designation unnecessary. Although a number of ground water protection measures are available at the Federal, State and local level, none of these, either individually or collectively, permit EPA to act as directly and comprehensively as would a sole source designation in the review and approval of Federal financially assisted projects. In addition, EPA feels that the sole source project review process will foster integration rather than duplication of environmental review efforts.

Two commenters, although generally in favor of the designation, expressed concern that sole source designation might preclude the use of land application as a wastewater treatment technique on Cape Cod. If properly sited, designed, operated and maintained, land application treatment can be an environmentally sound and cost effective waste management alternative. Sole source designation will not interfere with the development of any environmentally sound weste management solutions for Cape Cod municipalities. Federal financial assistance will only be withheld in those instances where it is determined that a proposed project may contaminate the aquifer so as to create a significant hazard to public health and no acceptable remedial measures are available to prevent the potential hazard.

VII. Economic and Regulatory impact

Pursuant to the provisions of the Regulatory Flexibility Act (RFA), 5 U.S.C. 605(b). I hereby certify that the attached rule will not have a significant impact on a substantial number of small entities. For purposes of this Certification the term "small entity" shall have the same meaning as given in Section 601 of the RFA. This action is only applicable to Cape Cod. The only affected entities will be those Capebased businesses, organizations or governmental jurisdictions that request Federal financial assistance for projects which have the potential for contaminating the aquifer so as to create a significant hazard to public health. EPA does not expect to be reviewing

small isolated commitments of financial assistance on an individual basis, unless a cumulative impact on the equifer is anticipated; accordingly, the number of affected small entities will be minimal.

For those small entities which are subject to review, the impact of today's action will not be significant. Most projects subject to this review will be preceded by a groundwater impact assessment required pursuant to other Federal laws, such as the National Environmental Policy Act, as amended [NEPA], 42 U.S.C. 4321, et seq. Integration of those related review procedures with sole source aquifer review will allow EPA and other Federal agencies to avoid delay or duplication of effort in approving financial assistance. thus minimizing any adverse effect on those small entities which are effected. Finally, today's action does not prevent grants of Federal financial assistance which may be available to any affected small entity in order to pay for the redesign of the project to assure protection of the aquifer.

Under Executive Order 12291, EPA must judge whether a regulation is "major" and therefore subject to the requirement of a Regulatory Impact Analysis. This regulation is not major because it will not have an annual effect of \$100 million or more on the economy. will not cause any major increase in costs or prices, and will not have significant adverse effects on competition, employment, investment, productivity, innovation, or the ability of United States enterprises to compete in domestic or export markets. Today's action only affects Cape Cod. It provides an additional review of groundwater protection measures, incorporating State and local measures whenever possible. for only those projects which request Federal financial assistance. This regulation was submitted to OMB for review under EO 12291.

Dated: July 6, 1982.

Anne M. Gorsuch,

Administrator.

[FR Doc. 82-1880 Fine f-12-82 843-89]

BILLING CODE 6561-80-81.

[OPTS-00034; TSH-FRL 2168-5]

Interagency Toxic Substances Data Committee; Cancellation of Meeting

AGENCY: Environmental Protection Agency (EPA).

ACTION: Notice.

SUMMARY: The August meeting of the Interegency Toxic Substances Data Committee has been cancelled. DATE: The next meeting of the Committee has been scheduled for September 14, 1982.

FOR FURTHER INFORMATION CONTACT: Mary Belferman (TS-771). Executive Secretary, Interagency Toxic Substances Data Committee, Office of Pesticides and Toxic Substances, Environmental Protection Agency, 401 M St., SW., Washington, D.C. 20460, (202-554-1404).

SUPPLEMENTARY INFORMATION: The regular meetings of the Interagency Toxic Substances Data Committee usually take place on the first Tuesday of alternate months at 9:30 a.m. and are open to the public. The meetings are held in: Run. 2010, New Executive Office Bullding, 17th St. and Pennsylvania Ave., NW., Weshington, D.C. 20006.

The August meeting has been cancelled, the next meeting of the Interagency Toxic Substances Data Committee will take place on the second Tuesday in September, September 14, 1962. The meeting after that will be held on November 2, 1982.

Deted: July 6, 1982.

Mary Belferman.

Executive Secretary. Interagency Toxic
Substances Date Committee

(FR Date &1-1980 Fire 1-12-80 & 45 km)
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FEDERAL COMMUNICATIONS COMMISSION

Interconnection of Customer-Provided Telephone Equipment With Nationwide Telephone Network; Grant of Request for Permanent Exemption

AGENCY: Federal Communications Commission.

ACTION: Great of request for permanent exemption.

SUMMARY: Section 68.2(e) of the Commission's Rules and Regulations, 47 CFR 68.2(e), permits governmental departments, agencies or administrations to apply for exemption from the technical and legal requirements of Part 68 of the Commission's rules, in the interest of national defense and security. Part 68 governs the interconnection of customer-provided telephone equipment with the nationwide telephone network.

The Department of Energy has requested permanent exemption under § 68-2(e). The Commission hereby grants the Department of Energy's request. FOR FURTHER INFORMATION CONTACT: James M. Talens, Senior Attorney,

James M. Talens, Senior Attorney, Common Carrier Bureau, Federal Communications Commission, Washington, D.C. 20054, [202] 634–1832 Appendix G

RESPONSES TO COMMENTS

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Appendix G

RESPONSES TO COMMENTS

California Office of Historic Preservation

1. <u>Comment</u>: "The Department believes it inappropriate to suggest that surface collection and shovel testing are advisable actions to take during a field reconnaissance. The need for such actions may not be apparent in all cases, at least in California. Appropriate field actions should be determined on a case-by-case basis."

<u>Response</u>: The PEIS (p. 4-25) states that, "if necessary, at the time of the in-depth site survey, (available information) will be examined to determine whether cultural resources have been previously identified at the site in question" and that certain actions will be taken.

Thus, the PEIS inadvertently appears to commit to a course of action that, we agree, may be inappropriate in certain circumstances. The PEIS Summary is more general (p. S-6): "If actifacts are found, prescribed procedures for recording and preserving or recovering them will be followed."

Our intent was to indicate that coutlon will be exercised in the site selection process. As the Summary states: Cultural resources "are not expected to be found on existing radar sites because this land has already been disturbed. Special care will be taken at new, relatively undisturbed sites, especially in isolated locations, to prevent inadvertent damage."

In these latter cases and those where the potential for affecting cultural resources is unknown, we intend to coordinate with the state historic preservation office to obtain both information and advice on appropriate mitigation measures. The text of the PEIS on p. 4-25 has been revised to show this.

Kentucky Department for Facilities Management

2. <u>Comment</u>: "It is our hope that the deployment of the total system will provide complete coverage of Kentucky's geography and its people. In addition, we would hope that KEWS [Kentucky Emergency Warning System] could continue to be utilized to distribute the output of the radar to all parts of the Commonwealth providing the greatest advance notification period possible... Should Kentucky be at all limited in the

number of NEXRAD installations, we would encourage installations at least in Paducah, Louisville and Jackson."

Response: The list of sites in the PEIS is preliminary; final selection has not yet been made. The selection of sites will be based on the criteria outlined in Section 2.3.2 of the PEIS.

Lower Rio Grande Valley [Texas] Development Council

3. Comment: "I disagree with the deactivation of the existing radars, but rather suggest that they be maintained, not as the major data gathering source, but as a back-up to the NEXRAD units; if not to supplement them,"

Response: The continued usefulness of existing raders once NEXRAD units have been put into operation cannot yet be determined. Only after the network of NEXRAD radars has been defined can it be determined whether continued operation of a specific existing radar would be useful. The possibility of continuing to operate existing radars for local warning and NEXRAD backup purposes will be considered.

4. <u>Comment</u>: "In this Tornado Region, it is strongly encouraged that the weather rader site at the City of Brownsville be selected as a NEXRAD site due to its existence at the airport, plus its rural density and agricultural land use classification. (Identified by the Joint System Program Office)"

Response: Please see the response to Comment No. 2.

Virginia Council on the Environment

5. Comment: "We agree that archaeological surveys and necessary mitigation measures should be undertaken at sites for the facility prior to construction (pages 4-25, 4-26). Appropriate state or local approvals for potable water sources and wastewater disposal plans will be required. Site selection criteria should address the potential for chemical spills and their impacts on downstream water supply intakes."

Response: Please see the response to Comment No. 1 for more on cultural resources.

The Department of Commerce will apply for the necessary approvals for potable water sources and wastewater disposal plans. According to the Site Survey Plan prepared for the NEXRAD project, information on these and other similar requirements will be gathered beginning with the preliminary site survey for each site. Detailed requirements will be determined during the in-depth site survey.

The PEIS notes on p. 4-17 that chemicals may be used at NEXRAD sites, as they may now be at existing sites, for deicing and for soil stabilization, fertilization, weed prevention, and insect control. No other chemicals are expected to be used in construction or operation of the sites. Current site survey research includes determining the existence of nearby water bodies. Survey guidance will be elaborated to include assessment of the potential for contamination of such water bodies.

A summary of these remarks has been added to Section 2.3.5.

6. Comment: "Inasmuch as the State Office of Emergency and Energy Services depends on the Richmond National Weather Service Forecast Office for weather warnings and information during hazardous weather conditions or emergencies, we recommend that the Richmond Office be added to the list of potential sites for the NEXRAD project (page 2-22). The Southeastern Virginia Planning District Commission has indicated its willingness to assist you in site selection in the event the Hampton Roads area is chosen."

Response: Please see the response to Comment No. 2.

Wisconsin Department of Natural Resources

7. <u>Comment</u>: "We are concerned . . . with the potential effects on birds due to their possible attraction to the antennas. We are also aware that although no known adverse effects, other than thermal, from non-ionizing radiation at this end of the spectrum are known at this time further study by organizations such as the National Academy of Sciences may be advisable."

Response: Section 4.1.2.2 (pp. 4.7 and 4-8) of the DPEIS deals with potential effects on birds. As stated there, on the basis of existing information, the anticipated effects, if any, are unclear. Birds may avoid the antenna site, or they may be attracted to it. However, experience at existing military and civilian radar sites where RFR fields are similar to those expected for NEXRAD shows no evidence of ecological damage from the electromagnetic fields.

The Assembly of Life Sciences of the National Academy of Sciences (NAS) has analyzed possible biological effects of the RFR from the PAVE PAWS radar system now in operation at Otis Air National Guard Base, Massachusetts. The NAS report, entitled "Analysis of the Exposure Levels and Potential Biologic Effects of the PAVE PAWS Radar System," which was published in April 1979, concluded: "There are no known irreversible effects of such exposure on either morbidity or mortality in humans or other species."

8. Comment: "Mitigation measures for potential impacts should be developed. If mitigation is developed, monitoring of possible effects of NEXRAD and the mitigative measures should be conducted in accordance with section 1505.2(c) of the Council of Environmental Quality Regulations implementing NEPA."

Response: If mitigation measures are found necessary and practical ones can be developed, they will be adopted and their performance monitored, where applicable.

 Comment: "The state natural resource agency and the U.S. Fish and Wildlife Service should be coordinated with as sites are planned and subsequently constructed or modified."

<u>Response</u>: The Department of Commerce will coordinate with these agencies beginning at the time of the in-depth site survey for specific sites at which effects on birds are likely. A statement of this intention has been added to Section 2.3.5.

National Weather Service Western Region

10. <u>Comment</u>: "On page 2-11, backup power equipment is discussed. This should include mention of an uninterruptible power system to protect equipment when power is switched to the backup source."

Response: The NEXRAD radar subsystem (RDA) will have the ability to switch automatically to backup power in less than 60 seconds after an unexpected loss of primary power. The NEXRAD system will maintain all acquired data during a momentary power loss. Each NEXRAD site will routinely switch to its backup power supply as severe weather approaches to avoid the consequences of an interruption to its operations. Batteries will be installed to protect computer memories. However, a so-called uninterruptible power system will not be installed.

11. Comment: "Section D.2.3, p. D-9. The explanation of refraction is not correct. A standard or 'well mixed' lower atmosphere causes refraction of the beam and illumination of targets beyond the optical horizon, not straight line propagation. This is due to a lapse of refractive index with height even in a well-mixed atmosphere."

Response: The explanation of refraction and ducting in Section D.2.3 has been revised and expanded.

National Weather Service Alaska Region

12. Comment: "Page S-1, Description of Action, paragraph 5 -- Should you consider easements on adjoining land such as limiting height of new construction or maintaining cable and power rights-of-way?"

Response: In the site selection process, the local area is examined for tall buildings and towers. The existence of tall structures is taken into account in the evaluation of a site. The problem of new, tall construction is expected to be generally avoided by siting NEXRAD units on government land and coordinating site selection with the managing and other responsible agencies. The use of easements will be considered at sites where circumstances raise concerns.

13. <u>Comment</u>: "Page S-2, <u>Radiofrequency Radiation and Human Health</u>--Do your calculations consider the antenna in an elevation scan mode and/or helicopter operations at the airport?"

Response: The calculations are readily interpreted to treat aircraft and helicopters, which may occasionally intercept the axis of the main beam. As shown in Appendix B, the maximum pulse power density will be $2.7 \times 10^9/R^2$ mW/cm², and the average power density will be $16,000/R^2$ mW/cm². Airborne exposure is discussed in Section 4.1.2.1.1 (p. 4-5).

14. <u>Comment</u>: "Page S-2, <u>Environmental Effects</u> -- Should you not mention in your text how you handle your subsurface (site) fuel tanks for emergency power or the facility heating plant, if oil?"

Response: Fuel tank installation will be addressed in greater detail in the in-depth site survey and later in the detailed design of the site preceding construction. Good design and construction practices will be followed. Potential impacts are discussed on p. 4-16 of the DPEIS.

15. <u>Comment</u>: "Page 2-13, Figure 2-5 CONCEPTUAL NEXRAD SITE DEVELOPMENT--The building appears very large for people on shift and equipment based on the President's recent order of 135 square feet per person. The parking area is too small to handle your day shift."

Response: Activities and circumstances will vary greatly from site to site. As a conceptual illustration, Figure 2-5 was not intended to be accurate in every detail and therefore is unfortunately misleading. In fact, sites will be designed according to specific requirements and circumstances and to conform with all applicable standards.

16. <u>Comment</u>: "Page 2-17, 2.3.2, <u>Site Selection Criteria</u>, 1st paragraph, sentences 1 and 2 -- If the FPS-77 sites are in acceptable locations, why is AWS not planning to use those sites? This sentence, perhaps, should be moved to the end of the paragraph."

Response: The opening sentence has been corrected according to Comment No. 35 received from the Air Force.

17. Comment: "We understand NEXRAD is scheduled for Alaska and Hawaii by DOT or DOD. Do you want to include these sites in your Table 2-1 on pages 2-21 or 2-22?"

Response: The projected sites for Alaska, Hawaii, and Puerto Rico have been added to Table 2-1.

National Ocean Service

18. <u>Comment</u>: "Geodetic control survey monuments may be located in the proposed project area. If there is any planned activity which will disturb or destroy these monuments, HOS requires not less than 90 days' notification in advance of such activity in order to plan for their relocation. We recommend that funding for this project includes the cost of any relocation required for NOS monuments."

Response: Geodetic control survey monuments will be added to the site survey checklist to ensure that their presence is investigated. Their location will be considered in the site layout decision. If necessary, the Department of Commerce will fund the protection or relocation of monuments.

Federal Aviation Administration Northwest Mountain Region

19. Comment: "Par 2.3.2. 'Sites should be on government owned land, preferably Federally owned. Private land will be considered only as a last resort.' It would be imprudent to sacrifice significant operational characteristics for 'real estate' reasons. Considering the total long-term cost of the facility, skimping on site acquisition costs, and accepting a consequent performance penalty does not make sense."

Response: The Department of Commerce concurs with this view. The criterion quoted in the comment was meant to establish a priority among land ownership only. If performance is seriously compromised by siting on available public land, private land will be sought. The PEIS text has been modified.

20. Comment: "Sec 2.3.3, 4th Par. Many airports are poor locations for a long-range weather radar. For example, both Portland, Oregon, and Salt Lake City, Utah, airports are surrounded by hills or mountains which will obscure distant weather because of high horizon elevation angles. It is unclear why airports are favored as a site for weather radars."

Response: The Department of Commerce is aware that many airports are poor locations. On the other hand, many other airports, especially outside of mountainous areas, offer quite satisfactory locations. The

site selection process focuses on identifying locations where the required spatial radar coverage can be achieved. The cited DPEIS text reflects both the fact that most existing radars are at airports and the preference to use existing sites whenever possible, as long as coverage requirements can be met.

21. <u>Comment</u>: "<u>Chapt 4</u>. There is no analysis or mention of interference to high fidelity audio equipment or computer equipment in homes and offices near the site. Granted that such interference usually results from poor design of the vulnerable equipment, such interference has been a major problem near some urban FAA sites and at FAA Academy sites."

<u>Response</u>: Two new sections, 4.1.3.2.3 Effects on Other Electronic Systems and D.5 Susceptibility of Other Electronic Equipment, have been added to address this comment and Comment No. 26.

U.S. Department of the Air Force

22. <u>Comment</u>: "The programmatic EIS needs to address the required topics in the areas of Threatened and Endangered Species, Prime and Unique Farmlands, Wilderness Areas, and Floodplains and Wetlands. A short discussion of these topics should discharge the federal requirements in those areas."

<u>Response</u>: Pages 4-13 and 4-14 of the DPEIS note that biologists will be consulted concerning threatened and endangered species. To clarify the consultation process, the text has been modified to say that federal and state resource agencies will be consulted as required by law for information and review with respect to threatened and endangered species.

Prime and unique farmlands, wilderness areas, and floodplains and wetlands will generally be avoided as NEXRAD sites. Additional guidance concerning these matters will be incorporated into site survey procedures.

23. <u>Comment</u>: "The issue of frequency interference with other radars (for example, Air Traffic Control) is a concern. In preliminary planning, Air Force Communications Command has discovered areas, such as California and Washington, DC, where interference of NEXRAD on other radar systems will be a major problem. Resolving this issue is a critical item to successful deployment of the system."

<u>Response</u>: This comment and Comment No. 25 address the question of mutual interference between NEXRAD units and existing radars operated by the Air Force, FAA, and other government agencies. The JSPO is aware of this issue, and steps are being taken to avoid creating a problem.

At the JSPO's request, the Electromagnetic Compatibility Analysis Center (ECAC) will perform an EMI analysis for each candidate NEXRAD site. ECAC calculations to date indicate that it will be possible to select a noninterfering frequency for every projected NEXRAD site.

The NEXRAD transmitter is being designed to minimize the occupied spectrum and hence its potential for interfering with existing systems. This will be accomplished by using a klystron final amplifier with a very well filtered and regulated power supply, a direct current filament, stable frequency of drive pulses with controlled-envelope shape, and, at selected congested sites, a narrow bandpass filter. The resulting spectrum will be much narrower than those of most existing radars, especially those that use magnetron transmitters.

24. <u>Comment</u>: "Recommend worst case situations be used in lieu of average when discussing radio frequency radiation (RPR). The antenna will be capable of a -1 degree tilt and assumptions of essentially flat terrain out to 3000 feet will be difficult to find whether near an airport or metropolitan area."

Response: Ground clutter will completely obscure weather returns if the main beam strikes the ground at relatively close ranges. Therefore, the -1 degree tilt will be useful only on an isolated mountain top. The "worst case" described on p. 4-5 of the DPEIS is clearly not the worst case if local terrain is not flat. However, that case helps define the zone of possible risk. In the site selection process, possible deviations from the assumptions on which this case rests are being checked. If necessary, site-specific calculations will be made to ensure that no unacceptable risks are created.

25. <u>Comment</u>: "Page 2-17. DOD will have electromagnetic interference problems when attempting to site on existing government real estate and in close proximity to GPN-20, FPN-47 and GPN-12 ASRs."

Response: Please see the response to Comment No. 23.

26. <u>Comment</u>: "Page 4-11, Paragraph 4.1.3.2.1.4. and Page B-10, paragraph D.3.2. Recommend including a reference to potential interference to digital processing equipment."

Response: Two new sections, 4.1.3.2.3 Effects on Other Electronic Systems and D.5 Susceptibility of Other Electronic Equipment, have been added to address this comment and Comment No. 21.

27. <u>Comment</u>: "Page A-4, paragraph A.2.3. The system engineer for AFCC is unaware of an interlock so that transmission cannot occur when the antenna is not moving. Recommend this be clarified."

Response: The NEKRAD system must comply with OSHA regulations and the personnel safety requirements of MIL-STD-454. Further, the NEKRAD Technical Requirements now specify that the high voltage to the transmitter be interrupted whenever the antenna stops rotating for more than 30 seconds. Both NEKRAD system contractors must submit for government approval a safety plan including the preceding provisions.

28. Comment: "Page B-8, last paragraph. Equation '1/(13x360)' should be changed to '1/(3x360).'"

Response: Correct; this is a typographical error.

29. <u>Consident</u>: "Page S-2 and Page C-6, Paragraph C.2.4. The maximum allowable E-field, 100K volts/meter, should be included. (Reference AFOSH-STD-161-9)."

Response: The maximum permissible average power densities in the current AFOSH-STD-161-9 standard and proposed revisions thereto are discussed on p. C-8 of the DPEIS. The proposed revision states: "All exposures will be limited to a peak electric field intensity of 100 kV/m. [Fields of this magnitude and greater are sometimes generated by electromagnetic pulse (EMP) facilities.]" Calculations indicate that the maximum pulsed electric field in the main beam of NEXRAD will nowhere exceed 6 kV/m, more than an order of magnitude lower than this standard.

30. <u>Comment</u>: "The biophysical discussion should address, or defer to site-specific environmental analysis, the potential effects of uncovering hazardous waste, use of asbestos (or removal in old structures), cathodic protection of POL tanks, and use of hazardous chemicals either in crastruction or operation of the radar."

<u>Response</u>: The issues raised will be addressed during the site-specific analysis. Site survey guidelines will be expanded to explicitly cover the subjects anumerated in the comment. See also the response to Comment No. 5. The PEIS text has been modified to include reference to these issues.

Military Airlift Command, U.S. Air Force

31. Comment: "Page 2-10, first para, line 7. Change '. . . Station and to ARTCC via telephone lines.' to '. . . Station, Automated Weather Distribution System, Air Force Global Weather Central, and the European and Korean Forecast Offices via telephone lines.'"

Response: This has been done.

32. Comment: "Page 2-10, first para, line 8. Change ' . . . ARTCC.' to ' . . . ARTCC via telephone line.'"

Response: This has been done.

33. Comment: "Page 2-16, first para, line 7. Add following sentences after ' . . . NWS offices.': 'The principal user facility at Air Force sites will be staffed by an average of 16 people (1 commander, 11 forecasters/observers, 3 maintenance technicians, and 1 clerk). No change in Air Force staffing is planned nor will new facilities be built.'"

Response: This has been done.

34. <u>Comment</u>: "Page 2-17, first para, next to the last line. Change '. . . AWS requires that the radar be located . . .' to ' . . . AWS radars will frequently be located . . . '"

Response: This has been done.

35. Comment: "Page 2-17, second para, line 2. Change ' . . . AWS is not planning to use . . . ' to ' . . . AWS will not always use . . . '"

Response: This has been done.

36. Comment: "Page 2-17, second para, line S. Change ' . . in most cases . . . ' to ' . . . in most NWS cases . . . '"

Response: This has been done.

37. Comment: "Page 2-17, second para, line ... Change ' ... existing site . . . ' to ' . . . existing NWS site '"

Response: This has been done.

38. Comment: "Page 2-18, first para. AWS has forwarded a siting list and map to the JSPO. These sites should be included in Table 2-1 and Figure 2-7."

Response: This information has been included in Section 2.

39. Comment: "Page 2-18, third para. AWS sites can be characterized because a list has been forwarded."

Response: Limited characterization of AWS sites has been included in Section 2.

40. <u>Comment</u>: "Page 4-19, second para, line 5. Add following sentence after ' . . . NEXRAD facility.': 'No increase in Air Force staffing is anticipated.'"

Response: This has been done.

41. Comment: "Page A-4, first para. Which scan strategy has these characteristics (0.5 rpm, elevation angle change of 4 degrees, and scan time of 12 minutes)?"

Response: This scan strategy was defined to represent a possible worst case for RFR exposure, though not necessarily a specific strategy that has or will be defined. Section A.2.2 has been revised to explain this. A second scan at 0 deg elevation has been added to the scan strategy because, depending on the scanning mode, 0 deg elevation may be scanned twice in succession to improve clutter suppression.

42. Comment: "Page B-2, pare (7). When will we scan at 0 degrees?"

Response: The adopted scan strategy (see Comment No. 41) has two sweeps at zero degrees elevation.

43. Comment: "Page 8-6, fourth para. Why not use the slow speed of 3 degrees/second? Isn't this the worst case?"

Response: The objective of the cited paragraph is to demonstrate that the actual pulsed beam can be considered equivalent to a continuous wave beam. The slow scan rate of the adopted scenario (see Comment No. 41) was used for the calculations of average power density.

44. Comment: "Page B-13, first para. A 4-degree elevation angle change is not the worst case."

Response: Given the NEXRAD beam parameters (Table A-1), the first non-zero beam elevation will be at least 1 deg. Figure B-1 shows that a beam elevated as little as 1 deg will contribute a negligible amount to the power density. See also the response to Comment No. 41.

U.S. Department of the Interior

45. Comment: "Although it is not discussed in this program document, we are assuming a site specific environmental assessment (EA) or environmental impact statement (EIS), as necessary, will be prepared for each facility in accordance with the National Environmental Policy Act."

Response: The relationship of the environmental reviews of specific sites to this programmatic document is described in Sections 2.1.4 and 2.3.5 of the DPEIS. Environmental assessments of specific sites take the form of a detailed checklist. Supplements to the PEIS will be prepared "if particular site features or necessary variations in the site plan raise the possibility of significant adverse impacts that were not anticipated in the Programmatic EIS. [The supplement) will be prepared after the in-depth site survey . . . using additional information pertinent to the impact, or impacts, of concern gathered during the survey."

46. Comment: "The FEIS should analyze the impacts of the radar's electromagnetic waves on migratory and/or resident bird populations more fully and include mitigation measures as necessary. Since birds cannot be excluded from the site or from the effects of the radar by fencing, the following issues should be discussed in more detail in the final EIS:

- 1. Chronic exposure effects on birds and wildlife within the fenced transmitter sites.
- 2. Effects of the radiation and electromagnetic field on nesting birds and eggs.
- Effects of the NEXRAD System on birds migrating through the radar field.
- Bird strikes and kills related to powerlines, towers, and guy wires.
- 5. Potential for bird electrocutions.

"To support additional analysis, a list of references not already cited in the document has been provided."

Response: Many of the references supplied by the commenter pertain to extremely-low-frequency fields and are not relevant to possible effects from NEXRAD. Others are reviews rather than primary research papers. Still others are cited in the DPEIS or in SAM-TR-83-1. Several of the references listed in the DPEIS bibliography were inadvertently not cited in Section 4.1.2.2.1. The text of that section has been revised to include those citations and an additional one (which has also been added to the bibliography).

As stated in the response to Comment No. 7, experience at existing military and civilian radar sites shows no evidence of ecological damage from RFR. Also, as indicated on p. 4-8 of the DPEIS, animal behaviorists and ornithologists have used radars for decades to study bird migration, navigation, and homing without apparent detrimental effects.

The NEXRAD radar towers will require no guy wires. On or near existing or other built-up sites, power lines will be buried. Extensive above-ground power lines may be required in remote or undeveloped areas. Such lines will be designed to prevent electrocution of birds perching on them (see p. 4-14).

47. Comment: "Page 2-16, Section 2.3.2. Site Selection Criteria. This section of the final EIS should indicate that all units of the National Park System will be excluded from consideration as sites for proposed radar installations and that radar sites will not be within the visible range of any National Park Service area. Such protection is alluded to in Sections 4.3.6 and 4.3.7, but needs to be made a part of site selection criteria in Section 2.3.2."

Response: NEXRAD radars will not be sited in any national wilderness, park, or monument or other federal, state, or local wilderness or park with equivalent statutory protection. Section 4.3.6 (p. 4-25) of the DPEIS states that "the visual appearance of the radar tower from wilderness and open space areas, parks, or national monuments will. be considered." The Department of Commerce will attempt to minimize visual conflicts, but it cannot rule out the possibility that a site may be within the visual range of a National Park Service area.

48. Comment: "Page 3-4, Paragraph 1, Section 3.2. Biophysical Environment. It should not be assumed that wildlife, especially birds, are absent from existing airport sites. The undeveloped open spaces buffering airport facilities often attract birds and other wildlife."

Response: Such an assumption was not made. The text observes that "minimal" habitat is available for endangered species at airports.

49. Comment: "Page 4-7, Section 4.1.2.2. Plants and Animals. The determination that significant effects on plants and animals are not expected to result from the system is not fully established by discussion in the DEIS.

"A limited literature review leads us to the conclusion that the potential exists for the NEXRAD System to adversely affect wildlife resources. Orientation of birds migrating in the axis of the main beam may be affected. Studies show some birds will turn and change altitude, while others may be attracted and strike the radar facility. Additional information is needed on the effects of this system on bird migration. Many of the proposed candidate sites lie within the major flyway routes of waterfowl. It is suggested that a bird monitoring program be developed as part of the operation of the system."

Response: See the response to Comments No. 46 and 8. Site managers will be requested to report any bird strikes or similar incidents. If a

NEXRAD radar is to be sited in a particularly sensitive bird area or migratory route, additional monitoring will be considered.

50. Comment: "Page 4-13, Section 4.2.1.1. Plants. Paragraph 1. When removing 'tall trees' during site preparation, the potential value of the trees for the conservation of eagles and other threatened and endangered species should be considered."

Response: Agreed.

51. Comment: "Page 4-13, Section 4.2.1.1. Plants. Paragraph 3. Vegetative cover that does not attract birds should be used when revegetating disturbed areas to minimize ecosion."

Response: This advice will be considered during site design.

52. Comment: "Page 4-13, Section 4.2.1.1. Plants. Paragraph 4. This paragraph describes measures to be taken to comply with State and local environmental protection and conservation. Mention of the need for compliance with Federal fish and wildlife resource protection laws or regulations should also be included. A discussion of such compliance is necessary to inform the reader that the authors are familiar with federally mandated resource protection. For example, Federal requirements in regard to the Endangered Species Act must be complied with when considering federally listed or candidate threatened and endangered plan [sic] species. For assistance in dealing with such species, the Fish and Wildlife Service's Office of Endangered Species, Washington, D.C. 20240 should be contacted."

Response: Please see the response to Comment No. 22.

53. Comment: "Page 4-14, Section 4.2.1.2. Animals. Paragraph 1. Here, as well as on page 3-4, reference is made to the temporary displacement of wildlife at the constructed antenna sites. Displaced animals will seek shelter and food elsewhere, but will be forced to compete with organisms already residing in those areas. Competition for essential life requirements will most likely result in a permanent loss, not a temporary displacement."

<u>Response</u>: The PEIS text has been modified to reflect this possibility. Neither the probability nor the extent of such loss is predictable. The effect will be potentially more significant at new, rural sites than at existing sites in developed areas.

54. Comment: "Page 4-14, Section 4.2.1.2. Animals. Last Sentence. Caution should be exercised not to plant new vegetation that would attract wildlife."

Response: This advice will be considered during site design.

SS. <u>Comment</u>: "<u>Page 4-14</u>, <u>Section 4.2.1.2</u>. <u>Animals</u>. <u>Paragraph 3</u>. The discussion of potential adverse effects to birds from radar towers, powerline/poles, and guidewires should be expanded to include mitigation measures to minimize losses."

Response: Please see the response to Comment No. 46.

56. Comment: "Page 4-17, Paragraph 1, Section 4.2.3. Water and Water Quality. There is no discussion of the potential impacts to fish and wildlife from the use of chemicals at radar sites. These impacts, if applicable, as well as measures to mitigate potential contamination of surface and ground water, should be discussed in the final EIS."

<u>Response</u>: Please see the response to Comment No. 5. Direct effects are also possible, but unlikely. The text has been changed to note that adverse effects will be avoided by good storage, handling, and application procedures as well as by careful evaluation of the need for chemicals and by judicious selection of chemicals.

U.S. Environmental Protection Agency

57. <u>Comment</u>: "We suggest that additional items be added to this [environmental impact] worksheet to reflect required permits and special regulated resources such as wetlands and sole source aquifers."

Response: Please see the response to Comment No. 30.

58. Comment: "... [Whe suggest that the discussion of the health effects should be refined and that an expanded discussion of current scientific uncertainties be included. To assist in this assessment we have enclosed a prepublication copy of <u>Biological Effects of Radiofrequency Radiation</u>... We ... suggest that additional discussion of the data limitations associated with potential health effects of RF radiation be provided in the final EIS for completeness and to assist the decisionmaker."

Response: The text on pp. 4-2 and C-1 of the DPEIS has been revised to mention the forthcoming EPA review.

We believe that, taken together, Sections C.2.3 (Problems of Risk Assessment), C.3 (Assessment of Scientific Information), C.8 (Unresolved Issues), and C.10 (Other Viewpoints) provide an adequate and balanced presentation of the current major uncertainties regarding RFR bioeffects. Persons interested in detailed aspects of this subject are referred to SAM-TR-83-1 and the forthcoming EPA review.

S9. Comment: "General. We agree with the conclusions that the maximum time-averaged exposure power density will not exceed 100 $\mu\text{W/cm}^2$ at heights of 6 feet above ground (even in the near-field) and will be less than 0.4 $\mu\text{W/cm}^2$ at a distance of 550 feet from the antenna at a height of 6 feet above ground (an off-axis distance of approximately one antenna diameter). However, since this DEIS is not system or site-specific, we would encourage calculations be made for the specific system to be used at a site if the perimeter fence falls in the near field. We would assume that the perimeter fence could be adjusted if necessary at the actual site design stage."

Response: The purpose of the perimeter fence is to provide security. Because radar sites will generally be relatively small, the fence will be well within the near field. Relatively level sites are being chosen to facilitate construction and operations. Revised calculations show that the maximum average power density in the specified circumstances will not exceed 30 $\mu\text{W/cm}^2$. Site survey teams watch for unusual combinations of terrain, structures, and site location, and tower heights will be chosen so that the radar beam clears nearby structures and terrain. If unusual combinations do create the possibility of exposure, measures will be taken to prevent exposure to the radar beam. However, potential risk is extremely low inasmuch as the average power density in the main beam will fall below 100 $\mu\text{W/cm}^2$ beyond about 200 ft.

60. Comment: "Pages 4 - 2 through 4 - 7. This section should provide a more detailed discussion of the health impacts and make use of specific references beyond the Air Force report, (Report SAM-TR-83-1). The authors should refer to EPA's recent health assessment document, Biological Effects of Radiofrequency Radiation. Publication is scheduled for July; a copy of the final is enclosed."

<u>Response</u>: The brief discussion of RFR bioeffects on pp. 4-2 through 4-7 is a summary in which references would be inappropriate. Additional detail appears in Appendix C. Considerably more detailed descriptions and reference citations to original research papers appear in SAM-TR-83-1. To facilitate cross-reference, Appendix C and SAM-TR-83-1 have parallel structures.

The text on pp. 4-2 and C-1 has been revised to mention the forthcoming EPA review.

61. Comment: "Page 4-2, first paragraph of Section 4.1.2.1. The last sentence states that time-average power densities are '... consistent with the current U.S. exposure standards.' This statement may be misleading to the reader. By inference, one might assume this means Federal or governmental standards, but there are no Federal population exposure standards and only a few State standards. The statement primarily refers to the American National Standards Institute's (ANSI) voluntary standard.

The ANSI standard should be viewed as an occupational exposure standard and, at most, only on [sic] upper limit for general population exposure:

"'Because of the limitations of the biological effects data base, these guides are offered as upper limits of exposure, particularly for the population at large.' (ANSI C95.1-1982, page 11.)"

"The paragraph should state explicitly what standard is being referenced."

Response: The first paragraph of Section 4.1.2.1 (p. 4-2) has been revised appropriately.

62. Comment: "Page S, second paragraph of Section 4.1.2.1.1, Airborne Exposure. First, greater detail and citations are needed when discussing a threshold pulse power density for the RF hearing effect, since certain studies have reported different values. The RF hearing phenomenon is discussed in the enclosed EPA report, and that write up might be helpful. Second, as stated in the last sentence, it is true that there is no experimental evidence of harm to people exposed to such levels of pulse power density. This is because consequences of such exposure and of RF hearing have not been adequately studied:

"'Because a very low average power density can cause an acoustic response in the head and there is the potential for exposure of the public to pulsed fields that induce the effect, an unresolved issue is the need to assess the psychological effects of RF hearing, particularly in populations that may have no knowledge as to the origin of the RF sounds in the head.' (EPA, Biological Effecs [sic] of RF page 5-277.)"

<u>Response</u>: More detailed discussion of the RFR hearing effect appears in Section C.6.5.1 of the DPEIS (and in the corresponding section of SAM-TR-83-1). As indicated there, even though the average threshold for human perception of 15- μ s pulses (in the Cain and Rissman (19781 study) was 700 mW/cm², three of the eight human subjects were able to perceive such pulses at 300 mW/cm². To be conservative, the latter value was taken as representative for humans.

Because persons likely to be exposed to pulse power densities above the threshold for the RPR hearing effect are primarily the minute percentage of the general population that is airborne in the vicinity of high-power radars and because such exposures would be relatively brief, we do not regard the lack of additional studies of this effect as an important unresolved issue. However, further studies of this phenomenon would be of interest for scientific reasons and possibly for special situations.

63. <u>Comment</u>: "<u>Page 4 - 6, second paragraph</u>. Why epidemiological studies are not regarded as evidence should be discussed."

Response: The DPEIS text on p. 4-6 has been changed. Epidemiology studies are discussed in detail in Section C.6.1.

64. Comment: "Page 4 - 6, third paragraph, second sentence concerning effects at or above 2 mW/cm². It would be better to say 'most such effects are thermal . . . ' since, in some studies, a clear linkage with temperature changes has not been made."

Response: Agreed. The text has been changed.

65. Comment: "Page 4 - 6, fourth paragraph, last sentence, 'The heat produced by . . . processes or thermoregulation.' This statement might be true for healthy young men but may not be true for the population at large. Sensitive subgroups, e.g., the young, elderly, ill, or pregnant women, may not be as adaptive and can have compromised thermoregulatory systems. Effects in such subgroups, in general, and under adverse environmental conditions (high temperature and humidity and in combination with other pollutants), have not yet been thoroughly evaluated. In addition, one must generally assume, as ANS1 did, the following:

"'Because of the paucity of reliable data on chronic exposure . . . the assumption is that reversible disruption during an acute exposure is tantamount to irreversible injury during chronic exposure.' (ANSI c95.1-1982, page 13).

"Chronic effects and long-term exposures are, thus, not well understood. Thermal physiology vis-a-vis RF radiation is a controversial subject, and should not be oversimplified.

"Also, it is not clear whether or not the threshold value being discussed is 2 mW/cm^2 ."

Response: Changes and additions to Sections 4.1.2.1.2 (p. 4-6) and C.9 (pp. C-51 and C-52) have been made. We believe that the added thermal burden from exposure of the general population to the RFR from NEXRAD, including those with impaired or otherwise compromised thermoregulatory systems, would be very small relative to the metabolic changes induced by common activities (e.g., walking) by such individuals, even under adverse environmental conditions.

66. <u>Comment</u>: "<u>Page 4 ~ 6, fifth paragraph</u>. At what level(s) did irreversible adverse effects occur? It would be helpful to include a discussion of effects below 2mW/cm² and to comment on relative adversity and problems, if any, with that data."

Response: Please see changes to the text on p. 4-6.

67. <u>Comment</u>: "<u>Page 4-7</u>, <u>first paragraph</u>. It would be helpful to discuss why RF hearing has been characterized as nonthermal, for example, the temperature change can be so slight (about 10^{-6} °C per pulse) so as to be nondetectable."

Response: This point is discussed in Section C.5.1.5.

68. Comment: "Page 4 - 7, second paragraph. We believe that the conclusion is overstated. The scientific data base is much more uncertain than implied here for both the health effects and the population subgroups listed. It creates the misimpression that "no reliable evidence" means negative studies/no effects when actually, many issues have not been evaluated or the available research data are limited in some fashion. Effects of modulation are also not yet clear:

"It was recognized by the subcommittee that the specific absorption rate (SAR), which provides that basis for limiting power densities, does not contain all the factors that could be of importance in establishing safe limits of exposure. First, other characteristics of an incident field such as modulation frequency and peak intensity may pose a risk to health. Again, the data base does not provide the evidence of adversity by which to recommend special provisions for modulated fields. There was an intuitive concern by some members of the subcommittee that caution should be exercised when individuals are exposed to a pulse-modulated field of high peak but low averaged density, or to a sinusoidally-modulated field, when either field has a recurrence rate in the range of bioelectric rhythms. A supportable way of expressing this concern, which would be applicable to all exposed populations, could not be reached.' (ANSI C95.1-1982, page 14.)

"This paragraph should be rewritten and include more thorough discussion of uncertainties and limits of the available health effects data."

Response: The term "no reliable evidence" is used as it is in law, i.e., to distinguish fact from hearsay or hypothesis. Its use does not deny or negate the possibility of (adverse) effects other than those considered. However, as stated in the DPRIS, "there is no reliable evidence [emphasis added] to suggest that chronic exposure . . . will be deleterious to . . . health"

The effects of modulation on calcium efflux are discussed in Section C.6.5.2. This phenomenon is also mentioned in Sections C.9 and C.10.

69. <u>Comment</u>: "<u>Worksheet (Appendix E)</u>. A heading for permits required should be added. Applicable statutes might include: Clean Water Act, Clean Air Act, Safe Drinking Water Act, Resources Conservation and Recovery Act, etc.

"A specific heading should be added for special resource areas such as wetlands and sole source aquifers."

Response: Regarding wetlands and sole source aquifers: see the response to Comment No. 30.

Information on permits will be gathered beginning with the preliminary site survey. Complete requirements will be assembled at the time of the in-depth site survey. See the revision to Section 2.3.5 of the PSIS.

70. Comment: "Worksheet (Appendix E). We note that the initial list of candidate sites for NEXRAD radars includes the existing Boston (Chatham), Massachusetts, weather radar site, a site located within the recharge zone of the Cape Cod sole source aquifer. (See enclosed notice) The Programmatic EIS should acknowledge that the construction and operation of a NEXRAD installation on Cape Cod will be subject to an EPA review pursuant to Section 1424(e) of the Safe Drinking Water Act. We recommend that the NEXRAD - Joint System Program Office contact the appropriate EPA Regional Drinking Water Branch during preliminary site surveys to discuss the information needed to be included in the site specific environmental assessments/programmatic EIS supplements for EPA's sole source review."

<u>Response</u>: Information of this type will be developed beginning with the preliminary site survey. See the response to Comment No. 30 and the revision to Section 2.3.5 of the PEIS.