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RECORD OF DECISION
for the
PAVE PAWS EARLY WARNING RADAR OPERATION
CAPE COD AIR FORCE STATION, MASSACHUSETTS

INTRODUCTION

This document records the decisions of the United States Air Force with regard to the Supplemental Environmental Impact Statement (SEIS) for the continued operation of the Pave PAWS radar at Cape Cod AFS (*December 2008*) that was prepared to evaluate potential impacts to the human environment of the continued operation of the Solid-State Phased-Array Radar System (SSPARS), also known as PAVE (an Air Force program name) Phased Array Warning System (PAWS), at Cape Cod Air Force Station (AFS), Massachusetts.

In making this decision, the information, analysis, and public comments contained in the SEIS were considered, among other relevant factors. This Record of Decision (ROD) has been prepared in accordance with the National Environmental Policy Act (NEPA) and the regulations implementing NEPA promulgated by the President's Council on Environmental Quality (CEQ), specifically Title 40 Code of Federal Regulations (CFR), Part 1505.2, Record of Decision in cases requiring an environmental impact statement (EIS). Accordingly, the ROD:

- States the Air Force's decision (See page 10)
- Identifies the alternatives considered by the Air Force in reaching the decision and specifies the environmentally preferable alternative (See pages 3 and 4)
- Identifies and discusses relevant factors including technical considerations, the Air Force mission, and any essential consideration of national policy which were balanced by the Air Force in making its decision, and states how those considerations entered into this decision (See Pages 5 to 9)
- States whether all practicable means to avoid or minimize environmental harm from the alternative selected have been adopted, and if not, why they were not, and summarizes any monitoring and enforcement programs adopted where applicable (See page 10).

BACKGROUND

The Pave PAWS radar at Cape Cod AFS is the only radar in the nation that is able to confirm a detected missile launch toward the United States or Canada from the east. The radar provides launch detection and subsequent confirmation to provide the necessary information to make critical, nation-affecting decisions about an incoming threat.

In 2000, the Air Force had originally planned to prepare an EIS to evaluate the potential effects of the Service Life Extension Program (SLEP) (SEIS, Pg. 1-3, et al) and continued operation of the radar at Cape Cod AFS. However, during the scoping process, the community identified concerns related to the potential for adverse health impacts from operation of the Pave PAWS radar, not environmental impacts associated with the SLEP hardware upgrade. Therefore, the Air Force prepared an environmental assessment (EA) for proposed SLEP activities, analyzing potential environmental effects of replacing hardware components, and prepared an SEIS to evaluate the continued operation of the radar.

The SEIS supplements the analysis provided in a Final EIS entitled, "Operation of the PAVE PAWS RADAR System at Otis Air Force Base, Massachusetts," May 1979.[i] The SEIS is based on updated information and recent studies in order to address potential health effects of radiofrequency energy (RFE) from the continued operation of the Pave PAWS radar at Cape Cod AFS.

PURPOSE OF AND NEED FOR THE ACTION

The Air Force is aware that some members of the local community have had concerns regarding possible health effects from operation of the Pave PAWS radar at Cape Cod AFS. To address these concerns, the Air Force elected to prepare the SEIS. The results of several Air Force funded studies and literature reviews (in cooperation with the PAVE PAWS Public Health Steering Group [PPPHSG]) (SEIS, Pg. 1-5, et al) to address the community's health concerns regarding the radar's continued operation are more specifically detailed in the SEIS.

PUBLIC INVOLVEMENT

The public involvement (SEIS, Pg. 1-4, §1.1.2) process used by the Air Force for the SEIS included the following steps:

1) A Notice of Intent (NOI) to prepare an EIS was published in the *Federal Register* (Volume 65, Number 18, page 4406) on January 27, 2000.
2) An amended NOI was published in the *Federal Register* (Volume 67, Number 140, pages 47776-47777) and converted the ongoing SLEP EIS into separate and distinct environmental analyses efforts on July 22, 2002.
3) Public meetings were held to solicit comments and concerns from the general public, as follows:
   - May 8, 2000, Forestdale Elementary School in Sandwich, Massachusetts
   - May 11, 2000, Bourne Best Western in Bourne, Massachusetts
   - May 15, 2000, Mashpee High School in Mashpee, Massachusetts
   - May 16, 2000, Falmouth Holiday Inn in Falmouth, Massachusetts
   - August 14, 2000, Forestdale Elementary School in Sandwich, Massachusetts
   - August 16, 2000, Woods Hole Oceanographic Institute in Woods Hole, Massachusetts
   - August 17, 2000, Barnstable Marstons Mills Middle School in Marstons Mills, Massachusetts
   - March 17, 2003, Human Services Building in Sandwich, Massachusetts
   - March 19, 2003, Jonathan Bourne Public Library in Bourne, Massachusetts
   - March 20, 2003, Falmouth Town Hall in Falmouth, Massachusetts
   - March 24, 2003, Mashpee High School in Mashpee, Massachusetts.

4) The Pave PAWS Public Health Steering Group (PPPHSG) was established in response to public requests for an independent evaluation of possible health effects associated with exposure to the Pave PAWS radar. The meetings were open to the public and meeting agendas and minutes were published on the world-wide-web at www.pavepaws.org.

5) A Notice of Availability (NOA) was published in the *Federal Register* (Volume 73, Number 120, Page 35133) on June 20, 2008 to initiate the public comment period of the Draft SEIS. A NOA was also published in local newspapers (Cape Cod Times and The Enterprise) on July 2, 3, 4, 7, 10, and 11, 2008.

6) A public hearing was held on July 15, 2008 in Bourne Massachusetts, during the public comment period, which ended on August 4, 2008. The Air Force considered comments received during the public comment period in preparing the Final SEIS and responded to them as required by NEPA and its implementing regulations.

7) A NOA was published in the *Federal Register* with regard to the Final SEIS on March 13, 2009.

AGENCY CONSULTATION AND COORDINATION

The Air Force consulted and coordinated with federal, state, and local agencies regarding the Proposed Action at Cape Cod AFS throughout the Environmental Impact Analysis Process. A Public Health Steering Group (the PPPHSG) was established in response to public requests for an independent evaluation of possible health effects associated with exposure to the Pave PAWS radar. The PPPHSG was made up of representatives from local Boards of Health, the County Department of Health and Environment, and the State Department of Public Health.

ALTERNATIVES CONSIDERED

The SEIS evaluated the potential health effects from operation of the Pave PAWS radar (the Proposed Action) and the No-Action Alternative. The alternatives are briefly described in the following paragraphs (SEIS, Pg. 2-1):

Proposed Action. The Proposed Action (the preferred alternative) is the continued operation of the SSPARS, or PAVE PAWS radar. This action addressed the concerns from the local community on the potential associated health effects. The specific studies and literature reviews that were completed to address phased-array radar operation include:

- *Preliminary Measurements of the Pave PAWS Radar*
- *Time Domain Waveform Characterization Measurements of the Pave PAWS Radar*
- *Survey of Radio Frequency Energy Field Emissions from the Pave PAWS Radar*
- *Assessment of Potential Health Effects from Exposure to Pave PAWS Low-Level Phased-Array Radiofrequency Energy*
- *Literature Review, Public Health Evaluation of Radiofrequency Energy from the Pave PAWS Radar*
- *Risk Assessment of Low-Level Phased-Array Radio Frequency Energy Emissions, and*
- *Public Health Assessment of Exposure to Low-level Radio Frequency Energy Emitted from the Pave PAWS Radar.*

The SEIS incorporates the findings of these studies as well as other relevant data in summary format.

No-Action Alternative. The No-Action Alternative involves no longer operating the Pave PAWS radar at Cape Cod AFS. The Air Force would no longer accomplish its missile warning and space surveillance missions, leaving all or portions of North America vulnerable to intercontinental ballistic missile (ICBM) or sea-launched ballistic missile (SLBM) attacks.

Alternatives Eliminated from Further Consideration

The 1979 FEIS presented a discussion of alternatives considered but eliminated from further consideration with regard to siting the radar facility and postponing the construction of the radar facility. In addition, the SEIS considered two alternative operational options. The first option considered the construction of physical barriers (i.e., earthen berms, wire mesh fencing, and trees) around the radar site to help reduce the radar side lobe RFE. The barrier option provided little to no significant reduction in radar emissions and was dismissed as having negligible benefit. The second option involved reducing the hours of operation at the radar. This option would reduce the emissions of the radar; however, any time the radar was powered down, the United States and Canada would have no ground-based warning of a missile attack on the East Coast as well as result in degraded Space Situational Awareness. This option was dismissed as being operationally unacceptable due to national security.

Because the primary concerns raised during the scoping process for this SEIS involved the potential health effects from the continued operation of the Pave PAWS radar, the SEIS focus was on recent health studies and literature reviews that address RFE emitted from the radar. Other than the options discussed above, no other alternatives were considered in the SEIS.

ENVIRONMENTALLY PREFERABLE ALTERNATIVE

The Proposed Action is the environmentally preferred alternative. The evaluation which included additional studies and literature reviews concluded that there is currently no credible evidence for adverse health effects associated with the operation of the Pave PAWS radar system. Rates for most of the cancers that initially led to concerns about possible adverse health effects from Pave PAWS radar exposure were found to be elevated on Cape Cod prior to 1978 when the radar facility began operation.

The Air Force has and will continue to operate the radar in accordance with applicable safety standards and has implemented appropriate administrative controls to prevent personnel and general public exposure to RFE.

ENVIRONMENTAL CONSEQUENCES

Environmental Consequences of the proposed action were detailed in the SEIS (pg. 4-1) The primary concern raised during the scoping process was the potential health effects of operating the Pave PAWS radar. This concern has been raised because of the higher than expected rate of a number of cancers on Cape Cod. Based on public input, three primary actions regarding the operation of the Pave PAWS radar were identified, including:

- Measuring the average and peak radar exposures experienced by the community and then using these measurements to develop models to predict radar exposure of people living in the area,

- Analyzing plausible health outcomes from the radar exposure using descriptive epidemiology, and
- Characterizing special features of the Pave PAWS waveform based on hypotheses proposed by the public.

A recent (2004) action that occurred at Cape Cod AFS was the implementation of the Service Life Extension Program (SLEP). SLEP replacement equipment, computer components, and rehosting software would not change the power output or characteristics of the RFE being emitted from the radar. No cumulative impacts have occurred as a result of implementing SLEP activities at Cape Cod AFS. Other RFE emitting sources on or in the vicinity of Cape Cod AFS were evaluated to determine whether cumulative environmental impacts could result from the continued operation of the Pave PAWS radar in conjunction with other past, present, or reasonably foreseeable future actions.

The Defense Satellite Communication System (DSCS) and Milstar communication system contributions to the general RFE environment would not adversely impact the health and safety of the surrounding communities. An EA addressing the installation and operation of the Milstar fixed-communication control station at Cape Cod AFS was completed in April 2002; the EA resulted in a FONSI. No cumulative impacts are anticipated.

The measurements conducted around the DSCS antenna indicated that exposures were below the occupational exposure limits for the system, as specified in Institute of Electrical and Electronics Engineers (IEEE) C95.1-1999. Accordingly, the highest measurement was obtained directly in front of the feedhorn (i.e., extension protruding from the aperture), which is the actual RFE source for the aperture. This measurement was only obtained by using a man lift; therefore, this exposure is not possible at ground level. Furthermore, due to the operational angles that DSCS uses to communicate with satellites, the potential impact of sidelobe energy within surrounding communities is unlikely, and impact of the main beam is not possible. No cumulative impacts are anticipated.

A. HEALTH AND SAFETY

As discussed in the SEIS (Pg. 41-, et al), measurements collected during RFE surveys at Cape Cod AFS and outside the Cape Cod AFS boundary were below the applicable IEEE general public exposure limit. The RFE exposure levels measured during the surveys indicate that no known health hazards exist based on the low-intensity RFE from Pave PAWS. None of the RFE measurements outside the boundaries of Cape Cod AFS could produce a Specific Absorption Rate (SAR) greater than the 0.08 watts per kilogram (W/kg) permissible exposure level (PEL) established by IEEE, Federal Communications Commission (FCC), and other regulatory agencies.

The impact of RFE from the Pave PAWS radar and other existing and proposed RFE emitters would not adversely impact the health and safety of workers at Cape Cod AFS or individuals living in the surrounding communities. No RFE measurements were above applicable safety limits. Therefore, based on the available data, no adverse health effects would be associated with the RFE emissions from the Pave PAWS radar.

The Air Force will continue to operate the Pave PAWS radar and other RFE emitters at Cape Cod AFS in accordance with Air Force Occupational Safety and Health (AFOSH) Standard 48-9, Radiofrequency Radiation Safety Program, which includes implementation of appropriate administrative controls to prevent personnel exposure to RFE.

B. CAPE COD AIR FORCE STATION RADIOFREQUENCY STUDIES/REVIEWS

Although the scientific evidence indicates that adverse health effects related to RFE in general are limited primarily to thermal effects, some theories have been put forward that suggest low-level RFE may have biological effects. These theories and supporting research are reviewed by the IEEE and considered during their standard setting process. It is recognized that health concerns have been raised by some individuals on Cape Cod dealing with the continued operation of the Pave PAWS radar. The studies and literature reviews listed below specifically address the general concerns brought forth regarding low-level exposures to RFE as well as the Pave PAWS pulsed waveform generated by a phased-array radar:

Preliminary Measurements of the Pave PAWS Radar, Phase II – Single and Double Dipole Field Measurements & Phase III – Spectrum Background Analysis, Final Report - This document presents a summary of investigative preliminary measurements of the Cape Cod AFS Pave PAWS radar. These measurements were used to guide the measurements team when performing the Phase IV Waveform Characterization Study.

Phase IV – Time Domain Waveform Characterization Measurements of the Pave PAWS Radar, Final Report - This document presented the time-domain waveform measurement data that was collected during the Phase IV time-domain waveform characterization of the Cape Cod AFS Pave PAWS radar. The data acquired during the Phase IV survey indicated that the electric fields produced by the Pave PAWS radar are highly changeable, likely depending on a number of factors such as the direction of the beam, multi-path effects such as ground-bounce and scattering from neighboring objects, and the type of pulse being radiated. The electromagnetic environment is made even more complex by other radiators in the region such as TV and radio stations. Significant changes in measurement readings were observed by simply moving a sensor less than a foot in any direction. This suggests that any effort to bound electromagnetic exposures should carefully consider the possible scenarios for the potential radiators to ensure that the correct conditions are used for the bounding process.

Final Test Report on a Survey of Radio Frequency Energy Field Emissions from the Cape Cod Air Force Station Pave PAWS Radar Facility -This document provided the results of measurements, modeling, and analysis of the RFE from the Cape Cod AFS Pave PAWS radar. The study also compared the measurements from the current survey with those taken in 1978 and 1986. Overall, the previous studies' measurements appeared to be generally higher than the current measurements. There could be several reasons for this difference, including limitations of the previous test systems, or the manner in which the power density was derived from the measurements. The study also found that the highest average Pave PAWS emission level at any of the Pave PAWS test sites was comparable to the lowest ambient level observed among the ambient sites.

During this survey, peak/average power density measurements and peak/average electric field measurements were completed at various locations on Cape Cod. RFE measurements collected during the survey were below the applicable IEEE general public exposure limit.

An Assessment of Potential Health Effects from Exposure to Pave PAWS Low-Level Phased-Array Radiofrequency Energy - Based on the review of available scientific evidence (including classified information), the National Research Council concluded that there are no adverse health effects to the general population resulting from continuing or long-term exposure to the Pave PAWS phased RFE emissions. The committee also concluded that there was no observable increase in total cancers or cancers of the prostrate, breast, lung, or colon due to exposure to Pave PAWS RFE. The committee found many studies and data that support the finding of no health or biological effects from RF exposures. Although there are a number of possible mechanisms and pathways by which electric and magnetic fields could lead to changes at higher power density levels than the public is exposed to from the Pave PAWS radar, the committee did not identify any evidence of a mechanism shown to change biologic processes at the power levels that are associated with the Pave PAWS radar. The committee also found that the wave-form characterization data collected for the Pave PAWS radar is similar to exposure from "dish" radars to which the public are commonly exposed.

The committee recommended that studies of tree growth in the vicinity of the Pave PAWS facility should be conducted. A study of long-term exposures under conditions similar to human exposures may provide useful information as to possible mechanisms for a biological response that currently does not exist. The committee also recommended that a replication of a central nervous system endocrine function study be undertaken to confirm or refute a previous study (Toler, 1988) that shows a significant and extended influence on brain dopamine levels during low-level RFE exposures similar to that of Pave PAWS.

The committee also recommended that any future health investigations or epidemiologic studies in the vicinity of the Pave PAWS site should look at exposures at both the census-tract and census-block levels, and try to better estimate personal exposure and consider the types of factors known to complicate human-health investigations. Future or ongoing health studies should also specifically address possible early age of exposure and/or early age at onset of an adverse health effect. Future epidemiologic studies should not be conducted unless they are expected to have sufficient statistical ability to be able to detect any possible health effects in the Cape Cod population.

Public Health Evaluation of Radiofrequency Energy from the Pave PAWS Radar, Cape Cod Air Station, Massachusetts (Agreement No. 29292), Draft Literature Review - This report was simply a literature review focused on identifying studies that link RFE emissions to adverse health effects. The study suggested that RFE and adverse health effects studies be prioritized to concerns with leukemia, brain cancer, lung cancer in women, birth defects, auto-immune diseases such as lupus erythematosus, Alzheimer's disease, and Parkinson's disease.

Memorandum regarding Risk Assessment of Low-Level Phased-Array Radio Frequency Energy Emissions – 2002-03 - This memorandum from the Armed Forces Epidemiological Board (AFEB) states that published studies do not convincingly suggest that exposures to continuous wave RFE at or below IEEE standards result in adverse health effects, and current scientific data do not indicate that phased-array RFE is any different. Current exposure standards as established by the IEEE, although based primarily on continuous RFE, appear completely adequate to protect worker and general population health in relation to potential health effects of the Pave PAWS phased-array system.

In review of the literature, the AFEB did not identify adverse health outcomes in animal or human studies related to exposures to continuous or phased RFE at levels found at the Cape Cod AFS Pave PAWS facility that should be studied or could be used as outcome variables to study. There was no evidence to suggest a cause-and-effect relationship between the county or town level elevated standardized rate ratios of disease in Massachusetts and the Pave PAWS phased-array system. There was no immediate indication to support either initiation of new, or further analysis of existing epidemiological investigations of the association between RFE emissions from the Cape Cod AFS Pave PAWS facility and any specific health outcome.

A Public Health Evaluation of Radiofrequency Energy from Pave PAWS Radar, Cape Cod Air Station, Massachusetts, Final Report, Descriptive Studies of Disease Occurrence and Pave PAWS Radar - The International Epidemiology Institute's (IEI's) evaluation concluded that there is currently no credible evidence for adverse health effects associated with the operation of the Pave PAWS radar system. Rates for most of the cancers that initially led to concerns about possible adverse health effects from Pave PAWS radar exposure were found to be elevated on Cape Cod prior to 1978 when the Pave PAWS facility began operation.

Because the community was concerned that elevated cancer rates among residents of Cape Cod compared to the rest of Massachusetts could be due to the radar system, the PPPHSG was organized. Although a number of descriptive and analytic studies had been conducted to learn whether environmental factors might be contributing to these higher rates, no conclusive associations were identified. The IEI was contracted to conduct a descriptive epidemiologic analyses in order to evaluate the possibility that continuous RFE exposure from the Pave PAWS radar might be associated with adverse health effects among Cape Cod residents. In cooperation with the PPPHSG, public meetings were held and an agreement was reached on the specific health outcomes to be studied. The study included certain cancers, neurological disorders, autoimmune diseases, and birth weight. Secular trend analyses were conducted to learn whether the patterns of cancer mortality in Barnstable County changed after 1978 when the Pave PAWS early warning system became operational in comparison with three other Massachusetts counties (Berkshire, Hampshire, and Worcester), which have demographic and socioeconomic characteristics similar to those of Cape Cod residents.

It was concluded that in the absence of reliable new scientific evidence implicating radar exposure as a risk factor for specific disease, additional epidemiologic investigations concerning Pave PAWS radar exposure are not warranted.

MITIGATIONS

Because no significant impacts from implementation of the Proposed Action were identified, additional mitigation measures are not warranted and will not be implemented. The Air Force supports the recommendations made by the National Research Council and is investigating funding sources and qualified agencies to perform dopamine and tree growth studies.

DECISION

The potential consequences of the continued operation of the Solid-State Phased-Array Radar System (SSPARS) (PAVE PAWS Radar) at Cape Cod AFS, the Proposed Action and No-Action alternative as analyzed in the SEIS, inputs from agencies and the public, environmental and health considerations, and the matters addressed in this ROD have been considered.

Consequently, it is my decision that the Air Force has and will continue to operate the radar in accordance with applicable safety standards.

JUL 24 20[illegible]

MICHAEL F. MCGHEE, YF-03
Acting Deputy Assistant Secretary of the Air Force
(Energy, Environment, Safety, and Occupational Health)

Date

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[i] HQ AFSC TR 79-04, Part 1 and Contract Number F08635-76-D-0132-0008

FINAL
SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT
June 2009

PAVE PAWS
EARLY WARNING RADAR OPERATION
CAPE COD AIR FORCE STATION, MA

FINAL

SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT

PAVE PAWS
EARLY WARNING RADAR OPERATION

CAPE COD AIR FORCE STATION, MASSACHUSETTS

June 2009

COVER SHEET
SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT FOR PAVE PAWS EARLY WARNING RADAR OPERATION CAPE COD AIR FORCE STATION, MASSACHUSETTS

a. Responsible Agency: U.S. Department of the Air Force

b. Proposed Action: Continued operation of the PAVE PAWS radar at Cape Cod Air Force Station, (AFS), Massachusetts.

c. Written comments and inquiries regarding this document should be directed to: Ms. Lynne Neuman, HQ AFSPC/A7PP, 150 Vandenberg Street, Suite 1105, Peterson AFB, CO 80914-2370; facsimile, (719) 554-3849.

d. Designation: Supplemental Environmental Impact Statement (SEIS)

e. Abstract: This SEIS has been prepared in accordance with the National Environmental Policy Act to evaluate potential impacts to the human environment and enrich man's understanding of the continued operation of the Solid-State Phased-Array Radar System (SSPARS), also known as PAVE (an Air Force program name) Phased Array Warning System (PAWS), at Cape Cod Air Force Station (AFS), Massachusetts. The Air Force is aware that some members of the local community have had concerns regarding possible health effects from operation of the PAVE PAWS radar at Cape Cod AFS. The Air Force has taken the initiative to study the effects of radiofrequency energy (RFE), specifically those effects pertaining to the concerns expressed by the local community. To address these concerns, the Air Force has elected to prepare this SEIS. In addition, the Air Force has funded several studies to address the community's health concerns regarding the radar's continued operation. This SEIS incorporates the findings of these studies as well as other relevant data. The Cape Cod AFS PAVE PAWS radar is the only radar in the nation that is able to confirm a detected missile launch towards the United States from the east. The document describes and addresses the potential health effects of RFE from the continued operation of the PAVE PAWS radar at Cape Cod AFS. The Air Force has and will continue to operate the radar in accordance with applicable safety standards and has implemented appropriate administrative controls to prevent personnel and general public exposure to RFE.

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SUMMARY

PURPOSE AND NEED FOR ACTION

The Air Force is aware that some members of the local community have concerns regarding possible health effects from operation of the PAVE (an Air Force program name) Phased-Array Warning System (PAWS) radar at Cape Cod Air Force Station (AFS). To address these concerns, the Air Force has elected to prepare this supplemental environmental impact statement (SEIS). In addition, the Air Force has also funded several studies to address the community's health concerns regarding the radar's continued operation. This SEIS incorporates the findings of these studies as well as other relevant data.

ALTERNATIVES INCLUDING THE PROPOSED ACTION

Proposed Action. The Proposed Action is the continued operation of the Solid State Phase Array Radar System (SSPARS), or PAVE PAWS radar, as it is better known, at Cape Cod AFS.

As part of an early warning network, the Air Force operates the PAVE PAWS radar to provide warning of intercontinental ballistic missile (ICBM) and sea-launched ballistic missile (SLBM) attacks against North America. The PAVE PAWS radar also performs a space surveillance mission.

The PAVE PAWS radar is a phased-array radar that transmits pulsed radiofrequency (RF) signals within the frequency range of 420 to 450 megahertz (MHz). Signals are reflected by objects back to the radar. These signals are analyzed to determine the location, distance, size, and speed of the object. The PAVE PAWS radar is housed in a 32-meter (105-foot) -high building. Two flat arrays transmit and receive RF signals generated by the radar. Each array face contains 1,792 active antenna elements out of a total of 5,354 elements. The additional 3,562 elements per array face are not used. There are no plans to use these additional elements, and these elements cannot be easily activated due to a lack of solid-state transmitter/receiver modules and a lack of necessary infrastructure for heating and cooling the elements. The two array faces are 31 meters (102 feet) wide, and are tilted back 20 degrees (°) from vertical. The active portion of each array face is situated in the center of a circle 22.1 meters (72.5 feet) wide. Each active antenna element is connected to a separate solid-state transmitter/receiver within the radar building that provides 322 watts of power for transmitting RF signals and amplifies the returning signal.

The RF signals transmitted from each of the array faces form one narrow main beam. Most (approximately 90 percent) of the energy is contained in the main beam. Each of the main beams can be directed electronically between 3° and 85° above horizontal.

No-Action Alternative. The PAVE PAWS radar at Cape Cod AFS is the only radar in the Nation that is able to confirm a detected missile launch towards North America from the east. The radar provides launch detection and subsequent confirmation to provide the necessary information to make critical, nation-affecting decisions about an incoming threat. The No-Action Alternative is not a truly viable alternative as it would result in the Air Force being unable to accomplish its missile warning and space surveillance missions, leaving all or portions of North America vulnerable to ICBM or SLBM attacks.

SCOPE OF STUDY

In 2000, the Air Force had originally planned to prepare an environmental impact statement (EIS) to evaluate the potential effects of the Service Life Extension Program (SLEP) and continued operation of the radar at Cape Cod AFS. However, because the radar was becoming unsupportable due to a lack of replacement parts, the Air Force decided to prepare an environmental assessment (EA) for proposed SLEP activities and prepare a supplemental EIS to evaluate the continued operation of the radar.

A Notice of Intent (NOI) was published in the Federal Register (65 Fed. Reg. 4406) on January 27, 2000, and seven scoping meetings were held on Cape Cod. On July 22, 2002, the Air Force amended the NOI (67 Fed. Reg. 47,776) and converted the ongoing SLEP EIS into two separate environmental analyses (an EA for SLEP activities and an SEIS for public health concerns from continued radar operations).

The EA was completed in September 2002 and resulted in a Finding of No Significant Impact (FONSI).

The SEIS supplements the analysis provided in the 1979 EIS based on updated information and recent studies in order to address potential health effects of RFE from the continued operation of the PAVE PAWS radar at Cape Cod AFS.

SUMMARY OF ENVIRONMENTAL IMPACTS

During the scoping process, health concerns were raised by some individuals on Cape Cod regarding the continued operation of the PAVE PAWS radar. These concerns have been addressed by several Cape Cod AFS site-specific studies and radiofrequency energy (RFE) literature reviews. These studies and literature reviews specifically address the general concerns brought forth regarding low-level exposures to RFE as well as the PAVE PAWS pulsed waveform generated by a phased-array radar.

Seven studies and literature reviews have recently been completed that address phased-array radar operation, these studies include:

- Preliminary Measurements of the PAVE PAWS Radar
- Time Domain Waveform Characterization Measurements of the PAVE PAWS Radar
- Survey of Radio Frequency Energy Field Emissions from the PAVE PAWS Radar

- Assessment of Potential Health Effects from Exposure to PAVE PAWS Low-Level Phased-Array Radiofrequency Energy

- Literature Review Public Health Evaluation of Radiofrequency Energy from the PAVE PAWS Radar

- Risk Assessment of Low-Level Phased-Array Radio Frequency Energy Emissions, and

- Public Health Assessment of Exposure to Low-level Radio Frequency Energy Emitted from the PAVE PAWS Radar.

A brief overview of the studies that have been performed is provided below:

Preliminary Measurements of the PAVE PAWS Radar. The Preliminary Measurements of the PAVE PAWS Radar conducted in March 2002 provided information about the time-domain waveform characterization of the PAVE PAWS radar that was used in planning the next phase of measurements. The preliminary measurements helped determine the feasibility of low-level measurements, determined electromagnetic signal screening feasibility, established the community radiofrequency background level, and provided insight about the problems that could be encountered when performing the time domain measurements.

Time Domain Waveform Characterization Measurements of the PAVE PAWS Radar. Time-domain waveform measurement data was collected in April 2003 and was used by medical and biological researchers to assess the existence, and perhaps the importance, of radial electric field components, slopes of the electric field, and phasing or "zero crossing" changes.

The data acquired indicated that the electric fields produced by the PAVE PAWS radar are highly changeable, likely depending on a number of factors such as the direction of the beam, multi-path effects such as ground-bounce and scattering from neighboring objects, and the type of pulse being radiated. The electromagnetic environment is made even more complex by other radiators in the region such as television and radio stations. Significant changes in measurement readings were observed by simply moving a sensor less than a foot in any direction. This suggests that any effort to bound electromagnetic exposures should carefully consider the possible scenarios for the potential radiators to ensure that the correct conditions are used for the bounding process.

Survey of Radio Frequency Energy Field Emissions from the PAVE PAWS Radar. During this survey in 2004, peak/average power density measurements and peak/average electric field measurements were completed at various locations on Cape Cod. Radiofrequency energy measurements collected during the survey were below the applicable Institute of Electrical and Electronics Engineers (IEEE) general public exposure limit. The validated geographic exposure data from this study was used by a public health expert to support the epidemiological study. Key findings of the survey include:

- The radar's average power density at all 50 PAVE PAWS test sites was well below the maximum permissible exposure (MPE) specified by known safety standards.

- The difference in power density measured at an antenna height of 30 feet and at a height of 8 feet was highly variable. However, when averaged over 14 measurement sites, the high sites showed an approximately 5 decibel (dB) greater signal, consistent with the "rule of thumb" that doubling the height of a very high frequency (VHF) or ultra high frequency (UHF) antenna in proximity to the earth's surface approximately doubles the signal strength.

- Samples of all classes of the PAVE PAWS waveform were observed. Long range search doublets and triplets were observed independent of the azimuth from the radar antenna, indicating the presence of secondary sidelobes and/or reflections.

- At many PAVE PAWS test sites, numerous received pulses appeared to have amplitude modulation imposed upon them. Since the steady-state amplitude of the transmitted PAVE PAWS signal is constant, the amplitude modulation was likely produced by the environment. It was determined that the most likely source is reflection from a multitude of "targets" such as aircraft, water tanks, radio towers, and the smokestack at the Sandwich power plant.

- When observing the 24 PAVE PAWS channels in a "max hold" mode on the spectrum analyzer for extended periods, frequency-selective fading produced by multiple transmission paths was frequently observed.

- Signals observed from behind the radar were most likely produced from backscatter from the main beam of the radar, rather than from "behind the array" sidelobes or "edge diffraction" effects.

- The received signal level measured behind the radar is similar to paging, land mobile, and lower powered frequency modulation (FM) station transmitters, suggesting that considering the power of the radar, there is little radiation "behind" the plane of the antenna.

- On the roof of the PAVE PAWS facility, with the instrument penetrating the plane of the radar face from behind, the measured radiofrequency energy occasionally peaked to 5 percent of the occupational MPE limit. With the instrument repositioned above the roof, just behind the plane of the radar face, the radiofrequency energy limit fell below the sensitivity of the instrument. This observation supports the findings that there is little radiation behind the plane of the antenna.

- It was not possible to distinguish first sidelobe pulses from secondary sidelobe pulses that were received at a test site. There were variations in signal levels from pulse to pulse caused by beam pointing, propagation, and the like that blur the distinction between received first sidelobe energy and received secondary sidelobe energy.

- Even when miles away, large commercial aircraft have sufficient radar cross section to return a measurable signal to the instrumentation via "backscatter" when the plane is illuminated by the PAVE PAWS main beam.

The survey also compared the measurements from the current survey with those taken in 1978 and 1986. Overall, the previous studies' measurements appear to be generally higher than the current measurements. There could be several reasons for this difference, including limitations of the previous test systems, or the manner in which the power density was derived from the measurements. The radiofrequency measurements collected during the 2004 survey were below the applicable IEEE general public exposure limit.

Assessment of Potential Health Effects from Exposure to PAVE PAWS Low-Level Phased-Array Radiofrequency Energy. This assessment, prepared by the National Research Council, consisted of a review of scientific data and literature related to radiofrequency energy in the range of the PAVE PAWS system. This was done because there were no specific studies of a phased-array system similar to PAVE PAWS in the public domain. The review included classified documentation of research that could be relevant to the PAVE PAWS system and the recent waveform characterization study.

Based on the review of available scientific evidence (including classified information), the National Research Council committee concluded that there are no adverse health effects to the general population resulting from continuing or long-term exposure to the PAVE PAWS phased radiofrequency emissions. The committee also concluded that there was no observable increase in total cancers or cancers of the prostate, breast, lung, or colon due to exposure to PAVE PAWS radiofrequency energy.

The committee also found that the waveform characterization data collected for the PAVE PAWS radar is similar to exposure from "dish" radars to which the public are continuously exposed.

The committee recommended that studies of tree growth in the vicinity of the PAVE PAWS facility should be conducted. A study of long-term exposures under conditions similar to human exposures could provide useful information as to possible mechanisms for a biological response that currently does not exist.

The committee also recommended that a replication of a central nervous system endocrine function study be undertaken to confirm or refute previous Air Force-sponsored studies that show a significant and extended influence on brain dopamine levels during low-level radiofrequency exposures similar to that of PAVE PAWS.

Future epidemiologic studies should not be conducted unless they are expected to have sufficient statistical ability to be able to detect any possible health effects in the Cape Cod population.

The Air Force supports the recommendations made by the National Research Council and intends to pursue the dopamine and tree growth studies. As they were not included in the scope of this SEIS as defined during the public scoping process, the dopamine and tree growth studies will be pursued independent of the SEIS.

Literature Review Public Health Evaluation of Radiofrequency Energy from the PAVE PAWS Radar. This literature review conducted in 2004 focused on identifying studies that link radiofrequency energy to adverse health effects. The study suggested that radiofrequency energy and adverse health effects studies be prioritized to concerns with the listed diseases.

- Leukemia
- brain cancer
- lung cancer in women
- birth defects
- auto-immune diseases such as lupus erythematosus
- Alzheimer's Disease
- Parkinson's Disease

Risk Assessment of Low-Level Phased-Array Radio Frequency Energy Emissions. The Armed Forces Epidemiological Board, or Armed Forces Epidemiology Board (AFEB), met in February 2002 to consider a request from the Air Force Surgeon General regarding a risk assessment of low-level phased-array radiofrequency energy emissions, as phased-array radar systems are used throughout the Department of Defense (DOD) and in the commercial and private sectors, and concern had been raised regarding potential adverse health risks from low-level exposures at the Air Force PAVE PAWS facility on Cape Cod.

The AFEB received presentations, briefings, and materials regarding various aspects of RFE, epidemiological studies, and operation of phased-array systems. The AFEB also reviewed several hundred studies focusing on epidemiological studies of RFE exposure, IEEE and DOD exposure standards and standards setting process for radiofrequency energy, studies on RFE bio-effects, and over 45 studies and public health assessments specifically for exposure and health outcomes of Cape Cod residents.

The AFEB found that published studies do not convincingly suggest that exposures to continuous wave radio frequency energies (as opposed to pulse RFE) at or below IEEE standards result in adverse health effects, and current scientific data does not indicate that phased-array are any different. Current exposure standards as established by the IEEE, although based primarily on continuous wave RFE, appear completely adequate to protect worker and general population health in relation to potential health effects of the PAVE PAWS phased-array system.

The AFEB did not identify any evidence suggesting a cause-and-effect relationship between the county or town level elevated standardized rate ratios of disease in Massachusetts and the PAVE PAWS phased-array system. There was no immediate indication to support either initiation of new, or further analysis of existing epidemiological investigations of the association between radiofrequency energy emissions from the PAVE PAWS facility and any specific health outcome.

Public Health Assessment for Exposure to Low-level RFE Emitted from the PAVE PAWS Radar. This assessment, conducted in 2005, evaluated the potential health effects of public exposure to low-level RFE emitted from the PAVE PAWS radar system at Cape Cod AFS.

This assessment analyzed available data for county mortality and county cancer mortality and from the hospital discharge registry. Data provided by the Massachusetts Department of Public Health regarding cancer incidence, birth defects, and birth weight were compiled and analyzed. The available radiofrequency energy characterization survey results for the PAVE PAWS radar in terms of the known and biologically plausible hypothesized public health effects were analyzed and interpreted. The analysis utilized the analyses of the outcomes data and information in relevant scientific literature to describe the relationship among the various radiofrequency energy exposure characteristics and existing health outcomes determined to be biologically plausible. The assessment was submitted to the Massachusetts Department of Public Health for review to confirm that the health data provided had been used in conformance with the requirements of applicable laws and regulations.

The evaluation concluded that there is currently no credible evidence for adverse health effects associated with the operation of the PAVE PAWS radar system. Rates for most of the cancers that initially led to concerns about possible adverse health effects from PAVE PAWS radar exposure were found to be elevated on Cape Cod prior to 1978 when the PAVE PAWS facility began operation.

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LIST OF ACRONYMS AND ABBREVIATIONS

AFB	Air Force Base
AFEB	Armed Forces Epidemiology Board
AFI	Air Force Instruction
AFOSH	Air Force Occupational Safety and Health
AFRL	Air Force Research Laboratory
AFS	Air Force Station
ALS	amyotrophic lateral sclerosis
AM	amplitude modulation
ANGB	Air National Guard Base
ANSI	American National Standards Institute
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
°	degree
dB	decibel
DNA	Deoxyribonucleic Acid
DOD	Department of Defense
DSCS	Defense Satellite Communications System
EA	environmental assessment
EHS	Environmental Health and Safety
EIS	environmental impact statement
EPA	Environmental Protection Agency
EWR	Early Warning Radar
FCC	Federal Communications Commission
FM	frequency modulation
FONSI	Finding of No Significant Impact
GHz	gigahertz
GMD	Ground-based Midcourse Defense
ICBM	intercontinental ballistic missile
IEEE	Institute of Electrical and Electronics Engineers
IEI	International Epidemiology Institute
IRPA	International Radiation Protection Association
JSC	Joint Spectrum Center
kHz	kilohertz
kW	kilowatt
LORAN	Long Range Aid-to-Navigation
MDPH	Massachusetts Department of Public Health
MHz	megahertz
MMR	Massachusetts Military Reservation
MPE	maximum permissible exposure
ms	millisecond
mV/m	milliVolts per meter
mW/cm^2	milliwatts per square centimeter
NEPA	National Environmental Policy Act
nm	nautical mile
NMD	National Missile Defense
NOI	Notice of Intent
nW/cm^2	nanowatt per square centimeter

OET	Office of Engineering and Technology
PAVE	an Air Force program name
PAWS	Phased-Array Warning System
PCS	personal communication system
PPPHSG	PAVE PAWS Public Health Steering Group
RF	radiofrequency
RFE	radiofrequency energy
RFR	radiofrequency radiation
rms	root mean square
ROD	Record of Decision
SATCOM	satellite communication
SEIS	supplemental environmental impact statement
SLBM	sea-launched ballistic missile
SLEP	Service Life Extension Program
SSPARS	Solid-State Phased-Array Radar System
TV	television
UEWR	Upgraded Early Warning Radar
UHF	ultra high-frequency
VDT	video display terminal
VHF	very high-frequency
V/m	volts per meter
W/kg	watts per kilogram
W/m^2	watts per square meter

1.0 PURPOSE AND NEED FOR ACTION

This supplemental environmental impact statement (SEIS) supplements the 1979 environmental impact statement (EIS) on the operation of the PAVE (an Air Force Program name) Phased-Array Warning System (PAWS) Radar at Otis Air National Guard Base (ANGB), Massachusetts. This SEIS evaluates the potential for impacts as a result of the continued operation of the Solid-State Phased-Array Radar System (SSPARS) (also known as PAVE PAWS) at Cape Cod Air Force Station (AFS), Massachusetts (Figure 1.1-1).

1.1 PURPOSE AND NEED FOR ACTION

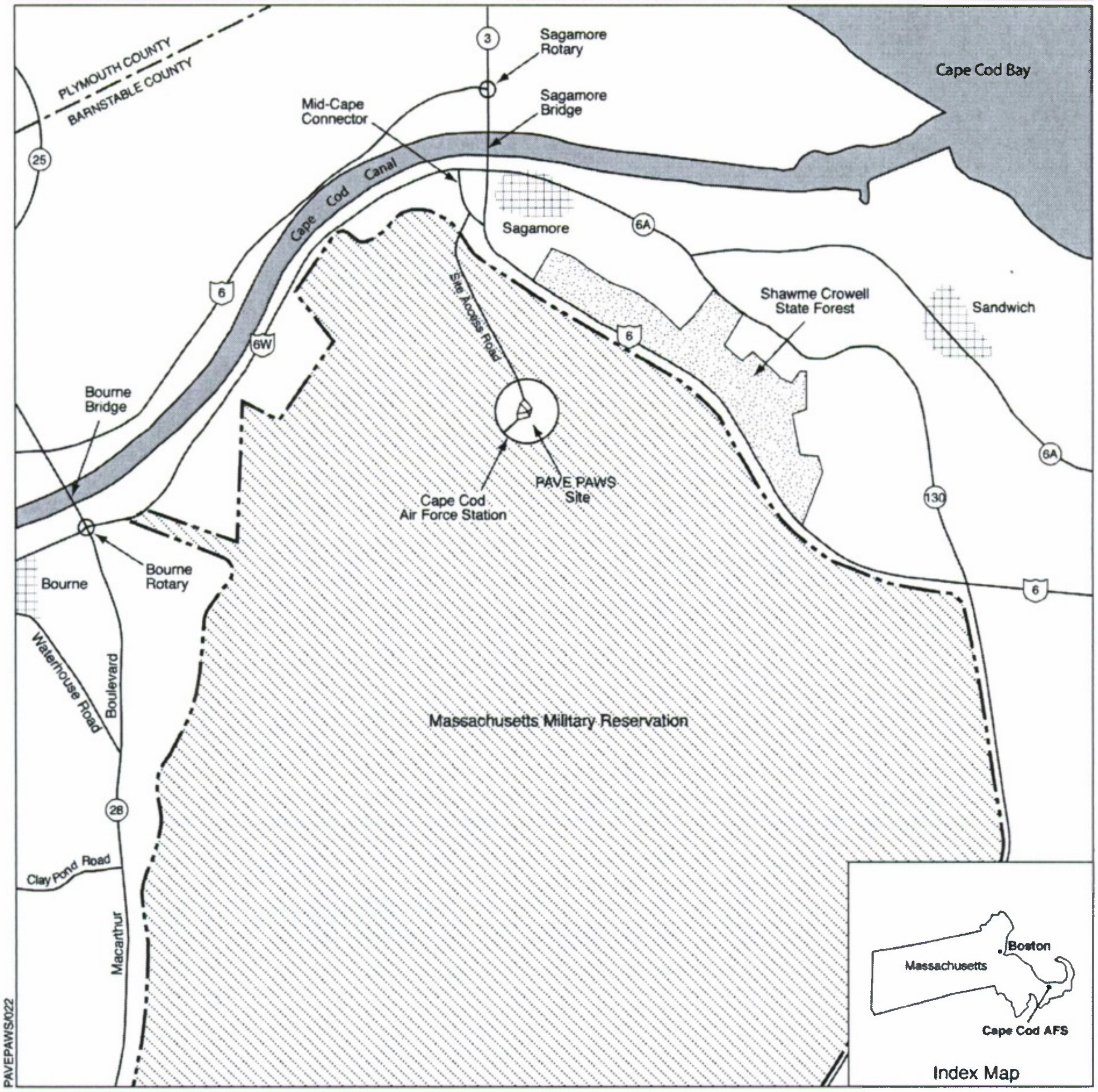
The Air Force is aware that some members of the local community have had concerns regarding possible health effects from operation of the PAVE PAWS radar at Cape Cod AFS. To address these concerns, the Air Force has elected to prepare this SEIS. In addition, the Air Force has also funded several studies to address the community's health concerns regarding the radar's continued operation. These studies are briefly summarized below:

- The Armed Forces Epidemiology Board (AFEB) addressed specific issues raised by the Air Force Surgeon General
- The Air Force Research Laboratory conducted a series of studies characterizing the PAVE PAWS waveform
- The National Academy of Science conducted a literature review of available radiofrequency energy (RFE) studies to determine potential biological and health effects of the phased-array system
- The PAVE PAWS Public Health Steering Group (PPPHSG) conducted an exposure study and public health assessment for areas on Cape Cod.

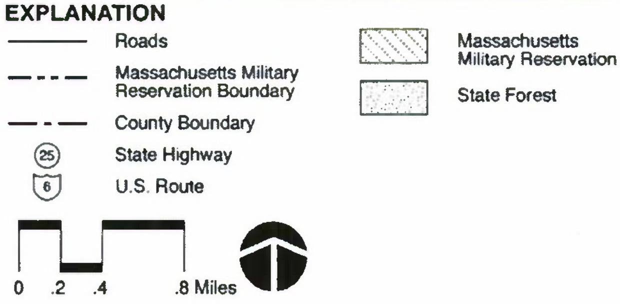
This SEIS incorporates the findings of these studies as well as other relevant data.

1.1.1 Environmental Impact Analysis Process

In 1969, the National Environmental Policy Act (NEPA) established a national policy to protect the environment and ensure that federal agencies consider the environmental effects of their actions in their decision making. The Council on Environmental Quality (CEQ) published regulations that describe how NEPA should be implemented. The CEQ regulations encourage federal agencies to develop and implement procedures that address the NEPA process in order to avoid or minimize adverse effects on the environment. 32 CFR Part 989 addresses the implementation of NEPA as part of the Air Force planning and decision-making process.



EXPLANATION



Vicinity Map, Cape Cod Air Force Station

Figure 1.1-1

To comply with these regulations, the Air Force is required to prepare an EIS if a major federal action would significantly affect the human environment. Routine operation of an established facility does not require preparation of an EIS or SEIS. However, to further the purposes of NEPA and to address concerns over possible health effects from operation of the radar, the Air Force elected to prepare this SEIS.

This SEIS has been prepared in accordance with NEPA (42 United States Code [U.S.C.] 4321-4347), CEQ (40 Code of Federal Regulations [CFR] Parts 1500-1508), and Air Force Instruction (AFI) 32-7061 as promulgated at 32 CFR Part 989, et seq., Environmental Impact Analysis Process.

Originally, the Air Force intended to prepare an EIS for the Service Life Extension Program (SLEP) action at the early warning radars located at Cape Cod AFS, Massachusetts, Beale Air Force Base (AFB), California, and Clear AFS, Alaska. The SLEP action involved the replacement of outdated computer components and the rehosting of software (installation of existing and/or new software on new hardware components). The replacement of components and the rehosting of software would not change the power output of the radar or the characteristics of the RFE emitted from the radar. A Notice of Intent (NOI) was published in the Federal Register (65 Fed. Reg. 4406) on January 27, 2000, and seven scoping meetings were held on Cape Cod. Through the review process, which took into account comments received during the public scoping process, the Air Force determined that public concerns centered around the possible health effects arising from operation of the radars, rather than from the Proposed Action of replacing outdated computer hardware and rehosting software. On July 22, 2002, the Air Force amended the NOI (67 Fed. Reg. 47,776) and converted the ongoing SLEP EIS into separate and distinct environmental analyses efforts: an SEIS to the 1979 EIS on the operation of the PAVE PAWS Radar System (Cape Cod AFS, Sagamore, Massachusetts), in order to address community concerns over possible health effects from operation of the radar; and three environmental assessments (EAs) to address the SLEP actions at the three radar sites. The EAs were completed in September 2002 and resulted in Findings of No Significant Impact (FONSI).

The process for preparing this SEIS mirrors the process for preparing an EIS. Following the publication of the amended NOI, the Air Force held four scoping meetings on Cape Cod. The draft SEIS was filed with the U.S. Environmental Protection Agency (EPA), and circulated to the interested public and government agencies for a period of 45 days for review and comment. During this period, a public hearing was held so that the public could make comments on the draft SEIS. At the end of the review period, all substantive comments received were addressed. This final SEIS contains responses to comments as well as changes to the document (see Chapter 8).

The final SEIS will be filed with the U.S. EPA and distributed in the same manner as the draft SEIS. Once the Final SEIS has been available for at least 30 days, the Air Force may publish its Record of Decision (ROD).

1.1.2 Scoping Process

A scoping process was used to identify potentially significant environmental issues and provided an opportunity for public involvement. Notification of public scoping was made through local media and letters to federal, state, and local agencies and officials, and interested groups and individuals. Notification was also made through the Federal Register (Federal Register: January 27, 2000 [Volume 65, Number 18], page 4406) with a subsequent Federal Register amendment (Federal Register: July 22, 2002 [Volume 67, Number 140] page 47776-47777).

Public meetings were held on the following dates to solicit comments and concerns from the general public:

- May 8, 2000 at the Forestdale Elementary School in Sandwich, Massachusetts
- May 11, 2000 at the Bourne Best Western in Bourne, Massachusetts
- May 15, 2000 at the Mashpee High School in Mashpee Massachusetts
- May 16, 2000 at the Falmouth Holiday Inn in Falmouth, Massachusetts
- August 14, 2000 at the Forestdale Elementary School in Sandwich, Massachusetts
- August 16, 2000 at the Woods Hole Oceanographic Institute in Woods Hole, Massachusetts
- August 17, 2000 at the Barnstable Marstons Mills Middle School in Marstons Mills, Massachusetts
- March 17, 2003 at the Human Services Building in Sandwich, Massachusetts
- March 19, 2003 at the Jonathan Bourne Public Library in Bourne, Massachusetts
- March 20, 2003 at the Falmouth Town Hall in Falmouth, Massachusetts
- March 24, 2003 at the Mashpee High School in Mashpee Massachusetts.

At each of these meetings, representatives of the Air Force presented an overview of the meeting's objectives, agenda, and procedures, and described the NEPA process. In addition to verbal comments, written comments were received during the scoping process. These comments, as well as information from the local community, experience with similar decisions to be made, and NEPA requirements, were used to determine the scope and direction of studies/analyses needed to accomplish this SEIS.

1.1.3 Public Comment Process

The Draft SEIS was made available for public review and comment in May 2008. Copies of the Draft SEIS were made available for review in local libraries and provided to those requesting copies (Appendix B). At a public hearing held in Bourne, Massachusetts in July 2008, the findings of the Draft SEIS were presented and the public was invited to make comments. All comments were reviewed and addressed, when applicable, and have been included in their entirety in this document. Responses to comments offering new or changes to data and questions about the presentation of data are also included. Comments simply stating facts or opinions, although appreciated, did not require specific response. Chapter 8, Public Comments and Responses, more thoroughly describes the comment and response process.

1.2 CHANGES FROM THE DRAFT SEIS TO THE FINAL SEIS

The text of this SEIS has been revised, when appropriate, to reflect concerns expressed in public comments. The responses to the comments indicate the relevant sections of the SEIS that have been revised. The major comments received on the Draft SEIS involved:

- Alternative action of moving the radar facility
- Operational characteristics of the radar
- Health and safety considerations of operating the radar
- Technical clarification of recent RFE studies and literature reviews.

Based on comments from the public, the following section of the SEIS has been updated or revised:

- Figure 3.1-8 has been revised to show sidelobe energy above and below the main beam.

1.3 SCOPE OF THE ENVIRONMENTAL REVIEW

A primary concern raised during the scoping process was the potential health effects of operating the PAVE PAWS radar as there is a higher than expected rate of a number of cancers on Cape Cod. A PAVE PAWS Public Health Steering Group (PPPHSG) was established in 2001 in response to public requests for an independent evaluation of possible health effects associated with exposure to the PAVE PAWS radar. The PPPHSG was made up of representatives from local Boards of Health, the County Department of Health and Environment, and the State Department of Public Health. Based on public input, three primary study efforts with regard to operation of the PAVE PAWS radar were identified, including:

- Measuring the average and peak radar exposures experienced by the community and then using these measurements to develop models to predict radar exposure of people living in the area,
- Analyzing plausible health outcomes from the radar exposure using descriptive epidemiology, and
- Characterizing special features of the PAVE PAWS waveform based on hypotheses proposed by the public, which contended that the PAVE PAWS radar wave form characteristics differ from dish radar wave forms and affect the human Deoxyribonucleic Acid (DNA) as a result of long-term exposure.

This SEIS describes and addresses the potential health effects of RFE from the continued operation of the PAVE PAWS radar at Cape Cod AFS. The affected environment and the potential environmental consequences from RFE emissions relative to the continued operation of the PAVE PAWS radar are described in Chapters 3.0 and 4.0, respectively.

1.4 RELATED ENVIRONMENTAL DOCUMENTS

The NEPA documents listed below have been prepared for similar actions being evaluated in this SEIS. These documents provided supporting information for the environmental analysis contained within this SEIS and are incorporated by reference.

<u>Environmental Assessment for Phased-Array Warning System, PAVE PAWS, Otis Air Force Base, Massachusetts</u> (U.S. Air Force, 1976).

<u>Final Environmental Impact Statement for Operation of the PAVE PAWS Radar System at Otis Air Force Base, Massachusetts</u> (U.S. Air Force, 1979).

<u>Environmental Assessment for the Installation of Milstar Fixed Communications Control Station at Cape Cod AFS, Massachusetts</u> (U.S. Air Force, 2002a).

<u>Environmental Assessment for the Early Warning Radar System, Service Life Extension Program Cape Cod AFS, Massachusetts</u> (U.S. Air Force, 2002b).

2.0 ALTERNATIVES INCLUDING THE PROPOSED ACTION

2.1 DESCRIPTION OF THE PROPOSED ACTION

The Proposed Action (the preferred alternative) is the continued operation of the SSPARS, or PAVE PAWS radar, as it is better known, at Cape Cod AFS.

The PAVE PAWS radar at Cape Cod AFS is the only radar in the nation that is able to confirm a detected missile launch towards the United States or Canada from the east. Cape Cod AFS is operated by U.S. and Canadian personnel. The radar provides launch detection and subsequent confirmation to provide the necessary information to make critical, nation-affecting decisions about an incoming threat.

2.1.1 Solid-State Phased-Array Radar System Description

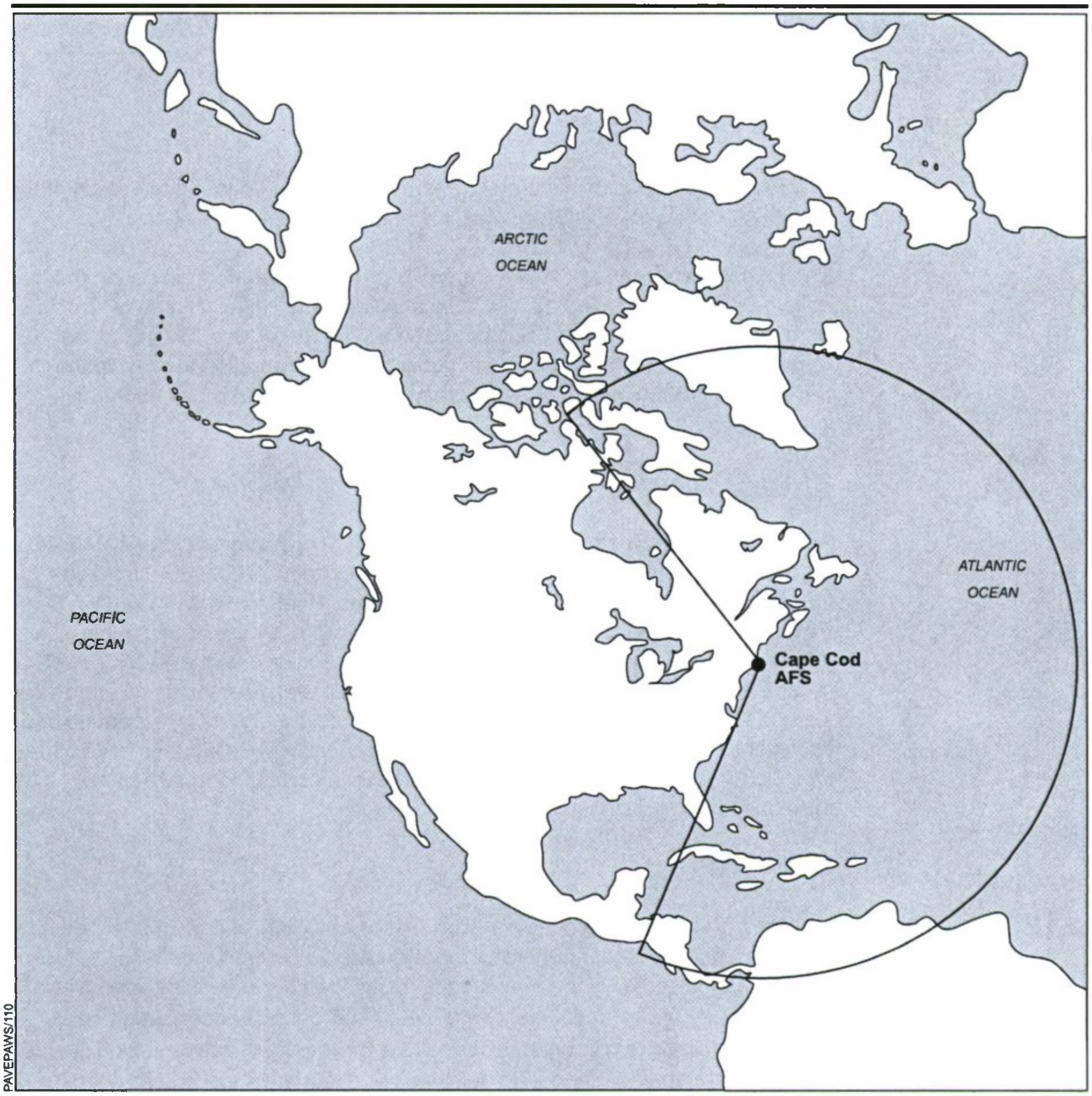
As part of an early warning network, the Air Force operates the PAVE PAWS radar to provide warning of intercontinental ballistic missile (ICBM) and sea-launched ballistic missile (SLBM) attacks against North America. The PAVE PAWS radar facility also performs a space surveillance mission. In general, during the missile warning and space surveillance missions, the PAVE PAWS radar is transmitting, at most, 25 percent of the time and listening for return signals 75 percent of the time. The specific duty cycles for missile warning and space surveillance are discussed below. Cape Cod AFS is situated at its current location to maximize its ability to perform these important national defense missions for the east coast (Figure 2.1-1).

Missile Warning

To detect and determine attack characteristics of ICBMs and SLBMs aimed at North America, the radar generates what is called a "surveillance fence." This constitutes the center of the main beam scanning at elevations between 3 and 10 degrees (°) above horizontal over a 240° (120°per face) scan area (Figure 2.1-2). The surveillance fence is normally at 3°; the radar's construction is such that the beam actually cannot go below a 3° elevation. In the missile warning mode, the direction of the beam is steered according to a computer-programmed pattern, moving from one position to another. In the surveillance mode, both faces of the radar are simultaneously active, sending out two parallel beams moving in a fashion similar to windshield wipers. Under normal operational circumstances, the radar is transmitting 11 percent of the time to maintain the surveillance fence, and waiting/receiving the return signal 89 percent of the time. The PAVE PAWS radar is capable of transmitting for up to 18 percent of the time to perform the missile warning mission with no space surveillance mission.

Space Surveillance

The space surveillance mission is conducted to track and catalog earth satellites and to identify other space objects. The radar is capable of focusing on



EXPLANATION

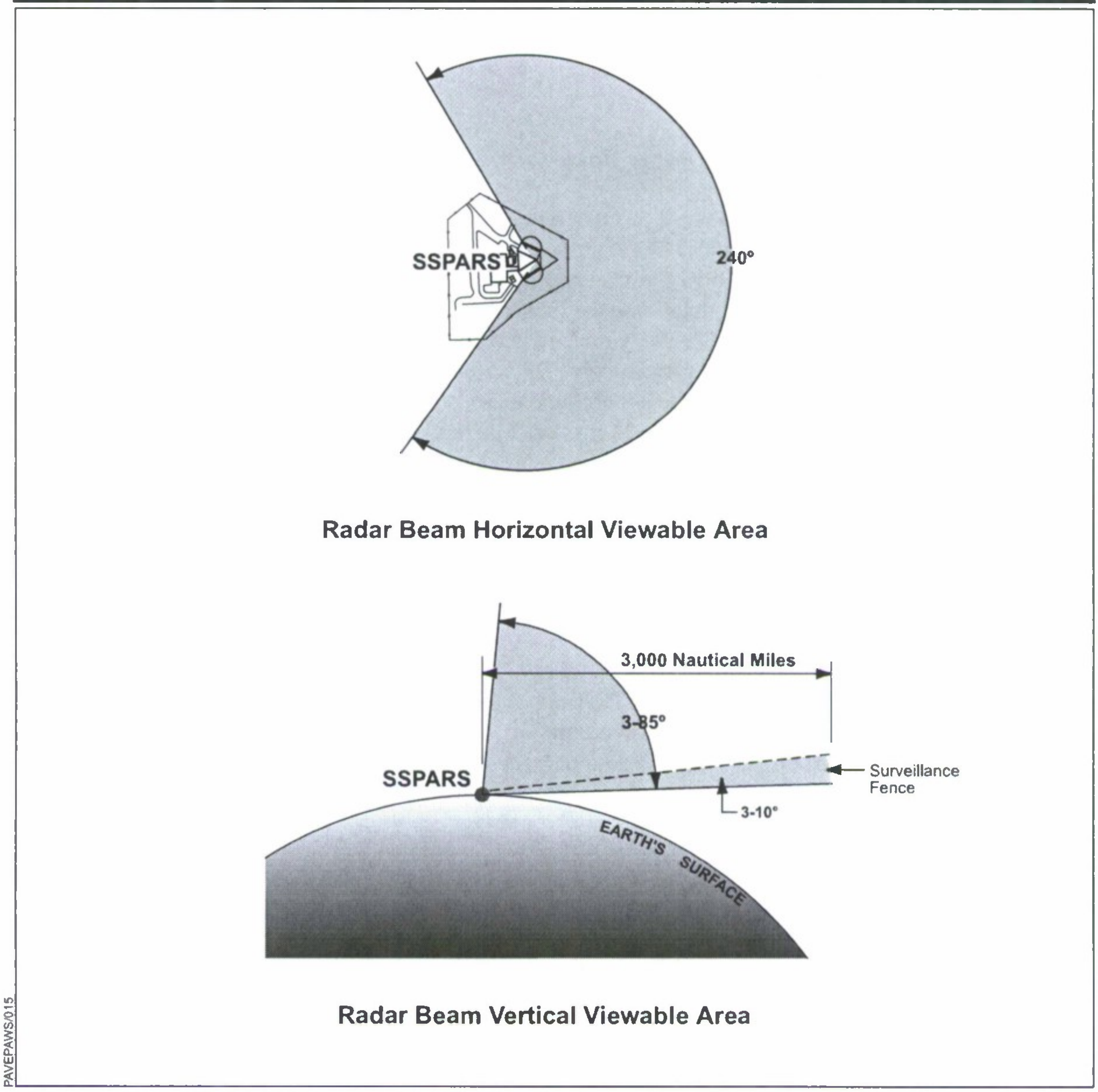
Radar viewable area

Cape Cod AFS Radar Coverage

Not to Scale

Note: Radar coverage to the south is provided by other radar systems.
Source: Weitze, 1999.

Figure 2.1-1



EXPLANATION

(shaded box)	Viewable Area
SSPARS	Solid State Phased Array Radar System

Radar Beam Viewable Areas

Figure 2.1-2

particular objects or a small cluster of objects. The radar can transmit from 7 to 25 percent of the time, as long as the maximum average time, in any combination of modes (i.e., missile warning and space surveillance), does not exceed 25 percent.

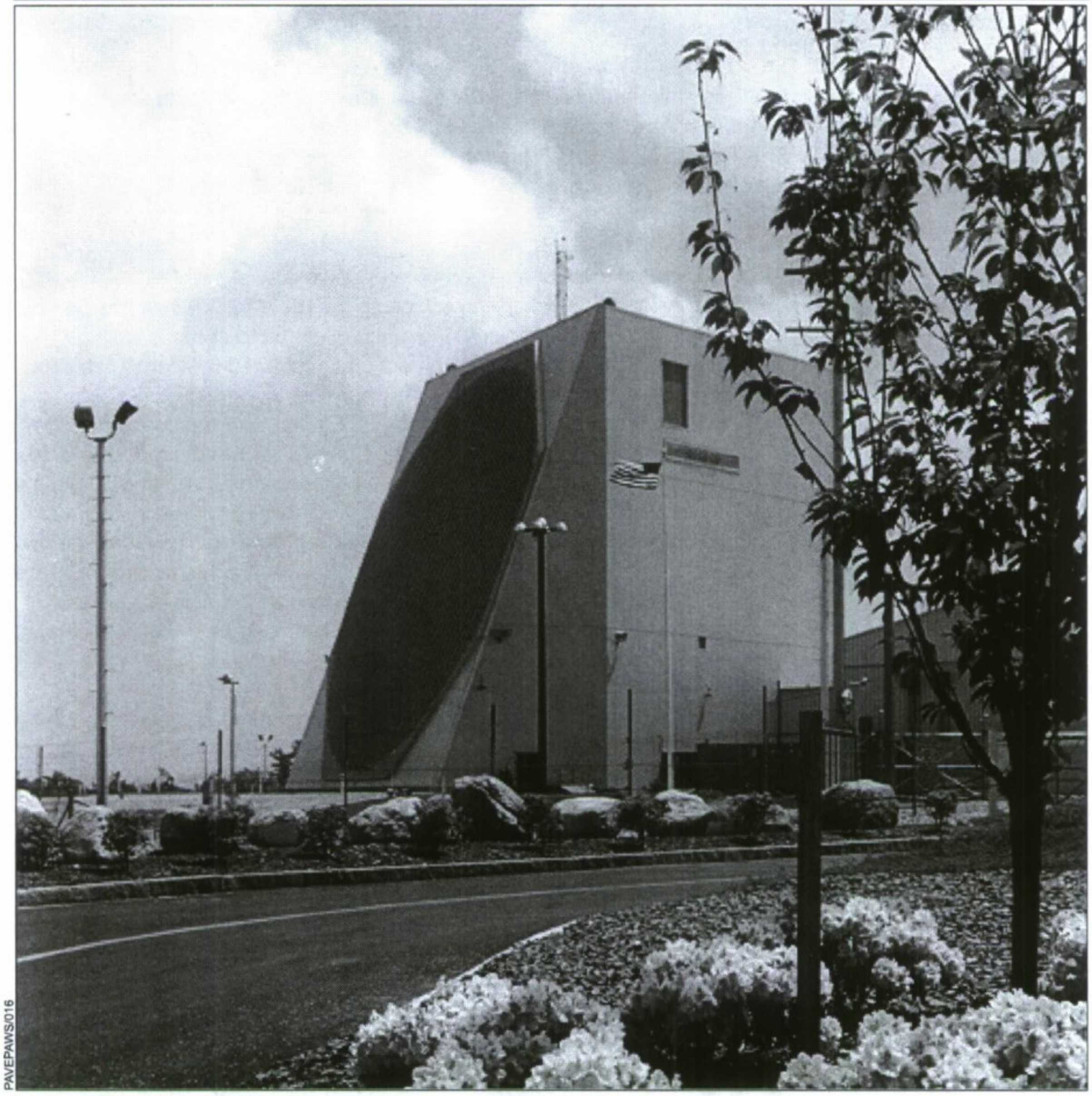
PAVE PAWS Radar Operations

The PAVE PAWS radar is a phased-array radar that transmits pulsed radiofrequency (RF) signals within the frequency range of 420 to 450 megahertz (MHz). Signals are reflected by objects back to the radar. These signals are analyzed to determine the location, distance, size, and speed of the object. The PAVE PAWS radar is housed in a 32-meter (105-foot) -high building. Two flat arrays transmit and receive RF signals generated by the radar. Each array face contains 1,792 active antenna elements out of a total of 5,354 elements. The two array faces are 31 meters (102 feet) wide, and are tilted back 20° from vertical (Figure 2.1-3). The active portion of each array face is situated in the center of a circle 22.1 meters (72.5 feet) wide. Each active antenna element is connected to a separate solid-state transmitter/receiver within the radar building that provides 322 watts of power for transmitting RF signals and amplifies the returning signal. The peak power from the radar is determined by the solid-state modules.

The RF signals transmitted from each of the array faces form one narrow main beam with a width of 2.2°. Most (approximately 90 percent) of the energy is contained in the main beam (MITRE Corporation, 2000). Each of the main beams can be directed electronically between 3° and 85° above horizontal. Figure 2.1-2 shows the minimum and maximum vertical angles to which the main beams can be directed.

2.2 NO-ACTION ALTERNATIVE

The 1979 EIS evaluated the potential impacts of constructing the PAVE PAWS radar as well as the potential health effects of RFE based on studies available at the time the EIS was prepared. The PAVE PAWS radar at Cape Cod AFS is the only radar in the nation that is able to confirm a detected missile launch towards the United States or Canada from the east. The radar provides launch detection and subsequent confirmation to provide the necessary information to make critical, nation-affecting decisions about an incoming threat. The No-Action Alternative involves no longer operating the SSPARS at Cape Cod AFS. The Air Force would no longer accomplish its missile warning and space surveillance missions, leaving all or portions of North America vulnerable to ICBM or SLBM attacks.



PAVEPAWS/016

Cape Cod AFS Solid-State Phased-Array Radar Facility

Figure 2.1-3

2.3 ALTERNATIVES ELIMINATED FROM FURTHER CONSIDERATION

CEQ regulations require that an EIS evaluate reasonable alternatives, briefly discuss those alternatives eliminated from detailed analysis in the environmental impact analysis, and provide the reasons for elimination of any alternatives (40 CFR Part 1502.14(a)). "Reasonable" is defined as practical or feasible from a common sense, technical, and economic standpoint (51 FR 15618, April 25, 1986).

The 1979 EIS presented a discussion of alternatives considered but eliminated from further consideration with regard to siting the radar facility and postponing the construction of the radar facility. In addition, this SEIS considered two alternative operational options. The first option considered the construction of physical barriers (i.e., earthen berms, wire mesh fencing, and trees) around the radar site to help reduce the radar side lobe RFE. Detailed descriptions of the barriers are provided in Appendix E2.1. The barrier option provided little to no significant reduction in radar emissions and was dismissed as having negligible benefit. The second option involved reducing the hours of operation at the radar. This option would reduce the emissions of the radar; however, any time the radar was powered down, the United States and Canada would have no ground-based warning of a missile attack on the East Coast as well as result in degraded Space Situational Awareness. This option was dismissed as being operationally unacceptable due to national security.

Because the primary concerns raised during the scoping process involved the potential health effects from the continued operation of the PAVE PAWS radar, this SEIS focuses on recent health studies and literature reviews that address RFE emitted from radar. Other than the options discussed above, no other alternatives were considered for this SEIS. This SEIS addresses the continued operation of the PAVE PAWS radar at Cape Cod AFS only.

3.0 AFFECTED ENVIRONMENT

Cape Cod AFS is situated atop Flat Rock Hill on Cape Cod, Massachusetts, within the northern portion of the Massachusetts Military Reservation (MMR) (Figure 3.1-1). The site is operated by the 6th Space Warning Squadron. The installation occupies approximately 100 acres at an elevation of approximately 265 feet above mean sea level. The leased area includes 87 acres for the installation, 11.5 acres for the access road, and 2 acres for electrical transmission lines. Cape Cod AFS is within Barnstable County and is approximately 70 miles south of Boston, 3 miles east of Bourne, and 2 miles west of Sandwich (see Figure 3.1-1).

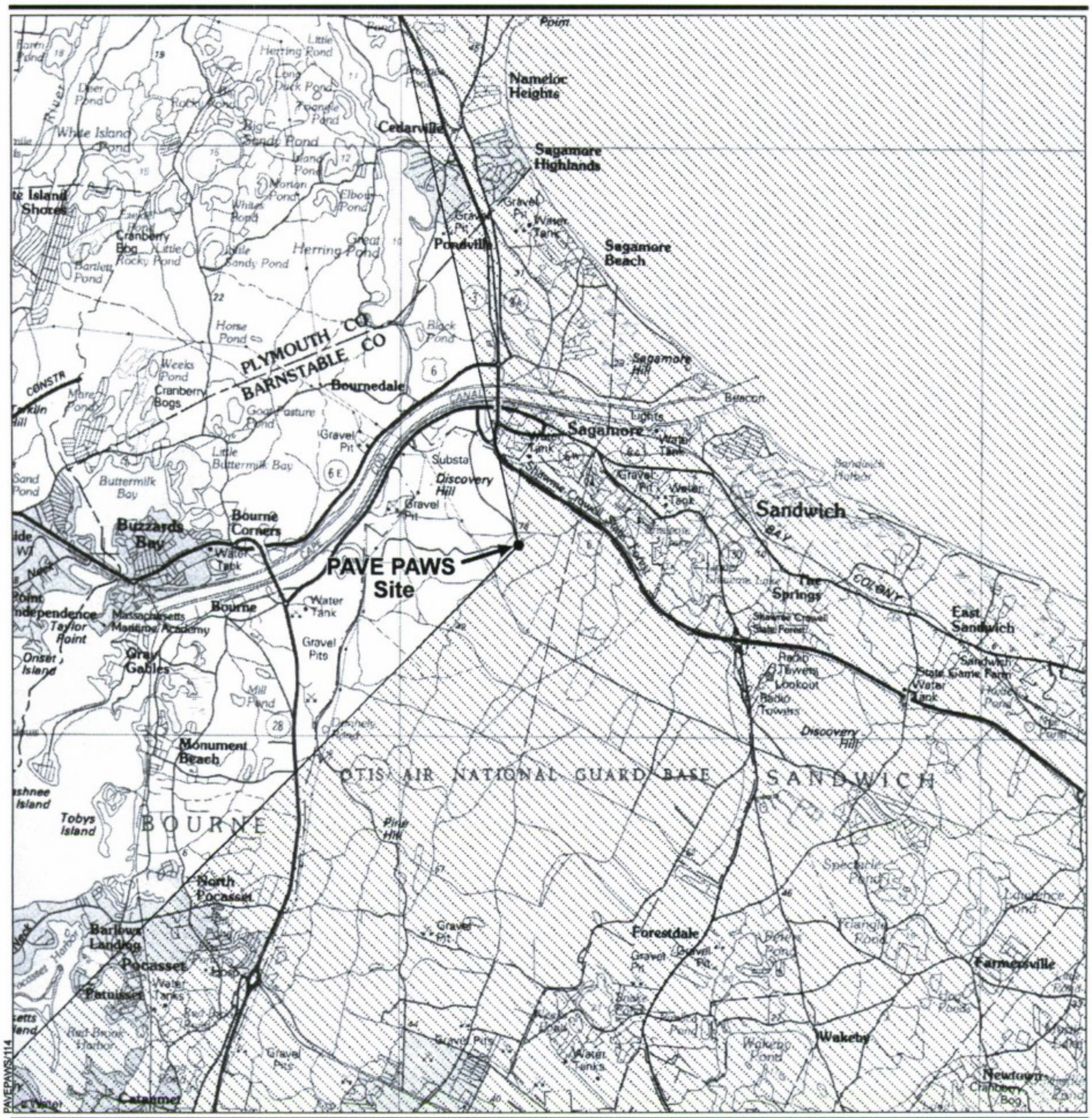
The PAVE PAWS radar is a phased-array radar that transmits energy at a frequency range that is higher than radio stations but lower than cellular telephones and microwave ovens (see Appendix D, Figure D-1). The radar operates at elevations between 3° and 85° above horizontal and at a peak power level of 340 watts with 1,792 active antenna elements (total of 3,584 active elements). The average power level is approximately 152.5 kilowatts (kW). Access in the immediate vicinity of the radar is restricted to authorized personnel for reasons of both public safety and mission security.

The intent of this section is to provide information for both the interested public and technical experts to understand the characteristics of the PAVE PAWS radar and the potential effects of RFE.

3.1 SOLID-STATE PHASED-ARRAY RADAR SYSTEM/RADIOFREQUENCY SPECTRUM

The SSPARS, or PAVE PAWS as it is better known, is an early-warning radar system capable of detecting ICBM and SLBM attacks against North America. The PAVE PAWS radar is a long-range search/surveillance and tracking system whose primary mission is missile warning. Its secondary mission involves space surveillance in order to estimate trajectories of launched objects, as well as tracking earth satellites and other space objects. The PAVE PAWS radar at Cape Cod AFS provides early-warning coverage of the United States East Coast and Atlantic Ocean. The striking difference between the PAVE PAWS and rotating dish radars is the mode in which the radar steers its beam. Unlike radars that rotate in order to sweep their beam over a given area, the PAVE PAWS does not move. Rather than mechanical steering, the PAVE PAWS electronically steers its beam across the horizon. Each array face spans an azimuth of 120° resulting in a total azimuth coverage of 240° (i.e., scan area of 240°).

The PAVE PAWS radar operates at 24 discrete frequencies that lie in the band between 420-450 MHz. The radar has two modes in which it operates, tracking and surveillance. Each of these radar modes is dependent on the mission requirements at the time. These operating parameters and others are shown in Table 3.1-1.



EXPLANATION

SSPARS Scan Area

0 2,500 5,000 10,000 Feet

Source: U.S. Geological Survey, 1986, New Bedford, Massachusetts

Cape Cod AFS Site Map

Figure 3.1-1

Table 3.1-1. PAVE PAWS Operating Parameters

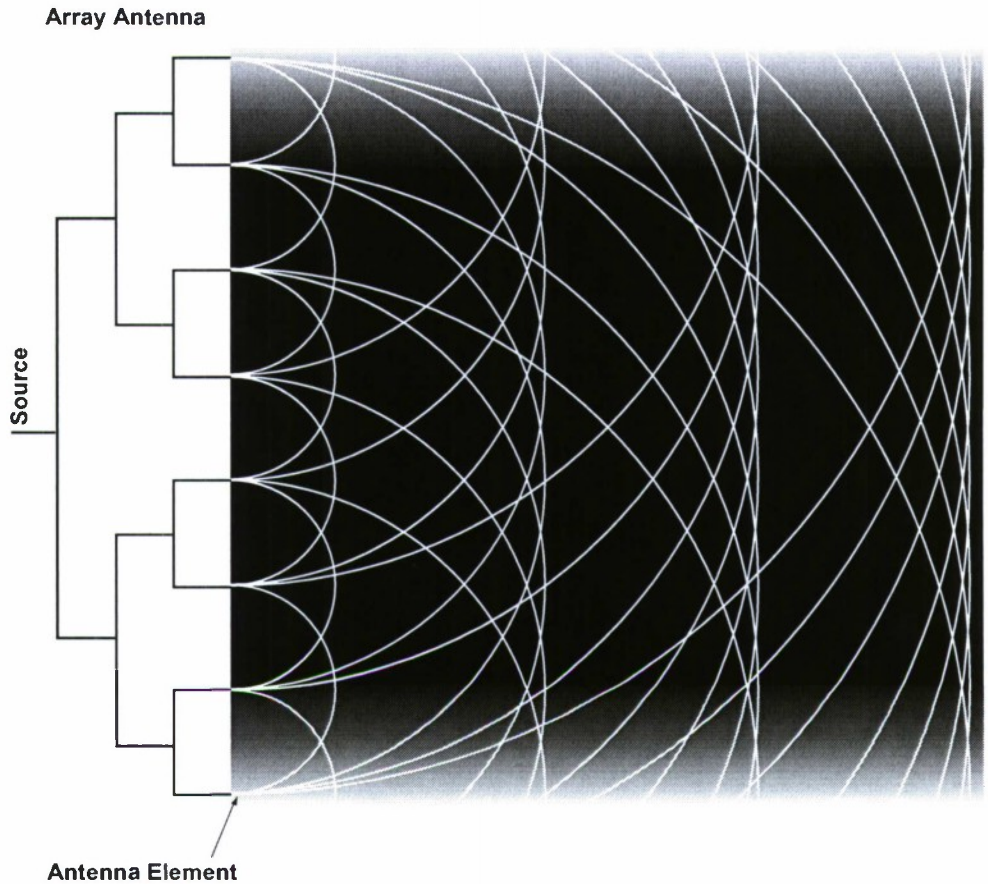
Parameter	Value
Peak Power	1,792 active elements at 325 watts = 582.4 kW
Duty Factor	25% (11% search, 14% track)
Average Power	152.5 kW
Transmit Gain $_{effective}$	37.92 decibel (dB)
Active Radar Diameter	22.1 meters
Frequency Band	420 MHz to 450 MHz
Wavelength	0.69 meters at 435 MHz
Sidelobes	-20 dB (first), -30 dB (second), -38 dB (rms)
Face Tilt	20 degrees
Pulse Rate	18 to 72 pulses per second
Pulse Width	0.25, 0.5, 1, 2, 4, 8, 16 milliseconds (ms) in tracking mode, 0.3, 5, 8 ms in surveillance
Number of Array Faces	2
3 dB Beam Width (on boresight)	2.2 degrees

dB = decibel
kW = kilowatt
MHz = megahertz
ms = millisecond
rms = root mean square

3.1.1 Transmitting a Radiofrequency Signal

The PAVE PAWS radar is a phased-array radar, which transmits pulsed RF signals. A phased-array is typically made up of a flat, regular arrangement of radiating elements (transmitters) in which each element is fed a microwave signal of equal amplitude and controlled phase. A central oscillator generates the RF signal, then transistors or specialized microwave tubes, such as traveling-wave tubes, amplify it. The RF signal is transmitted from the 1,792 active antenna elements per array face, or a total of 3,584 active elements. Figure 3.1-2 illustrates an example of the signal pattern emitted by the PAVE PAWS radar. When all the elements radiate in phase, yielding wave crests that move forward in step, the waves become superposed along the perpendicular axis of the array. The signals interfere constructively to produce a strong sum signal, resulting in a beam directed straight ahead (called the boresight). At greater angles to the boresight, individual signals from different radiating elements must travel different distances to reach a target. As a result, their relative phases are altered and they interfere destructively, weakening or eliminating the beam. An example of destructive interference is illustrated in Figure 3.1-3. The sidelobes of the radar beam are the fault of destruction interference. Because of the characteristics of interference patterns, the width of the radar beam “cone” is directly proportional to the operating wavelength and inversely proportional to the size of the array (Brookner, 1985).

The phasing of the RF signal refers to signals from various radiating elements that are emitted at different time intervals in order to "steer" the radar beam. In order for the PAVE PAWS radar to emit a signal in-line with the boresight or straight ahead, the signals from all array elements must be in phase.



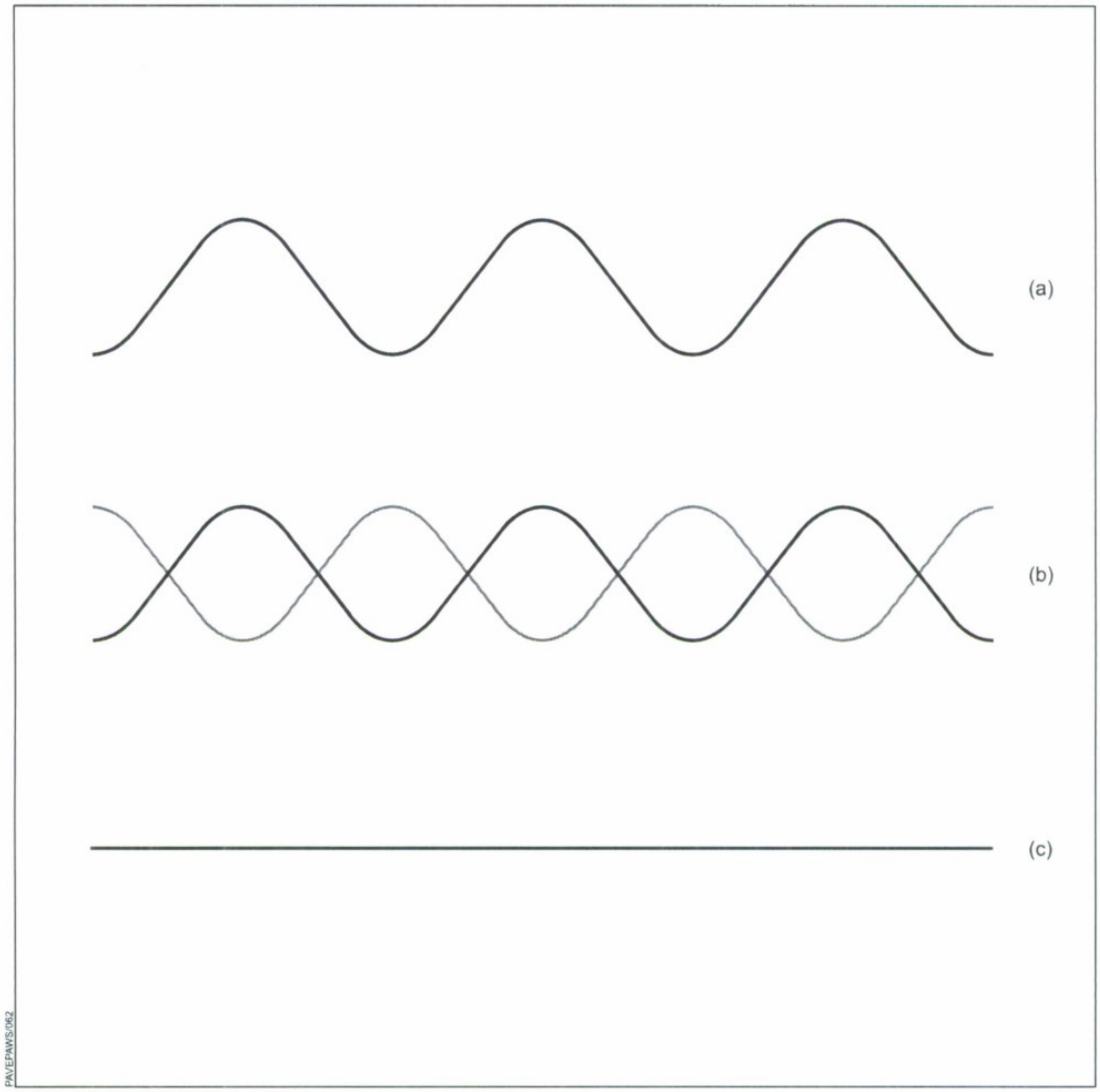
EXPLANATION

Antenna elements in a phased-array emit separate microwave signals. When all the elements radiate precisely in phase, yielding wave crests that move forward in step, the waves become superposed along the perpendicular axis of the array. They interfere constructively to produce a strong sum signal, resulting in a beam directed straight ahead.

Antenna Elements in a Phased-Array Radar

Source: Scientific American, 1985.

Figure 3.1-2



EXPLANATION

(a) Represents the initial signal.

(b) Represents the initial signal with another signal of equal power, but opposite wavelength.

(c) Resulting signal from the destructive interference of both signals.

Example of Destructive Interference

Figure 3.1-3

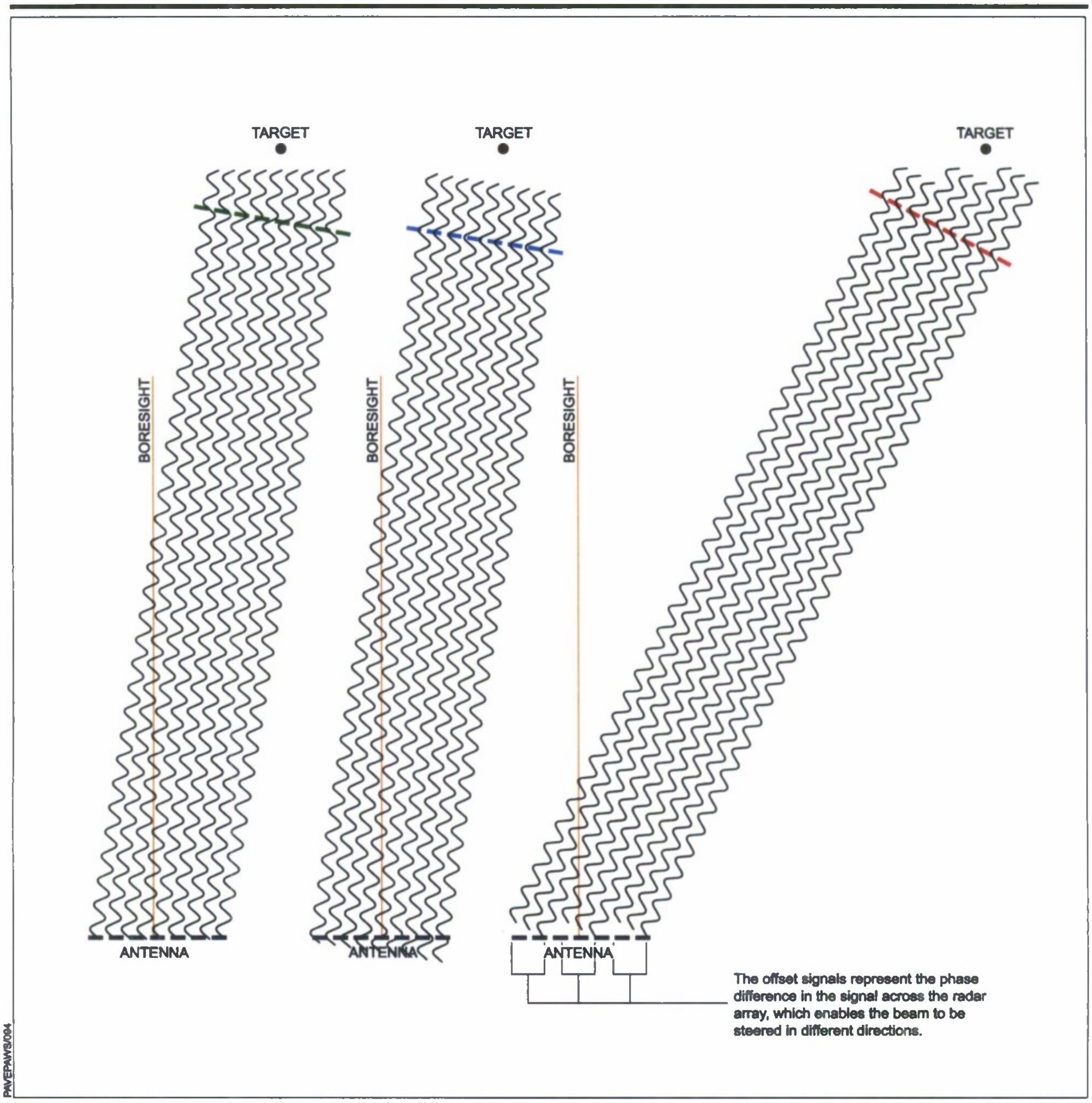
In order for the radar beam to "look" in a different direction, the signals from each radiating element must be delayed electronically by amounts that increase steadily across the face of the array. Each delay causes a signal to lag a fraction of a wavelength behind the signal from an adjacent element (Brookner, 1985). Figure 3.1-4 illustrates this aspect of beam steering. As seen in the first graphic of Figure 3.1-4, the RF signals do not coincide at the target or are out of phase, resulting in a weakened signal due to destructive interference. The second and third graphics in Figure 3.1-4 illustrate the application of phased signals in the acquisition of a target off boresight. As the signals leave the antenna, each element in the array transmits its delayed signal by a fraction of a wavelength as seen by the distance of the signal from the antenna array. As the signals coincide at the target, the signals are in phase and interfere constructively resulting in a strong signal. The zone in which the individual signals add up in phase to produce a strong sum signal, capable of detecting targets, lies not straight ahead, down the boresight of the antenna, but off to the side in the direction of increasing phase delay (Brookner, 1985). Even at the most severe angle the radar beam can achieve, the beam takes the form of a slender cone surrounded by regions of destructive interference.

The transmitted RFE is characterized by its waveform. The different functions that the radar performs, tracking and surveillance, require different signal characteristics. The radar transmits a series of signals that are pulsed. This means that the radar transmits a series of pulses followed by silent periods. During the silent periods, the radar is awaiting the return echo (reflected energy beam) from its target, so that an analysis of the target may be completed. A primary feature of the pulsed nature of the PAVE PAWS radar is that the power is on during transmission of the pulses and off during the silent periods. The radar transmits varying pulsewidths, in other words each pulse can have a different duration or transmitted time period. The PAVE PAWS radar uses pulsewidths of 0.25, 0.3, 0.5, 1, 2, 4, 5, 8, and 16 milliseconds (Kramer, 2000). During these pulses, the radar frequency changes or "chirps." Chirping allows the radar to utilize a long pulse to detect smaller objects, while simultaneously obtaining the better range resolution otherwise achieved with a shorter pulse (Kramer, 2000).

3.1.2 Sidelobes

The region(s) surrounding the main beam of the radar, where the signals interfere destructively, is (are) known as the sidelobe(s). Unlike the narrow, cone-shaped main beam, the sidelobes represent energy in a more diffuse form. Figure 3.1-5 illustrates the direction of the main beam and first four sidelobes (black arrows), as well as their width and relative intensity (shaded area) (Kramer, 2000).

Approximately 90 percent of the radiated power is contained within the main beam; therefore, the sidelobes contain very little energy. The maximum intensity of the first sidelobe is 1/100 of the main beam intensity or -20 decibels (dB). A dB is defined as:



EXPLANATION

Electronic Beam Steering

Source: Scientific American, 1985.

Figure 3.1-4

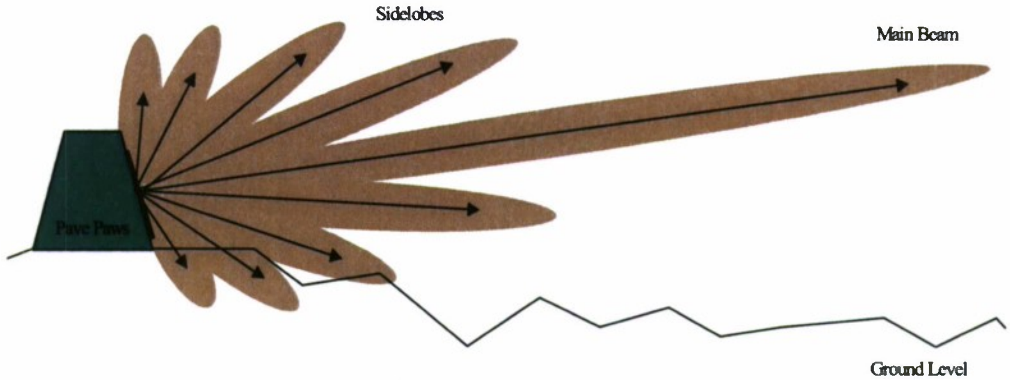


Figure 3.1-5. Profile of the Main Beam and Sidelobes
Source: Kramer, 2000.

$$dB = 10 \log \frac{I_o}{I}$$

Where:

I_o, main beam power density, milliwatts per square centimeter (mW/cm^2)
I, power density in a specific sidelobe, mW/cm^2
dB, decibel

The maximum intensity of the second sidelobe is 1/1000 of the main beam intensity or -30 dB. Since the sidelobes are all around the main beam, in some instances, they point lower than the horizontal (Kramer, 2000). The second sidelobe is the primary source of ground-impacting RFE within the far-field region, which lies within public areas surrounding the radar. Although the second sidelobe impacts the ground, the main beam, which contains 90 percent of the radiated power, does not. Interlock systems and computer software prevent the main beam from reaching an elevation lower than 3° above horizontal. It is in the basic nature of a phased-array antenna that component or equipment failures are unlikely to cause radiation to be directed into public areas in any undesignated direction in excess of the amounts estimated for normal operation (National Research Council, 1979a).

The relative power in dBs for the main beam and sidelobes of the radar in relation to the angle relative to beam peak is shown in Figure 3.1-6. The main beam is identified by the highest peak and reflects its boresight width of 2.2°. Each subsequent peak represents a sidelobe, starting with the first sidelobe, and descending sequentially in order.

It is the nature of high gain antennas that the sidelobe pattern is "spiky" in the sense that it is characterized by narrow lobes separated by deep nulls (National Research Council, 1979a). The nulls are represented in Figure 3.1-6 as the valleys between the peaks. Designed as the PAVE PAWS radar is, with particular attention to minimizing the large lobes, a pattern may have a few tens

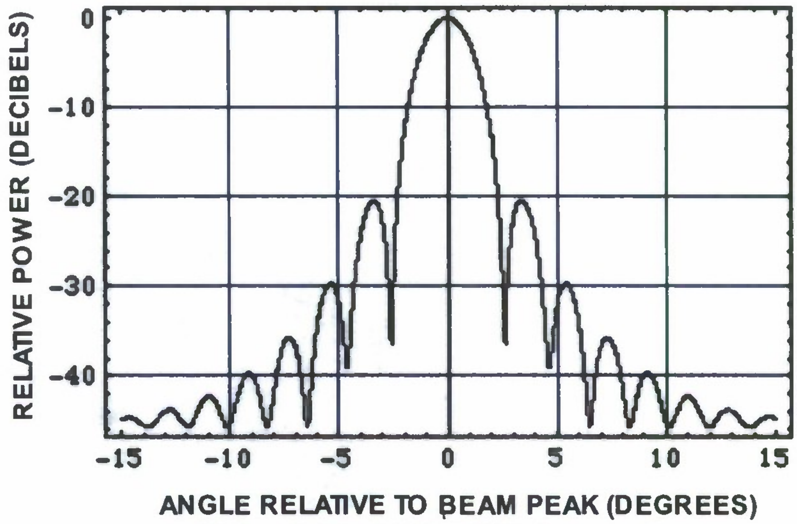


Figure 3.1-6. PAVE PAWS Antenna Pattern

Source: Kramer, 2000.

of lobes with peaks within 5 dB of the design maximum (e.g., for PAVE PAWS, between 30 and 35 dB below the main beam) (National Research Council, 1979a).

The main beam and first sidelobe are azimuthally symmetrical, that is they have the same lateral (horizontal) deviation. The higher order sidelobes exhibit some randomness due to amplitude and phase errors at individual array elements, mutual interactions between array elements, and individual hardware component failures (Kramer, 2000). Figure 3.1-7 shows a 3-D representation of the antenna pattern.

The illustration in Figure 3.1-7 applies when the beam is steered to broadside (e.g., normal to the plane of the antenna array that is +20° in elevation and either 47° or 167° azimuth) (Kramer, 2000). The large peak and the surrounding peak represent the main beam and first sidelobe, respectively. Both the main beam and first sidelobe are highly regular and symmetrical. The higher order sidelobes are represented by the multitude of smaller peaks. These sidelobes are lower intensity and are irregularly distributed throughout the antenna pattern. The pattern seen during normal surveillance will differ as a function of the beam steering angles (Kramer, 2000).

3.1.3 Near-field RFE Region

In regions close to RFE emitting sources, the fields are called near fields. In the near-fields, the electric and magnetic fields are not necessarily perpendicular; in fact, they are not always conveniently characterized by waves (Durney et al., 1986). The near-field is defined as a region generally in proximity to an antenna or other radiating structure, in which the electric and magnetic fields do not have a substantially plane-wave character, but vary considerably from point to point.

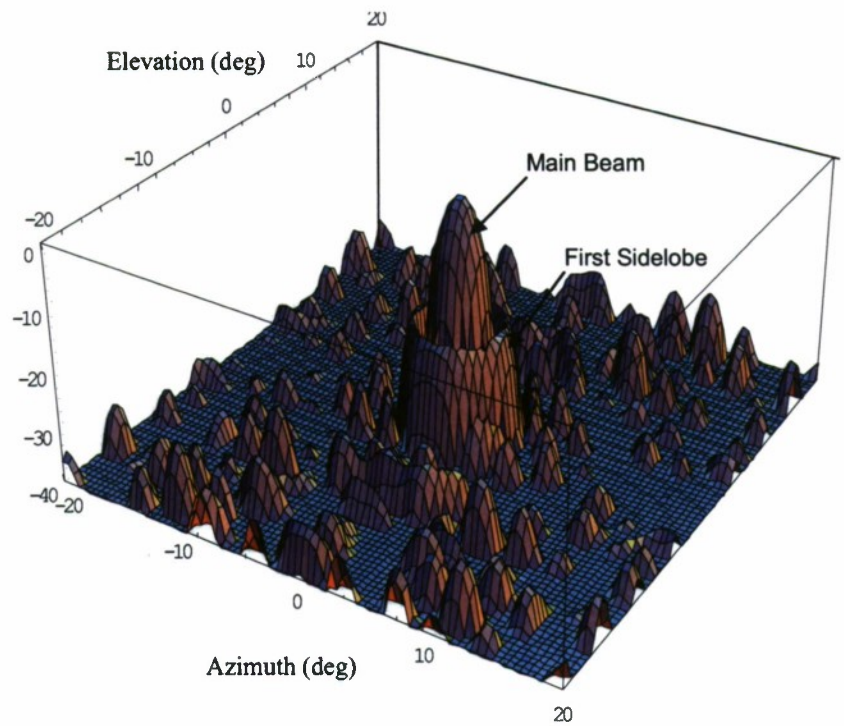


Figure 3.1-7. 3-D View of the PAVE PAWS Antenna Pattern

Source: Sparagna, 1999.

The near-field region is further subdivided into the reactive near-field region, which is closest to the radiating structure and contains most or nearly all of the stored energy, and the radiating near-field region where the radiation field predominates over the reactive field, but lacks substantial plane-wave character and is complicated in structure (Institute of Electrical and Electronics Engineers, 1999a). The electric and magnetic fields are often more nonpropagating in nature and vary rapidly with distance (Durney et al., 1986). The reactive region at the PAVE PAWS frequencies extends less than 10 meters from the face of the antenna. The near-field is primarily associated with controlled exposure environments or occupational exposures. The controlled environment exposure applies to the people working at the site, who are aware of their potential exposure and the hazards of exposure to RFE.

The characteristics of the near-field are very complex as the lack of uniform dispersal of RFE within the near-field makes measurements of the electric and magnetic fields difficult. Unlike the parallel, plane-wave nature of the far-field, the near-field shape changes with distance. The near-field for the PAVE PAWS radar at Cape Cod AFS extends out to a distance of 1,440 feet or 439 meters (Sparagna, 1999). Sparagna (1999) used a half wavelength criteria that corresponded to a phase difference of 180 degrees, as used in the 1979 EIS. The more conventional near-field boundary is the constraint that the difference in path length from an element at the edge of the aperture and an element at the center of the aperture is either 0.25 or 0.125 times the wavelength. The values correspond to a phase difference of 45 and 90 degrees, respectively. This distance is outside the 1,000-foot boundary of the installation. The near-field boundary occurs at a frequency of 450 MHz and a 180° (half wavelength) difference between the center element and the edge element. Figure 3.1-8 shows an illustration of the near-field region around the PAVE PAWS radar.

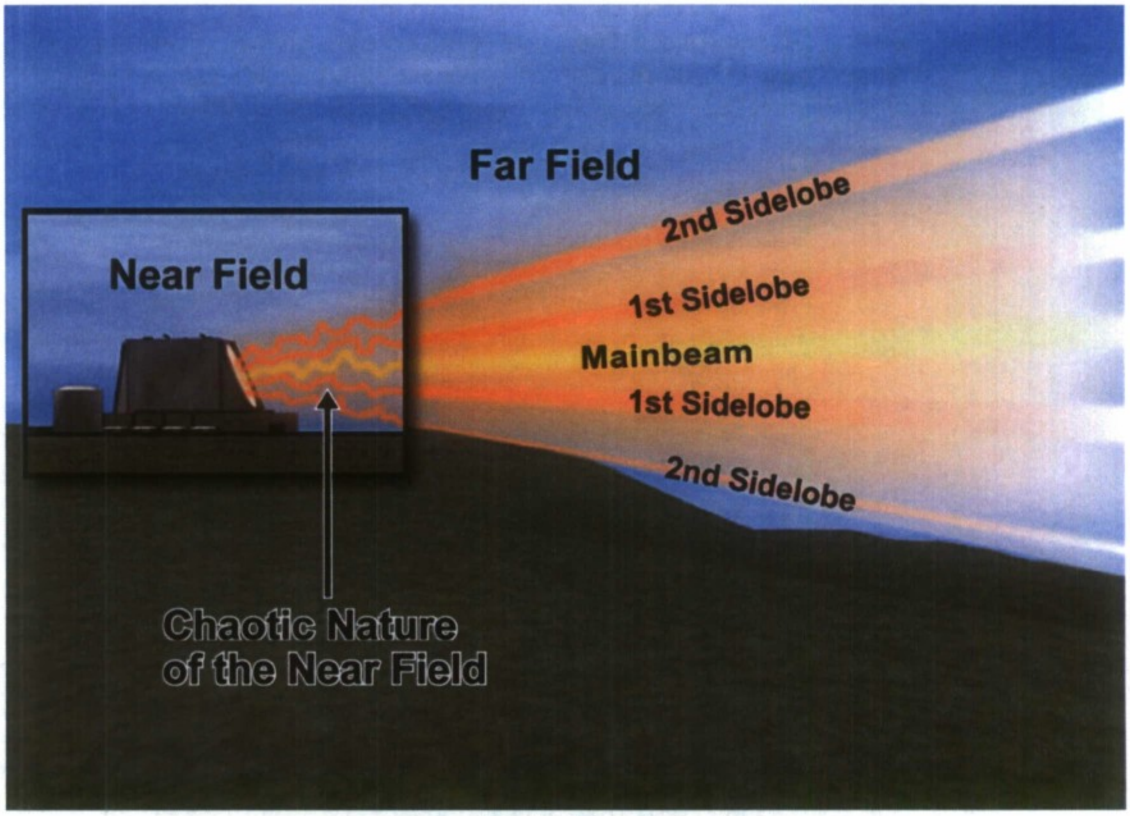


Figure 3.1-8. Illustration of the PAVE PAWS Near-field Region

3.1.4 Far-field RFE Region

The far-field region is defined as that region of the field of an antenna where the angular field distribution is essentially independent of the distance from the antenna (Institute of Electrical and Electronics Engineers, 1999a). Within the far-field region, the RFE field has a predominantly plane-wave character. Unlike the near-field region, which is not uniformly dispersed over space, the far-field region has locally uniform distribution of the electric and magnetic fields. The electric and magnetic field strengths both fall off at a rate of *1/d*, where *d* is the distance from the radiating structure (Smith, 1998).

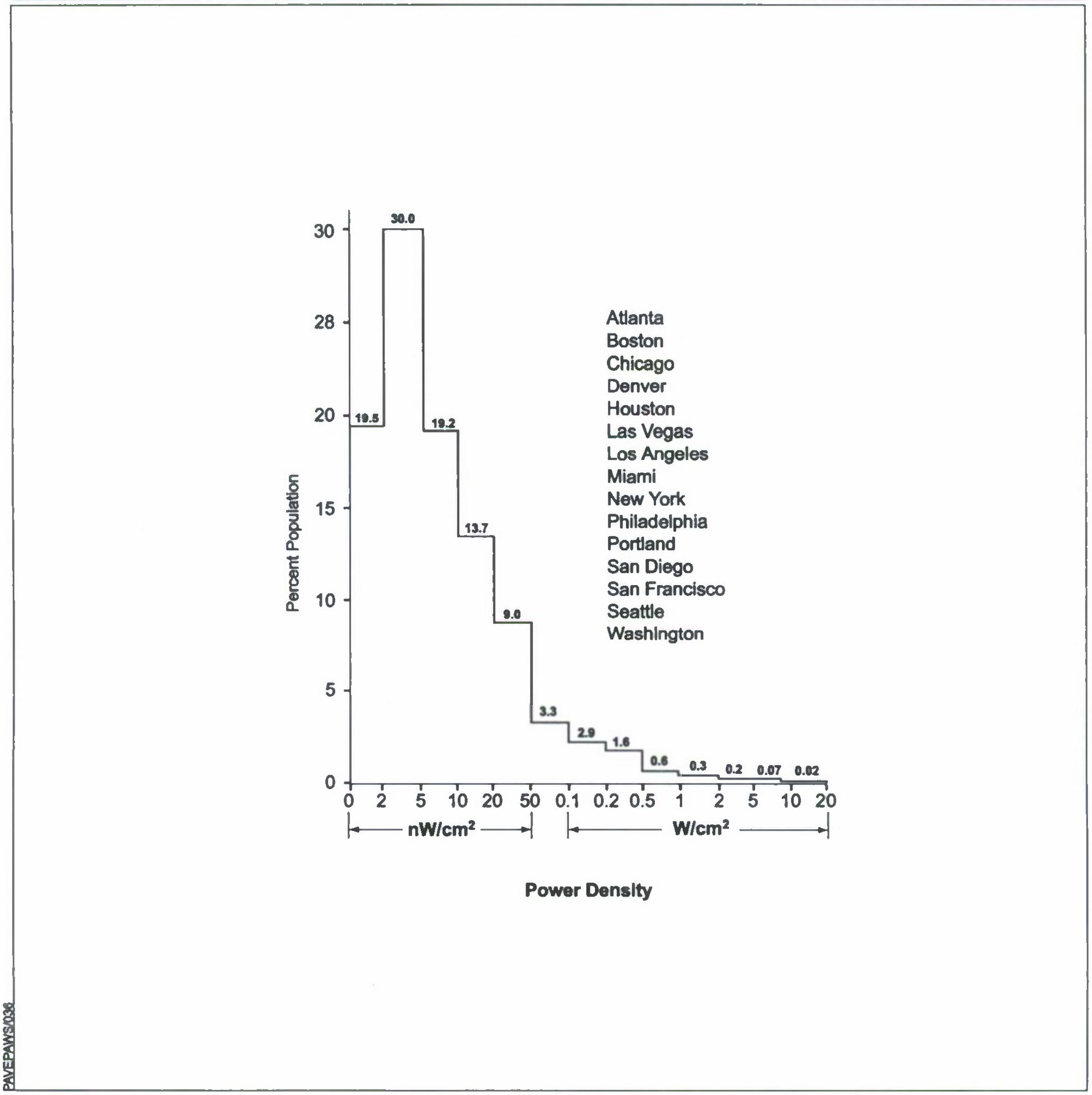
According to Sparagna (1999), the far-field region begins at a distance of 1,440 feet or 439 meters using the methodology used by the U.S. EPA in 1979 during their initial assessment of the PAVE PAWS radar; however, Kramer (2000) cites the far-field region beginning at a distance of 2,345 feet or 739 meters. The boundary between the near-field and far-field regions is not sharp because the near-fields gradually become less important as the distance from the source increases (Durney et al., 1986). As seen in Figure 3.1-8, within the far-field region, the RFE fields appear as propagating plane waves. The main beam is a conical shape and uniformly dispersed through space.

Making measurements is usually easier in the far-field than in the near-field, and calculations for far-field absorption are much easier than for near-field absorption (Durney et al., 1986). The far-field region is primarily associated with uncontrolled environment exposure limits or public exposures. The uncontrolled exposure limits apply to personnel who may be unaware of their exposure scenario and the hazards associated with RFE. In many instances, this is the case for public access areas nearby RFE emitting structures.

3.1.5 Other Sources of Radiofrequency Energy

The rapid expansion of telecommunications services, cellular telephones, digital music/television, and paging services has brought RF/microwave energy sources into everyday life. Tall, metal towers with an array of relays on top of them are common sites around communities and roadways today, as the infrastructure for the telecommunications industry continues to expand. Although many of these towers do not actively transmit RF/microwave signals, they do relay signals produced by cellular telephones and pagers to their intended destinations. Electric field strengths at ground level beneath microwave relay towers are in the range of 20 milliVolts per meter (mV/m) to 0.6 Volts per meter (V/m) (0.00000016 mW/cm^2 to 0.000095 mW/cm^2) (Hankin, 1985). The electric field strength can be converted to a power density measurement using the following equation: $S = E^2/377\Omega$ where power density is (S), watts per square meter (W/m^2) and the electric field strength are (E). Other common sources of RF/microwave energy include garage door opener remote controls, security systems (remote keyless entry), video display terminals (VDTs), and remote controlled toys.

Urban areas experience higher background RF/microwave concentrations because of the higher concentration of RF/microwave transmitters, such as amplitude modulation (AM)/frequency modulation (FM) radio stations and very high-frequency/ultra high-frequency (VHF/UHF) television transmitters. Broadcast stations are significant sources of RF exposure (Janes et al., 1977). Figure 3.1-9 shows the differential fraction of population exposed within given power density intervals based on data from 15 major cities in the United States. Approximately 30 percent of the populations within these cities were exposed to power densities of 2 to 5 nanowatts per square centimeter (nW/cm^2), which is approximately six orders of magnitude less than the current uncontrolled exposure limit for PAVE PAWS. Of the community RF measurements taken in 1986 around the Cape Cod AFS PAVE PAWS radar, the highest average power density was 61 nW/cm^2 (0.000061 mW/cm^2) as measured at the rest area on Route 6. As shown in Figure 3.1-9, approximately 3.3 percent of the population within these specific cities were exposed to power densities of 61 nW/cm^2. Furthermore, more than 88 percent of the population within these cities was exposed to power densities in the nW/cm^2 range, with substantially smaller populations exposed at higher power density levels.



EXPLANATION

W/cm² microwatt per square centimeter

nW/cm² nanowatt per square centimeter

Source: Shleien et al., 1998.

Differential Fraction of Population Exposed Within Given Power Density Intervals (15 cities)

Figure 3.1-9

A study conducted in 1997, explored the exposure to RF in the general and work environments. It was noted that RF fields in the general urban environment are principally associated with radio and television broadcast services. Studies of general population exposure in the United States showed that approximately 3 percent of the urban population was exposed to electric field strengths greater than 1 V/m (0.000265 mW/cm^2) from AM broadcast services (Mantiply et al., 1997). A major difference between AM and FM transmitters is that the entire broadcast tower is the AM transmitting antenna, while the broadcast tower serves strictly as the support structure for the much smaller FM antenna. As a result, AM broadcast services can emit much stronger RF fields at ground level than FM broadcast services and can induce electric currents within objects inside the RF field. The median electric field strengths reported in urban areas in the United States from FM broadcast services is approximately 0.1 V/m (0.0000026 mW/cm^2) with 0.5 percent of the population exposed to field strengths above 2 V/m (0.00106 mW/cm^2) (Tell and Mantiply, 1980; Hankin, 1985). The maximum electric field strengths at ground level beneath FM towers in the United States vary from about 2 to 200 V/m (0.00106 mW/cm^2 to 10.61 mW/cm^2) (Gailey and Tell, 1985).

VHF/UHF television broadcast services are another major source of RF fields in the urban environment. Calculations based on measurements in the late 1970s showed that approximately 16 percent of the population was exposed to fields above 0.1 V/m (0.0000026 mW/cm^2) and 0.1 percent was exposed to fields above 2 V/m (0.00106 mW/cm^2) from low band VHF-television (TV) (channels 2-6) (Mantiply et al., 1997). For high band VHF-TV (channels 7-13), 32 percent of the population was exposed to electric field strengths above 0.1 V/m (0.0000026 mW/cm^2) and approximately 0.005 percent were exposed to fields above 2 V/m (0.00106 mW/cm^2) (Mantiply et al., 1997). The maximum fields at ground level beneath VHF-TV towers were estimated to be between 1 and 30 V/m (0.000265 mW/cm^2 to 0.23872 mW/cm^2) (Gailey and Tell, 1985). For UHF-TV (channels 14-67), general population exposure calculations showed that about 20 percent of the population was exposed to fields above 0.1 V/m (0.0000026 mW/cm^2) and approximately 0.01 percent was exposed above 1 V/m (0.000265 mW/cm^2) (Tell and Mantiply, 1980).

3.1.5.1 Private Microwave Congested Areas.

The Federal Communications Commission (FCC) has designated areas within the United States where the density of RF/microwave emitters, across certain frequencies, has produced RF/microwave congestion. In order to identify these congested areas, the FCC staff analyzed the microwave database and sorted stations according to frequency bands and geographical areas. They plotted the stations on a map of the United States divided into areas of approximately 1,000 square miles, then determined congestion based on such criteria as the number, average power, antenna sizes, and growth rates of existing stations in each of the different frequency bands. Taking all factors into consideration, the FCC staff identified those areas that, in its judgment, would likely be congested. One of the primary factors taken into consideration is where a predictable risk of interference to other stations exists. Using the existing FCC data, maps were compiled that showed the private microwave congested areas around Cape Cod AFS.

Figure 3.1-10 shows the FCC private microwave congested areas around the Boston, Massachusetts area, including Cape Cod AFS. Cape Cod AFS is within two of the three private microwave congested areas shown in Figure 3.1-10. The specific frequencies for these congested areas are 952-960 MHz and 1850-1990 MHz.

In addition to these two frequency ranges, the Boston metropolitan area is also a private microwave congested area for the 12 gigahertz (GHz) frequency. Figure 3.1-10 indicates that the Boston area, including Cape Cod AFS, has a high density of RF/microwave emitters within the specified frequencies, resulting in a risk of interference to other stations. The private microwave congested areas for the Cape Cod AFS area and those specific frequencies represent services such as broadcasting, fixed/mobile RF/microwave sources, personal communication systems (PCSs), satellite communication (SATCOM) systems, and fixed/mobile RF/microwave sources.

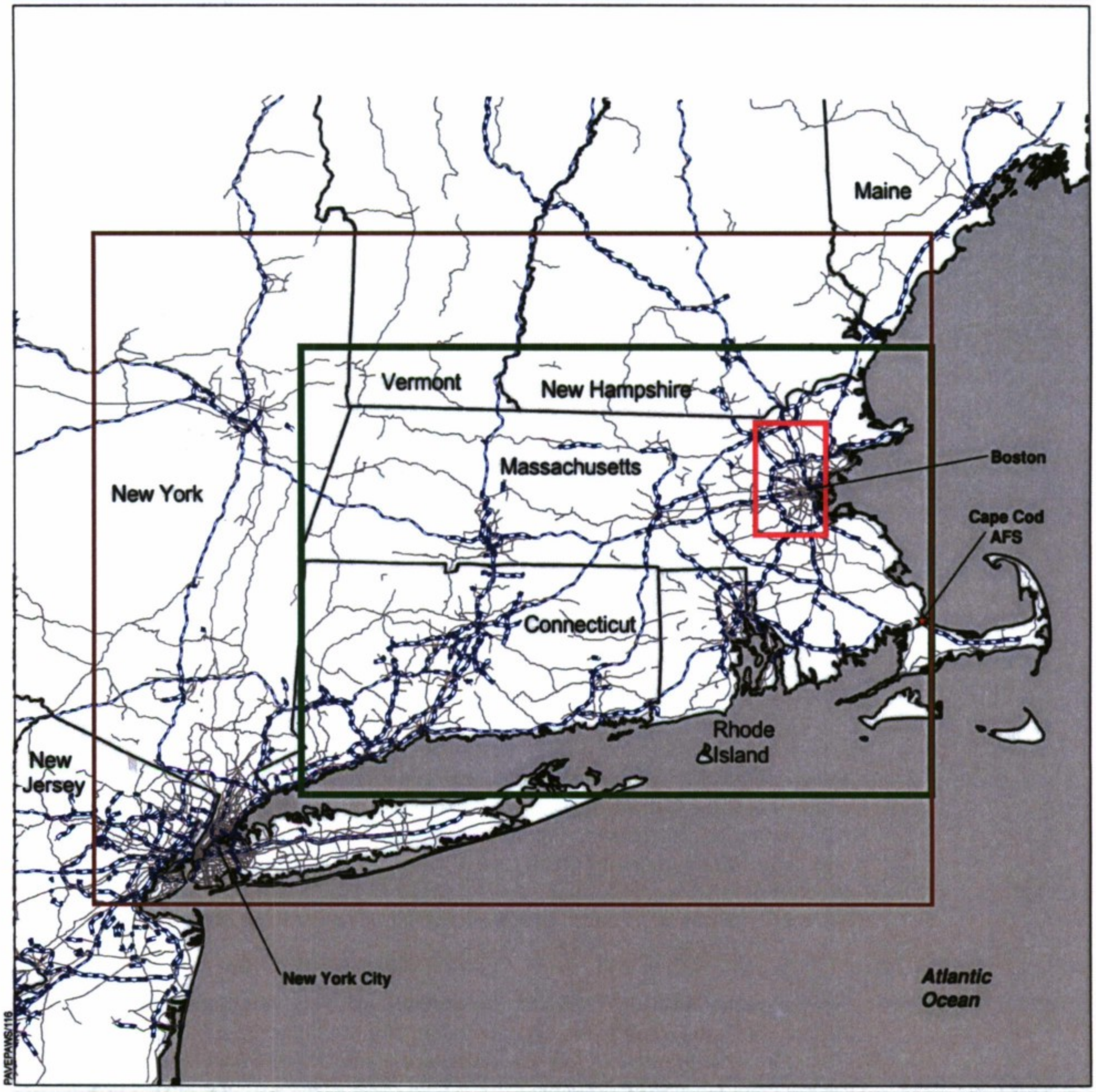
3.1.5.2 Multiple Emitters within the PAVE PAWS Frequency Range.

The frequency range in which the PAVE PAWS radar operates is 420 to 450 MHz. According to the FCC, this frequency range has been restricted to include only amateur "Ham" radio emitters (70 cm wavelengths only), military radars, and radiolocation emitters. The Joint Spectrum Center (JSC) completed a search of the Frequency Record Resource System, FCC, Government Master File, and International Telecommunications Union databases to determine the number of emitters within a 100 nautical mile (nm) radius of Cape Cod AFS that operate within the same frequency range as the PAVE PAWS radar. Including the PAVE PAWS radar at Cape Cod AFS, a total of 17 emitters were identified that operate within the same frequency range as PAVE PAWS within a 100 nm radius of Cape Cod AFS. Many of these emitters are situated in or near the Boston metropolitan area. Figure 3.1-11 shows the locations of the emitters within a 100 nm radius of Cape Cod AFS.

3.1.5.3 Coastal Impacts of RF/Microwave Energy from Radars and Emitters.

Although the PAVE PAWS radar is a ground-based unit, the Cape Cod AFS radar is located close to the coastal waters of the Atlantic Ocean. Additional RF emitters exist throughout the coastal waters of the United States and other countries to provide navigational support to ships. One example of this type of RF emitter is the Long Range Aids-to-Navigation (LORAN) transmitters.

The LORAN systems are long-range, low frequency (e.g., 100 kilohertz [kHz]) pulsed and phased RF, hyperbolic navigation systems developed in the 1960s primarily for maritime navigation purposes. Although these systems are centered on the frequency of 100 kHz, the LORAN emissions often overflow into the 90 to 110 kHz frequency range. The LORAN transmitters are omni-directional, meaning they transmit in all directions. Like PAVE PAWS, these systems are pulsed and phased RF signals; however, the frequency that the LORAN system operates on is a frequency 4,200 times lower than the PAVE PAWS frequency range. At a distance of 300 meters from the LORAN antenna base, the electric



EXPLANATION

★ Cape Cod Area

Private Microwave Congested Areas

952-960 MHz Congested Area

1850-1990 MHz Congested Area

12 GHz Congested Area

0 15 30 Miles

Planimetric Features

Highway

Roads

Private Microwave Congested Areas Boston Area

Figure 3.1-10

EXPLANATION

- ★ RF Station Location
- Roads
  - Primary Road with Limited Access
  - Primary Road
  - State Lines

0 15 30 Miles

RF Emitters within 100-mile Radius Cape Cod AFS, MA.

Figure 3.1-11

field strength varied from 3 to 9 V/m (power densities of 0.002 mW/cm^2 to 0.021 mW/cm^2) and the magnetic field strength varied from 6 to 41 milliamps/meter.

Although many of the LORAN transmitters are situated near coastal areas, other LORAN systems are situated within the interior of the United States. Only one LORAN site (on Nantucket Island approximately 45 miles from Cape Cod AFS) operates within proximity to Cape Cod AFS. The effective transmission distance of the LORAN system is approximately 600 to 1,100 miles, depending upon the transmitter power and the atmospheric noise level (U.S. Coast Guard, 2001). Therefore, the LORAN system transmissions are capable of reaching the PAVE PAWS radar location.

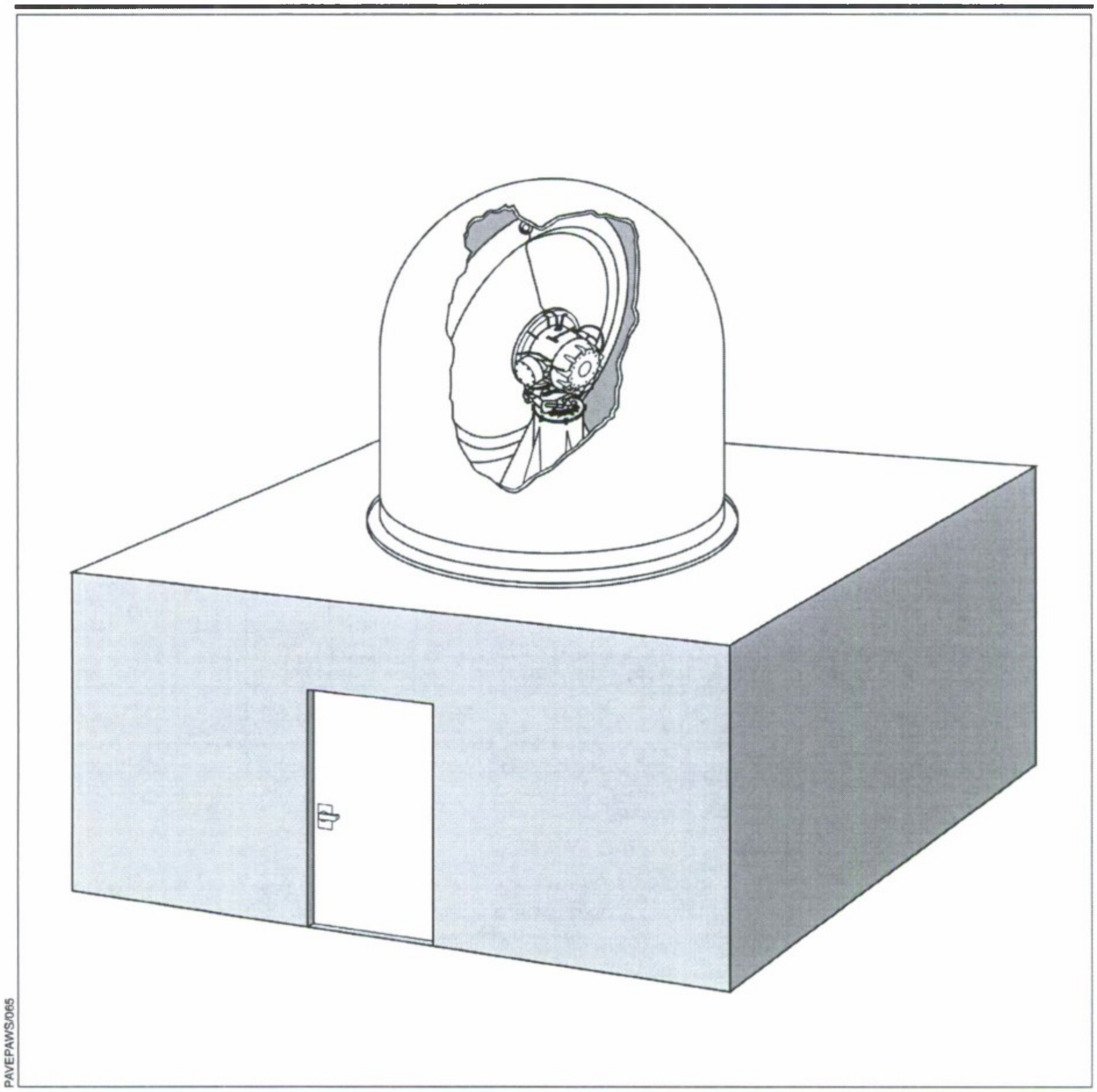
3.1.5.4 Air Traffic Control Radars.

Another contributor to the overall RF environment is air traffic control radars used at airports. Although many of these radars are rotational in nature, current technology has progressed to include the use of phased-array radars, like PAVE PAWS, as air traffic control radars. In areas surrounding air traffic control radars, workers can be exposed to power densities of up to tens of W/m^2, but are normally exposed to fields in the range of 0.03 to 0.8 W/m^2 (0.003 mW/cm^2 to 0.08 mW/cm^2) (World Health Organization, 1993). In an exposure survey of civilian airport radar workers in Australia, it was found that, unless working on open waveguide slots, or within transmitter cabinets when high voltage arcing was occurring, personnel were, in general, not exposed to levels of radiation exceeding the specified limits in the Australian and International Radiation Protection Association (IRPA) RF exposure standards (Joyner and Bangay, 1986). These exposures represent occupational exposures and would not be representative of far-field exposures as in the case of uncontrolled or public exposure scenarios.

3.1.5.5 Milstar Fixed Communications Control Station.

The Air Force operates a Milstar fixed communication control station at Cape Cod AFS. The Milstar antenna support shelter is approximately 20 feet by 16 feet in size and 9 feet high (Figure 3.1-12). The Milstar antenna is a 90-inch-diameter parabolic dish with receive/transmit capability. A white spherical radome, approximately 10 feet across by 10 feet high, encloses the antenna for weather protection.

The Milstar communications system is designed as an inaccessible emitter by the Air Force, meaning the system is not normally accessible to personnel. Existing controls on the Milstar system, such as an interlock system, prevent maintenance personnel from inadvertent RFE exposure during maintenance activities.



Milstar Fixed Communication Control Station

Figure 3.1-12

The operational angle that the Milstar system uses to communicate with satellites is 41.5°± the satellite's differential from the Earth's equator. As a result, it is not possible for Milstar's main beam to impact the ground. The Milstar system transmits RFE at a frequency of 44 GHz. The 1839th Engineering Installation Group conducted a ground-level RFE evaluation of the Milstar antenna in 1989 (1839th Engineering Installation Group, 1989). These measurements were not conducted at Cape Cod AFS; however, these measurements are representative of the predicted measurements of the Milstar communications system at Cape Cod AFS. Measurements were taken at six different distances, ranging from the radome edge to 600 feet from the Milstar antenna. These measurement locations evaluated the main beam and were selected based on power density calculations and distance from the antenna. The Milstar measurements are presented in Table 3.1-2.

Table 3.1-2. 1989 Milstar RFE Measurements

Location	Distance (feet)	Average Power Density (mW/cm^2)	Controlled Environment Standard (mW/cm^2)	General Public Standard (mW/cm^2)	Magnitude Below Controlled Environment Standard
1	600	0.046	5	1	108
2	327	0.265	5	1	18
3	184	0.461	5	1	10
4	75	0.472	5	1	10
5	27	0.450	5	1	11
6	Radome Edge	0.839	5	1	6

mW/cm^2 = milliwatts per square centimeter

Source: 1839th Engineering Installation Group, 1989.

These measurements represent occupational exposures; therefore, they were compared to the controlled environment standard. No measurements exceeded or significantly approached the IEEE controlled environment exposure limit of 5 mW/cm^2. No individuals living in the surrounding communities would be exposed to RFE levels in excess of the applicable IEEE safety standard. In addition, the Milstar system does not produce significant sidelobe RFE patterns that would approach the IEEE uncontrolled environment limit of 1 mW/cm^2.

3.1.5.6 Defense Satellite Communications System.

In June 2000, the U.S. Air Force completed an RFE survey of the Defense Satellite Communication System (DSCS) at Cape Cod AFS. The DSCS system is a 38-foot-wide aperture satellite dish used for military satellite communications. DSCS transmits in the frequency range from 7.9 to 8.4 GHz, which is much higher than the SSPARS frequencies. In order to transmit to satellites, DSCS must be pointed upward; therefore, the system is prohibited electrically from radiating with the antenna below 7°. Unlike the SSPARS, DSCS is a satellite communications antenna that uses narrow-beam transmission to geosynchronous satellites, not a sweeping beam over large scan areas. Also, DSCS is a continuous wave transmitter, not a pulsed emitter. The narrow beam width is due to the nature of satellite communications, which require a narrow antenna pattern for communication purposes. The DSCS satellite dish continuously points at 41.5° above the horizon to communicate with the geosynchronous satellite. The DSCS measurements completed in June 2000 are presented in Table 3.1-3, and the measurement locations are shown on Figure 3.1-13.

Table 3.1-3. 2000 DSCS RFE Measurements

Test Location	Antenna Position[a]	Antenna Output Power (dBm)	Power Density at Operating Power (mW/cm^2)	Controlled Environment Standard[b] (mW/cm^2)	Magnitude below Standard[b]
1	Primary Satellite	37.1	<0.01	10	>1000
2	Secondary Satellite	38.1	0.04	10	250
3	Secondary Satellite	38.1	0.15	10	66
4	Alternate 1	55	6.20	10	1
5	Alternate 1	55	2.20	10	4
6	Alternate 1	55	0.40	10	25
7	Alternate 1	55	0.25	10	40
8	Alternate 1	55	0.05	10	200
9	Alternate 1	55	0.0875	10	114
10	Alternate 2	55	0.237	10	42

Notes: The above azimuths and elevations are based on the alignment of the DSCS with its appropriate satellites from Cape Cod AFS.

(a) Primary-azimuth 154.08° and elevation 38.9°; secondary-azimuth 105.55° and elevation 9.75°; alternate 1-azimuth 215.82° and elevation 7.49°; alternate 2-azimuth 296.7° and elevation 7.49°.

(b) The measurements taken in June 2000 represent occupational exposures, not general public exposures; therefore, the IEEE C95.1-1999 controlled environment exposure limit was used.

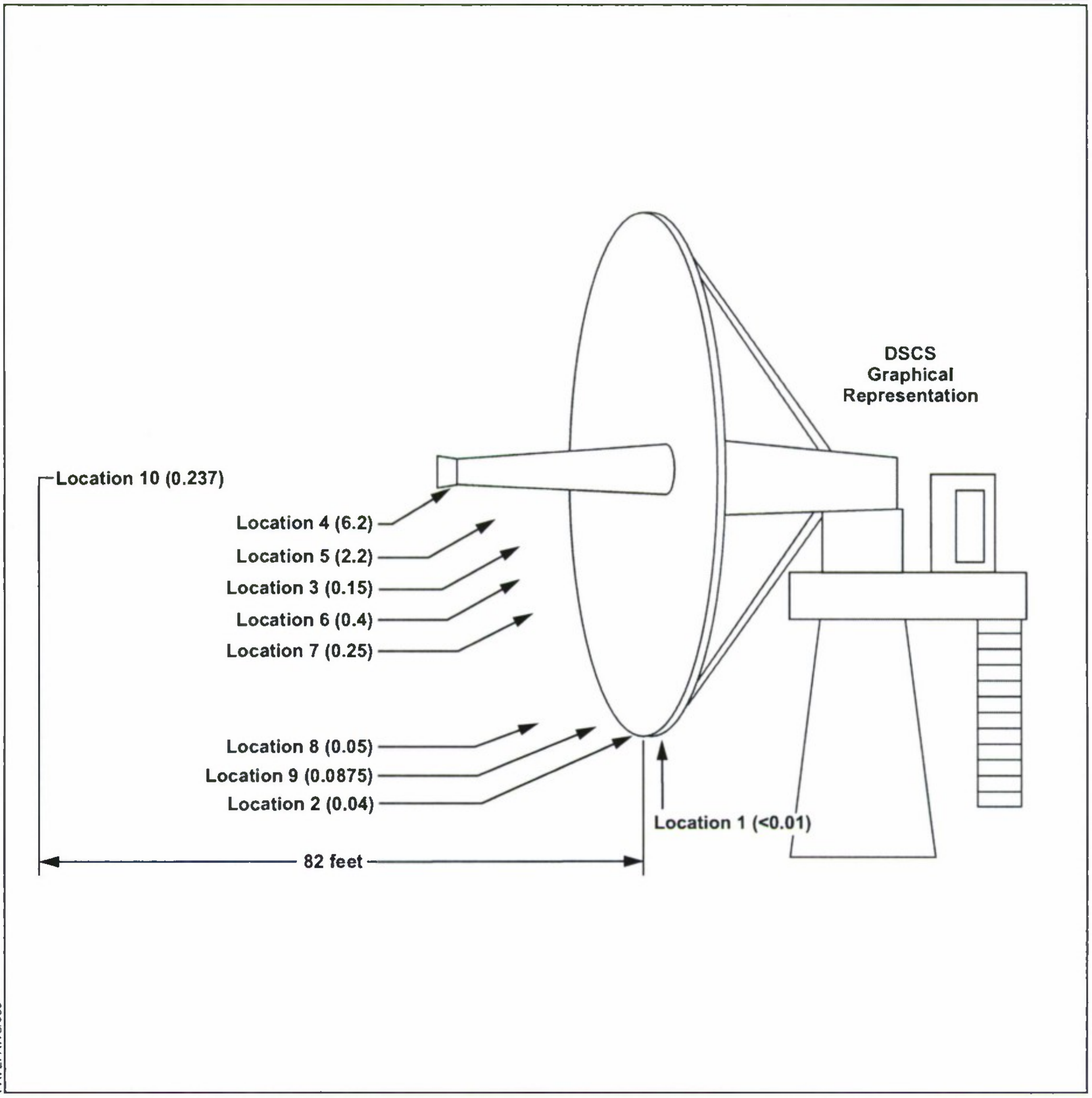
° = degree
dB = decibel
dBm = dB referenced to 1 milliwatt
mW/cm^2 = milliwatts per square centimeter

Source: 738th Engineering Installation Squadron, 2000.

The measurements taken around the DSCS indicated that exposures were below the occupational exposure limits for the system, as specified in IEEE C95.1-1999. Accordingly, the highest measurement was obtained directly in front of the feedhorn (i.e., extension protruding from the aperture), which is the actual RF source for the aperture. This measurement was only obtained by using a man lift; therefore, this type of exposure is not possible at ground level. Furthermore, due to the operational angles that DSCS uses to communicate with the various satellites, no individuals living in the surrounding communities would be exposed to RFE levels in excess of the applicable IEEE safety standard.

3.2 HEALTH AND SAFETY

This section discusses the affected environment of the PAVE PAWS radar with regard to public health and safety. The following section discusses the existing RFE in the vicinity of Cape Cod AFS, other emitters of RFE at Cape Cod AFS, and RFE measurements taken at Cape Cod AFS and within the surrounding communities.



EXPLANATION

DSCS	Defense Satellite Communications System
mW/cm^2	milliwatts per square centimeter

DSCS Measurement Locations

Note: Power Density levels are shown in mW/cm^2.

Source: 738th Engineering Installation Squadron, 2000.

Figure 3.1-13

Exposure to RFE is controlled in accordance with national exposure standards (e.g., federal and voluntary exposure standards), which are set by experts in biophysics, medicine, engineering, and epidemiology, as set forth in the following documents:

- Institute of Electrical and Electronics Engineers (IEEE) C95.1-1999, IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz, May 1999.
- Department of Defense (DOD), Protection of DOD Personnel from Exposure to Radio Frequency Radiation and Military Exempt Lasers, DOD 6055.11, February 21, 1996.
- Air Force Occupational Safety and Health (AFOSH) Standard, Radio Frequency Radiation (RFR) Safety Program, AFOSH Standard 48-9, August 1, 1997.
- FCC, Office of Engineering and Technology (OET) Bulletin 65: Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields, Edition 97-01, August 1997.

The IEEE International Committee for Electromagnetic Safety produces an RFE standard that has been adopted by the American National Standards Institute (ANSI) as an IEEE/ANSI standard. This voluntary standard is based on numerous sources of scientific information that are subject to rigorous review by experts in biophysics, medicine, electrical engineering, and epidemiology.

After reviewing the biological effects database, scientific committees concluded that the threshold for potential adverse biological effects was 4 watts per kilogram (W/kg) of absorbed RFE per unit mass of tissue. The standards-making organizations have adopted safety factors for RFE exposures in occupational and general public settings. These safety factors are set at 10 for occupational exposures and 50 for general public exposures, thereby reducing the adverse biological effects threshold to 0.4 and 0.08 W/kg, respectively. For ease of measurement, these limits are expressed in units of incident power density (mW/cm^2), which is the accepted RFE parameter used to quantify RFE exposure (Institute of Electrical and Electronics Engineers, 1999a).

The general population exposure limit for the PAVE PAWS radar is 0.28 mW/cm^2 averaged over a 30-minute period, while the occupational exposure limit is 1.4 mW/cm^2 averaged over a 6-minute period. These limits are based on the IEEE C95.1-1999 and FCC maximum permissible exposure of 420 MHz, which represents the most conservative exposure limit within the PAVE PAWS frequency range.

The scientific community believes that the IEEE/ANSI standard is applicable to both continuous-wave and pulsed, phased-array emitters. However, a small number of individuals have questioned whether the standard is applicable to phased-array systems. Although the scientific evidence indicates that adverse health effects are limited primarily to thermal effects, some theories have been put forward that suggest low-level RFE may have biological effects. These theories and supporting research are reviewed by the IEEE and considered during their standard setting process. It is recognized that health concerns have been raised by some individuals on Cape Cod dealing with the continued operation of the PAVE PAWS radar. These concerns have been addressed by several Cape Cod AFS site-specific studies and RFE literature reviews including:

- *Preliminary Measurements of the PAVE PAWS Radar, Phase II – Single and Double Dipole Field Measurements & Phase III – Spectrum Background Analysis, Final Report* (Air Force Research Laboratory, 2002).
- *Phase IV – Time Domain Waveform Characterization Measurements of the PAVE PAWS Radar, Final Report* (Air Force Research Laboratory, 2003).
- Final Test Report on a Survey of Radio Frequency Energy Field Emissions from the Cape Cod Air Force Station PAVE PAWS Radar Facility (Broadcast Signal Lab, LLP, 2004).
- *An Assessment of Potential Health Effects from Exposure to PAVE PAWS Low-Level Phased-Array Radiofrequency Energy* (National Research Council, 2005a).
- *Public Health Evaluation of Radiofrequency Energy from the PAVE PAWS Radar, Cape Cod Air Station, Massachusetts (Agreement No. 29292), Draft Literature Review* (International Epidemiology Institute [IEI], 2004).
- *Memorandum regarding Risk Assessment of Low-Level Phased-Array Radio Frequency Energy Emissions – 2002-03* (Armed Forces Epidemiological Board, 2003).
- A Public Health Evaluation of Radiofrequency Energy from PAVE PAWS Radar, Cape Cod Air Station, Massachusetts (Agreement No. 29292), Final Report, Descriptive Studies of Disease Occurrence and PAVE PAWS Radar (International Epidemiology Institute, 2006).

These studies and literature reviews specifically address the general concerns brought forth regarding low-level exposures to RFE as well as the PAVE PAWS pulsed waveform generated by a phased-array radar. A summary review of these studies is provided in Section 3.3, Recent Cape Cod Air Force Station Radiofrequency Studies/Reviews.

3.2.1 Cape Cod Air Force Station Radiofrequency Energy Measurements

Ground level (3-6 feet) RFE measurements were completed around the PAVE PAWS radar and throughout the surrounding communities in 1978, 1986, and 2004. In 1978, peak power density measurements, average power density measurements, and peak electric field measurements were completed in order to assess the potential exposure differences under both peak and average power conditions. The measurements from the 1978 survey are presented in

Table 3.2-1 and their locations are shown on Figure 3.2-1. RFE measurements collected during the 1978 survey were below the applicable IEEE general public exposure limit.

Table 3.2-1. Cape Cod AFS, 1978 Power Density Measurements

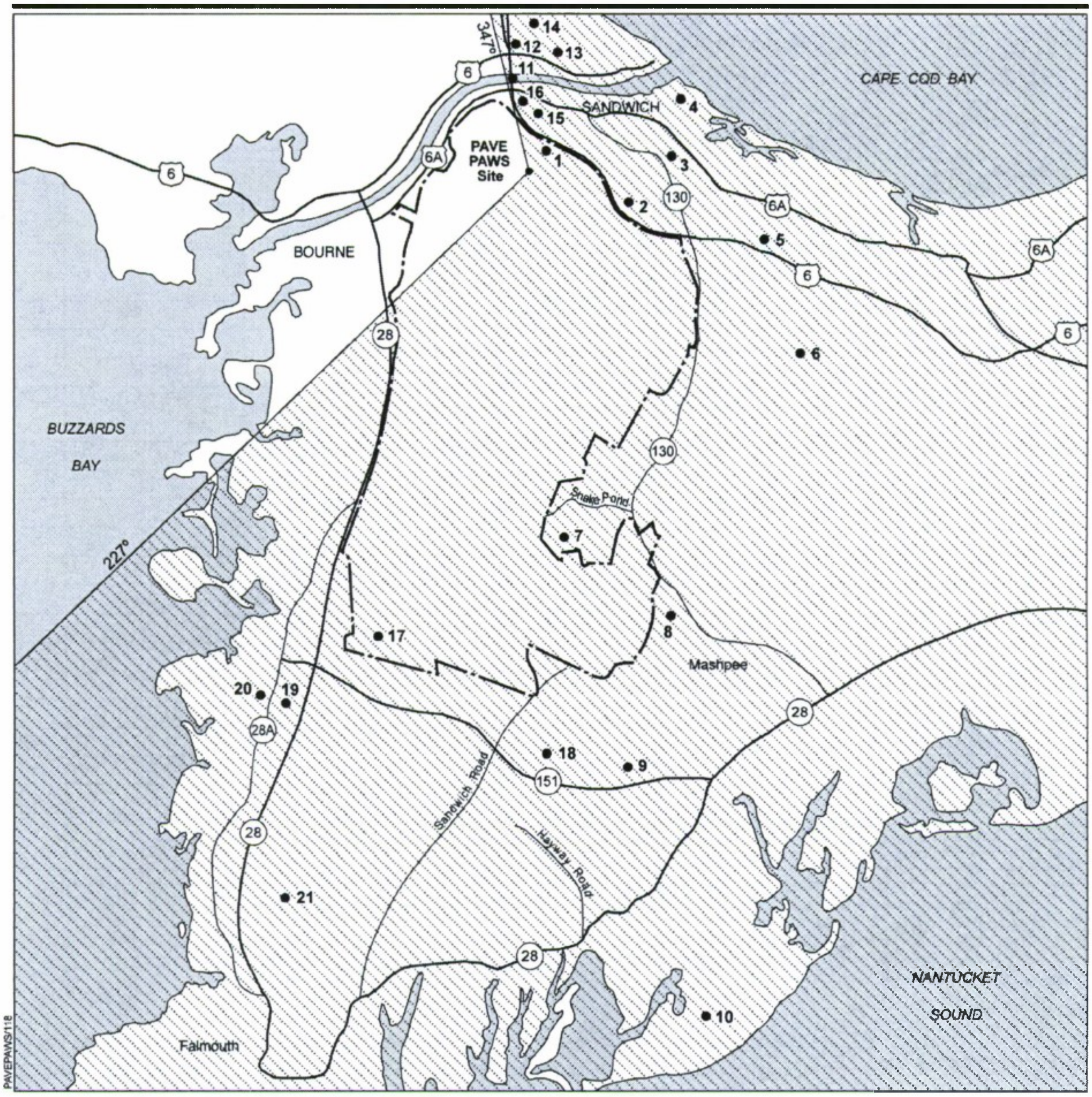
Test Location	Location	Distance from Radar (miles)	Average Power Density (mW/cm^2)	General Public Standard[(a)] (mW/cm^2)	Magnitude Below Standard
1	Rest Area, Route 6	0.6	0.000061	0.28	4,590
2	Shawme and Shaker House Roads	2.1	0.000027	0.28	10,370
3	Henry T. Wing School	2.1	<0.000001	0.28	>280,000
4	Dillingham and Knott Roads	2.4	0.00002	0.28	14,000
5	Sandwich High School	4.4	0.000001	0.28	280,000
6	Lakewood Hills Development (entrance)	4.6	<0.000001	0.28	>280,000
7	Knolltop and Greenhouse Roads	5.4	<0.000001	0.28	>280,000
8	Mashpee Police Department	7.3	<0.00001	0.28	>280,000
9	Mashpee Middle School	9.2	<0.000001	0.28	>280,000
10	Seabury Golf Club	13.8	<0.000001	0.28	>280,000
11	Sagamore Bridge	1.6	0.000051	0.28	5,490
12	Canalside Apartments	2.0	0.000016	0.28	17,500
13	Hoxie Elementary School	1.7	0.000001	0.28	280,000
14	Old Plymouth Road	2.8	0.000002	0.28	140,000
15	Hilltop Drive (Maiolini residence)	1.0	0.000003	0.28	93,333
16	Keith Field	1.4	<0.000001	0.28	>280,000
17	Stone School (Otis ANGB)	7.1	<0.000001	0.28	>280,000
18	Ashumet Development (Hatchville)	8.8	<0.000001	0.28	>280,000
19	Benthos Corporation	8.9	<0.000001	0.28	>280,000
20	North Falmouth Elementary School	9.0	<0.000001	0.28	>280,000
21	Falmouth High School	11.8	<0.000001	0.28	>280,000

Note: (a) General public standard from IEEE C95.1-1999. The standard used in 1978 was IEEE C95.1-1974 that cited 10 mW/cm^2 as the exposure limit.
ANGB = Air National Guard Base
mW/cm^2 = milliwatts per square centimeter

Source: Electromagnetic Compatibility Analysis Center, 1978.

In 1986, average power density measurements were completed in order to verify that the measurements taken in 1978 were still valid and representative of the potential RFE exposures from the radar. The measurements from the 1986 survey are presented in Table 3.2-2 and their locations are shown on Figure 3.2-2. As with the 1978 measurements, these measurements were also below the applicable IEEE general public exposure limit; therefore, the 1978 measurements were validated and remained representative of the general public RFE exposures from the PAVE PAWS radar.

In 2004, peak/average power density measurements and peak/average electric field measurements were completed at various locations on Cape Cod. The measurements from the 2004 survey are presented in Table 3.2-3 and their locations are shown on Figure 3.2-3. RFE measurements collected during the 2004 survey were below the applicable IEEE general public exposure limit.



EXPLANATION

—·— MMR Boundary

● Power Density Measurement Location

SSPARS Scan Area

Cape Cod AFS, 1978 Power Density Measurements at Selected Locations

Not to Scale

Source: Electromagnetic Compatibility Analysis Center, 1978. Measurement locations correspond to those listed in Table 3.2-1

Figure 3.2-1

Table 3.2-2. Cape Cod AFS, 1986 Power Density Measurements

Test Location	Location	Distance from Radar (miles)	Average Power Density (mW/cm^2)	General Public Standard[(a)] (mW/cm^2)	Magnitude Below Standard
1	Cardinal Road (Christopher Hollow)	2.8	0.000026	0.28	10,769
2	Sandwich Fire Tower (86 feet above ground in view of the radar)	3.2	0.000139	0.28	2,014
3	Sandwich Public Library	2.3	<0.000001	0.28	>280,000
4	Crowley State Park (Les Perry's House)	1.2	0.000012	0.28	23,333
4a	Crowley State Park (Near Camp Site A-10)	1.2	0.00002	0.28	14,000
5	Route 130 and Greenway and Gibbs (Across from base gate)	3.5	<0.000001	0.28	>280,000
6	Corner of Friendly and Freedom Road (Near Snake Pond Area)	5	<0.000001	0.28	>280,000
7	Beach area (Snake Pond)	4.8	<0.000001	0.28	>280,000
8	Intersection of Route 130 before Central Road	7.4	<0.000001	0.28	>280,000
9	Near Mashpee Middle School on Lowell Road	8.4	<0.000001	0.28	>280,000
10	Lowell Road near Quessot Golf Course	8.8	<0.000001	0.28	>280,000
11	Nickelodeon Theatre on Route 151	7.8	<0.000001	0.28	>280,000
12	Otis ANGB Central Tower	5.9	0.000003	0.28	93,333
13	VA Cemetery near entrance on Route 151	5.6	<0.000001	0.28	>280,000
14	Scusett Beach Fishing Pier	1.9	0.000004	0.28	70,000
15	Henry Wing School (Sandwich)	2.1	<0.000001	0.28	>280,000

Note: (a) General public standard from IEEE C95.1-1999. The standard used in 1986 was IEEE C95.1-1974 that cited 10 mW/cm^2 as the exposure limit.

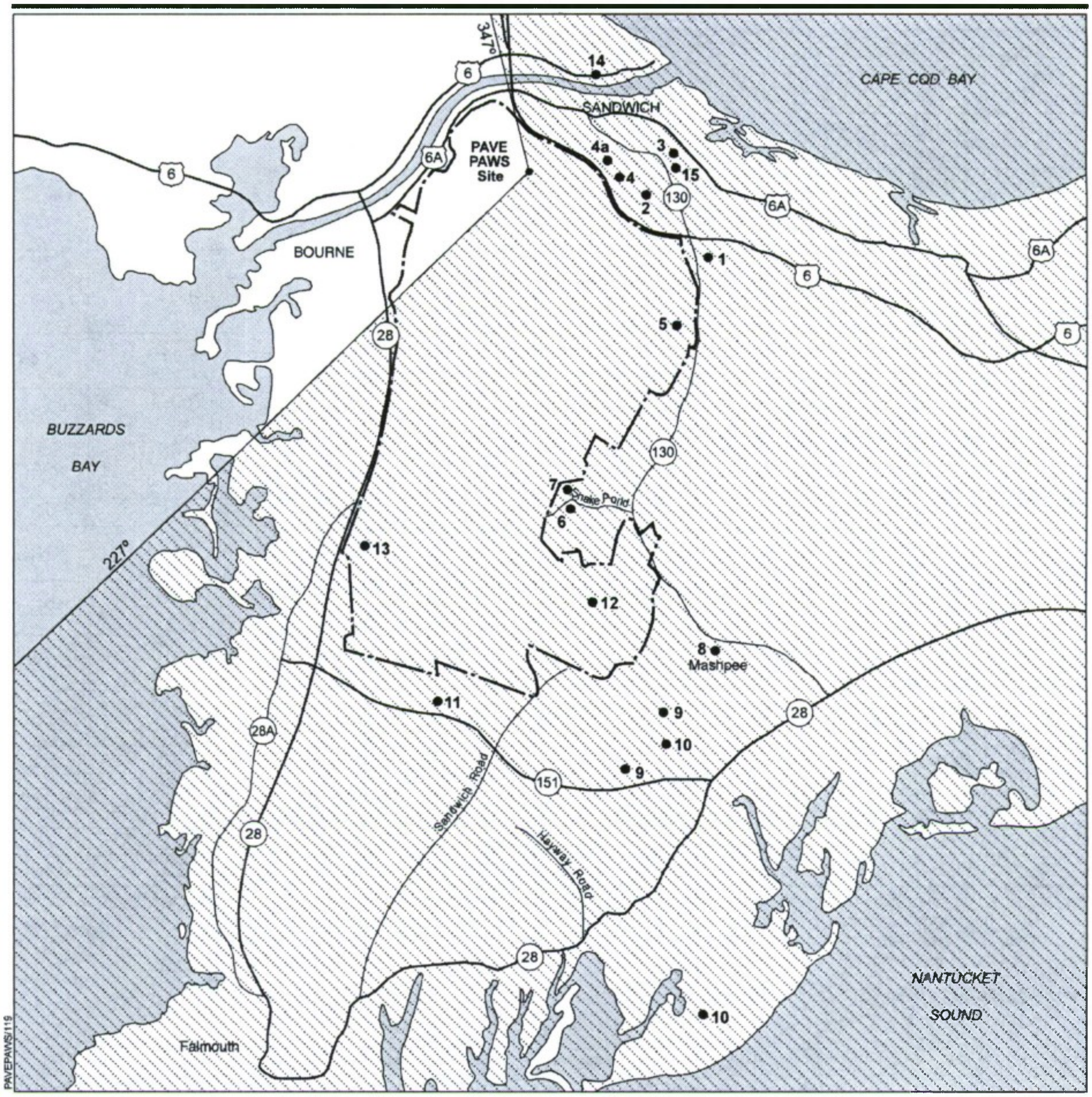
ANGB = Air National Guard Base

mW/cm^2 = milliwatts per square centimeter

Source: 1839th Installation Engineering Group, 1986.

The Air Force performed RFE measurements in November 2003 (pre-SLEP upgrade) and in August 2005 (post-SLEP upgrade) at the Cape Cod AFS PAVE PAWS to determine if the SLEP upgrade caused a change in the power output from the radar. The measurements from the 2003 and 2005 surveys are presented in Table 3.2-4 and their locations are shown on Figure 3.2-4. RFE measurements collected during the surveys did not show a significant change in the power output and were below the applicable IEEE general public exposure limit (U.S. Air Force, 2004, 2005).

Measurements of the near-field at Cape Cod AFS taken in 1979 are presented in Figure 3.2-5. The measurements do not address the electric and magnetic fields individually; rather, the measurements represent the total power density. Total power density is used to evaluate the potential effects of operating the radar.



EXPLANATION

—·— MMR Boundary

● Power Density Measurement Location

SSPARS Scan Area

Not to Scale

Source: Electromagnetic Compatibility Analysis Center, 1978. Measurement locations correspond to those listed in Table 3.2-2

Cape Cod AFS, 1986 Power Density Measurements at Selected Locations

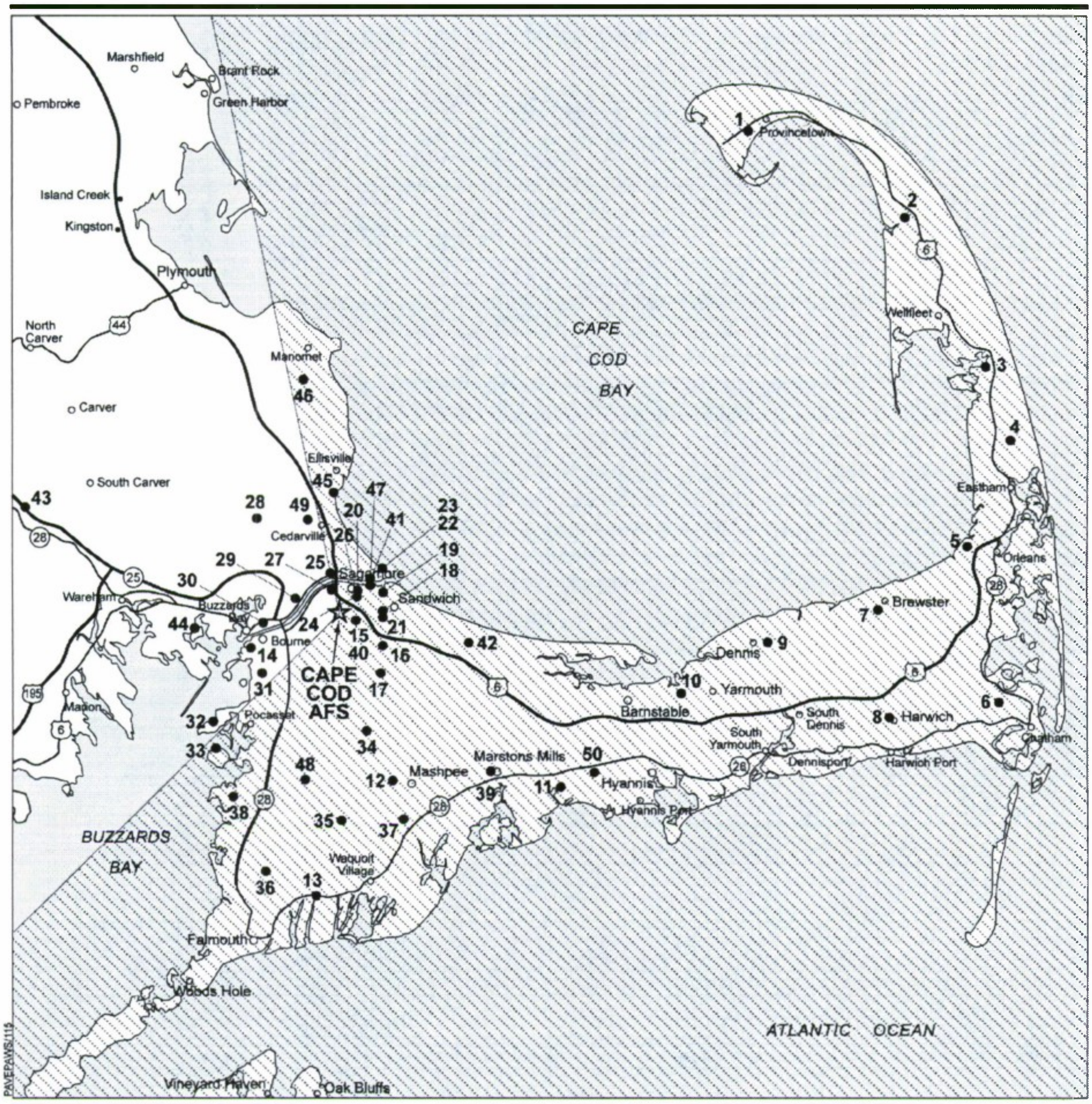
Figure 3.2-2

Table 3.2-3. Cape Cod AFS, 2004 Power Density Measurements

Test Location	Location	Distance from Radar (miles)	Average Power Density (mW/cm^2)	General Public Standard[(a)] (mW/cm^2)	Magnitude Below Standard
1	Pilgrim Monument Site	27.4	0.0000449	0.28	6,240
2	Snows Field, Snowfield Road	30.1	0.0000093	0.28	30,107
3	Cape Cod Naval Station Headquarters	30.7	0.0000013	0.28	215,385
4	Nauset Light Parking	31.1	0.0000006	0.28	466,667
5	Rock Harbor Parking	27.5	0.0000730	0.28	3,835
6	Great Hill	29.3	0.0000288	0.28	9,722
7	Keith Lane Circle	23.6	0.0000132	0.28	2,212
8	Island Pond Cemetery, Harwich Center	24.1	0.0000004	0.28	700,000
9	Scargo Hill	18.5	0.0038167	0.28	73
10	Woodside Cemetery, Yarmouth, off Summer Street	15.5	0.0000026	0.28	107,692
11	Main Street, Centerville	12.3	0.0000056	0.28	50,000
12	Athletic Field, Route 130, North of Ashumet Road	7.2	0.0000821	0.28	3,410
13	Davisville Road, E. Falmouth School	12.3	0.0000022	0.28	127,273
14	Hashnee Island Grill	5.6	0.0001590	0.28	1,761
15	Shawme Crowell State Park	1.0	0.0346000	0.28	8
16	Cardinal Road Circle	2.8	0.0007775	0.28	360
17	Route 130 at Cotuit Road	3.7	0.0000104	0.28	26,923
18	Mt. Hope Cemetery, Route 6A	2.8	0.0001323	0.28	2,116
19	Jarves Road at Factory Street	2.5	0.0002228	0.28	1,257
20	Sandwich Public Library	2.1	0.0000589	0.28	4,754
21	Holder Lane Circle	2.6	0.0025595	0.28	109
22	Scusset Beach Parking 1	2.6	0.0001935	0.28	1,447
23	Scusset Beach Parking 1	2.6	0.0049833	0.28	56
24	Sagamore Athletic Field	1.4	0.0000200	0.28	14,000
25	Church Lane at Cape Pine Road	2.2	0.0006477	0.28	432
26	Sagamore School, Williston Road	1.8	0.0002408	0.28	1,163
27	Brigantine Passage Drive	1.9	0.0007808	0.28	359
28	Eagle Road	4.3	0.0000008	0.28	350,000
29	Route 6E Canal Overlook	1.9	0.0000109	0.28	25,688
30	Cypress Street at Route 6 Bypass	3.3	0.0000010	0.28	280,000
31	Monument Beach Former Water Tank	4.3	0.0000107	0.28	26,168
32	Wings Neck Road at Harbor Drive	6.6	0.0000061	0.28	45,901
33	Scraggy Neck Road at Cataumet Club	7.4	0.0000007	0.28	400,000
34	Carolyn Circle Forestdale	5.5	0.0000252	0.28	11,111
35	Barnstable County Fairgrounds	9.3	0.0000010	0.28	280,000
36	Falmouth High School, Brickklin Road	11.7	0.0000001	0.28	2,800,000
37	Mashpee Senior Center	9.3	0.0000004	0.28	700,000
38	N. Falmouth School	9.1	0.0000002	0.28	1,400,000
39	Marstons Mills School, 2095 Main Street	9.6	0.0000002	0.28	1,400,000
40	Shawme Crowell State Park	1.0	0.0039367	0.28	71
41	Burbank Street and Main (Route 130)	1.3	0.0000572	0.28	4,895
42	Old County Road, near State Hatchery	5.7	0.0000003	0.28	933,333
43	Assawompset School	22.1	<0.0000001	0.28	>2,800,000
44	Onset School, Union Avenue	6.3	0.0000002	0.28	1,400,000
45	Ellisville Road	5.3	0.0000777	0.28	3,604
46	October Lane Circle, Cedar Bushes	10.1	0.0000005	0.28	560,000
47	Freezer Road at Tupper Road	2.0	0.0004528	0.28	618
48	Stone School Circle, Otis ANGB	7.0	0.0000009	0.28	311,111
49	Post 'n Rail Avenue, Cedarville	4.0	0.0000264	0.28	10,606
50	Banstable High School	13.0	0.0000002	0.28	1,400,000

Note: (a) General public standard from IEEE C95.1-1999.
ANGB = Air National Guard Base
mW/cm^2 = milliwatts per square centimeter

Source: Broadcast Signal Lab, LLP, 2004.



EXPLANATION

- 13 ● Power Density Measurement Location
- ☆ Cape Cod Air Force Station
- ▨ SSPARS Scan Area

0 3.25 6.5 Miles

Source: Broadcast Signal Lab, 2004.
Note: Measurement locations correspond to those listed in Table 3.2-3.

Cape Cod AFS, 2004 Power Density Measurements at Selected Sites

Figure 3.2-3

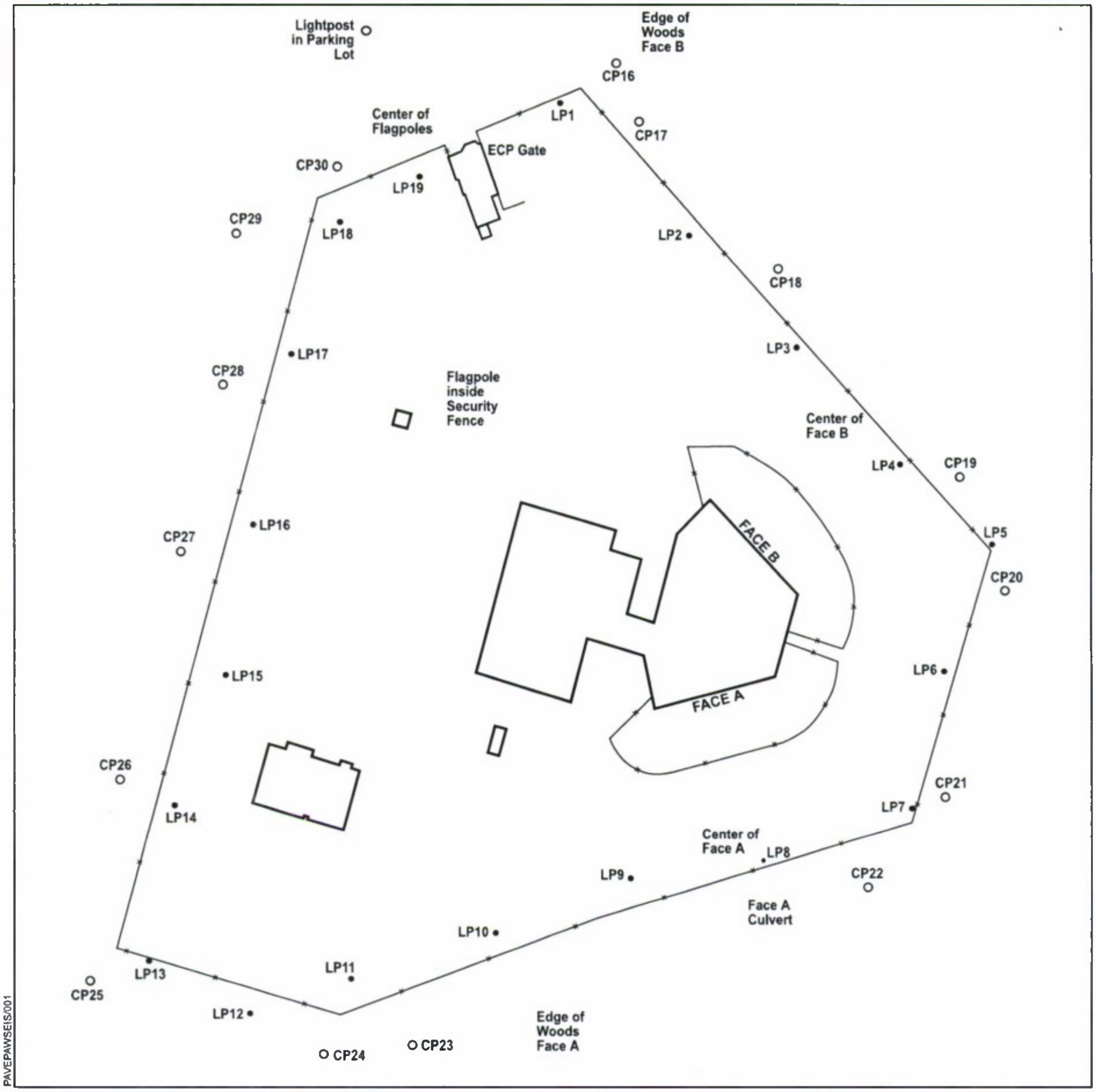
Table 3.2-4. Pre- and Post-SLEP Upgrade Power Density Measurements (2003 and 2005)

Location	2003 Average Power Density (mW/cm^2)	2003 Max Power Density (mW/cm^2)	2005 Average Power Density (mW/cm^2)	2005 Max Power Density (mW/cm^2)	PEL (mW/cm^2)
CP16	0.14	0.17	0.07	0.02	1.40
CP17	0.0625	0.088	0.05	0.06	1.40
CP18	0.0775	0.15	0.09	0.13	1.40
Center of Face B	0.106	0.35	0.11	0.19	1.40
CP19	0.117	0.30	0.07	0.13	1.40
CP20	0.115	0.22	0.12	0.16	1.40
Building Center	0.17	0.21	0.12	0.13	1.40
CP21	0.130	0.20	0.14	0.15	1.40
CP22	0.142	0.22	0.16	0.20	1.40
Center of Face A	0.159	0.28	0.17	0.22	1.40
Face A Culvert	0.138	0.25	0.14	0.18	1.40
CP23	0.105	0.12	0.11	0.11	1.40
CP24	0.108	0.13	0.12	0.12	1.40
CP25	0.108	0.12	0.11	0.11	1.40
CP26	0.113	0.13	0.13	0.13	1.40
CP27	0.113	0.13	0.13	0.14	1.40
CP28	0.115	0.13	0.13	0.12	1.40
CP29	0.116	0.13	0.13	0.13	1.40
CP30	0.113	0.12	0.14	0.15	1.40
ECP Gate	0.104	0.12	0.15	0.16	1.40
Light Pole in Parking Lot	0.116	0.13	0.13	0.14	1.40
Center of Flagpoles	0.161	0.18	0.13	0.13	1.40
Edge of Woods Face B	0.203	0.46	0.10	0.10	0.28[a]
Edge of Woods Face A	0.219	0.49	0.12	0.12	0.28[a]
LP19	0.0987	0.12	0.16	0.16	1.40
LP18	0.0225	0.043	0.13	0.13	1.40
LP17	0.0281	0.048	0.12	0.12	1.40
LP16	0.0406	0.056	0.13	0.13	1.40
LP15	0.0531	0.068	0.13	0.13	1.40
LP14	0.0931	0.11	0.13	0.13	1.40
LP13	0.0618	0.08	0.12	0.12	1.40
LP12	0.0925	0.11	0.11	0.11	1.40
LP11	0.0225	0.05	0.11	0.11	1.40
LP10	0.0950	0.11	0.11	0.12	1.40
LP9	0.113	0.17	0.13	0.15	1.40
LP8	0.156	0.25	0.18	0.21	1.40
LP7	0.129	0.16	0.14	0.15	1.40
LP6	0.0218	0.066	0.12	0.13	1.40
LP5	0.0575	0.10	0.06	0.10	1.40
LP4	0.0368	0.20	0.10	0.16	1.40
LP3	0.0006	0.052	0.10	0.14	1.40
LP2	0.0787	0.10	0.06	0.07	1.40
LP1	0.0612	0.10	0.01	0.01	1.40

Note: [a] Measurement location is outside the installation perimeter fence; therefore, the general population exposure limit is presented rather than the occupational exposure limit.

CP = camera pole
LP = light pole
mW/cm^2 = milliwatt per square centimeter
PEL = permissible exposure limit

Sources: U.S. Air Force 2004, 2005.



EXPLANATION

- o Camera Pole
- • Light Pole
- —+— Perimeter Fence

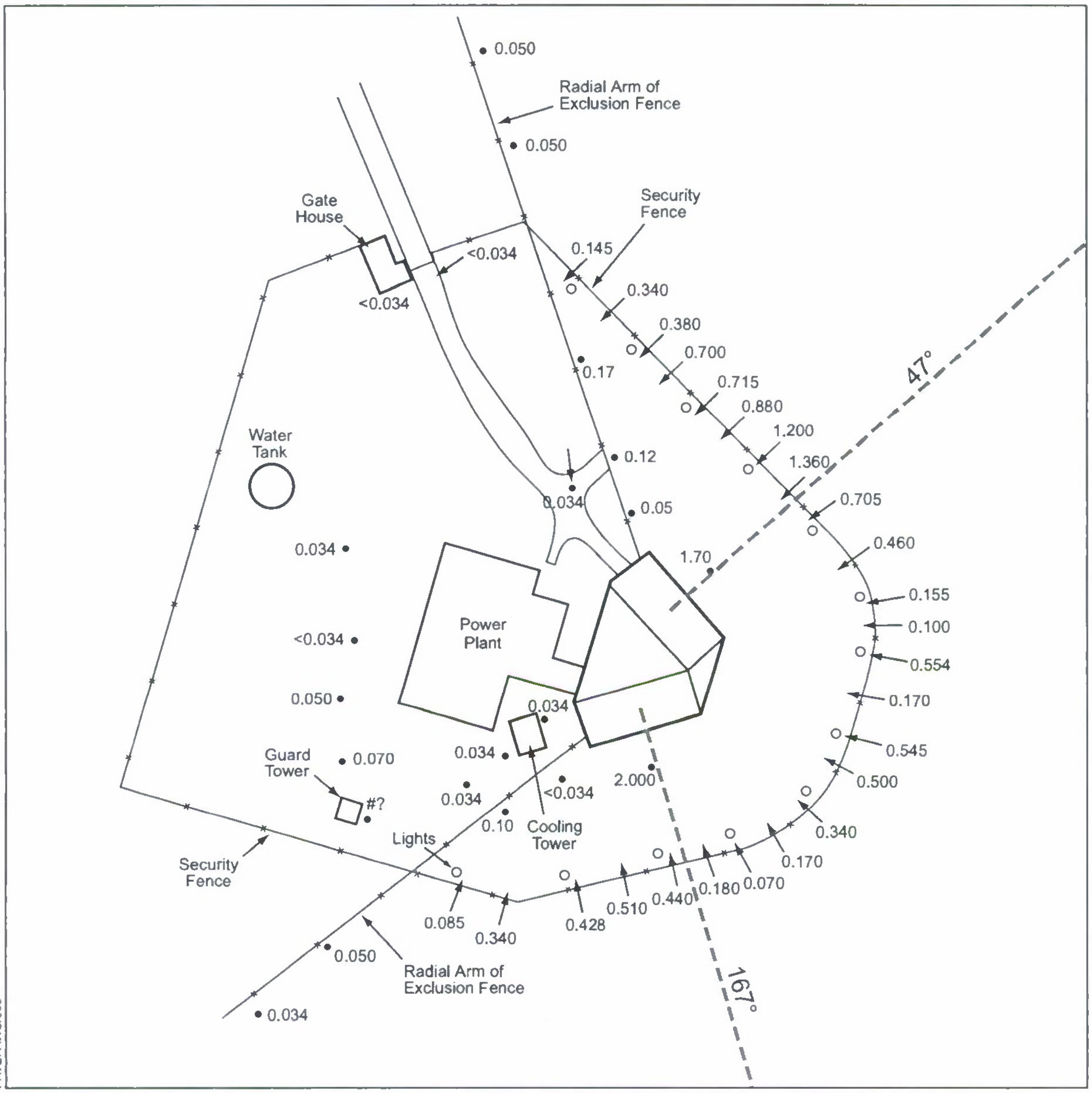
Not to Scale

Source: U.S. Air Force 2004, 2005.

Note: Measurement Locations correspond to those listed in Table 3.2-4

Cape Cod AFS, 2003 and 2005 Power Density Measurements at Selected Locations

Figure 3.2-4

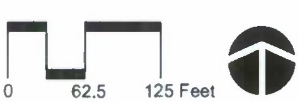


EXPLANATION

Perimeter Fence

All measurements are in microwatts/square centimeter (mW/cm^2)

All measurements have been taken at ground level except the guard tower measurements



Source: Raytheon Corporation, 1999.

1979 Near-Field Survey Power Density Measurements and Locations, Cape Cod AFS

Figure 3.2-5

The two measurements directly in front of each array exceeded the controlled environment exposure limit of 1.4 mW/cm^2; however, these areas are demarcated and secured to ensure no unauthorized personnel gain access to the area

3.3 RECENT CAPE COD AIR FORCE STATION RADIOFREQUENCY STUDIES/REVIEWS

It is recognized that health concerns have been raised by some individuals on Cape Cod regarding the continued operation of the PAVE PAWS radar. These concerns have been addressed by several Cape Cod AFS site-specific studies and RFE literature reviews. These studies and literature reviews specifically address the general concerns brought forth regarding low-level exposures to RFE as well as the PAVE PAWS pulsed waveform generated by a phased-array radar. A summary of these studies/literature reviews is provided in the following sections.

3.3.1 Preliminary Measurements of the PAVE PAWS Radar, Phase II – Single and Double Dipole Field Measurements & Phase III – Spectrum Background Analysis, Final Report

This document, prepared by the Air Force Research Laboratory (AFRL), presents a summary of investigative preliminary measurements of the Cape Cod AFS PAVE PAWS radar conducted in March 2002. These measurements were designed to guide the measurements team in the time-domain waveform characterization of the PAVE PAWS radiated output (Phase IV Waveform Characterization Study).

Phase II measurements provided information about the time-domain waveform characterization from a single element and from two elements of the PAVE PAWS radar that will assist in planning the Phase IV measurements. The Phase II measurements also provided data to support the modeling effort, determined the instantaneous bandwidth, and described the early-time transient dipole fields. The Phase III measurements helped determine the feasibility of low-level measurements, determined electromagnetic signal screening feasibility, established the community RF background level, and provided insight about the problems that could be encountered when performing Phase IV measurements.

3.3.2 Phase IV – Time Domain Waveform Characterization Measurements of the PAVE PAWS Radar, Final Report

This document, prepared in September 2003 by the AFRL, presents the time-domain waveform measurement data that were collected in April 2003 during the Phase IV time-domain waveform characterization of the Cape Cod AFS PAVE PAWS radar. The team consisted of representatives from Air Force Space Command, AFRL, and the PPPHSG.

During the study, detailed characteristics of the time-domain waveform from the PAVE PAWS radar were measured in accordance with the Environmental Health and Safety (EHS) Program. This effort was undertaken based on a letter sent to the Secretary of the Air Force from the Massachusetts Federal delegation (consisting of Senators John Kerry and Edward Kennedy, and Congressman William Delahunt) requesting that the Air Force perform time-domain electromagnetic measurements at the PAVE PAWS site.

The study included the measurement methods, the validity of measurements taken, and data necessary to meet technical requirements so that it could be used to evaluate EHS program parameters. A health analysis was not included in the report. The data provided in the study will be used by medical and biological researchers to assess the existence, and perhaps the importance, of radial electric field components, slopes of the electric field, and phasing or "zero crossing" changes. The report did not compile a complete statistical description of such phenomena; the purpose of the report was to simply provide the data so that such an analysis can be conducted.

3.3.3 Final Test Report on a Survey of Radio Frequency Energy Field Emissions from the Cape Cod Air Force Station PAVE PAWS Radar Facility

This document, prepared in June 2004 by Broadcast Signal Lab, LLP, provides the results of measurements, modeling, and analysis of the RFE from the PAVE PAWS radar at Cape Cod AFS. Three distinct tasks were performed:

1. The RFE emissions of the radar were measured in open, publicly accessible locations throughout Cape Cod (50 locations both on and near Cape Cod were selected)

2. The ambient emissions were measured from other sources in the VHF and UHF radio frequency spectrum (ten locations on Cape Cod were selected)

3. A mathematical model of the PAVE PAWS antenna was used to prepare a radiofrequency propagation plot of the emissions from the radar into the Cape Cod environment.

The validated geographic exposure data from this study were used by a public health expert to support the epidemiological study.

During this survey, peak/average power density measurements and peak/average electric field measurements were completed at various locations on Cape Cod. The measurements from this survey are presented in Table 3.2-3 and their locations are shown on Figure 3.2-3. RFE measurements collected during the 2004 survey were below the applicable IEEE general public exposure limit.

3.3.4 An Assessment of Potential Health Effects from Exposure to PAVE PAWS Low-Level Phased-Array Radiofrequency Energy.

This report, prepared in 2005 by the National Research Council, consisted of a review of scientific data and literature related to RFE in the range of the PAVE PAWS system. This was done because there were no specific studies of a phased-array system similar to PAVE PAWS in the public domain. The review included classified documentation of research that could be relevant to the PAVE PAWS system and the recent wave-form characterization study.

3.3.5 Public Health Evaluation of Radiofrequency Energy from the PAVE PAWS Radar, Cape Cod Air Station, Massachusetts (Agreement No. 29292), Draft Literature Review

This literature review, prepared in March 2004, focused on identifying studies that link RFE emissions to adverse health effects. The study found that the following diseases have been studied for links to RFE:

- Leukemia
- brain cancer
- lung cancer in women
- birth defects
- auto-immune diseases such as lupus erythematosus
- Alzheimer's Disease
- Parkinson's Disease.

The study suggested that RFE and adverse health effects studies be prioritized to concerns with the above diseases.

3.3.6 Memorandum Regarding Risk Assessment of Low-Level Phased-Array Radio Frequency Energy Emissions – 2002-03

The AFEB met in February 2002 to consider a request from the Air Force Surgeon General regarding a risk assessment of low-level phased-array RFE emissions, as phased-array radar systems are used throughout the DOD and in the commercial and private sectors, and concern had been raised regarding potential adverse health risks from low-level exposures at the Air Force PAVE PAWS facility on Cape Cod.

The AFEB received presentations, briefings, and materials regarding various aspects of RFE, epidemiological studies, and operation of phased-array systems including:

- Air Force risk assessment of low-level phased-array RFE emissions

- Technical and operational overview of the Cape Cod PAVE PAWS facility

- Summary of findings from Upper Cape public health evaluations

- Overview of the organization and functions of the IEEE and the IEEE standards process

- Summary of published epidemiological studies on health effects of exposure to RFE

- Presentation on the PAVE PAWS SLEP

- Presentation on Cape Cod epidemiological studies
- Presentation on the Air Force occupational health program and RFE protection program
- Briefing on electromagnetic theory and data applied to living organisms
- Classified briefing and discussion on the Air Force Environmental Health and Safety program
- Briefing on phased-array radar and radiofrequency bio-effects
- Briefing on Air Force RFE bio-effect studies in direct support of PAVE PAWS
- Briefing on human studies of RFE bio-effects
- Briefing on RFE cancer studies.

The AFEB also reviewed several hundred studies focusing on epidemiological studies of RFE exposure, IEEE and DOD exposure standards and standards setting process for RFE, studies on RFE bio-effects, and over 45 studies and public health assessments specifically for exposure and health outcomes of Cape Cod residents. The AFEB findings from their review are presented in Section 4.2.5.

3.3.7 Public Health Evaluation of Radiofrequency Energy from PAVE PAWS Radar, Cape Cod Air Station, Massachusetts – 2006 (Descriptive Studies of Disease Occurrence and PAVE PAWS Radar)

This report, prepared in April 2006 by the IEI, evaluated the potential health effects of public exposure to low-level RFE emitted from the PAVE PAWS radar system at Cape Cod AFS.

In preparing this evaluation, IEI analyzed available data for county mortality and county cancer mortality and from the hospital discharge registry. IEI also compiled and analyzed data provided by the Massachusetts Department of Public Health (MDPH) regarding cancer incidence, birth defects, and birth weight. IEI analyzed and interpreted the available RFE characterization survey results for the PAVE PAWS radar in terms of the known and biologically plausible hypothesized public health effects. The analysis utilized the analyses of the outcomes data and information in relevant scientific literature to describe the relationship among the various RFE exposure characteristics and existing health outcomes determined to be biologically plausible. The report was submitted to the MDPH for review to confirm that the health data provided by the MDPH had been used in conformance with the requirements of applicable laws and regulations.

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4.0 ENVIRONMENTAL CONSEQUENCES

This section discusses the potential environmental consequences associated with the continued operation of the PAVE PAWS radar at Cape Cod AFS.

The primary concern raised during the scoping process was the potential health effects of operating the PAVE PAWS radar as there is a higher than expected rate of a number of cancers on Cape Cod. Based on public input, three primary issues regarding the operation PAVE PAWS radar were identified, including:

- Measuring the average and peak radar exposures experienced by the community and then using these measurements to develop models to predict radar exposure of people living in the area.
- Analyzing plausible health outcomes from the radar exposure using descriptive epidemiology.
- Characterizing special features of the PAVE PAWS waveform based on hypotheses proposed by the public.

These concerns are addressed in Sections 4.1 and 4.2.

Cumulative impacts result from "the incremental impact of actions when added to other past, present, and reasonable foreseeable future actions regardless of what agency undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time" (Council on Environmental Quality, 1978). Section 4.3 summarizes other future projects planned at or in the vicinity of Cape Cod AFS and their potential effect.

4.1 HEALTH AND SAFETY

4.1.1 Proposed Action

Measurements collected during RFE surveys at Cape Cod AFS (Electromagnetic Compatibility Analysis Center, 1978; 1839th Installation Engineering Group, 1986; Broadcast Signal Lab, LLC, 2004) were below the applicable IEEE general public exposure limit. The RFE exposure levels measured during the surveys indicate that no known health hazards exist based on the low-intensity RFE resulting from the PAVE PAWS emissions. RFE measurements outside the Cape Cod AFS boundary were well below the established limit. None of the RFE measurements outside the boundaries of Cape Cod AFS could produce an Specific Absorption Rate (SAR) greater than the 0.08 W/kg level established by IEEE, FCC, and other regulatory agencies.

The impact of RFE from the PAVE PAWS radar and other existing and proposed RFE emitters would not adversely impact the health and safety of workers at the installation or individuals living in the surrounding communities. No RFE measurements were above applicable safety limits. Therefore, based on the available data (see Appendix G for a bibliography of radiofrequency studies), no adverse health effects would be associated with the RFE emissions from the PAVE PAWS radar.

The Air Force would continue to operate the PAVE PAWS radar and other RFE emitters at Cape Cod AFS in accordance with Air Force Occupational Safety and Health (AFOSH) Standard 48-9, RFR Safety Program, which includes implementation of appropriate administrative controls to prevent personnel exposure to RFE.

4.1.2 No-Action Alternative

No impacts to health and safety would result from implementation of the No-Action Alternative. Because missile warning and space surveillance missions would no longer be accomplished, RFE would no longer be emitted from the radar or other RFE sources at Cape Cod AFS. No significant impacts are anticipated. The No-Action Alternative would result in the Air Force no longer accomplishing its missile warning and space surveillance missions, leaving all or portions of North America vulnerable to ICBM or SLBM attacks.

Mitigation Measures

The Air Force would continue to operate the PAVE PAWS radar and other RFE emitters at Cape Cod AFS in accordance with applicable safety standards to minimize and prevent exposure to RFE. Because applicable RFE exposure safety limits would not be exceeded, no adverse impacts are anticipated; therefore, no mitigation measures would be required.

4.2 RECENT CAPE COD AIR FORCE STATION RADIOFREQUENCY STUDIES/REVIEWS

Although the scientific evidence indicates that adverse health effects are limited primarily to thermal effects, some theories have been put forward that suggest low-level RFE may have biological effects. These theories and supporting research are reviewed by the IEEE and considered during their standard setting process. It is recognized that health concerns have been raised by some individuals on Cape Cod dealing with the continued operation of the PAVE PAWS radar. These concerns have been addressed by several Cape Cod AFS site-specific studies and RFE literature reviews including:

- *Preliminary Measurements of the PAVE PAWS Radar, Phase II – Single and Double Dipole Field Measurements & Phase III – Spectrum Background Analysis, Final Report* (Air Force Research Laboratory, 2002).

- *Phase IV – Time Domain Waveform Characterization Measurements of the PAVE PAWS Radar, Final Report* (U.S. Air Force, 2003).

- *Final Test Report on a Survey of Radio Frequency Energy Field Emissions from the Cape Cod Air Force Station PAVE PAWS Radar Facility* (Broadcast Signal Lab, LLP, 2004).

- *An Assessment of Potential Health Effects from Exposure to PAVE PAWS Low-Level Phased-Array Radiofrequency Energy* (National Research Council, 2005).

- *Public Health Evaluation of Radiofrequency Energy from the PAVE PAWS Radar, Cape Cod Air Station, Massachusetts (Agreement No. 29292), Draft Literature Review* (International Epidemiology Institute, 2004).

- Memorandum regarding Risk Assessment of Low-Level Phased-Array Radio Frequency Energy Emissions – 2002-03 (Armed Forces Epidemiological Board, 2003).

- A Public Health Evaluation of Radiofrequency Energy from PAVE PAWS Radar, Cape Cod Air Station, Massachusetts (Agreement No. 29292), Final Report, Descriptive Studies of Disease Occurrence and PAVE PAWS Radar (International Epidemiology Institute, 2006).

These studies and literature reviews specifically address the general concerns brought forth regarding low-level exposures to RFE as well as the PAVE PAWS pulsed waveform generated by a phased-array radar. A summary review of these studies is provided in Section 3.3, Recent Cape Cod Air Force Station Radiofrequency Studies/Reviews. Results of these studies are briefly summarized below.

4.2.1 Preliminary Measurements of the PAVE PAWS Radar, Phase II – Single and Double Dipole Field Measurements & Phase III – Spectrum Background Analysis, Final Report

This document presented a summary of investigative preliminary measurements of the Cape Cod AFS PAVE PAWS radar. These measurements were used to guide the measurements team when performing the Phase IV Waveform Characterization Study.

4.2.2 Phase IV – Time Domain Waveform Characterization Measurements of the PAVE PAWS Radar, Final Report

This document presented the time-domain waveform measurement data that was collected in April 2003 during the Phase IV time-domain waveform characterization of the Cape Cod AFS PAVE PAWS radar.

The data acquired during the Phase IV survey indicated that the electric fields produced by the PAVE PAWS radar are highly changeable, likely depending on a number of factors such as the direction of the beam, multi-path effects such as ground-bounce and scattering from neighboring objects, and the type of pulse being radiated. The electromagnetic environment is made even more complex by other radiators in the region such as TV and radio stations. Significant changes in measurement readings were observed by simply moving a sensor less than a foot in any direction. This suggests that any effort to bound electromagnetic exposures should carefully consider the possible scenarios for the potential radiators to ensure that the correct conditions are used for the bounding process.

4.2.3 Final Test Report on a Survey of Radio Frequency Energy Field Emissions from the Cape Cod Air Force Station PAVE PAWS Radar Facility

The document provided the results of measurements, modeling, and analysis of the RFE from the Cape Cod AFS PAVE PAWS radar. Key findings of the study include:

- The radar's average power density at all 50 PAVE PAWS test sites was well below the maximum permissible exposure (MPE) specified by known safety standards. At all 50 sites, the total MPE measured with NARDA broadband instrument covering 300 kHz to 50 GHz was below the noise level of the instrument, and fully compliant with applicable safety standards.

- The differences in power density measured at an antenna height of 30 feet (to minimize local ground effects) and at a height of 8 feet was highly variable. However, when averaged over 14 measurement sites, the high sites showed approximately 5dB greater signal, consistent with the "rule of thumb" that doubling the height of a VHF or UHF antenna in proximity to the earth's surface approximately doubles the signal strength.

- At PAVE PAWS test sites where time domain waveforms were observed on the spectrum analyzer (these measurements were performed to insure that the radar was operational), samples of all classes of the PAVE PAWS waveform were observed. In addition, long range search doublets and triplets were observed independent of the azimuth from the radar antenna, indicating the presence of secondary sidelobes and/or reflections. This indicates that signals were received at the test site when the radar's search azimuth was not aligned with the test site.

- At many PAVE PAWS test sites, numerous received pulses appeared to have amplitude modulation imposed upon them. Other pulses observed at the same site were quite clean, or modulated in a different fashion. The frequency of this modulation ranged from a few Hz up to tens of kHz. The choice of spectrum analyzer parameters precluded observing higher frequency modulation. The modulation depth was highly variable. Since the steady-state amplitude of the transmitted PAVE PAWS signal is constant, the "amplitude modulation" was likely produced by the environment. It was determined that the most likely source is reflection from a multitude of "targets" including aircraft, water tanks, radio communication towers, the smokestack at the Sandwich power plant, etc.

- When observing the 24 PAVE PAWS channels in a "max hold" mode on the spectrum analyzer for extended periods, frequency-selective fading produced by multiple transmission paths was frequently observed. The depth of these fades was highly site dependent. A quantitative measurement of the frequency-selective fading parameters (e.g., depth of fade, correlation bandwidth) was not performed. However, they exhibited fairly broad "flat fading" characteristics over portions of the radar band.

- Signals observed from behind the radar were most likely produced from backscatter from the main beam of the radar, rather than from "behind the array" sidelobes or "edge diffraction" effects.

- Behind the radar, the received signal level measured from the 455 MHz beacon antenna mounted above the roof of the PAVE PAWS facility was within 0 to 20 dB of the measured radar emissions at similar locations. This is not unlike the power of paging, land mobile, and lower powered FM station transmitters, suggesting that considering the power of the radar, there is little radiation "behind" the plane of the antenna.

- On the roof of the PAVE PAWS facility, with the broadband survey instruments above the radar array (that is, penetrating the plane of the radar face from behind), the measured RFE occasionally peaked to 5 percent of the occupational MPE limit. With the instrument repositioned above the roof, just behind the plane of the radar face, the RFE limit fell below the sensitivity of the instrument. These observations support the findings discussed above that there is little radiation "behind" the plane of the antenna.

- Of the 50 test sites, 40 were situated where the primary sidelobe of a few beams per sweep cycle may appear. It was not possible to distinguish first sidelobe pulses from secondary sidelobe pulses that were received at a test site. There were variations in signal levels from pulse to pulse caused by beam pointing, propagation, and the like that blur the distinction between received first sidelobe energy and received secondary sidelobe energy.

- Even when miles away, large commercial aircraft have sufficient radar cross section to return a measurable signal to the instrumentation via "backscatter" when the plane is illuminated by the PAVE PAWS main beam. No effort was made to correlate the observed signals with aircraft traffic.

The study also compared the measurements from the current survey with those taken in 1978 and 1986. Overall, the previous studies' measurements appear to be generally higher than the current measurements. There could be several reasons for this difference, including limitations of the previous test systems, or the manner in which the power density was derived from the measurements.

The study also found that the highest average PAVE PAWS emission level at any of the PAVE PAWS test sites was comparable to the lowest ambient level observed among the ambient sites.

During this survey, peak/average power density measurements and peak/ average electric field measurements were completed at various locations on Cape Cod. The measurements from this survey are presented in Table 3.2-3 and their locations are shown on Figure 3.2-3. RFE measurements collected during the 2004 survey were below the applicable IEEE general public exposure limit.

4.2.4 An Assessment of Potential Health Effects from Exposure to PAVE PAWS Low-Level Phased-Array Radiofrequency Energy

Based on the review of available scientific evidence (including classified information), the National Research Council committee concluded that there are no adverse health effects to the general population resulting from continuing or long-term exposure to the PAVE PAWS phased RFE emissions. The committee also concluded that there was no observable increase in total cancers or cancers of the prostrate, breast, lung, or colon due to exposure to PAVE PAWS RFE. The committee found many studies and data that support the finding of no health or biological effects from RF exposures. Although there are a number of possible mechanisms and pathways by which electric and magnetic fields could lead to changes at higher power density levels than the public is exposed to from the PAVE PAWS radar, the committee did not identify any evidence of a mechanism shown to change biologic processes at the power levels that are associated with the PAVE PAWS radar.

The committee also found that the wave-form characterization data collected for the PAVE PAWS radar is similar to exposure from "dish" radars to which the public are continuously exposed.

The committee recommended that studies of tree growth in the vicinity of the PAVE PAWS facility should be conducted. A study of long-term exposures under conditions similar to human exposures may provide useful information as to possible mechanisms for a biological response that currently does not exist. The committee also recommended that a replication of a central nervous system endocrine function study be undertaken to confirm or refute previous Air Force-sponsored studies that show a significant and extended influence on brain dopamine levels during low-level RF exposures similar to that of PAVE PAWS.

Also, any future health investigations or epidemiologic studies in the vicinity of the PAVE PAWS site should look at exposures at both the census-tract and census-block levels, and try to better estimate personal exposure and consider the types of factors known to complicate human-health investigations. Future or ongoing health studies should also specifically address possible early age of exposure and/or early age at onset of an adverse health effect. Future epidemiologic studies should not be conducted unless they are expected to have sufficient statistical ability to be able to detect any possible health effects in the Cape Cod population.

4.2.5 Public Health Evaluation of Radiofrequency Energy from the PAVE PAWS Radar, Cape Cod Air Station, Massachusetts (Agreement No. 29292), Draft Literature Review

This report was simply a literature review focused on identifying studies that link RFE emissions to adverse health effects. The study suggested that RFE and adverse health effects studies be prioritized to concerns with leukemia, brain cancer, lung cancer in women, birth defects, auto-immune diseases such as lupus erythematosus, Alzheimer's disease, and Parkinson's disease.

4.2.6 Memorandum regarding Risk Assessment of Low-Level Phased-Array Radio Frequency Energy Emissions – 2002-03

This memorandum from the AFEB states that published studies do not convincingly suggest that exposures to continuous wave radio frequency energies at or below IEEE standards result in adverse health effects, and current scientific data do not indicate that phased-array are any different. Current exposure standards as established by the IEEE, although based primarily on continuous RFE, appear completely adequate to protect worker and general population health in relation to potential health effects of PAVE PAWS phased-array system.

In review of the literature, the AFEB did not identify adverse health outcomes in animal or human studies related to exposures to continuous or phased RFE at levels found at the Cape Cod AFS PAVE PAWS facility that should be studied or could be used as outcome variables to study. There was no evidence to suggest a cause-and-effect relationship between the county or town level elevated standardized rate ratios of disease in Massachusetts and the PAVE PAWS phased-array system. There is no immediate indication to support either initiation of new, or further analysis of existing epidemiological investigations of the association between RFE emissions from the Cape Cod AFS PAVE PAWS facility and any specific health outcome.

4.2.7 Public Health Evaluation of Radiofrequency Energy from PAVE PAWS Radar, Cape Cod AS, Massachusetts – 2006 (Descriptive Studies of Disease Occurrence and PAVE PAWS Radar)

The IEI's evaluation concluded that there is currently no credible evidence for adverse health effects associated with the operation of the PAVE PAWS radar system. Rates for most of the cancers that initially led to concerns about possible adverse health effects from PAVE PAWS radar exposure were found to be elevated on Cape Cod prior to 1978 when the PAVE PAWS facility began operation.

Because the community was concerned that elevated cancer rates among residents of Cape Cod compared to the rest of Massachusetts could be due to the radar system, they organized the PPPHSG. Although a number of descriptive and analytic studies had been conducted to learn whether environmental factors might be contributing to these higher rates, no conclusive associations were identified. The IEI was contracted to conduct a descriptive epidemiologic analyses in order to evaluate the possibility that continuous radiofrequency exposure to PAVE PAWS radar might be associated with adverse health effects among Cape Cod residents. In cooperation with the PPPHSG, public meetings were held and an agreement was reached on the specific health outcomes to be studied by IEI. The study included certain cancers, neurological disorders, autoimmune diseases, and birth weight. Secular trend analyses were conducted to learn whether the patterns of cancer mortality in Barnstable County changed after 1978 when the PAVE PAWS early warning system became operational in comparison with three other Massachusetts counties (Berkshire, Hampshire, and Worcester), which have demographic and socioeconomic characteristics similar to those of Cape Cod residents. Using estimates of PAVE PAWS radiofrequency levels for all of Cape Cod and for portions of Plymouth County provided by Broadcast Signal Lab for small geographical areas, conclusions for exposure-response analyses are summarized below. Data was obtained from the MDPH.

Secular Trend Analysis. The secular trend analyses revealed no changes in the patterns of county mortality over time for lung cancer, female breast cancer, leukemia, brain cancer, childhood cancer, colorectal cancer, or prostate cancer that could be related to the operation of the PAVE PAWS radar system. The secular trend analyses provided a plausible explanation for the elevated lung cancer rates among women in terms of increased smoking rates.

Cancer Mortality Exposure-Response Analysis. The exposure-response analyses revealed no evidence for an increase in cancer mortality rates with increasing levels of PAVE PAWS radiofrequency energy levels, i.e., there were no significant positive exposure-response relationships for death resulting from female breast cancer, female lung cancer, brain cancer, or leukemia.

Cancer Incidence Exposure-Response Analysis. The exposure-response analyses revealed no evidence for an increase in cancer incidence with increasing levels of PAVE PAWS radiofrequency energy levels, i.e., there were no significant positive exposure-response relationships for the incidence of female breast cancer, female lung cancer, brain cancer, or leukemia.

Neurological Disease Mortality Exposure-Response Analysis. The exposure-response analyses revealed no evidence for an increase in mortality due to neurological disease with increasing levels of PAVE PAWS radiofrequency energy levels, i.e., there were no significant positive exposure-response relationships for deaths resulting from Parkinson's disease, Alzheimer's disease, or amyotrophic lateral sclerosis (ALS).

Neurological and Autoimmune Disease Hospitalization Analysis. The exposure-response analyses revealed no evidence for an increase in hospitalization rates due to neurological disease or autoimmune disease with increasing levels of PAVE PAWS radiofrequency energy levels, i.e., there were no significant positive exposure-response relationships for hospitalizations due to Parkinson's disease, Alzheimer's disease, ALS, systemic lupus erythematosus, multiple sclerosis, or autoimmune thyroiditis.

Birth Weight Exposure-Response Analysis. The exposure-response analyses revealed no evidence for an increase in low birth weight with increasing levels of PAVE PAWS radiofrequency energy levels, i.e., average birth weight did not decrease with increasing radar exposure and there were no significant positive exposure-response relationships for the percentage of newborns having birth weights of less than 2,500 grams.

IEI concluded that in the absence of reliable new scientific evidence implicating radar exposure as a risk factor for specific disease, additional epidemiologic investigations concerning PAVE PAWS radar exposure are not warranted (International Epidemiology Institute, 2006).

The Air Force supports the recommendations made by the National Research Council and intends to pursue the dopamine and tree growth studies. As they are not included in the scope of this SEIS as defined during the public scoping process, the dopamine and tree growth studies will be pursued independent of this SEIS.

4.3 CUMULATIVE ENVIRONMENTAL CONSEQUENCES

Cumulative impacts result from "the incremental impact of actions when added to other past, present, and reasonably foreseeable future actions regardless of what agency undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time" (Council on Environmental Quality, 1978).

A recent (2004) action that occurred at Cape Cod AFS was the implementation of the SLEP. SLEP replacement equipment, computer components, and rehosting software would not change the power output or characteristics of the RFE being emitted from the radar. No cumulative impacts have occurred as a result of implementing Early Warning Radar (EWR) SLEP activities at Cape Cod AFS. Other actions in the vicinity of the EWR installation were evaluated to determine whether cumulative environmental impacts could result from the continued operation of the PAVE PAWS radar in conjunction with other past, present, or reasonably foreseeable future actions.

The DSCS and Milstar communication systems contributions to the general RFE environment would not adversely impact the health and safety of the surrounding communities. An EA addressing the installation and operation of the Milstar fixed-communication control station at Cape Cod AFS was completed in April 2002; the EA resulted in a FONSI (U.S. Air Force, 2002a). No cumulative impacts are anticipated.

The measurements conducted around the DSCS (738th Engineering Installation Squadron, 2000) indicated that exposures were below the occupational exposure limits for the system, as specified in IEEE C95.1-1999. Accordingly, the highest measurement was obtained directly in front of the feedhorn (i.e., extension protruding from the aperture), which is the actual RFE source for the aperture. This measurement was only obtained by using a man lift; therefore, this exposure is not possible at ground level. Furthermore, due to the operational angles that

DSCS uses to communicate with the various satellites, the potential impact of sidelobe energy within surrounding communities is unlikely, and impact of the main beam is not possible. No cumulative impacts are anticipated.

Future upgrades to the radar are possible. If radar upgrades are proposed, NEPA analysis would be performed at that time.

5.0 CONSULTATION AND COORDINATION

The federal and state agencies contacted during preparation of this EIS are listed below:

FEDERAL

U.S. EPA, Region 1

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8.0 PUBLIC COMMENTS AND RESPONSES

8.1 INTRODUCTION

The Air Force has complied with the NEPA mandate of public participation in the environmental impact analysis process primarily in three ways:

- Public scoping meetings were held at the following locations at which the Air Force presented an overview of the PAVE PAWS radar system, described the Proposed Action and alternatives, and invited public comments:
    - May 8, 2000 at the Forestdale Elementary School in Sandwich, Massachusetts
    - May 11, 2000 at the Bourne Best Western in Bourne, Massachusetts
    - May 15, 2000 at the Mashpee High School in Mashpee Massachusetts
    - May 16, 2000 at the Falmouth Holiday Inn in Falmouth, Massachusetts
    - August 14, 2000 at the Forestdale Elementary School in Sandwich, Massachusetts
    - August 16, 2000 at the Woods Hole Oceanographic Institute in Woods Hole, Massachusetts
    - August 17, 2000 at the Barnstable Marstons Mills Middle School in Marstons Mills, Massachusetts
    - March 17, 2003 at the Human Services Building in Sandwich, Massachusetts
    - March 19, 2003 at the Jonathan Bourne Public Library in Bourne, Massachusetts
    - March 20, 2003 at the Falmouth Town Hall in Falmouth, Massachusetts
    - March 24, 2003 at the Mashpee High School in Mashpee Massachusetts.
- A public hearing was held in Bourne, Massachusetts, on July 15, 2008 at which the Air Force presented the findings of the Draft SEIS and invited public comments.
- The Draft SEIS was made available for public review and comment in June 2008.

Public comments received both verbally at the public hearing and in writing during the review period have been considered and are addressed by the Air Force in this section.

8.2 ORGANIZATION

This Public Comment and Response section is organized into several subsections, as follows:

- This Introduction, which describes the process, organization, and approach taken in addressing public comments
- A consolidated comment-response document
- An index of commentors
- A transcript of the public hearing
- Photocopies of written comments received.

These sections are described below.

Comments received that are similar in nature or address similar concerns have been consolidated to focus on the issues of concern, and a response is provided that addresses all of the similar comments. Some comments simply state a fact or opinion; for example "the Draft SEIS adequately assesses the impacts on [a resource area]." Such comments, although appreciated, do not require a specific response and are not called out herein. The comments and responses are grouped by area of concern, as follows:

1.0 Air Force Policy

2.0 Purpose and Need for Action

3.0 Alternatives Including the Proposed Action

4.0 Solid State Phased-Array Radar

5.0 Health and Safety

6.0 Recent Cape Cod Air Force Station Radiofrequency Studies/Reviews

Within each area, each consolidated comment-response is numbered sequentially. For example, under 5.0 Health and Safety, individual comments-responses are numbered 5.1, 5.2, etc. At the end of each numbered comment-response is a set of numbers that refer to the specific comment in the documents received that were combined into that consolidated comment. The numbers of the individual comments are indicated in parentheses (e.g., 3-1, 6-2, 9-7). Comment 3-1, for example, refers to document 3, comment number 1. A reader who wishes to read the specific comment(s) received may turn to the photocopies of the documents included in this section. Below each comment number is the number of the consolidated comment in which the specific comment has been encompassed (e.g., 6.1). Thus the reader may reference back and forth between the consolidated comments-responses and the specific comment documents as they were received.

It should be emphasized that not only have responses to SEIS comments been addressed in this comment-response section, as explained, but the text of the SEIS has also been revised, as appropriate, to reflect the concerns expressed in the public comments.

The list of commentors includes the name of the commentor, the identifying document number that has been assigned to it, and the page number in this section on which the photocopy of the document is presented.

1.0 Air Force Policy

1.1 Comment: Opposed to the operation of the PAVE PAWS radar. (7-3)

Response: In order to detect ICBM and SLBM raids against North America, the U.S. military operates an extensive early warning network consisting of ground-based radars and space-based sensors. The PAVE PAWS radar at Cape Cod AFS is the only radar in the nation that is able to confirm a detected missile launch towards the United States or Canada from the east. The Solid-State Phased-Array Radar System or SSPARS, is used to accomplish the missions of missile warning and space surveillance.

2.0 Purpose and Need for Action

No comments were received for this area of concern.

3.0 Alternatives Including the Proposed Action

3.1 Comment: The SEIS did not address the alternative action of moving the PAVE PAWS radar to a remote location. (7-7)

Response: The 1979 EIS presented a discussion of alternatives considered but eliminated from further consideration with regard to siting the radar facility. In addition, the 2002 EA for the PAVE PAWS Service Life Extension program considered the alternative to move the radar facility; however, this alternative was eliminated from further consideration because it did not meet the purpose and need of the Proposed Action. Because the primary concerns raised during the scoping process involved the potential health effects from the continued operation of the PAVE PAWS radar, this SEIS focuses on recent health studies and literature reviews that address RFE emitted from radar.

4.0 Solid State Phased-Array Radar System

4.1 Comment: A description of the polarization of the radar waves has been omitted. (9-1)

Response: Polarization of the radar waves is right-hand circular on transmit and left-hand circular on receive.

4.2 Comment: The peak power level of the radar is mistakenly shown as 340 watts. (9-2)

Response: The correct peak power for the active antenna elements is 340 watts.

4.3 Comment: Figures depicting sidelobe energy are not correct. (9-3)

Response: Figures depicting sidelobe energy are for illustrative purposes only. Figure 3.1-8 has been revised to show sidelobe energy above and below the main beam.

4.4 Comment: A number of the specifications and operational characteristics of the PAVE PAWS radar has changed since the 1979 EIS was prepared. (9-4)

Response: The specifications presented in the 1979 EIS identified the design specifications as the radar was being constructed. Based on analysis and study of actual operational conditions of the radar, the SEIS presents the most resent statistics for the operation of the facility.

4.5 Comment: Is the repetition rate the same during the tracking mode as it is during the search mode (i.e., 54 millisecond [mSec] cycle)? (10-1)

Response: Tracking associated with range/elevation to include type of pulse used is classified SECRET. However, the fact that the radar uses the 17 Hz (or 18 Hz) 54 mSec resources for scheduling/planning purposes does not mean anything is tracked at that rate. There is no "surveillance" vs "tracking " mode. The radar performs all of its scheduling using the 54 mSec resource periods assigning surveillance or track to a given resource period as needed. Except for special higher elevation taskings, it only uses a once per 4 second or once per second tracking rate. The radar uses a Linear Frequency Modulated chirp waveform. It is not stepped.

5.0 Health and Safety

5.1 Comment: The conclusions regarding the potential health effects of the operation of the PAVE PAWS radar are reasonable. (2-1)

Response: The purpose of the SEIS is to describe and address the potential health effects of RFE from the ongoing operation of the PAVE PAWS radar at Cape Cod AFS and incorporate the findings of studies and literature reviews (identified during the scoping process) regarding RFE and radar operations.

5.2 Comment: A discussion of RFE attenuation is provided; however, a discussion of RFE enhancement is not provided in the SEIS. (9-5)

Response: Based on scoping comments regarding exposure to sidelobe energy, a discussion of RFE attenuation alternatives was provided to illustrate the degree of RFE exposure that could be attained with various barriers. A discussion of RFE enhancement is not provided; however, Appendix F of the SEIS provides an explanation of the difficulties that exist in assessing the potential health hazards to man from exposure to RFE because of the complex relationship between the exposure conditions and the energy absorbed. The absorbed dose and rate of energy absorption depend critically on such variables as frequency, power density, field polarization, the size and shape of the exposed subject, and environmental factors. This appendix summarizes information regarding RFE/microwave bioeffects including scientific/peer-reviewed studies completed by both electromagnetic energy research organizations and scientists related to the biological effects resulting from the interaction of RFE/microwave energy with biological matter and systems.

5.3 Comment: The SEIS makes no mention of enhanced energy deposition rates in the human body as discussed in a National Research Council report released in 1979. (9-6)

Response: In support of the findings presented in the SEIS, the National Research Council performed a literature review of RFE studies that link RFE exposure to adverse health effects. Appendix F of the SEIS also provides a brief explanation of the difficulties that exist in assessing the potential health hazards to man from exposure to RFE because of the complex relationship between the exposure conditions and the energy absorbed. This appendix summarizes information regarding RFE/microwave bioeffects including scientific/peer-reviewed studies completed by both electromagnetic energy research organizations and scientists related to the biological effects resulting from the interaction of RFE/microwave energy with biological matter and systems.

5.4 Comment: The enhanced search mode of operation was not mentioned in the review of PAVE PAWS potential health effects or the SEIS. Note that this question refers to a National Academy of Science (NAS) statement that ends "This scan is not interrupted for other functions and repeats approximately every 2.5 seconds." (9-7)

Response: The enhanced search (surveillance) mode of operation is a normal mode of the radar, which it uses all the time. The NAS description does not clearly explain the enhanced search mode. The enhanced search mode is the lowest item on the radar's list of priorities. The radar uses available duty cycle for the enhanced search mode when it has no other tasks to perform. The radar cannot exceed its duty cycle (25 percent) to perform enhanced search. The enhanced search scan is not completed within a 2.5 second period. When the system performs enhanced search, the radar completes its surveillance scan in less than 41 seconds. For example, it may take 34 seconds to complete the surveillance scan, rather than 41 seconds. Also, the enhanced search operation would be interrupted if there are other tasks for the radar to perform. Since enhanced search is always in operation, RFE measurements have been taken with enhanced search in effect and all measurements were below the permissible exposure limit (PEL).

5.5 Comment: As requested in 1979, continuous environmental monitoring of the PAVE PAWS radar should be conducted. (9-8)

Response: The Air Force has begun and will continue to conduct periodic monitoring of the RFE emitted from the PAVE PAWS radar at Cape Cod AFS.

6.0 Recent Cape Cod Air Force Station Radiofrequency Studies/Reviews

6.1 Comment: The Air Force should reconsider its proposal to separate the study of tree growth in the vicinity of the PAVE PAWS facility, and the influence of low level RFE exposures on brain dopamine levels from the SEIS. (3-1, 4-2, 7-8)

Response: Because the tree growth study and brain dopamine level study were not included in the scope of the SEIS as defined during the public scoping process, the Air Force will pursue these studies independent of the SEIS and results will be communicated to concerned agencies and the public.

6.2 Comment: Technical comments received on the Draft SEIS related to the methods employed or interpretation of studies conducted within the scope of the SEIS on RFE and/or potential public health effects from the PAVE PAWS radar should be directed to the National Research Council. (4-1)

Response: Comments received regarding methodology and interpretation of studies will be forwarded to the National Research Council and/or appropriate knowledgeable experts for consideration.

6.3 Comment: Studies conducted in support of the SEIS should be made available to the public at local libraries and maintained on the internet for the period of time that PAVE PAWS remains operational. (4-3)

Response: Studies conducted in support of the SEIS were posted in local libraries when they were released. The length of time those studies are maintained at the libraries varies based on the library policy. All studies will be maintained in perpetuity at Cape Cod AFS. The public may request copies of the studies by contacting the 6th Space Warning Squadron Public Affairs office.

In addition to distribution to local libraries, the draft SEIS was posted to the 21st Space Wing website, on the PAVE PAWS fact sheet. The final SEIS will also be posted at that location, and filed with the Environmental Protection Agency, and with the Defense Technical Information Center.

6.4 Comment: More research is required in a laboratory where controlled conditions can help identify phased array radar response biomarkers in the exposed populations of cells/organisms. If laboratory studies show a dose/response relationship, then a human health risk assessment can be pursued to evaluate potential adverse health outcomes. (5-1)

Response: The National Research Council (NRC) concluded that phased array radiation is in fact similar to that of continuous narrow-band reflectors, or "dish antennas." There are no known physical mechanisms that cause an RFE-tissue interaction to result in biological changes due to exposure at power densities on the order of 1 uW/cm^2. Studies indicate that adverse impact to tissue is from the thermal effect of RFE exposure. Where RFE is not sufficient to significantly raise the temperature in tissue, there is no evidence of adverse effects on mammalian reproduction and development.

Phased array systems are not used in bioeffects research because the scientific community has determined they are not necessary or practical. The World Health Organization, in its research priorities for the International Electromagnetic Fields Projects, does not identify phased array radar bioeffects among the listed research deficiencies. The fact that electromagnetic fields are formed by a phased array of multiple antenna elements rather than by a single antenna is not relevant to biological exposures. The overwhelming body of scientific evidence indicates injury to biological systems can only occur if the energy content of microwave radiation exceeds IEEE limits. In the case of PAVE PAWS, the energy of microwave emissions reaching the public is hundreds, if not thousands, of times below the level where biological damage can occur due to thermal impacts. The Air Force Research Laboratory will continue to conduct scientific studies on the biological effects of RFE to support other military applications of microwave energy.

6.5 Comment: The SEIS does not document publicly funded and civilian sponsored studies. (6-1, 7-2)

Response: The SEIS incorporates the findings of studies and literature reviews regarding RFE and radar operations. The site-specific studies and RFE literature reviews that were completed to specifically address the general concerns brought forth regarding low level exposures to RFE as well as the PAVE PAWS pulsed waveform generated by a phased-array radar include:

- Preliminary Measurements of the PAVE PAWS Radar
- Time Domain Waveform Characterization Measurements of the PAVE PAWS Radar
- Survey of RFE Field Emissions from the PAVE PAWS Radar
- Assessment of Potential Health Effects 1 from Exposure to PAVE PAWS Low-Level Phased-Array RFE
- Literature Review Public Health Evaluation of RFE from the PAVE PAWS Radar
- Risk Assessment of Low-Level Phased-Array RFE Emissions, and
- Public Health Assessment of Exposure to Low-level RFE Emitted from the PAVE PAWS Radar.

The SEIS provides an overview of these peer-reviewed studies that address the operation and potential health effects of RFE emitted from the PAVE PAWS radar.

6.6 Comment: The SEIS does not accurately reflect community concerns. (6-2, 7-1, 7-4, 9-9, 9-14)

Response: The purpose of the SEIS is to describe and address the potential health effects of RFE from the ongoing operation of the PAVE PAWS radar at Cape Cod AFS and incorporates the findings of studies and literature reviews regarding RFE and radar operations.

The primary concern raised during the public scoping process was the potential health effects of operating the PAVE PAWS radar as there is a higher than expected rate of a number of cancers on Cape Cod. A PAVE PAWS Public Health Steering Group (PPPHSG) was established in 2001 in response to public requests for an independent evaluation of possible health effects associated with exposure to the PAVE PAWS radar. The PPPHSG was made up of representatives from local Boards of Health, the County Department of Health and Environment, and the State Department of Public Health. Based on public input, three primary issues regarding the operation PAVE PAWS radar were identified, including:

- Measuring the average and peak radar exposures experienced by the community and then using these measurements to develop models to predict radar exposure of people living in the area,
- Analyzing plausible health outcomes from the radar exposure using descriptive epidemiology, and
- Characterizing special features of the PAVE PAWS waveform based on hypotheses proposed by the public.

Several Cape Cod AFS site-specific studies and RFE literature reviews were completed to specifically address the general concerns brought forth regarding low level exposures to RFE as well as the PAVE PAWS pulsed waveform generated by a phased-array radar. These studies include:

- Preliminary Measurements of the PAVE PAWS Radar
- Time Domain Waveform Characterization Measurements of the PAVE PAWS Radar
- Survey of RFE Field Emissions from the PAVE PAWS Radar
- Assessment of Potential Health Effects 1 from Exposure to PAVE PAWS Low-Level Phased-Array RFE
- Literature Review Public Health Evaluation of RFE from the PAVE PAWS Radar
- Risk Assessment of Low-Level Phased-Array RFE Emissions, and
- Public Health Assessment of Exposure to Low-level RFE Emitted from the PAVE PAWS Radar.

The SEIS provides an overview of the peer-reviewed studies that address the operation and potential health effects of RFE emitted from the PAVE PAWS radar.

6.7 Comment: The timeline of events and referenced documents listed on the Coalition for the Operation of PAVE PAWS Safely website should be printed in the SEIS. (7-5)

Response: The timeline of events as provided will be incorporated into the SEIS with other public comments received.

6.8 Comment: The SEIS did not include the results of the Massachusetts Department of Public Health (MDPH) study of childhood cancer in the towns of Sandwich, Mashpee, and Barnstable. (7-6)

Response: As part of the PPPHSG scope of studies for the PAVE PAWS radar, a public health assessment for exposure to low-level RFE emitted from the PAVE PAWS radar was conducted in 2005, to evaluate the potential health effects of public exposure to low-level RFE emitted from the PAVE PAWS radar system at Cape Cod AFS.

This assessment analyzed available data for county mortality and county cancer mortality and from the hospital discharge registry. Data provided by the MDPH regarding cancer incidence, birth defects, and birth weight were compiled and analyzed. The available RFE characterization survey results for the PAVE PAWS radar in terms of the known and biologically plausible hypothesized public health effects were analyzed and interpreted. The analysis utilized the analyses of the outcomes data and information in relevant scientific literature to describe the relationship among the various RFE exposure characteristics and existing health outcomes determined to be biologically plausible. The assessment was submitted to MDPH for review to confirm that the health data provided had been used in conformance with the requirements of applicable laws and regulations. The evaluation concluded that there is currently no credible evidence for adverse health effects associated with the operation of the PAVE PAWS radar system.

The recently released childhood cancer study by MDPH was not available at the time the public health assessment was conducted in 2005.

6.9 Comment: The 2004 measurement data did not consider peak measurement data and shows possible instances of "clipping"; therefore, the data is inappropriate to use in health effects analysis. (1-1, 1-2, 1-3, 9-10, 9-11, 9-12, 9-13, 9-15)

Response: The epidemiological work was based primarily on antenna and propagation modeling, rather than the 50 field measurements. The field measurements served to validate the propagation modeling. Therefore, even if some of the peak data and some of the average data from the field measurements were corrupt, the concerns are irrelevant to the outcome of the epidemiology study. The epidemiological study was based on detailed propagation mapping which in turn was based on a detailed modeling of the radar average antenna pattern and a detailed drive-test assessment of the accuracy of the propagation model of ultra high-frequency (UHF) emissions from the radar site.

The Test Plan concluded that the best outcome of the RFE study would be to estimate the average radiofrequency power density for the entire Cape Cod region with a geographical resolution sufficient to characterize the exposure levels within each Census Block Group. With respect to the epidemiological study, the measurements from the 50 sites were only a small representative sampling of Cape Cod locations and were chosen for their variability in distance, terrain, azimuth, and the like. The measurements at these sites would not have been sufficient to base an epidemiological study upon. The results of the 50-site survey were simply employed as a cross-check of the more geographically precise propagation modeling. In lieu of being a statistical database of Cape-wide radar, the field measurements at the 50 sites provides a set of empirical data points for understanding the behavior of the radar emissions in the Cape Cod environment, which may be particularly useful to make comparisons with applicable safety standards and previous surveys.

Context of the Term "Peak". The primary measurement task of the 2004 survey was to measure the average ambient radar emissions at 50 locations; peak radar emission data was also gathered at the locations during the survey.

The average power of a radar pulse for the duration of the pulse is considered the "peak pulse power." Radar pulses can be modulated by reflections, creating minor peaks and valleys in what would originally have been a flat-top pulse. The peak pulse power of the received pulse would still be the average over the duration of the rippled pulse.

During signal sampling, a peak was identified as the highest level recorded in a set of samples. While the duration of a pulse peak is by definition the duration of the pulse, a sampling peak may have a different duration. Power sampling was taken 20 million times a second, representing a 50 nanosecond (ns) duration for each sample. Thus, the highest average power among a large set of 50 ns samples is considered the peak value for the set.

Each peak sample represents about 22 cycles of the radio waves of the radar at about 440 megahertz (MHz). The measurement methodology of the Final Test Report indicates that brief power excursions above the peak pulse power captured by the fast method would be lost in a longer time sample averaging the entire pulse. The 2004 peak sampling method was termed "fast peak" measurement. In 2007-2008 this measurement was termed "instantaneous peak."

Extremely Large Data Set. The entire 2004 data set was very large, offering a highly effective resource for analyzing the average power of the received radar signal. The 2004 study captured and stored 6.75 million average power data points representing about 75 hours of monitored PAVE PAWS emissions.

The 2004 study was, overall, focused on modeling the radar's environmental emission levels based on potential human exposures with respect to the consensus safety standards. Those standards are based on average exposure to emissions in a broad spectrum. While averages are computed from numerous collected samples, peak values are by definition based on the single highest-level event in a data set. At each location there were 90 minutes of data collection, and six sets of 22,500 average samples recorded. As described, the test system accumulated power samples at a rate of 20 million samples per second. To limit the sheer volume of the stored data, every 1/25th of a second the instrumentation averaged the most recent 800,000 samples, recorded one average power data point, and cleared the buffer of the most recent 800,000 samples. Meanwhile, the peak detector was tracking each of those 20 million samples per second for the duration of the measurement set and storing only the highest level observed. In the course of taking measurements at one site, a total of 108 billion samples were distilled to a single maximum peak value. This was termed the fast or instantaneous peak value. It is the total power received during a single 20-millionth of a second sample.

Ample Headroom Established. A careful examination of the data sets and the instrument settings reveals that the average power measurements were taken with typically >20 decibel (dB) headroom between the consistently highest 40 ms averages and the 1 dB compression level, accounting for the gain-set of the instrument at the time. This is a far greater margin than needed for the 4 dB pulse-peak-to-average ratio expected in any higher level 40 millisecond (ms) sample.

The transient nature of any purported fast-peak clipping therefore resulted in an infinitesimal impact on the average data. Also, since those measured peaks that resulted in the purported clipping events were more than 20 dB above the consistently highest 40 ms averages, they were not necessarily indicative of received peak pulse power. Since there are not sequences of adjacent maximum-level average data points contained in the numerous data sets examined, that the purported clipping events were not the result of longer duration (i.e., over multiple 40 ms windows) interference.

Outlying Average Data Points Prove Headroom Was Present. There were two outlying data points that were most likely the result of aircraft reflections. Calculations presented in the 2004 Final Test Report indicate the strong possibility that the outlying data points were opportunistic reflections off nearby aircraft which can produce single, non-repetitive, random received pulses that could be stronger than the strongest received pulse propagating from the radar.

With a not-to-exceed average input level in the range of -4 to -10 dBm (decibels referenced to one milliwatt), the higher of the two outlying data points was in that range and may have included fast peak levels above the threshold of the instrumentation. If a peak were clipped in such a circumstance, it would have no material impact on the average power measurement for the site. In general, there are some measurement sets with such outlying 4 ms average data points and many without. However, there is not necessarily a correspondence between measurements that show a supposedly clipped peak data point and measurements that have outlying average data points. Therefore, it was concluded that if some 50 ns fast peaks were clipped, they are more likely the result of very short duration impulsive noise events than of high or rippled received radar pulses.

Scargo Hill. On the subject of Scargo Hill measurements, computation indicates that the summit of Scargo Hill is at the nominal radar horizon (160 feet elevation at about 18 miles from the radar). If the ideal antenna pattern, with a 2.6 degree nominal first null, were emitted from the radar, Scargo Hill would be just below the null of a 3 degree elevation search beam. If it is assumed that the first null for the 3 degree elevation beam is offset greater than 3 degrees from the beam center, then the summit of Scargo Hill and any other location on the radar horizon is exposed to a point that is low on the skirt of the main beam. This could be in the vicinity of 20 dB below the peak of the main beam, which is a power level similar to the peak of the first sidelobe that is emitted below the horizontal.

Employing the free space loss calculation, because the path to Scargo Hill is line of sight, and assuming that at the radar horizon a site has an exposure that is approximately -20 dB below the Effective Radiated Power of the radar, the higher than typical signal levels measured at Scargo Hill are consistent with this assessment. The environmental emissions of the radar are therefore consistent with the theoretical analysis.

Differences Between 2004 and 1978/1986 Results. The lower average environmental levels of radar energy in 2004 was likely the result of the use of more precise instrumentation than was available in the 1970's and 1980's. Power measurement has progressed significantly in two decades. The instrumentation used in 2004 had a noise floor that was three orders of magnitude more sensitive while at the same time was designed to collect pulses from all channels of the radar under normal operation. The accuracy of current day sensors in the face of pulsed signals is significantly improved. The 2004 average measurements can be relied upon as a state-of-the-art assessment of environmental levels of the radar emissions.

Circular Polarization. Circular polarization is not an exotic means of emitting radiofrequency signals. FM broadcast facilities have employed circular polarization for decades and many television broadcast facilities also employ circular polarization. Further, UHF television transmission facilities frequently are licensed to operate with effective power levels of between 500 kilowatt (kW) and 2,000 kW in the horizontal plane (compared to the radar's pulse effective power of about 600 kW, 3 degrees and greater above horizontal). The radar also operates within the UHF band.

6.10 Comment: A statistically significant excess of Ewing's sarcoma has temporal and spatial relationships to the radar operation that was missed in the epidemiologic study supporting the SEIS. (9-16)

Response: The epidemiologic study performed by IEI considered several disease endpoints selected by the PPPHSG in concert with input from the public. Childhood cancer (all types aggregated) was among the endpoints considered. The overall incidence of childhood cancers on the Cape was not statistically different from the reference locations in Massachusetts. Specific childhood cancers, such as Ewing's sarcoma/Ewing's family of tumors (EFOT), were not addressed. Subsequent public comments raised concern about the elevation in the incidence of this rare tumor type on the Cape relative to expected cases. The public asked whether these rare tumors could be linked causally to exposure of residents to radar emissions from the PAVE PAWS facility.

In response to the public's concern, the Massachusetts Department of Health (MDPH) conducted an investigation that confirmed the elevated incidence (i.e., new cases) of EFOT on the Cape during the ten year period of 1995 to 2004. MDPH identified and characterized the patients with EFOT, determined their temporal and geographic histories with respect to years at their domicile at time of diagnosis and locations frequented, and contracted with BSL to measure peak radar emissions at domiciles and frequently visited locations as well as a variety of reference locations. The report of this investigation (Massachusetts Department of Public Health, 2007) is thoughtful and thorough. The report carefully addresses the use of statistics as just one tool used in the interpretation of epidemiology studies and notes that "statistical significance does not necessarily imply public health significance (p. 6)."

The MDPH report notes that while the incidence of EFOT on the Cape is higher than expected, generally the patients did not live near each other (absence of geographical clustering). In the only case of nearby domiciles, the patients were diagnosed over 5 years apart. There are mitigating factors with regard to the temporal clustering noted in the years 2003-04, when 5 cases of EFOT were diagnosed. Two of these patients were short-time Cape residents (less than one year) making it unlikely that their conditions resulted from residence on the Cape. In addition, none of the patients lived in areas that experienced the highest quartile of peak power density measurements from PAVE PAWS.

Taken together, the information collected and generated by the MDPH led the Department to conclude that it is unlikely that PAVE PAWS radar emissions are a causative factor in the incidence of EFOT on the Cape. The MDPH states that it will persist in monitoring EFOT incidence on the Cape and will work with local health officials and the public.

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PUBLIC HEARING

Supplemental Environmental Impact Statement for PAVE PAWS Early Warning Radar Operation Cape Cod Air Force Station, Massachusetts

Held at: The Bourne Best Western
Bourne, MA 02532
Tuesday, July 15, 2008
7:00 p.m.

Mary E. Phillips, RPR
M&M Phillips Enterprises, Inc.
P.O. Box 160, Sagamore Beach, MA 02562-0160
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PANEL:

Colonel Dawn Eflein

Lynne Neuman

Lieutenant Colonel Paul Legendre

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P R O C E E D I N G S

COLONEL EFLEIN: Good evening, ladies and gentlemen. I would like to welcome you to the public hearing on the Draft Supplemental Environmental Impact Statement for the phased-array radar at Cape Cod Air Force Station.

I am Colonel Dawn Eflein, and I will be the presiding officer for tonight's hearing. My purpose here tonight is to ensure that we have a fair, orderly hearing and all who wish to be heard have a fair chance to speak.

Since cell phones and pagers can be distracting, it would be greatly appreciated if you would turn off or change the setting to non-audible or vibration mode on your cell phones and pagers.

The panel for this public hearing tonight is composed of myself, and Ms. Lynne Neuman from Headquarters Air Force Space Command who will present an overview of actions leading to the preparation of the Draft Supplemental Environmental Impact Statement and Lieutenant Colonel Paul Legendre also from headquarters Air Force Space Command who will also present the findings of the Draft Supplemental Environmental

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Impact Statement.

The purpose of tonight's hearing is to receive your comments, suggestions and criticisms of the Draft Supplemental Environmental Impact Statement or SEIS.

Those of you who have not had an opportunity to review the Draft SEIS, may want to read the summary of the major findings in the handout available at the door.

In the first part of tonight's meeting, the members of the panel will brief you on the details of the phased-array radar operation and the findings of the Draft SEIS.

The second part of the meeting will give you an opportunity to provide information and make statements for the record. This input ensures that the decision-makers may benefit from your knowledge of the local area and any adverse environmental effects you think may result from the continued operation of the radar.

Tonight's hearing is designed to give you an opportunity to comment on the adequacy of the Draft SEIS. Keep in mind that the SEIS is simply intended to ensure that the decision-makers will be fully apprised of the potential effects of

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the operation of the phased-array radar.

Consequently, comments on issues unrelated to the SEIS are really beyond the scope of this hearing and will not be addressed.

I would like to make a few administrative comments. First of all, if you wish to speak tonight, I ask that you fill out one of the cards that are located on the registration table as you came in to the room. From these cards I will call your name for you to come forward and state your comments.

If you did not pick up a card and would like to make a comment tonight, please raise your hand and one of our representatives will bring you a card.

After the panel has finished its presentations, we will have a 15-minute recess. During this time, we will collect the cards. When the meeting resumes, I will recognize elected officials first. Then I will call members of the public in random order from the cards that have been handed in.

For those of you who have not indicated on the cards that you want to make a statement, but wish to speak later, please fill out another

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card at the registration table during the break.

I want to make sure that we have an opportunity to fully consider the comments that you make tonight. We have an individual here who will record everything that is said so that we won't overlook any of your comments.

I'd like to establish a few ground rules so that all of us have the benefit of hearing individual comments and so that we have a good meeting transcript.

First, please speak only after I recognize you and address your remarks to me. If you have a written statement, you may place it in the box next to the podium or you may read it aloud within the time limit or you may do both.

Second, please speak clearly and slowly into the microphone stating your name and the capacity in which you appear. This will help our recorder with the transcript.

Third, each person will be recognized for five minutes. If you exceed this time limit, I will ask you to stop at that point. If you have more comments then you will be able to present in five minutes, please prioritize them so the most important comments are addressed first in case you

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run out of time.

After everyone has had the opportunity to comment, I will then address the audience to see if anyone would like to speak again.

Fourth, please do not speak while another person is speaking. Only one person will be recognized at a time.

If you decide later to make a comment after this public hearing or if you have additional considerations, we encourage you to send your written comments to the address shown on the screen or indicated on the written comment sheet.

Finally, if you would like a copy of the Final SEIS, you may state that on a written comment sheet or on the attendance card you filled out at the door.

Private addresses provided will be compiled to develop the mailing list for those requesting copies of the Final SEIS. Personal home addresses and phone numbers written on the written comment sheet or attendance card will not be published in the Final SEIS.

If no one has any questions at this time, I will turn the program over to Ms. Lynne

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Newman who will present an overview of actions leading to the preparation of the Draft SEIS.

MS. NEWMAN: Good evening, ladies and gentlemen. My name is Lynne Newman. I'm from Air Force Space Command in Colorado Springs.

In 1976, an Environmental Assessment was prepared to address the construction and operation of a radar installation at Otis Air Force Base. This Environmental Assessment resulted in an environmental determination for the proposed phased-array warning system.

In response to requests made by residents of Cape Cod, members of the Massachusetts Congressional Delegation and State officials, the Air Force prepared an EIS in 1979 to provide further study of the potential environmental effects of the phased-array radar facility.

In 2000, the Air Force had originally planned to prepare an EIS to evaluate the potential effects of the Service Life Extension Program and ongoing operation of the radar at Cape Cod Air Force Station. However, because the radar was becoming unsupportable due to a lack of replacement parts, the Air Force decided to

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prepare an Environmental Assessment for the proposed Service Life Extension Program activities and prepare a Supplemental EIS to evaluate the ongoing operations of the radar.

In 2002, an Environmental Assessment was prepared for Cape Cod Air Force Station to address the potential affects of the Service Life Extension Program. This program called for the replacement of outdated computer components and the rehosting of software to allow the radar to continue operating. This Environmental Assessment resulted in a finding of no significant impact.

We are now in the process of preparing the Supplemental Environmental Impact Statement for the potential health effects of operating the phased-array radar at Cape Cod Air Force Station.

The Supplemental EIS we are undertaking supplements analysis provided in the 1979 EIS based on updated information and recent studies regarding the operation of radar systems in order to address potential health effects of operating the phased-array radar at Cape Cod Air Force Station.

In addition to tonight's hearing, written comments on the Draft SEIS will continue

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to be accepted at this address until August 4th.

After the comment period is over, we will evaluate the comments, both written and verbal and perform additional analysis or change the SEIS where necessary.

Once the review process is complete, we will produce a Final SEIS scheduled for completion in the fall of 2008 and mail it to those on the original distribution list for the Draft SEIS.

If you are not on our mailing list, you can request a copy by writing to this address.

The Final SEIS will include comments received during the public review period and our responses to those comments. If appropriate, we will group comments into categories and respond accordingly.

The SEIS will serve as input for the Record of Decision. We expect to accomplish the Record Of Decision by the winter of 2008.

The Draft SEIS was prepared to comply with the National Environmental Policy Act or NEPA and the Council on Environmental Quality Regulations.

Efforts were made to reduce needless bulk, write in plain language, focus only on the

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issues that are clearly related to operation of the radar and to integrate with other documents required as part of the decision-making process.

In closing, I remind you that the SEIS is in draft stage. Our goal is to provide the decision-maker with accurate information on the potential environmental consequences of operating the phased-array radar.

To do this, we are soliciting your comments on the Draft SEIS. This information will support informed decision-making.

I would now like to turn the microphone over to Lieutenant Colonel Paul Legendre who will discuss the various radar studies that have been completed.

LIEUTENANT COLONEL LEGENDRE: Thank you, Ms. Newman.

Good evening. Tonight, I will give you a brief overview of the studies that have been performed regarding the phased-array radar system.

It is recognized that health concerns have been raised by some individuals on the Cape -- on Cape Cod regarding the ongoing operation of the PAVE PAWS Radar.

These concerns have been addressed by

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several Cape Cod Air Force Station site-specific studies and literature reviews. And these studies and literature reviews specifically address the general concerns brought forth regarding exposure to low-level radiofrequency energy as well as the PAVE PAWS pulse waveform generated by a phased-array radar.

The studies and reviews. Seven studies and literature reviews have recently been completed that address the phased-array radar operation.

These studies include the preliminary measurements of the PAVE PAWS Radar, the time-domain waveform characterization measurements of the PAVE PAWS Radar, survey of radiofrequency energy field emissions from the PAVE PAWS Radar, assessment of potential health affects from exposure to PAVE PAWS low-level phased-array radiofrequency energy, literature review public health evaluation of radiofrequency energy from the PAVE PAWS Radar, risk assessment of low-level phased-array radiofrequency energy emissions, and public health assessment of exposure to low-level radiofrequency energy emitted from the PAVE PAWS Radar.

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And I'll give you a brief overview of the studies that have been performed regarding the phased-array radar system at Cape Cod Air Force Station.

The preliminary measurement of the PAVE PAWS Radar. The preliminary measurement of the PAVE PAWS Radar conducted in March 2002 provided information about the time-domain waveform characterization of the PAVE PAWS Radar that was used in planning the next phase of measurements.

The preliminary measurements helped determine the feasibility of the low-level measurements, determined electromagnetic signal screening feasibility, established the community radiofrequency background levels and provided insight about the challenges that could be encountered when performing the time-domain measurements.

The time-domain waveform characterization measurements of the PAVE PAWS Radar. The time-domain waveform measurements data was collected in April of 2003 and was used to assess the existence, and perhaps the importance, of the radial electric field components, slopes of the electric field and phasing changes.

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The data acquired indicated that the electric fields produced by the PAVE PAWS Radar are highly changeable, likely depending on a number of factors; such as, the direction of the beam, multi-path effects; such as, ground-bouncing and scattering from the neighboring objects, and the types of pulses being radiated.

The electromagnetic environment is made even more complex by other radiators in the region; such as, a T.V. and radio station. Changes in measurement readings were observed by simply moving a sensor less than a foot in any direction. This suggests that any effort to bounce electromagnetic exposure should carefully consider the possible scenarios for the potential radiators to ensure that the correct conditions are used for the bouncing process.

Survey of the radiofrequency energy field emissions from PAVE PAWS Radar. During the survey in 2004, the peak average power density measurements and peak average electrical field measurements were completed at various locations on Cape Cod.

Radiofrequency energy measurements collected during the survey were well below the

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applicable IEEE general public exposure limit.

The validated geographic exposure data from this study was used by public health experts to support the epidemiological study.

Key findings of the surveys included the Radar's average power density at all 50 PAVE PAWS test sites was well below the maximum permissible exposure specified by IEEE safety standards.

The differences in power density measurements at an antenna height of 20 feet and at a height of 8 feet was highly variable. However, when averaged over the 14 measurement sites, the high sites showed approximately 5 dB greater signal, consistent with the "rule of thumb" that doubling the height of a VHF or a UHF antenna in proximity to the earth's surface approximately doubles the signal strength.

Samples of all classes of the PAVE PAWS waveform were observed. Long range search doublets and triplets were observed independent of the azimuth from the radar antenna indicating the presence of the secondary side lobes and/or reflections.

At many PAVE PAWS test sites, numerous

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received pulses appeared to have amplitude modulation imposed upon them. Since the steady-state amplitude of the transmitted PAVE PAWS signal is constant, the amplitude modulation was likely produced by the environment.

It was determined that the most likely source is reflection from a multitude of "targets"; such as, aircraft, water tanks, radio towers and the smoke stack at the Sandwich Power Plant.

When observing the PAVE PAWS channels in a "max hold" mode on the spectrum analyzer for extended periods, frequency-selective fading produced by multiple transmission paths was frequently observed.

Signals observed from behind the radar were most likely produced from back scatter from the main beam of the radar, rather than from "behind the array" side lobes or "edge diffraction" effects.

The receiver signal level measured behind the radar is similar to paging, land mobile and low-powered FM station transmitters, suggesting that considering the power of the radar, there is little radiation "behind" the

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plane of the antenna.

On the roof of the PAVE PAWS facility, with the instrument penetrating the plane of the radar face from behind, the measured radiofrequency energy occasionally peaked to five percent of the occupational exposure limit.

With the instruments repositioned above the roof, just behind the plane of the radar face, the radiofrequency energy limit fell below the sensitivity of the instruments.

This observation supports the findings that there is little radiation behind the plane of the antenna.

It was not possible to distinguish first side lobe pulses from secondary side lobe pulses that were received at a test site. There were variations in signal levels from pulse to pulse caused by beam pointing propagation and the like that blurred the distinction between received first side lobe energy and receiving second side lobe energy.

Even when miles away, large commercial aircraft have sufficient radar cross section to return a measurable signal to the instrumentation via "backscatter" when the plane is illuminated by

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the PAVE PAWS main beam.

The survey also compared the measurements from the current survey with those taken in 1978 and in 1986. Overall, the previous studies' measurements appeared to be generally higher than the current measurements. There could be several reasons for this difference, including limitations of the previous test systems or the manner in which the power density was derived from the measurements. The radiofrequency measurements collected during the 2004 survey were below the applicable IEEE general public exposure limits.

Assessment of potential health effects from exposure to PAVE PAWS low-level phased-array radiofrequency energy.

This assessment, prepared by The National Research Council, consisted of a review of the scientific data and literature related to the radiofrequency energy in the range of the PAVE PAWS system. This was done because there was no specific studies of a phased-array system similar to PAVE PAWS in the public domain.

The review included classified documentation of research that could be relevant to the PAVE PAWS system and the waveform

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characterization study.

Based on the review of available scientific evidence, the National Research Council Committee concluded that there was no adverse health effects to the general population resulting from the continued or long-term exposure to PAVE PAWS phased-array radiofrequency emissions.

The Committee also concluded that there was no observable increase in total cancer or cancers of the prostate, breast, lung or colon due to PAVE PAWS radiofrequency energy.

The Committee also found that the waveform characterization data collected for the PAVE PAWS Radar is similar to exposure from "dish" radars to which the public are continuously exposed.

The Committee recommended that the studies of tree growth in the vicinity of the PAVE PAWS facility should be conducted. A study of long-term exposures under conditions similar to human exposures could provide useful information as to the possible mechanisms for a biological response that currently does not exist.

The Committee also recommended that a replication of a central nervous system endocrine

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function study be undertaken to confirm or refute previous Air Force-sponsored studies that show a significant and extended influence on brain dopamine levels during low-level radiofrequency exposures similar to that of PAVE PAWS.

The Committee clarified that the future epidemiologic studies should not be conducted unless they are expected to have sufficient statistical ability to be able to detect any possible health effects in the Cape Cod population.

The Air Force supports the recommendations made by the National Research Council. These studies would be accomplished independent of the SEIS.

The literature review public health evaluation of radiofrequency energy from PAVE PAWS Radar.

This literature review focused on identifying studies that link radiofrequency energy to adverse health effects. The study found that the diseases listed in the slides have been studied for links to radiofrequency energy. The study suggested that radiofrequency energy and adverse health effect studies be prioritized to

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concerns with the listed diseases, which include leukemia, brain cancer, lung and breast cancer in women, low birth weight and birth defects, auto-immune diseases; such as, lupus, Alzheimer's disease and Parkinson's disease.

Risk assessments of low-level phased-array radiofrequency energy emissions.

The Armed Forces Epidemiological Board or AFEB, met in 2002 to consider a request from the Air Force Surgeon General regarding a risk assessment of low-level phased-array radiofrequency energy emissions, as phased-array radar systems are used throughout the Department of Defense and in the commercial and private sectors and concern had been raised regarding potential adverse health risks from low-level exposures at the Air Force PAVE PAWS facility on Cape Cod.

The AFEB received presentations, briefings and materials regarding various aspects of radiofrequency energy, epidemiological studies and operation of phased-array systems.

The AFEB also reviewed several hundred studies focusing on epidemiological studies of radiofrequency energy exposures, IEEE and DOD

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exposure standards and standards setting process for radiofrequency energy, studies on radiofrequency energy bio-effects and over 45 studies and public health assessments specifically for exposure and health outcomes of the Cape Cod residents.

The AFEB found that published studies do not convincingly suggest that exposures to continuous wave radiofrequency energies at or below the IEEE standards results in adverse health effects, and currently scientific data do not indicate that phased-array are any different.

Current exposure standards as established by the IEEE, although based primarily on continuous wave radiofrequency energy, appear completely adequate to protect workers and general population health in relation to potential health effects of the PAVE PAWS phased-array system.

The AFEB did not identify any evidence suggesting a cause and effect relationship between the county or town level elevated standardized rate ratios of disease in Massachusetts and the PAVE PAWS phased-array system.

There was no immediate indication to support either initiation of new or further

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analysis of existing epidemiological investigations of the association between radiofrequency energy emissions from the PAVE PAWS facility and any specific health outcomes.

And then the public health assessment for exposure to low-level radiofrequency energy emitted from the PAVE PAWS Radar.

As a follow-up -- a follow-on to the literature review conducted in 2004, this assessment evaluated the potential health effects of public exposure to low-level radiofrequency energy emitted from the PAVE PAWS Radar system at Cape Cod Air Force Station.

This assessment analyzed available data for county mortality and county cancer mortality and from the hospital discharge registry.

Data provided by the Massachusetts Department of Public Health regarding cancer incidence, birth defects and birth weights were compiled and analyzed.

The available radiofrequency energy characterization survey results for the PAVE PAWS Radar in terms of the known and biological plausible hypothesized public health effects were analyzed and interpreted.

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The investigation utilized the analysis of the outcomes, outcome data and the information and relevant scientific literature to describe the relationship among the various radiofrequency energy exposure characteristics and existing health outcomes determined to be biologically plausible.

The assessment was submitted to the Massachusetts Department of Public Health for review to confirm that the health data provided had been used in conformance with the requirements of applicable laws and regulations.

The evaluation concluded that there is currently no credible evidence for adverse health effects associated with the operation of the PAVE PAWS Radar system.

Rates for most of the cancers that initially led to concerns about the possible adverse health effects from PAVE PAWS Radar exposure were found to be elevated on Cape Cod prior to 1978 when the PAVE PAWS facility began operations.

That summarizes the findings of the recent studies and literature reviews that have been conducted. I'd like now to turn it back over

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to Colonel Bflein.

COLONEL BFLEIN: Thank you, Lieutenant Colonel Legendre. We're going to take a 15-minute recess at this time and then we will move into the public comment portion of the hearing.

Please fill out your cards, if you wish to speak, and place them in the box so we can address everybody when we come back.

(Short break was taken.)

COLONEL BFLEIN: Ladies and gentlemen, we're going to resume the hearing at this time.

Before we proceed, I will remind you of a couple of points. Please address your remarks to me so that they can be recorded in the official meeting transcript.

Please limit your comments to five minutes so that everyone can be heard. Also please state your name clearly before you make a statement for the record.

At this time I would like to call on the first speaker, Mr. Wayne Bellin. Sir, that microphone should be on for you so --

MR. WAYNE BELLIN: Wayne Bellin. Okay. I have participated with the Air Force and with the PAVE PAWS Steering Group working on the

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various studies and field studies and measurements and the quality of the engineer for the Navy submarine directorate. And the standards that they use for their measurements and for their fact finding and for their analysis have all been superb.

The situation was that we had a lot of people who were just being harmful to the process and to its finding the facts. They were dealt with in a very effective manner by just presenting facts until they just couldn't come up with anything more.

But this study has been very important not only for PAVE PAWS, but for other transmissions.

For instance, it does address cell phones and FM radio. If you want to talk about -- this is the same frequency as FM radio.

And the other one I would like to say a word about which he Doctor Adair from I think it's in Connecticut, I can't think of the school right now. But he came and gave a presentation before this got started addressing all of Doctor Albanese's comments. If anyone is interested, I have the original video tape of Doctor Albanese's

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comments.

Again, I would like to commend the Lieutenant Colonel here and the other Air Force people I've worked with -- oh, since 2002. And it's just been a superior performance and just well done. So thank you very much.

COLONEL BFLEIN: Thank you for your comment, sir. Next speaker is Mr. Bernard Young.

MR. BERNARD YOUNG: Thank you, Colonel. Bernard Young from Dennis. Dennis is a community which consistently gets the highest reported values of emissions from PAVE PAWS Radar. It was the highest measurement made in 2004 and it was the highest measurement made in 2007 from The Department Of Public Health.

I would like to point out that the measurements made in 2004 we're told tonight were

1 less than 1878 and 1888. Measurements made in

6.9 2004 were for the most part subject to an instrumentation there called clipping.

Of the 80 sites where measurements were made, 27 of those sites, the peak measurements had fell on three discrete values, 15 micro watts per square centimeter, 1.5 or .18. These three values are each a factor of ten or a hundred different

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from one another.

Immediately, that raises the suspicion of common instrumentation error called clipping. In that case, you don't know what the true value of the exposure is. The instrument couldn't read it that high.

Investigating further, we noted that when the firm that was making the measurements had used a gain of 20, because they knew the signal was being large, they got the largest value, 18 micro watts per square centimeter at five points. When the signal was not quite as large, they used more of a gain. And again they boosted the signal up to saturate an amplifier, and at the next nine points it produced 1.8 micro watts per square centimeter.

And finally, for the weaker signals 13 of the points were reported as .15 micro watts per square centimeter and a gain of 40 was used.

They also failed to compare the data with the specifications and the information we're given on the Environmental Impact Statement in 1879 Appendix C. If you do that, you'll see that the peak measurements at two of the points of the 50 stations measured throughout Cape Cod exceeded

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the envelope of the antenna pattern.

Indeed, the one in Dennis, 18 and a half miles away, was only 3 dB below the peak of the main beam.

So it's nice to talk about the energy coming from first side lobe or the second side lobe. A measurement made in Dennis is consistent with the main beam. We've been consistently told that the main beam never touches the earth. And that was reiterated by the people who took the measurements in 2004.

Looking into the matter even deeper, I went to the compact disk that was burned of the 292 measurements made at these various 50 sites. And we found in that case 240 -- or 142 of them, just about half, were traceable to the maximum output of one particular amplifier in the chain. That amplifier just couldn't put out any more data.

And if you would take a look, to plot the data in the order from the smallest to the largest, you can see that it reaches a step and it doesn't go any higher. That is clipping.

So we really don't know what the value of the exposure was in 2004 when these

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measurements were made.

2 Consequently, we can't be sure or we

6.9 really -- it would be inappropriate to use that data to come to any health effects conclusions.

And that corrupted data, therefore, corrupts the measurements reported in the Massachusetts Department of Public Health Report on PAVE PAWS and Ewing sarcoma.

In that report, they compared the peaks to the averages, and they reported that the value as decibels, it stands out like a sore thumb, that four of those cases the decibel value was negative.

That means the peaks were less than the averages. That's not possible. You don't take a course where based on three grades and get a 70, a 75 and an 80 and wind up with a 85 for your average. Peaks have to be greater than the averages.

When -- in addressing these objections, the firm that did the measurements in 2004 said that they -- the measurements in 2004 were from outside interferers. They said -- and they said they'd explain that in their 2004 report. They did no such thing.

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In the test plan, there was a question raised about taking precautions so that outside interfering didn't corrupt the measurements. And they explained twice that they were taking precautions to make sure that there were no outside interferers or outside transmissions, degradation from other sources interfering with their measurements.

When they made their report, six different times they explain that outside interferers were not corrupting the data.

But when confronted with the clipping problem in their data, the same contractor told the Massachusetts Department Of Public Health that those results are from outside interferers. That is a self-contradiction. That self-contradiction needs to be resolved.

I have a work in progress, which I will try to wrap up in time to provide a written comment that will have the figures, which I wasn't able to put together for tonight's discussion. Thank you.

COLONEL EFLEIN: Mr. Young, thank you for your comments.

Did you want to leave the handout or

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the visual that you showed, did you want to leave that for us? Or do you want to include that with your written comments, sir?

MR. BERNARD YOUNG: I'll file it with the written comments. It will probably be more clear.

COLONEL EFLEIN: Thank you, sir. Those are the only cards that I have. Does anybody else who did not fill out a card wish to speak.

(No response.)

COLONEL EFLEIN: Either Mr. Sellin or Mr. Young since apparently nobody else chooses to speak tonight, we still have more time if either of you would like to add anything.

Mr. Sellin, would you like to go again.

MR. WAYNE SELLIN: No, thank you.

THE COURT: Mr. Young, did you get cut off by the five-minute time period? Would you like some more time, sir?

MR. BERNARD YOUNG: I have some written comments that I could go through briefly.

COLONEL EFLEIN: Excuse me, for one moment.

Okay. He said he does have some written comments he would like to read briefly.

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Go ahead, sir.

MR. BERNARD YOUNG: These comments were presented in a letter to the Massachusetts Department Of Public Health. So I have them prepared and I can read them and I will just read a few paragraphs.

I am unable to reconcile SSL statements in the 2007 test plan -- that was the test plan for the measurements to support their study of Ewing sarcoma -- with statements SSL made in their 2004 report.

In the 2007 test plan, SSL says they explained in their 2004 report that peak data could be from other in band or near band emissions.

I scanned the 2004 SSL report that mentions possible interferers. There is a PDF document, so it's very easy to put in the word interferer and see where it was used.

Conclusion 10 on Page 61 of the 2004 SSL report was amateur radio operation in band caused no interference to measurements.

Their conclusion 11 was out of band interference not significant. From Page 6 of their Appendix A, measurement sites were chosen to

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be away from the location of potential interferers.

From Page 6 -- also from Page 6 of Appendix A, to pass a mobile transmitter overload preamplifier for a brief period, this event can readily be ascertained upon examining the recorded data. To date, only one data record has been identified in which such is the case. And they went on to explain that.

On Page 11 of Appendix A, additional photographs were made to show that the PAVE PAWS waveform in both the frequency and time-domain to illustrate normal operation of the radar and, two, the absence of in band interference.

Page 17 of Appendix A. It was determined that the relative amplitudes of the in band amateur radio signals were well below the level of the PAVE PAWS signals being measured.

Rather than explaining how the 2004 peak data was potential interferers, the 2004 report repeatedly explains the measurements were not subject to the interference from other sources.

So when they say they explain that the 2004 peaks were from outside interferers, they

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told that to the MDPH, that appears to be a contradiction.

I think there's something we should note about the 2004 report. If you pick it up, the first thing you note is it's a report with without any authors.

In my 15 years in scientific research, you just don't write reports that are author-less.

The second is that the radiofrequency emissions part of the 2004 study was to look at the peak and the average signals coming from PAVE PAWS, peak and average. And then as Colonel LeGendre mentioned that in his presentation.

But when we do look at the report, the first thing you note is there is no discussion of the peak values. They weren't plotted.

When they did their test plan for going to the 50 sites, they computed the losses, based on electromagnetic theory of signal propagation, projected the losses from the transmitter to the measurement site. These include a base loss just on the basis of distance, the further you get from the light bulb, the less bright it appears to be.

There are losses due to Fresnel effects, losses due to diffraction effects and

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other losses. And they computed and presented these losses, but they never used that data in a comparison with the measurements they made. They're just hanging out there.

You know, whenever you make a measurement and you have an ability to make a prediction or an ability to compare it with a predicted value, you ought to do it. It is a very simple one line calculation. It was presented to me in a Draft Environmental Impact Statement, Appendix C in 1979. It's a one line formula. And because it wasn't presented with any mathematical rigor, I rederived it. And I've come up with the same result.

3 So a simple calculation could have been made with all the peak data. And it was not made.

6.9 Why wasn't that done? And that raised my curiosity.

And now when we look and we see that if you did do that, you see tentative 50 points exceeded the specification. That is a cause for concern. We've been repeatedly told the main beam doesn't touch the earth, but yet the measurement made in Dennis is consistent with the main beam. It is only 3 dB less than the main beam. That's

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like half of the power of the peak of the main beam.

In comparison, the first side lobe is 10 dB down which is -- first side lobe is 20 dB down, is one percent of that.

So here we've got a measurement made in Dennis that's 46 times the specification. And well we're just not going to talk about that.

And when confronted with the data, your contractor, the national research contractor has come up with a contradiction a self-contradiction. I am disappointed that those who you rely on and we relied on and Senator Kennedy relied on. Senator Kennedy, if you don't remember, was the one who initiated this National Research Council study.

We relied on them for an honest and careful and diligent investigation. And how this -- these things could be overlooked is beyond comprehension.

I think we need to be concerned about this because the Chairman of that committee and the program administrator at NRC, yeah, NRC in Washington, are the same two who are heading the study on cell phones right now. And if we don't

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have any more diligent investigation of cell phones as we did in the PAVE PAWS issue and earlier in this decade, I don't know what the value of having them is. Thank you.

COLONEL SPLEIN: Thank you for your comments, Mr. Young.

As no one else has indicated they wish to speak, this concludes the public hearing.

If you should decide later to make additional comments or would like to receive a copy of the Final SEIS, you may do so through the address that's shown on the brochure or on the written comment sheet.

So appreciate your public -- excuse me. We appreciate your participation in this public hearing. Thank you for coming. Good night.

(Whereupon the hearing concluded at 8:02 p.m.)

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C E R T I F I C A T E

I, MARY E. PHILLIPS, Registered Professional Reporter, do hereby certify that the foregoing transcript, pages 2 through 39 inclusive, was taken by me stenographically and thereafter under my direction was reduced to typewriting and is a true record of the testimony of the proceedings to the best of my ability.

Dated at Sagamore Beach, Massachusetts, this 25th day of July, 2008.

Mary E. Phillips

MARY E. PHILLIPS, RPR

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 1
1 CONGRESS STREET, SUITE 1100
BOSTON, MASSACHUSETTS 02114-2023

OFFICE OF THE
REGIONAL ADMINISTRATOR

August 4, 2008

Ms. Lynne Neuman
HQ AFSPC/A4/7PP
150 Vandenberg Street, Suite 1105
Peterson AFB, CO 80914-2370

Re: Draft Supplemental Environmental Impact Statement for the PAVE PAWS Early Warning Radar Operation, Cape Cod Air Force Station, Massachusetts (CEQ # 20080239)

Dear Ms. Neuman:

The Environmental Protection Agency (EPA) has reviewed the United States Department of the Air Force's (Air Force) Draft Supplemental Environmental Impact Statement (DSEIS) for the PAVE PAWS Early Warning Radar Operation at the Cape Cod Air Force Station in Barnstable County, Massachusetts. We submit the following comments on the DSEIS in accordance with our responsibilities under the National Environmental Policy Act (NEPA) and Section 309 of the Clean Air Act.

The DSEIS for the PAVE PAWS radar was prepared by the U.S. Air Force to address the concerns of the local community about possible health effects from the PAVE PAWS operation. The criteria EPA used in evaluating the DSEIS are (1) the measured radiofrequency (RF) radiation exposure levels beyond the boundaries of PAVE PAWS radar site at locations accessible to the public, and (2) the exposure guidelines used by the Federal Communications Commission (FCC) to protect the public from adverse health effects that might result from exposure to the RF radiation emitted by the systems regulated by the FCC.

Based on our review of information provided in the DSEIS we conclude the following:

- The time-averaged radiofrequency (RF) radiation power density measured at 50 various locations on Cape Cod, accessible to the public beyond the radar installation's perimeter fence, with the exception of one location, are at and below 5 microwatt per square centimeter. These levels are well below the protective exposure standards used by the Federal Communications Commission (FCC) found in FCC/OET Bulletin 56, August 1999. http://www.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet56/oet56e4.pdf.

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- The one location noted is at Shawme Crowell State Park where the measured time-averaged power density was measured as 34.6 microwatt per square centimeter, still below current standards. The maximum permitted power density, used by the Federal Communications Commission to protect the public from adverse health effects from RF radiation in the frequency range of the PAVE PAWS radar is, 280 microwatts per square centimeter. This exposure guideline was recommended to the FCC by EPA in November 9, 1993.

In addition to radiofrequency (RF) environmental exposure measurements, EPA reviewed available scientific evidence presented in the DSEIS. These included a 2005 report from the National Academies' National Research Council that concluded that "there is no evidence of adverse health effects to Cape Cod residents from long-term exposure to radiofrequency energy from a nearby U.S. Air Force radar installation."

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5.1 Since the possible exposures, at locations on Cape Cod that are accessible to the public, comply with the standards that are used by the FCC to regulate telecommunications systems, the DSEIS's conclusions regarding the health affects of the operation of the PAVE PAWS radar are reasonable.

Based on our review of the DSEIS we have rated the DEIS "LO-1—Lack of Objections-Adequate" in accordance with EPA's national rating system, a description of which is attached to this letter. Please contact Timothy Timmermann (617-918-1025) of EPA's Office of Environmental Review with any comments or questions about this letter.

Sincerely,

Elizabeth A. Higgins, Director
Office of Environmental Review

Attachment

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Summary of Rating Definitions and Follow-up Action

Environmental Impact of the Action

LO--Lack of Objections
The EPA review has not identified any potential environmental impacts requiring substantive changes to the proposal. The review may have disclosed opportunities for application of mitigation measures that could be accomplished with no more than minor changes to the proposal.

EC--Environmental Concerns
The EPA review has identified environmental impacts that should be avoided in order to fully protect the environment. Corrective measures may require changes to the preferred alternative or application of mitigation measures that can reduce the environmental impact. EPA would like to work with the lead agency to reduce these impacts.

EO--Environmental Objections
The EPA review has identified significant environmental impacts that must be avoided in order to provide adequate protection for the environment. Corrective measures may require substantial changes to the preferred alternative or consideration of some other project alternative (including the no action alternative or a new alternative). EPA intends to work with the lead agency to reduce these impacts.

EU--Environmentally Unsatisfactory
The EPA review has identified adverse environmental impacts that are of sufficient magnitude that they are unsatisfactory from the standpoint of public health or welfare or environmental quality. EPA intends to work with the lead agency to reduce these impacts. If the potentially unsatisfactory impacts are not corrected at the final EIS stage, this proposal will be recommended for referral to the CEQ.

Adequacy of the Impact Statement

Category 1--Adequate
EPA believes the draft EIS adequately sets forth the environmental impact(s) of the preferred alternative and those of the alternatives reasonably available to the project or action. No further analysis or data collection is necessary, but the reviewer may suggest the addition of clarifying language or information.

Category 2--Insufficient Information
The draft EIS does not contain sufficient information for EPA to fully assess environmental impacts that should be avoided in order to fully protect the environment, or the EPA reviewer has identified new reasonably available alternatives that are within the spectrum of alternatives analyzed in the draft EIS, which could reduce the environmental impacts of the action. The identified additional information, data, analyses, or discussion should be included in the final EIS.

Category 3--Inadequate
EPA does not believe that the draft EIS adequately assesses potentially significant environmental impacts of the action, or the EPA reviewer has identified new, reasonably available alternatives that are outside of the spectrum of alternatives analyzed in the draft EIS, which should be analyzed in order to reduce the potentially significant environmental impacts. EPA believes that the identified additional information, data, analyses, or discussions are of such a magnitude that they should have full public review at a draft stage. EPA does not believe that the draft EIS is adequate for the purposes of the NEPA and/or Section 309 review, and thus should be formally revised and made available for public comment in a supplemental or revised draft EIS. On the basis of the potential significant impacts involved, this proposal could be a candidate for referral to the CEQ.

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Document 3

United States Department of the Interior

OFFICE OF THE SECRETARY
Office of Environmental Policy and Compliance
408 Atlantic Avenue – Room 142
Boston, Massachusetts 02210-3334

TAKE PRIDE IN AMERICA

July 30, 2008

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ER 08/638

Ms. Lynne Neuman
HQ AFSPC/A7PP
150 Vandenberg Street, Suite 1105
Peterson AFB, CO 80914-2370

RE: Comments
SEIS, PAVE PAWS
Early Warning Radar Operation
Cape Cod Air Station, MA

Dear Ms. Neuman:

The Department of the Interior (Department) has reviewed, and has the following comments on, the Draft Supplemental Environmental Impact Statement (SEIS) for PAVE PAWS Early Warning Radar Operation at Cape Cod Air Force Station, Massachusetts.

The scope of the environmental review in the SEIS was primarily human health effects from operation of the PAVE PAWS radar. The bioeffects of exposure to radiofrequency energy (RF) were examined by the National Research Council (NRC) and the results summarized on page 4-6. The bioeffects of radiofrequency energy on mammals and birds were reviewed in Appendix F.

1 The NRC recommended (page 4-6) studies of tree growth in the vicinity of the PAVE PAWS facility, and the influence of low level RF exposures on brain dopamine levels. The Air Force indicates support (page 4-9) for these studies, but states that these research studies will be
6.1 pursued independent of this SEIS.

The Department believes that a nexus exists between these additional research studies recommended by the NRC and the SEIS, and requests that the Air Force reconsider its proposal to separate these studies from this SEIS. The purpose of the tree growth study is to investigate possible mechanisms for a biological response to radiofrequency energy exposure that we currently do not recognize and therefore cannot properly evaluate. The central nervous system endocrine function (dopamine) study is likewise intended to resolve outstanding questions about the effects of radiofrequency energy on central nervous system function in wildlife and man.

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Questions regarding these comments may be directed to Mr. Vern Lang of the Fish and Wildlife Service at 603-223-2541.

Thank you for the opportunity to review and comment on this SEIS. Please contact me at (617) 223-8565 if I can be of assistance.

Sincerely,

Andrew L. Raddant
Regional Environmental Officer

Document 4

The Commonwealth of Massachusetts
Executive Office of Health and Human Services
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250 Washington Street, Boston, MA 02108-4619
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JOHN AUERBACH
COMMISSIONER

July 31, 2008

Ms. Lynne Neuman
HQ AFSPC/A7PP
150 Vandenberg Street, Suite 1105
Peterson AFB, CO 80914-2370

Subject: Comments on Draft Supplemental Environmental Impact Statement (SEIS)
Continued Operation of the PAVE PAWS Radar Facility
Cape Cod Air Force Station, MA

Dear Ms. Neuman:

Thank you for the opportunity to submit comments on the *Draft Supplemental Environmental Impact Statement* (SEIS) (May 2008) for the continued operation of the PAVE PAWS Radar Facility at the Cape Cod Air Force Station in Massachusetts.

The Massachusetts Department of Public Health's Bureau of Environmental Health has four major comments on the Draft SEIS:

1 1. MDPH strongly suggests that any technical comments received on the Draft SEIS related to the methods employed or interpretation of studies conducted within the scope of the SEIS on electromagnetic emissions and/or potential public health impacts from the PAVE PAWS facility be directed to the National Research Council's (NRC) Committee to Assess Potential Health Effects From Exposures to PAVE PAWS Low-Level Phased-Array Radiofrequency
6.2 Energy for its written response. While this committee may no longer have a formal relationship with the U.S. Air Force, the Committee served a key role as the de-facto scientific peer review group of the various studies conducted, as well as conducting their own independent analyses. It is appropriate and essential that the Air Force reach out to the NRC and ask that they continue to serve as an independent scientific review body for comments received on the Draft SEIS in order to maintain the credibility of the work performed.

2 2. MDPH strongly encourages the Air Force to follow through and implement the recommendations made by the NRC in its 2005 report *An Assessment of Potential Health*
6.1 *Effects from Exposure to PAVE PAWS Low-level Phased-Array Radiofrequency Energy*. The NRC committee recommended that the Air Force commission tree growth studies in the

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2 vicinity of the PAVE PAWS facility as well as a central nervous system endocrine function
6.1 study on the effect of low-level radiofrequency exposures on brain dopamine levels.

3. Amongst its conclusions, the NRC indicated in its report entitled "An Assessment of Potential Health Effects from Exposure to PAVE PAWS Low-Level Phased-Array Radiofrequency Energy" that the measurement data and models of the PAVE PAWS facility available at the time of its review in 2005 provided a good first-order characterization of the spatial distribution of exposures occurring throughout the communities of Cape Cod. While the NRC concluded that there are no adverse health effects to the Cape Cod population from continuing or long-term exposure to the PAVE PAWS radiation, it also concluded that there were limitations and uncertainties in estimating exposure at the individual level and that future studies should look at exposures at census tract and census block levels while attempting to estimate exposure at the individual level. Public health investigations at the individual level where exposures at specific locations are estimated rather than for larger populations are acknowledged as a data gap in the epidemiologic studies conducted for the SEIS.

3 4. MDPH requests that the full reports of the studies conducted as part of the SEIS, as well as the Final SEIS itself, be made available to the public at local public libraries and maintained on
6.3 the Internet for the period of time PAVE PAWS remains operational. Extensive and one-of-a-kind studies were conducted to evaluate the potential public health impact(s) of the PAVE PAWS facility and these studies not only will be of interest to the current and future residents of Cape Cod but to researchers and residents of other areas of the country who could benefit from the experience gained on Cape Cod in addressing their own similar public health issues. They also serve as a baseline for future investigations.

We appreciate the opportunity to provide these comments. If you have any questions regarding them, please feel free to contact us at 617 624-5757.

Sincerely,

Suzanne K. Condon, Associate Commissioner
Director, Bureau of Environmental Health

Cc: Frank E. Barnes, Chair, National Research Council Committee
The Honorable Edward M. Kennedy
The Honorable William Delahunt
Martha J. Steele, Deputy Director
Robert S. Knorr, Director, Environmental Epidemiology Program
Jan Sullivan, Director, Community Assessment Program

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SIERRA CLUB
FOUNDED 1892
Massachusetts Chapter

Sunday, July 27, 2008

Air Force Space Command
150 Vandenberg St, Suite 1105
Peterson Air Force Base, CO 80914-2370

Attn: Lynne Neuman
Re: HQ AFSPC/A4/7PP / PAVE PAWS SEIS

Dear Ms Neuman:

The Massachusetts Chapter of the Sierra Club has been involved for many years in the issue of the possible health impacts on Cape Cod from the PAVE PAWS phased array radar system that is being operated at the Massachusetts Military Reservation (MMR). We feel that the PAVE PAWS Supplemental Environmental Impact Statement continues the failed epidemiological studies decision making process from the past. Given the small population size of the Cape residents with various cancers that are possibly related to the phase array radar signal; the high background rate of many cancers in Massachusetts compared to national averages and the decision to require statistically significant results before public health management action is taken, conducting epidemiological studies is never likely to show an effect of the phased array radar on adverse health outcomes on Cape Cod. The recently released Massachusetts Department of Public Health's study on the role of the phased array radar on cases of childhood Ewing's sarcoma on the upper Cape is a good example of the futility of that approach. It follows the even weaker epidemiological studies approach pursued by the PAVE PAWS Public Health Steering Group (PPPHSG) that left the Sierra Club and many residents feeling that an alternative approach is required.

Many concerned residents stated that simply focusing the epidemiological studies on the intensity of the phased array signal and its potential health impacts was a "red herring" in light of Dr. Albanese's concerns. We feel that the epidemiological approach is too crude a tool to detect a potential impact of a potential adverse health impact from the phased array radar signal. The burden of proof for safety should fall on the Air Force to prove that this system is
causing no harm and not the concerned citizens of Cape Cod or Sierra Club to show that the radar generates harm. Dr. David Dow, Treasurer of the Cape Cod & the Islands Group, represented the Sierra Club at many of the PPPHSG meetings and witnessed numerous cases where the local citizens were not treated with respect and their concerns were dismissed out of hand. As a result public input diminished over time, with only two comments being received at the recent public hearing. We attribute this to the citizens feeling that nobody is seriously listening to their concerns and willing to think outside the box about how to resolve these concerns.

The Sierra Club supports the "precautionary principle" in cases where scientific uncertainty exists regarding the impacts human caused environmental stressors on public health. Dr. Richard Albanese, an Air Force researcher, raised concerns about the unique effects of phased array radar on the cells that he studied. Since the Sierra Club is an environmental advocacy organization, we will leave it up to the sci-
1 entific peer review process to evaluate the credibility of Dr. Albanese's research. We feel that more re-
6.4 search is required on this issue in the laboratory where one can control conditions and identify phased

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Air Force Space Command / Ms Lynne Neuman
PAVE PAWS SEIS
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1 array radar response biomarkers in the exposed populations of cells/organisms. The National Research Council/National Academy of Sciences evaluation of the PPPHSG products made some similar research
6.4 recommendations which to our knowledge have not been pursued by the Air Force Space Command. If these new laboratory studies show a dose (radar frequency and intensity)/response (biomarkers) relationship, then a human health risk assessment can be pursued to evaluate the potential response of the adverse health outcomes on Cape Cod to the PAVE PAWS radar signal using the Broadcast Signal Laboratory's field measurements/modelling estimates of non-ionizing radar exposure. From our perspective that would be thinking outside of the box in addressing citizen concerns. A risk assessment provides a range of potential risks based on the strength/frequency of the phased array radar signal that are easier for residents to grasp and are more readily incorporated into developing public health policy from an environmental stressor perspective. If the laboratory studies fail to detect a dose-response relationship, then it would not be necessary to conduct the risk assessment. It is extremely rare for an epidemiological study to detect a statistically significant effect and it is not designed to to evaluate cause-effect relationships. Given the population sizes involved in the Cape Cod studies, the ability of an epidemiological study to detect an effect is almost nil.

Thanks for your consideration in this matter.

Sincerely,

R Philip Dowds
Chair, Mass Chapter Executive Committee

David D Dow
Cape Cod and the Islands Group

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Collution for the Operation of PAVE PAWS Safely
Lt. Ronald Cronin, President

Lynne Neuman
HQ AFSPC/A4/7PP
150 Vandenberg St.
Suite 1105
Peterson AFB, CO 80914-2370

August 4, 2008

Dear Ms. Neuman,

I am enclosing my comments concerning the Draft Supplemental Environmental Impact Statement (DEIS) on the Precision Acquisition Vehicle Entry Phased Array Warning System (PAVEPAWS) in operation at Sandwich, Cape Cod Air Force Station, MA.

1 This report does not properly document or even acknowledge publicly funded studies and civilian sponsored studies undertaken after grass root efforts to conduct a parallel study.
6.5 The PFFM in conjunction with Boston University and Suffolk University engineering and my fellow graduate students devised a parallel study to run side by side with the Kirkland Air Force team.

2 The Draft Supplemental Environmental Impact Statement (DEIS) report does not accurately reflect community concerns and falls far short of expectations. It is a one sided report which fails to acknowledge involvement by citizens, professional organization and universities who attempted to assist and take part in the measurement effort. This DEIS document should not be used by federal or state lawmakers nor advanced as a complete
6.6 study by the USAF or Department of Defense (DOD) as it contains numerous errors, omissions, and lacks impartiality.

The study and specifically the PAVEPAWS Public Health Steering Group (PPPHSG) failed to address or acknowledge the significant and elevated Cape Cod childhood cancer rates (Ewings) that so many parents were concerned about. Out of frustration by the poor treatment by PPPSG members, some of the concerned parents formed the Collation for the Operation of PAVEPAWS Safely and conducted measurements on our own. These were presented to the Kirkland team and National Academy of Science committee after request.

Both the USAF and the PPPHSG alienated, discounted, discriminated against and interfered with citizens and students from the Coalition for the Operation of PAVEPAWS Safely (COPPS), the Professional Firefighters of Massachusetts (PFFM), Boston University and Suffolk University engineering students who all attempted to assist the USAF by volunteering to participate in the measurement effort of the PAVEPAWS radar on Cape Cod.

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During the process it became very obvious that PAVEPAWS commanders put the mission ahead of residential health concerns and sought control over any and all studies of the radar. Our bewilderment at the behavior and study practices of the USAF and PPPHSG turned to frustration by those of us with children living on the Cape and to apathy by the students and professors. It is documented that Air Force officials (Lt. Col. Bruce Ruscio) advised me that he contacted Boston University and was assured that no epidemiological studies would be organized or conducted between the engineering school and the medical school (conducted a 1999 study for the Massachusetts Department of Public Health (MDPH)) as was being suggested.

It is also well documented by formal complaint that USAF personnel harassed the engineering students and Dr. Albanese (see Cronin Deposition taken by USAF attorneys). The group of young engineers were not treated as younger peers, but instead was ostracized by Air Force staff and radar technicians.

The NAS suggestion to fund (under $100,000) the taking of field measurements on a continuous basis from every firehouse on Cape Cod in conjunction with the PFFM and Boston University and Suffolk University engineering students was denied by the USAF.

Upon my return from New York (WTC) on September 15, 2001 a sudden spike (tripling) in measurements were recorded at my home. These elevated measurements continued through the end of the month of September when the spectrum analyzer was returned.

The efforts of COPPS, the Professional Firefighters of Massachusetts (PFFM) and engineering students can be viewed on the web at capecodcancer.com , formally pavepaws.com.

Sincerely,

Lt. Ron Cronin

By email to : Lynne.Neuman@Peterson.af.mil
and by Certified Mail

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July 31 2008

Ms. Lynne Neuman
HQ AFSPC/A7PP
150 Vandenberg St. Suite 1105
Peterson AFB, CO 80914-2370
Fax (719)554-3849
cc: Senator Edward Kennedy
Senator John Kerry
Congressman William Delahunt
Dr. Richard Albanese

RE: COMMENTS ON DRAFT SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT FOR PAVE PAWS EARLY WARNING RADAR OPERATION CAPE COD AIR FORCE STATION, MASSACHUSETTS

1 The Draft Supplemental Environmental Impact Statement (DEIS) falls far short of community and
6.6 medical expectations to protect the general public from exposure to phased array radiation. This DEIS is an example of underreporting scientific knowledge and misleading the public by attempting to make
2 statements appear as fact. This DEIS does not properly document, and in some instances does not document at all, publicly funded studies and findings yielding this DEIS an insufficient document to be
6.5 used by lawmakers and Air Force (AF) and Department of Defense (DOD) decision makers.

3 We request the PAVE PAWS system be shut down. This will enable retrospective health outcome studies
1.1 to be included and health assessment of the damage to Cape Codders to be used in making decisions about the future operation of this machine.

4 The DEIS severely minimized public community concern regarding potential health effects of exposure to PAVE PAWS phased array radiation and in most instances did not address publicly held/recorded
6.6 hearings of hundreds of Cape Codders' concerns regarding health and safety issues. As a Selectman from Sandwich (Richard Judge) and a community leader (Sharon Judge), we are award that hundreds of instances of public protests were not addressed in this DEIS.

This DEIS appears to be an attempt to re-write the history. The struggle of thousands of Cape Cod citizens who had been trying to protect their families health has been reduced in this document to a few sentences about scattered public concern.

There was a large public outcry in the late 1970's when the public first saw PAVE PAWS construction begin. There was much press attention given to public concern at that time that was not documented in this DEIS. Several citizen groups fought the construction and operation of PAVE PAWS and fought for laboratory and long-term analytical epidemiological studies of the exposed population as well as continuous monitoring of PAVE PAWS radiation emissions.

Public concern did not disappear. It was not reported in the press significantly again however until the late 1990's. Residents including ourselves and many public groups pointed out the dearth of health studies since PAVE PAWS began operating in 1978 and called for the facility to be moved and/or shut

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down and for proper laboratory and analytical epidemiological studies to be carried out. The Association for the Preservation of Cape Cod called for the decommissioning of the PAVE PAWS facility.

Below is a timeline that is published on the C.O.P.P.S. (Coalition for the Operation of PAVE PAWS Safely) website at www.capecodcancer.org documenting key events in the PAVE PAWS history:

PAVE PAWS Timeline

1972 – Air Force begins preliminary planning for Project PAVE PAWS

1975 – A site assessment was done for the Cape Cod PAVE PAWS out of the public eye. Flatrock Hill on the Massachusetts Military Reservation (MMR) was not the Air Force's first choice.

1977 – PAVE PAWS construction begins despite a 1976 Defense Intelligence Agency document indicating the Air Force was aware of non-thermal effects of exposure to low intensity microwave radiation.

March, 1978 – Residents filed a lawsuit charging the Air Force had violated the National Environmental Policy Act (NEPA) of 1969 by failing to submit an Environmental Impact Statement (EIS). PAVE PAWS construction continues even though the EIS process is not completed.

March 31, 1978 – MA Senator Kennedy, Congressman Studds and Senator Brooke released a joint statement critical of Project PAVE PAWS and request that the National Academy of Sciences (NAS) perform a study of PAVE PAWS. Some excerpts from the NAS National Research Council (NRC) report; Analysis of the Exposure Levels and Potential Biologic Effects of the PAVE PAWS Radar System, 1979" include :

"The effects of long-term exposure to microwave radiation at low power densities have not been adequately assessed. There is no evidence of a cumulative effect on humans, but the question is unresolved."
"There are no data on the biological effects of microwave radiation with the specific characteristics of the PAVE PAWS radar, which because of its rather unusual function, differs from more commonly encountered sources of microwave and RF radiation."
"the possible exposure effects of PAVE PAWS should be restricted to transient, reversible functional alterations in the Central Nervous System that may or may not be perceived by the exposed persons."
"...the PAVE Paws radar may be anticipated to expose a limited number of members of the general public intermittently to low intensities of pulse-modulated fields... In view of the known sensitivity of the central nervous system to electromagnetic fields, especially those modulated at the brainwave frequencies, the possibility cannot be ruled out that exposure to PAVE PAWS radiation may have some effects on exposed people. Because these effects are still hypothetical, it is not feasible to assess their health implications. Such assessment will require additional research and surveillance and must be addressed in future evaluations of the potential exposure effects of PAVE PAWS and other high power-output radar systems"

December 22, 1978 – The Draft EIS is released for a 30-day public comment period just before the holidays.

January 22, 1979 – A public hearing on the draft EIS is held at Sandwich High School. Citizens protest the operation of PAVE PAWS. They use bumper stickers and pins that say "Keep Your P.A.W.S. Off Cape Cod.

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1979 – The final EIS is released. The Air Force states PAVE PAWS will be a short-term use of the environment and will operate continuously for 10-20 years. The Air Force conceded in the EIS that the long term chronic effects of exposure to PAVE PAWS pulsed microwave radiation were unknown at that time. Several urgent requests are made by the Cape Cod public in the EIS including:
1. That the Air Force do continuous Cape -wide monitoring of radiation levels on Cape Cod;
2. That epidemiological studies begin of the Cape Cod population from the moment the power was turned on;
3. That the public be notified if there was ever an upgrade to PAVE PAWS

Measurements were taken once in 1978 when PAVE PAWS was turned on in Upper Cape communities only. These measurements were time -averaged; the more powerful peak pulses were not measured; a proper scientifically valid epidemiological study using an individual's radiation exposure data has never been done and the public was not notified of a major upgrade to PAVE PAWS in 1996.

1986 – High cancer rates are reported on Cape Cod. The Massachusetts Department of Public Health (MDPH) funds a team of researchers from Boston University (BU) to look into potential causes of the high cancer rates on the Upper Cape. MDPH had time -averaged power density measurements taken in upper Cape towns only.

Controversy over PAVE PAWS and health concerns continue. The Air Force continues to say that PAVE PAWS radiation is safe because the measurements fall well below the existing safety standards for Radio frequency/Microwave (RF/MW) radiation and that there is no conclusive evidence that it is a hazard. The safety standard however is based on the "thermal model" (if the RF/MW heats your tissue, it is a hazard). It does not take into account the long -term chronic effects of "non-thermal" exposure to PAVE PAWS unique radiation (waveform, phasing, frequency and modulation).

1991 – BU releases the "Upper Cape Cancer Incidence Study." With regard to PAVE PAWS, the BU researchers stated in Microwave News, "While no association was seen for PAVE PAWS, the available exposure data is inadequate. We strongly recommend that systematic power density measurements be taken throughout the area covered by PAVE PAWS so that useful data will be available for future analysis of its potential health impact."

1994 – The "Public Health Assessment for MMR" recommended that relevant electromagnetic field monitoring data be provided for the PAVE PAWS radar facility. This recommendation was not followed up on by the MDPH or Air Force, despite numerous requests from citizens.

May, 1996 an official "Request for Radiofrequency Radiation Survey" is made following a "major modification which allows PAVE PAWS to operate in a more powerful configuration" according to official documents. The public is not notified at the time of the upgrade.

1997 - Sharon and Richard Judge of Sandwich, MA find out about PAVE PAWS while looking at military maps on the MMR researching the proposed county jail. They begin asking questions as they realize that no comprehensive health studies have ever been done for PAVE PAWS.

December 11, 1997 – The Silent Spring Institute (SSI) reports that breast cancer incidence remains 20% higher on Cape Cod than in the rest of MA for 1982-1994. SSI, funded at that time by MDPH, dismisses PAVE PAWS from further research based on data generated thus far. However, SSI lacked adequate exposure data and critical information regarding the technicalities of the radar system.

Sharon Judge begins attending meetings of the Community Assistance Panel (CAP) of the Agency

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for Toxics Substances and Disease Registry (ATSDR). She raises the issue of PAVE PAWS and her concerns that no studies have been done since the radar became operational despite the high incidence of disease on Cape Cod. MDPH officials agree there is a lack of data on PAVE PAWS but indicate that it is not an easy thing to study and may not be the thing to focus on at this time.

Ms. Judge continues to attend CAP meetings and pushes for proper studies. Judge learns that MDPH's Bureau of Environmental Health Assessment (BEHA) receives funding from the Air Force through the Environmental Public Health Center (EPHC), located on the MMR. The office was established on the MMR in 1997 to address health questions and concerns of the Upper Cape Cod community related to potential exposures to hazardous substances in the environment.

July 27, 1998 – The CAP was not allowed to address PAVE PAWS but MDPH announces they found a small amount of money to address the PAVE PAWS issue and were considering putting an advisory panel together. Citizen's urge that the panel be balanced and offer suggestions for panelists.

April 23, 1998 – The Association for the Preservation of Cape Cod, Inc. calls on MA Governor A. Paul Cellucci to "decommission and close down the obsolete PAVE PAWS facility."

July 7, 1998 – The public finds out at a CAP meeting that there had been "a major modification which allows the PAVE PAWS to operate in a more powerful configuration."

August, 1998 – Sharon Judge calls on Governor Cellucci, in the process of developing a Master Plan for the future of the MMR, to cut short the lease for PAVE PAWS as it sits atop MA state land.

October 5, 1998 – Cape Cod Citizens group, lead by Sharon Judge, holds a press conference calling for PAVE PAWS to be decommissioned

October 14, 1998, Sharon Judge and Cape Cod Citizens begin writing to MA Senators Edward Kennedy, John Kerry and Congressman William Delahunt documenting the long standing concerns with PAVE PAWS.

January 1999 – The "Sandwich Health Professionals Study" finds that higher cancer rates in Sandwich were found in the parts of town closest to the Cape Cod Electric Plant and PAVE PAWS.

February 16, 1999 – The MDPH hosts a public meeting in Sandwich to introduce their expert panel and to provide an opportunity for the public to present their concerns directly to the panel. Sharon Judge and Cape Cod citizens point out conflicts of interest with certain panel members and ask for their removal for a fair and balanced panel. They also call for the decommissioning of PAVE PAWS and retrospective health studies.

September 21, 1999 – The Ballistic Missile Defense Organization (now the Missile Defense Agency) announce their plans (at an invitation only meeting) to upgrade PAVE PAWS to play a key role in the $ 12 billion Missile Defense Program proposed by the Pentagon. Sharon Judge attends with her husband Richard, who had recently been elected to the Sandwich Board of Selectmen.

Fall, 1999 – The lead scientist/Chairwoman of the MDPH PAVE PAWS expert panel, Linda Erdreich, was asked to resign by MDPH when it became apparent that she was also a contractor for the Pentagon on their Missile Defense report for PAVE PAWS upgrades. The MDPH panel report was noted favorably in the Pentagon report she worked on. The public would not find out about this until February, 2000.

September 1999, the MDPH released an evaluation of childhood cancer on showing cancer rates 19% higher on Cape Cod. The most common types of cancer were lymphomas, leukemia, and central nervous system tumors. MDPH said "the results of the report did not suggest any common

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environmental factor as being responsible for the elevations." MDPH did not have adequate exposure data for PAVE PAWS, just as SSI and BU did not.

November 1999, the MDPH releases their expert panel report on PAVE PAWS the day after Thanksgiving. The panel concluded that there was insufficient evidence to determine whether radiation from PAVE PAWS is harmful to public health and recommends further measurements of radiation levels; a repeat of what the public requested back in 1978. The Cape Cod Coalition to Decommission PAVE PAWS pushes for PAVE PAWS to be shut down in the absence of proper studies and no real evidence of safety.

November 5, 1999 – Sharon Judge presents her concerns to the Sandwich Board of Selectmen regarding the lack of health data on PAVE PAWS and the need for proper studies as well as a full site-specific EIS for the Cape Cod PAVE PAWS. The Board voted to send a letter to the US Army Space and Missile Command to request an in-depth study on the effects that radar emissions from the facility may have on residents and that an EIS be completed.

November 8, 1999 – the Department of Defense announces the release of the draft EIS for the Ballistic Missile Defense EIS that includes PAVE PAWS. There is a 45-day public comment period.

November 9, 1999 – Richard and Sharon Judge travel to Virginia to testify at a public hearing of the Ballistic Missile Defense Organization (BMDO) regarding PAVE PAWS health and safety concerns. Selectman Richard Judge reads the official letter from the Sandwich Board of Selectmen into the record.

November 9, 1999 – The Sandwich Board of Health calls for the Air Force to file a site-specific EIS for PAVE PAWS

November 10, 1999 – Richard and Sharon Judge meet in Washington, DC with aides to Senator Kennedy, Senator Kerry and Congressman Delahunt about the Air Force and Missile Defense plans for PAVE PAWS and the long-term health concerns .

Richard and Sharon Judge continue writing letters to state and federal representatives, public health officials, DOD officials, and to the editors of local newspapers in an effort to inform leaders and citizens of the need for proper health studies and that the Air Force conduct a full-site specific EIS for the Cape Cod PAVE PAWS. They continue to push for PAVE PAWS to be relocated to a remote location since the DOD says it will be needed well into the future for missile defense.

November 30, 1999 – MDPH releases their panel reports on PAVE PAWS entitled; "Initial Report on the Environmental Health Assessments of the PAVE PAWS radar at the MMR," and "Assessment of Public Health Concerns Associated with PAVE PAWS Radar Installations, November 1, 1999." The reports are available at http://www.state.ma.us/dph/beha

December 10, 1999 – The Air Force announces that they have begun the process for a NEPA analysis which will culminate in a full EIS for PAVE PAWS.

January 22, 2000 – The Cape Cod Coalition to Decommission PAVE PAWS holds a public meeting in Sandwich to discuss the recently released MDPH report. They invite MDPH officials and the expert panel and the Air Force and BMDO officials and Raytheon representatives. MDPH declines but says they will hold a meeting in February. Raytheon declines the invitation. It is a standing room only crowd. The Air Force asserts PAVE PAWS safety based on 1000's of studies. However, none are PAVE PAWS unique phased array radiation.

March 13, 2000 – MDPH holds a public meeting in Sandwich with the PAVE PAWS panel members at which time they plan to answer questions about the panel choir.

March 2000 – The Air Force hires a facilitating agency and convenes a "Stakeholders Working

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Group" to address PAVE PAWS issues. Citizens express deep concerns that the Working Group was outside of the formal EIS process and reiterated the need for comprehensive, independent health studies. The "Working Group" is not independent of the Air Force and does not go forward.

March 14, 2000 – State Senator Therese Murray and State Representative Ruth Provost asked the Air Force to complete a cumulative health assessment before any changes are made to the PAVE PAWS facility.

April 13, 2000 – After the public demands it, BMDO announces a public hearing will be held on April 27, 2000 for the Draft EIS for proposed National Missile Defense (NMD) upgrades to PAVE PAWS. The notice is buried in the "Lifestyle and Arts" section of the Cape Cod Times newspaper. The BMDO reschedules the meeting for May 3, after citizens push for proper public notification.

April 29, 2000 – The Association for the Preservation of Cape Cod holds a conference; "The MA Military Reservation: The Unanswered Questions" and includes the PAVE PAWS issue on the agenda.

May 3, 2000 – The MDPH comments on the NMD EIS calling for radiation measurements before and after the proposed upgrades are completed.

May 8-11, 2000 – The Air Force holds "Scoping" meetings for the ir EIS for proposed changes to PAVE PAWS; this is separate from the ongoing EIS process.

May 11, 2000 – A Sandwich Board of Health consultant, James Reilly, an engineer working in the field of RF/MW radiation, made a presentation to the BOH downplaying PAVE PAWS' risks.

May 23, 2000 – Dr. Richard Albanese, a physician, scientist/researcher and long-time employee of the US Air Force, wrote a letter to the MDPH expressing his personal medical concerns regarding the unique aspects of the phased array radar, after reviewing the 1999 panel report. The public did not learn of Dr. Albanese's correspondence until October, 2000. The public would later learn that Albanese has studied phased array radiation for more than 15 years , and that the work, which he says is relevant to PAVE PAWS remains classified.

May 25, 2000 – Sandwich Board of Selectman provide input to the USAF calling for RF measurements and environmental epidemiology by an independent source; geographic mapping of various types of cancer and adverse health issues around the radar site; periodic independent monitoring of radiation levels; a retrospective health outcome study on Cape Cod for elevated cancer rates and other health disorders and the commencement of laboratory studies for long-term exposure to PAVE PAWS radiation. They suggest independent organizations that they believe would be appropriate to do this work.

July 11, 2000 – Dr. Richard Albanese provides further information to the MDPH regarding the importance of "time-domain" measurements that would provide data on the signal shape, amplitude and phasing (overlapping wave fronts) in order to measure tissue absorption for PAVE PAWS radiation. He provides MDPH concepts for the medical assessment of PAVE PAWS radiation. When AF management finds out he has communicated with MDPH, Albanese is silenced and forbidden to continue work on PAVE PAWS using his government resources.

July 2000 – The Air Force approaches the Barnstable County Commissioners to partner with them for an evaluation of PAVE PAWS health issues. The Commissioners expressed concern about the independence of the study and suggested that the Air Force distance itself as much as possible to minimize the perception of a potential conflict of interest. Negotiations broke down between the County Commissioners and Air Force when the Air Force could not provide independence.

July 28, 2000 – the Air Force releases a Draft DOPAA Document on PAVE PAWS Service Life

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Extension Program (SLEP), the so-called first step in the Air Force's EIS process for PAVE PAWS.
August, 2000 - MITRE Corp. releases "RF Power Density Exposure at Ground Level for the PAVE PAWS Radar at Cape Cod – Questions and Answers"
August 14-17, 2000 - Air Force holds public scoping meetings on Upper Cape Cod for the PAVE PAWS SLEP EIS
September 2000 – Local Cape Cod residents are invited on a tour of the PAVE PAWS facility.
September 30, 2000 – in a letter to local elected officials, the PAVE PAWS commander responds to medical concerns voiced by Dr. Richard Albanese and comments on an article that is to appear on Sunday October 1, in the Cape Cod Times
October 18, 2000 – The US EPA provides written comments of the AF SLEP EIS; among other things the EPA points out that the AF/County Commissioners study be under the Commissioner's control and not the AF, and also that there be a commitment to long-term measurements and correlation with observed health effects.
November 28, 2000 – Toxics Action Center presents the USAF PAVE PAWS with its annual "Dirty Dozen Award."
December 13, 2000 – Sandwich Health Agent, David Mason, at the invitation of an Air Force official, was flown out to Brooks Air Force Base, San Antonio, TX to attend discussions with scientists on both sides of the PAVE PAWS safety issue. Mr. Mason does not have the security clearance to hear Dr. Albanese's classified work, but does receive an unclassified briefing.
December 16, 2000 – Mr. Mason is flown to Washington, DC to meet with staff aides at Senator Kennedy's office. At the meeting with Kennedy aide Moada Pilo, Mason sought the declassification of the research material from Dr. Richard Albanese and to have him come up to Cape Cod for a public forum; that all data needed to come forward.
December 21, 2000 – the Air Force invites 40+ Cape Cod elected officials and civic leaders on a "Civic Leaders Tour" to Colorado and Las Vegas in February. Participants will be flown out from Otis AF Base to meet with Air Force Space Command officials to understand the importance of PAVE PAWS mission and to discuss relevant PAVE PAWS issues. In addition to visiting headquarters at Cheyenne Mountain Colorado, civic leaders will hear the AF band and see an AF air show. Sandwich Selectman Richard Judge, voices his concern that it is inappropriate to be taking civic leaders and elected officials on an Air Force trip during the legal EIS process.
December 27, 2000 – It is reported in the Cape Cod Times that Senator Kennedy took flights from special interests including Raytheon (the company that built PAVE PAWS and was awarded contracts for the NMD)
January 4, 2001 – The Air Force backs out of a proposed PAVE PAWS study with the Barnstable County Commissioners. According to County Commissioner Mary LeClair in a Cape Cod Times article on 1/5/01: "Federal lawyers just couldn't accept our restrictions," "They just couldn't agree with the independence we wanted, and (the study) would only have value with independence."
January 11, 2001 – MA Senator Kennedy writes to the Secretary of the AF requesting that;
1. Dr. Richard Albanese be allowed to continue with his studies related to the PAVE PAWS system;
2. the AF declassify the studies that Dr. Albanese has conducted related to the PAVE PAWS System;
3. the AF work closely with Dr. Albanese and allow him to express his opinions at a public forum

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hosted by the Sandwich Board of Health in the near future
4. the AF fund and independent study through the NAS/National Research Council that he said "would essentially be a reassessment of the 1979 (NRC) study."
5. the AF develop a pilot project on the Cape to develop a tracking network for environmental hazards and population exposures
State and local leaders continue to express concern regarding challenges with the US Air Force, not allowing independent studies of PAVE PAWS
January 2001 – The Sandwich Board of Health under the direction of chairman Richard Loring indicated that it would participate in an Air Force-funded health study of PAVE PAWS. Mr. Loring then invited members of Upper Cape Boards of health to participate in what the Air Force was calling "The PAVE PAWS Public Health Steering Group" (PPPHSG).
Residents expressed concern that the PPPHSG was not independent of the Air Force. Sandwich Selectman Richard Judge in a 1/5/01 Cape Cod Times article states; "They're looking for someone to partner with to do a study under their terms. But their terms aren't going to give us the type of health study we need, and deserve 22 years later."
Members of the PPPHSG did not have the expe rtise to conduct/oversee the necessary laboratory and analytical epidemiological work that Cape Cod citizens and elected officials had been calling for over 20 years.
The Air Force was able to exert a great amount of control over the PPPHSG decisions, including the Statements of Work for both the radiation measurement effort and a "descriptive" only epidemiological study. Members of the public were vocal at PPPHSG meetings that they felt the PPPHSG did not represent the public and that there was too much AF influence. From the very first PPPHSG meeting, residents called for independent time -domain radiation measurements (that capture signal shape, phasing, amplitude and modulation); an independent, comprehensive analytical epidemiological health study for PAVE PAWS such as the type that the SSI was performing for breast cancer; and laboratory studies using an actual phased array with the signal characteristics of PAVE PAWS. The Air Force would not fund such studies. The Air Force had membership on the PPPHSG and affected the Statements of Work for the PPPHSG and for the NAS/NRC Panel. It is interesting to note, the former Secretary of the Air Force, Sheila Widnall served on the NAS Governing Board that approves study panels while the PAVE PAWS panel was being formed. Citizens challenged the make-up of the NAS/NRC PAVE PAWS Panel. Many panelists had very close tie to the US Air Force and their contractors. Only a small subset of the NRC panel had the security clearance to view the classified re search performed by Dr. Richard Albanese's team, and those panelists had the closest ties to the US Air Force and RF/MW industry. Many representatives of the US Air Force and the RF/MW industry appear at public NAS, EIS and PPPHSG meetings promoting PAVE PAWS safety. The Air Force downplays Dr. Richard Albanese's expertise and his role in the study of phased arrays.
April 2001 – Dr. Richard Albanese meets with aides to Senator Kennedy and Kerry who are apparently briefed on his work though they do not have "Top Secret" Security clearances. The MA Federal delegation in a letter of April 6, 2001 to the Acting Sec. of the AF asks the AF "to conduct a study of the field measurements of PAVE PAWS radar as performed in the Environmental Health and Safety Program (EHS Program). These measurements are time -domain measurements, also called direct signal measurements, that provide accurate definition of wave front shapes and amplitudes." The AF is asked to do this as soon as possible and to provide the data to the NRC.
April 9, 2001 – Dr. Richard Albanese provides the protocol to the AF for the time domain measurement effort requested by the Senators. Dr. Albanese was the lead scientist for the classified

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EHS Program that has been reported in the press to be a multi-million dollar effort over a period of 15+ years. Air Force management insists on using an AF team from Kirtland AFB, that apparently did not work on EHS and did not have as much expertise in this area of signal measurement.
June 13, 2001 – The Air Force announces they are converting the SLEP EIS process into two separate EIS processes (these are separate from the NMD EIS process and the public and elected officials find the state of the ongoing EISs confusing).
June 16, 2001 – Dr. Richard Albanese submits his comments on the National Missile Defense EIS for PAVE PAWS and asked that the NMD EIS be withdrawn.
July 23, 2001 – Cape Cod citizens testify at a meeting of the NRC PAVE PAWS panel in Woods Hole.
July 25, 2001 – Sharon and Richard Judge present their concerns about the PAVE PAWS process in direct meetings with Senator Kennedy and Senator Kerry. The following day they meet with Congressman Delahunt. They point out the challenges with the many EIS processes, the narrow scope of NRC work, AF interference with Richard Albanese and adverse actions They asked the Senators to meet personally with Dr. Richard Albanese and hear his classified research as they have high level security clearances. They have not yet met with Dr. Albanese. Congressman Delahunt met with Albanese but does not have the security clearance and could only receive an unclassified briefing. Throughout the fall of 2001, citizens continue to point out the challenges with the ongoing study processes to the Senators and the need for proper and truly independent studies that would get us the answers we need. But the processes in place are allowed to continue.
Fall 2001 – the Air Force measurement team begins preparation for a step by step approach to gathering time -domain signal data requested by the Senators in April. They only take measurements near the facility and do not go beyond the Upper Cape Community. The PPPHSG measurement effort (by Broadcast Signal Lab) are only power density measurements and not time - domain like the public and Dr. Albanese requested. The Air Force refused to fund a comprehensive time -domain measurement effort on Cape Cod.
December 29, 2001 – Richard Judge files for a GAO investigation of the issues surrounding PAVE PAWS and is assigned 4 a case number. Richard Judge continues to ask Senator Kennedy and Senator Kerry to personally call for a GAO investigation to untangle the challenges with the NAS, EIS and EHS data withholding.
December 31, 2001 – the AF Surgeon General requests the Armed Forces Epidemiological Board (AFEB) to perform a "Risk Assessment of Low-Level Phased Array Radio Frequency Energy Emissions" for PAVE PAWS
February 12, 2001 – the Air Force announces they are adding a Milstar Fixed Communication Control Station at Cape Cod AF Station (PAVE PAWS) and release a Draft Environmental Assessment (EA). Air Force management continues to withhold papers Dr. Richard Albanese has written specific to phased arrays such as PAVE PAWS.
February 19-20 – some members of the PPPHSG are invited to attend the AFEB Meeting in San Diego, CA Dr. Robert Knorr of MDPH is a presenter, Linda Erdreich of the MDPH Panel of 1999 is a presenter. George Heufelder of the PPPHSG also attends.
February 28, 2002 – Dr. Robert Knorr releases "Upper Cape Public Health Evaluation" and makes recommendations for studies regarding PAVE PAWS
March 8, 2002 – the MA Medical Society invites Dr. Richard Albanese to attend a meeting of the MA Medical Society's Committee on Environmental and Occupational Health to discuss phased

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array radiation and the Cape Cod PAVE PAWS.
Spring/Summer – the Air Force measurement team continues to collect data of several of PAVE PAWS aspects
March 18, 2002 - Sandwich resident and firefighter Ronald Cronin submits the "PAVE PAWS Environmental Impact Study" to the PPPHSG, he also presents information to the NRC
March 15, 2002 – the Air Force makes their presentation to the NRC
March 2002 – Dr. Richard Albanese expresses his concerns to the NAS study directors that the EHS Program is not going to get a fair airing with the panelists.
September 2002 – PAVE PAWS receives a secret lease extension to end in September 2006 without local input. The Dept. of the Army's 25 year real estate permit to PAVE PAWS had been scheduled to expire on August 31, 2006.
October 2002 – Air Force gives raw PAVE PAWS measurement data to NAS. The Air Force downplays the presence of overlapping wave fronts (phasing), steep wave fronts including a measurement above 1 volt per meter per nanosecond – which Albanese has said publicly based on classified work there should be no exposure to levels of one volt per meter per nanosecond. There was also a radial component (ground wave) present in the Air Force measurements.
The PPPHSG contracts with the International Epidemiological Institute (IEI) to do descriptive only epidemiological study to see if there is a correlation with PAVE PAWS and health. The NAS and Dr. Richard Albanese are critical of the IEI work pointing out IEI's poor choice of control groups and statistical methods. Also, the measurements they used by BSL were not independent. They were paid for the Air Force.
February 2004 – newly released data from the SSI shows higher risk of breast cancer for long term residents.
October 2004 – Dr. Richard Albanese brings to the MA Senators attention that he has again been admonished by AF management and was told he is not to comment on the NAS report.
January 13, 2005 – the NAS/NRC PAVE PAWS report is released. The report does not find, based on currently available scientific data, that there is a human health hazard from PAVE PAWS, but they suggest further studies should be done such as a tree ring growth study and a study of dependent levels. There were limitations with the NAS study: there was no determination of individual exposures, duration of exposure, individual mobility, confounding factors. There is no positive evidence of safety indicated by a risk estimate.
July 2005 – It is reported in the news media that the MDPH has been quietly doing a study of childhood cancer in Sandwich in response to an e-mail from a concerned Sandwich resident in 2003. Sandwich Health Agent David Mason reports in a Sandwich Enterprise article of 7/1/05 that he was unaware of the ongoing study.
February 2006 – the MDPH finds an unusual pattern of childhood cancer cases in Sandwich and widens their study to include Mashpee and Barnstable. Residents push for the study to include the whole Cape but MDPH keeps the focus more narrow.
February 28, 2006 – A public forum to discuss the MDPH childhood cancer study is held in Sandwich. The meeting is packed. Citizens raise the concern about the high incidence of Ewings Sarcoma, a very rare cancer, in children across Cape Cod. The NAS, IEI and AFEB and PPPHSG all missed the childhood cancer incidence and the high rates of Ewings Sarcoma in their reports.
January 2007 – It is reported in the press that the MDPH is looking at a possible correlation between the PAVE PAWS radar and Ewings Sarcoma in children on Cape Cod, after Brookport [illegible]

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resident Bernard Young brings data to the MDPH

As of November 2007, Senator Kennedy and Senator Kerry have not personally met with Dr. Richard Albanese, they have not personally called for a GAO investigation. A GAO investigation is necessary to insure that a study is carried out independent of Air Force and DOD interference. We do not want to see the past repeated. The NAS has now been brought in twice by Senator Kennedy on this issue. Air Force funded and exerted a tremendous amount of control over the NAS study of PAVE PAWS and the PPPHSG work. We need independent laboratory, and analytical epidemiological studies using time -domain measurements by an independent group as far removed from the Air Force as possible. Citizens have been calling for this work since they first found out about PAVE PAWS in the late 1970's. Anything less is unacceptable almost 30 years later.

A sampling of recent television and newspaper reports are listed below:

11/15/07 Cape Cod Times report:
Silent Spring Will Expand Cancer Probe
11/8/07 Cape Cod Times report:
State Expects Conclusive Answers From Pave Paws Study
11/6/07 WBZ TV Special News report:
Lawmakers Alarmed By Cape Cancer Cases
11/5/07 WBZ TV Special News report:
State Seeks Cause For Cape Cancer Cases, Families Suspect Link To PAVE PAWS Radar
1/18/07 WCVB TV News report:
Cape Cancer Spike Eyed, Department of Public Health Launches Investigation
Upper Cape Cod Disease Incidence and Pave Paws Radiation
Pave Paws radiation is an Active Variable in the Upper Cape Community

2008, Ewings Sarcoma study is released; does not follow the protocol that concerned citizens such as Bernard Young (who lost his 22 year-old daughter to Ewings Sarcoma) presented to MDPH, BSL and the USAF). Dr. Richard Albanese, a USAF physician who has spent much of his 40+ career studying PAVE PAWS and phased arrays, and who was awarded a "Lifetime Achievement Award" by his employer (the USAF), pointed out fatal flaws with the MDPH PAVE PAWS/Ewings Sarcoma Study. Dr. Ann Aschengrau who lead the Boston University study of Cancer rates on Cape Cod in the 1990's also noted in the Cape Cod press that the study was flawed.

If you were to compare this timeline against the information provided by the AF in the DEIS, they will appear to be two completely different documents. If this was a DEIS meant to document necessary medical/community events it has failed in total.

5 We request that the timeline provided above and all the documents that are referencein this timeline be
6.7 printed in the DEIS.

6 The DEIS did not include the results of the MDPH study of childhood cancer in the towns of Sandwich,
6.8 Mashpee and Barnstable. The Cape Cod public publicly voiced their concerns on numerous occasions that the study should include the entire Cape.

We feel terrible that Senator Edward Kennedy has been diagnosed with a brain tumor of a form that has been associated with the type of radiation that PAVE PAWS emits and it is a shame that the AF had not

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informed Senator Kennedy nor Senator Kerry of PAVE PAWS' potential to lead to these type of diseases. We would hope that Senators Kennedy and Kerry will take another look at Dr. Richard Albanese's work regarding the real threat of exposing the general public to an untested radiation. Dr. Albanese is a physician with the USAF.

7 The DEIS did not address the alternative action of moving the Cape Cod PAVE PAWS to a remote
3.1 location where there is not a human population living in front of it. This was an alternative that was brought up repeatedly at scoping meetings, draft EA and SLEP EA hearings and in letters, etc.

8 The tree ring study and dopamine study should have been included in the scope of this DEIS. They
6.1 should be performed by an independent group; not the USAF. It is unacceptable 30+ years after PAVE PAWS began operating and the public began demanding laboratory studies of phased array radiation and analytical epidemiological studies of the exposed population, that there exists no such study today to support the AF's claim that PAVE PAWS is safe.

The AF's approach in changing the original EIS process (General Pavlovich letter, etc.); changing the entire EIS process from the beginning has been completely confusing to the public and public leaders. Splitting the process up into EA's for the SLEP upgrades, Milstar upgrade and the separate BMDO (NMD) upgrades has been unacceptable and has been a ploy to circumvent the intent of the NEPA (and EIS process).

This DEIS cannot be accepted as any type of decision making tool or legal document. It also cannot be used as a means to document any historically events in the story of the Cape Cod public vs. PAVE PAWS phased array microwave installation.

Thank you for the opportunity to comment.

Richard Judge
Former Sandwich Selectman

Sharon Judge

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PAVE PAWS RADAR CHARACTERISTICS COMPARED TO RADIO FREQUENCY MEDICAL DIATHERMY UNITS

A partial definition of Medical R.F. Diathermy: Treatment using heat produced by high-frequency current, to treat muscle complaints, etc. Raytheon diathermy units, used for decades by medical practices, **operate in the same** 2 to 3 GHz frequency band, used by Airborne Early Warning (AEW) Radar. -- (Raytheon diathermy units use a smaller low power version of the AEW magnetron 'tube'). A P2V patrol bomber AEW radar, transmits @ one Mw (peak power), various pulse rates and pulse widths; *frequency = ~ 2.4 GHz.*

I'm a former U.S.N. Chief Aviation Electronics Technician. Radar was my primary maintenance responsibility. USAF AEW planes have operated in Cape COD skies for decades! As far as I know, without health related complaints. **Is it** fashionable or politically valuable, for some protestors, to attend public forums to make some type of impression? I empathize with anyone having genuine fears of "the unknown, or partially known" --all the more reason, for listening and thinking more -- arguing & talking less!

How did PAVE PAWS RADAR become such a Boogey-man? Was it a tragic spin-off from the horrendously expensive & totally unnecessary EMF power line controversies? Where did all the protesting experts come from? How did they acquire their alleged expert Radar knowledge? Did some of it drop from the skies, to help them to fan the flames of public fear? Or, is there some possible business lust, to acquire low cost government surplus land, -- if, and when PAVE PAWS is de-commissioned?

Norm La Fleur Sr.
Korean War Vet.
rev. 08/04/08

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Bernard J. Young, P.E.
REGISTERED PROFESSIONAL ENGINEER

August 3, 2008

Lynne Neuman
HQ AFSPC/A4/7PP
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Suite 1105
Peterson AFB, CO 80914-2370

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Dear Ms. Neuman:

Please enter these comments into the Draft Supplemental Environmental Impact Statement MAY 2008 for PAVE PAWS Early Warning Radar Operation Cape Cod Air Force Station, MA.

A reading of the DSEIS reveals several cases of errors, omissions, and deceptions. It is not responsive to valid concerns regarding potential health effects from the intense radar pulses. The epidemiological study missed the statistically significant and elevated Cape Cod Ewing's sarcoma cluster which peaked in the years following the attack of 9-11-01. The possibility that PAVE PAWS played a role in this tragedy should not be overlooked.

It is disturbing that the Upper Cape selectmen received a copy of this DSEIS, but the selectmen and the board of health from the Town of Dennis, where the highest PAVE PAWS exposure was measured, were not on the distribution list.

This electronic formatted document contains color in the figures which should loose no content if reproduced in black and white.

Major issues to be raised are listed here for the reader's convenience.

Polarization Omitted
Peak Power Erroneously Stated
Sidelobe Illustrations Deceptive
Specifications Have Changed
Exposure Enhancements Omitted
Enhanced Search Mode Omitted
Energy Deposition Rates Omitted
Requests for Monitoring Ignored
Peak Intensity of Pulses Ignored
Scargo Tower Consistent with Main Beam

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2004 Measurements Subject to Instrumentation Error
BSL Response to Reanalysis
Comparison of 2004 to Previous Measurements Erroneous and Deceptive
Cape Cod Ewing's Sarcoma Cluster Cannot be Ignored
Other Concerns
Comments
Conclusions
Need for Further Investigations
References
Figures

Polarization Omitted

1 4.1 A description of the polarization of the radar waves has been omitted. This radar is circularly polarized. The public does not experience circularly polarized radiation from any other transmitter of comparable power and gain.

Since a rotating electrical field will exert a rotating force on any particle with a charge, or a moment on any particle with a polar moment, this radar may produce unique effects on DNA resulting in possible adverse health effects. Of particular concern is the ability of the electrical field to move DNA strands within the cell during replication, and thus promote a translocation error leading to carcinogenesis. Such an effect would occur at a discrete point in time and would not require a latency period.

Peak Power Erroneously Stated

2 4.2 Page 3-1 misstates the peak power level of the radar at 340 watts. It has been more accurately reported elsewhere as 582,200 and 543,000 watts.

Sidelobe Illustrations Deceptive

3 Figure 3.1-8 is deceptive. It only shows the first and second sidelobes above the main beam. Omitting the sidelobes below the main beam conveys the idea that people on the ground are not exposed to the radar, which is false.

4.3 Figure 3.1-5 is also deceptive, since the first sidelobe is not shown contacting the ground, and conveys the message that people on the ground are not exposed to the stronger first sidelobe, which is false.

Specifications Have Changed

4 4.4 A number of the specifications and operational characteristics of PAVE PAWS have changed, or different values have been reported at different times.

Two values have been provided for the peak power of a pulse. It has been reported as 582.4 KW (AF 1979) and as 543 KW (MITRE 2000).

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Two values have been reported for the gain. It has been reported as 6200 (AF 1979) and 38.4 dB=6918 (MITRE 2000, p24).

Two values have been provided for the vertical angle (also called depression angle, below the horizon) to the peak of the first sidelobe. It has been reported as 3.4 degrees off axis; with minimum axis elevation of 3.0 degrees above the horizon (AF 1979, pg A-1) the peak of the first sidelobe is 0.4 degrees below the horizon. This vertical angle has also been reported as 0.6 degrees below the horizon (MITRE 2000, pg 6).

We are unsure how much of the power is concentrated in the main beam. It has been reported as 60% (AF 1979, pg A-2) and as 90% (MITRE 2000 pg 6).

MITRE (2000) report includes two references I have not obtained, but which are of particular concern.

> MITRE (2000b) The Synthesis of an Antenna Pattern Meeting Pave Paws Constraints," MITRE Corp., Memo. D710-002927, 05 April 2000.
>
> AFMC 1996, "Computer Program Product Specifications for Tactical Application Software CPCI 2 Type B-5, Specification," No.G264302-2 Code Ident: 66401, HQ AFMC SSSG/SDWSE, 21 February, 1996.

The first reference prompts the question: Why would MITRE be concerned about the constraints of the PAVE PAWS station or the antenna pattern more than 20 years after the station became operational unless changes in the operational characteristics, specifically the antenna pattern, were being considered? The measurements made by BSL (BSL 2004b) are not consistent with the originally specified antenna pattern, but are consistent with an antenna whose minimum angle is 0.75 degrees above the horizon, instead of the 3.0 degrees specified, an apparent shift of 2.25 degrees (see below). The a [illegible] easurements is consistent with an antenna pattern different than that published in [illegible] ironmental impact statement (AF 1979, Appendix A).

The second reference concerns specifications for a computer program for controlling the [illegible] ars into the operation of the station, is a specification being written [illegible] the operational characteristics of the station are going to be made? The [illegible] ference raises the question: "What is different about the new [illegible]ation and when was the specification implemented, and how does that change the human exposure?" A change in the human exposure should not occur without a full environmental review.

Outside interference from amateur radio seems to have become an issue recently. After years of coexistence in this frequency band, the Department of Defense has forced amateur radio repeaters to reduce their power from 50 watts to 5 watts. This supports concerns that the human exposure from PAVE PAWS operation is different than previously existed.

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Taken together, there is reason to doubt that the information made public in 1979 is still true, and no account has been made as to when, how, or why these changes were made, or how they affect the human exposure.

Exposure Enhancements Omitted

5 5.2 The attenuation of radio frequency energy is discussed in Appendix E, but a discussion of enhancements has been omitted.

One of the characteristics of electromagnetic radiation is the trapping of energy in buildings. The phenomenon is discussed in NRC 1979a, p47: "Enclosed structures, such as rooms, may act as lossy resonators with electromagnetic fields being coupled from windows. If such structures have highly reflecting walls, field enhancements by one or two orders of magnitude may indeed be possible." One or two orders of magnitude confer a ten to one-hundred fold enhancement. The NRC advises: "Further research into the reflection characteristics of these structures is needed in order to describe precisely the nature of field enhancements." This phenomenon may be particularly problematic for the school buildings in line-of-sight of PAVE PAWS, which have second or third floors, and metal structural components.

On highly conducting ground, deposition rates for the legs may again be 5-10 times the whole body average (NRC 1979a, p47). A metallic sheet is the ideal "highly conducting ground," but salt water moistened sand (beach setting) is a good conductor too. Orientation would be an important factor, and since water tends to favor horizontal polarization, a person lying down (on the beach, a rescue board, or a surfboard) may experience the most absorption.

There is even the potential for enhancement for two or more persons standing close to one another.

Energy Deposition Rates Omitted

6 5.3 The DSEIS makes no mention of enhanced energy deposition rates in the human body.

An Air Force sponsored report, "Analysis of the Exposure Levels and Potential Biologic Effects of the PAVE PAWS Radar System," prepared by the National Research Council (NRC 1979a) identified several potential biologic effects mentioned in that report are of concern in the context of Ewing's sarcoma.

An electrical field (dimension volts per meter) will produce a force on an object possessing an electrical charge. The electrical field of the PAVE PAWS radiation rotates; the term given this characteristic is "circular polarization. It is appropriate to conclude that any orientation of the human body or limbs will be so aligned at some time so that the maximum effect of the electrical field will be experienced.

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"The highest rate of energy deposition occurs in fields that are polarized parallel to the longest dimension of the body" …and "the longest dimension is approximately 0.36-0.40 times the free space wavelength of radiation." (NRC 1979a, p45). With PAVE PAWS wavelengths in the range 23.6 to 27.6 inches, this condition is met for dimensions 8.50 to 11.0 inches, the approximate length of bones in arms, legs, and pelvis of children, sites commonly effected by Ewing's sarcoma. In free space, the neck, legs, and torso absorb considerably higher energy, perhaps 5-10 times the whole body average (NRC 1979a, p46).

Those arguing that PAVE PAWS radiation is safe generally concentrate on exposures averaged over time, and ignore the fact that peak radiation is 4000-6000 times the temporal average. With respect to Ewing's sarcoma, it is only necessary to create one chromosome translocation error which goes unrepaired to establish carcinogenesis. Furthermore, much of the research in biomedical effects cited to demonstrate radiation at these wavelengths is safe has been conducted with mice and rabbits, neither of which have bone lengths tuned to the higher rates of energy deposition discussed above.

Radiation at the PAVE PAWS wavelengths is capable of penetrating 4.5 centimeters through muscle tissue before being reduced to 37% of the value at the skin (Osepchuk 2001, Table 1). This is adequate to penetrate the muscle surrounding the bones, and may reach deep into the limbs where Ewing's is thought to originate. While written to tout the safety provided by existing standards, particularly with respect to cell phones, the paper reveals values for radiation at PAVE PAWS frequencies that are a cause for concern with respect to bones.

Enhanced Search Mode Omitted

The attacks of September 11, 2001, would be expected to have an effect on the operation of PAVE PAWS. It was from this Air Force Base that fighter planes were dispatched to New York City. Not knowing what was happening, or where the next attack was coming from, it is reasonable to expect the radar operational envelope would be pushed to the maximum. A description of an "enhanced search" mode which may have been implemented on 9-11 and the following days is given in NAS 1979b p24: "The most nearly regular and systematic operating mode of the radar is called enhanced search. In this mode, the main beam visits successively 120 different positions at 3 degrees above the horizon, seeking targets at maximum range. This scan is not interrupted for other functions and repeats approximately every 2.5 seconds. This is then a mode in which the greatest exposure is likely to occur at nearby points on the ground and is the most nearly repetitive pattern of pulses."

Normally, the surveillance pattern repeats every 41 seconds, so the enhanced search mode repeating every 2.5 seconds produces a human exposure over 16 times the normal.

7 5.4 The enhanced search mode of operation was not mentioned in the review of PAVE PAWS potential health effects (NRC 2005, MITRE 2000) or the present DSEIS.

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Requests for Monitoring Ignored

8 In AF 1979 requests for continuous environmental monitoring were made by two secretaries of the Office of Environmental Affairs, the Cape Cod Planning and Economic Development Commission, the Cape Cod Environmental Coalition, the Conservation Law Foundation, a representative in the General Court, and other concerned citizens.

5.3 There remains a need for continuous long term monitoring of the radiation from PAVE PAWS. In time such data could identify variability in the signal characteristics, effects of atmospheric inversions, atmospheric refraction, reflections from elements of the infrastructure such as water towers, power lines, the power plant smokestack, etc. In time, it should be possible to statistically predict the probability of exceeding a certain signal strength threshold.

Many potential environmental hazards are subject to monitoring, spanning installations as mundane as residential septic systems to complex nuclear power plants. The PAVE PAWS radar station has been given a "free pass" with respect to environmental monitoring, and the public will have no reason to believe PAVE PAWS is being operated according to the assurances we have been given until continuous monitoring is instituted.

Peak Intensity of Pulses Ignored

9
6.6 This DSEIS continues to ignore concerns among scientists and the public over potential health effects from intense pulsed rf electromagnetic radiation such as the PAVE PAWS radar. The Radio Frequency Interagency Work Group in commenting on the IEEE 1999 standard addresses these concerns with the following remarks. "Time-averaging erases the unique characteristics of an intensity-modulated RF radiation that may be responsible for producing an effect." "Time averaging for other features of RF exposure is not necessarily desirable, however, and should be reevaluated specifically as it deals with modulation of the signal, contact and induced current limits, and prolonged, or chronic exposure." (RFIAWG 1999). Remember that for children living at home, chronic exposure means 24 hours per day, 168 hours per week, not the 8 hours per day, 40 hours per week common in the work place.

The pulses were also of concern to the panel of experts convened to advise the Massachusetts Department of Public Health. "The pulsed nature of the PAVE PAWS signal generates high intensity of extremely short duration. However, during the pulse, RFR intensities are relatively high. Therefore, peak levels are of interest, and the available information on peak levels should be examined." "To avoid underestimating exposure, exposure assessments, whether by calculation or measurement, should be based on the level when the beam is present." (MDPH 1999).

In support of the Air Force EIS process, Broadcast Signal Lab received a contract to measure peak and average radio frequency emissions from the PAVE PAWS radar. But

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when the report was written and reviewed, the peak data were not plotted and were not compared with the specifications of the radar. BSL offers what may be construed as a rationale for not analyzing the peak emissions. In discussing the average exposure model (BSL 2004b, p56) they state: "No separate model of the peak emissions was performed because the peaks are not a function of the antenna pattern or propagation. Rather they appear to be distributed in a general way that in best described statistically as discussed in section 2.3.5. [sic 3.4.5?]."

This writer respectfully disagrees. The peak signal emissions represent a real exposure, are a valid concern to the southeastern Massachusetts community and the scientific community (RFIAWG 1999, MDPH 1999), and represent a potential cause for biologic effects not yet understood or identified. The peak measurements require an analysis, so that we may understand the complete picture of the exposure. Furthermore, an analysis by this writer (see below) suggests the peak measurements may not appear to be a function of antenna pattern and propagation laws because the beam has been shifted below its specified limit and the highest half of the peak and average measurements themselves were subject to an instrumentation error and are fatally flawed. (Young, 2008).

It is hard to comprehend how the PAVE PAWS Public Health Steering Group, its technical advisors, the National Research Council, and the Air Force could have allowed this peak data to be ignored.

Scargo Tower Consistent with Main Beam

10 No attempt was ever made to compare the peak measurements made by Broadcast Signal Lab in 2004with the signal strength which can be predicted from the published specifications for the radar (AF 1979) and the basic theory of electromagnetic wave propagation. Concerned about high peak signal strength measured in Dennis, at the Scargo tower, this writer undertook a comparison of the Scargo measurement with the theoretical prediction. The result (Young, 2006) revealed that the measurement was 46% of the peak of the main radar beam, and 46 times too large to be from the weaker first sidelobe which is the only part of the signal which reportedly can contact the ground
6.9 (Figure 1). The Scargo measurement is consistent with a signal near the center of the main beam.

A further analysis of all 50 sites shows measurements at ten sites lie outside the published antenna pattern, but within the pattern which has been artificially shifted downward 2.25 degrees (Young, 2007). The measurements have the characteristics of an instrumentation error which would result in the measurements being less than the true values.

2004 Measurements Subject to Instrumentation Error

11
6.9 In BSL 2004b little discussion of the peak power flux density values was made. The peak results were tabulated, and used in a comparison of peak to average signal strength, but were never plotted separately or compared with theoretical prediction expected to be

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11 quite good (AF 1979, Appendix A). In BSL 2004a path losses from the transmitter to the 50 test sites were computed, but never applied in such a comparison.

A semi-log plot of peak signal strength vs. distance from the antenna was prepared by this writer and is shown here in Figure 2. The data exhibit several characteristics of interest. Below 0.1mW/cm^2 (microwatts per square centimeter), the data is scattered. Above this scattered data a value of approximately 0.15mW/cm^2 was measured at 13 sites. There is a solitary measurement of 0.95uW/cm^2 measured at test site 1, the Provincetown monument parking lot. Above this a value of approximately 1.5mW/cm^2 was measured at 9 sites. The level of this group of 9 is approximately ten times the level of the group of 13. Still higher, at a level of approximately 15.0mW/cm^2, is a group of 5 measurements. Again, the level of this group of 5 is approximately ten times the level of the group of 9 at 1.5mW/cm^2, and 100 times the level of the group of 13 at 0.15mW/cm^2. There are 27 sites whose peak power measurements are near these three values. This result can be seen without engineering analysis by visually scanning the peak values in
6.9 BSL 2004b Table 2. The average values exhibit similar characteristics, albeit with more scatter as weak signals from adjacent radar beams contribute to the temporal average at a site but do not change the peak.

There is a recognized instrumentation error which explains this data: amplifier saturation. The output of every amplifier has an upper limit beyond which its output is not reliable. If the input signal tries to drive the output above this level, the amplifier becomes saturated, meaning its output is limited by its design characteristics independent of the input; the output is constant, or nearly so. This is more likely to occur if, during the measurement, signals were encountered that were higher than anticipated. The resulting signal is said to be "clipped" as if the crest of a wave were just "clipped off" to a level value. The peak signal measurements have characteristics that are indicative of saturated amplifiers and clipping.

This clipping is not restricted to the peak signal measurements. Since the peak *and* average signals pass through the same signal conditioning instruments, any clipping which occurred in the peak measurement would be reflected in the average measurement. In a case of clipping, the true value is higher than the value produced by the instrumentation.

Ahead of the peak and average power meter an attenuator and two microwave preamplifiers in series were used to condition the signals. Analysis of the data files reveals that when the strongest radar signals were encountered, attenuation was introduced lowering the net gain to 20 dB. When the gain was 20dB, the power meter returned values at 5 sites clustered about 5 dBm (dB referenced to 1 microwatt). When weaker signals were encountered less attenuation was inserted resulting in a gain of 30 dB. At 9 of 10 sites where the gain was 30 dB, the power meter returned values clustered about -5 dBm. For the weakest signals, no attenuation was employed producing a net gain of 40 dB. The 13 highest values were clustered about -15dBm. The result is illustrated in Figure 3 where the power measured by the power meter is plotted from smallest to largest. The levels which could not be exceeded because the last amplifier

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was saturated produce a staircase effect. The lower values at the left form a ramp and are not subject to saturation and are not clipped. When the clustered power measurements (-15, -5, 5 dBm) are converted (applying the effective antenna area, antenna gain, and line losses, and converting from decibel to linear values) the resulting power flux density values are clustered at 0.15, 1.5, and 15 microwatts per square centimeter.

At each of the 50 test sites six measurements were usually made, 292 total. Converting the reported values back to the output of the final preamplifier ahead of the power meter shows 143 of the 292 measurements were clustered at 25 dBm, the maximum output of the preamplifier at 1 dB compression, the "knee" where the clipping effect becomes significant. This result is seen in Figure 4 where values of preamplifier power output measured by the power meter is again plotted from smallest to largest. This is similar to Figure 3 but the complication of gain has been eliminated, and all data, not just the largest peak measurement at a site are presented. The 143 clipped measurements are seen concentrated along the level of the maximum specified output of the preamplifier.

BSL Response to Reanalysis

12 BSL was aware that this writer had found the peak power flux density reported in BSL 2004 to have exceeded the specifications of the radar at 10 of the 50 sites. They were
6.9 aware of concern about Scargo Tower where the excess was 17 dB (a factor of 46). They were also aware of concerns about clipping.

In the 2007 draft test protocol (BSL 2007a) for measurements in support of the MDPH investigation of Ewing's sarcoma on Cape Cod, BSL attempted to rebut this writer's findings:

> "We explained in our original PPHSG report that these peak levels were not necessarily strictly the power levels of the highest radar pulses, but could be instantaneous peaks of energy either from radar pulses and/or other in-band, or near-band emissions. The durations and sources of these measured instantaneous peak values are not known." (BSL 2007a, Pg 1)
>
> "In the initial 2004 study for PPHSG, Broadcast Signal Lab employed a calibrated apparatus to collect average and instantaneous peak power measurements at each site." (BSL 2007a Pg 2)

No figures, calculations, or photographs of instrumentation displays were offered to support this position.

I am unable to reconcile these statements with statements BSL made in their 2004 report. A scan of BSL 2004a and 2004b did not find the term "instantaneous peak" anywhere in either report.

Are these instantaneous peaks of energy from other in-band or near-band emissions? A scan of BSL 2004b for mention of possible interferers reveals the following comments:

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1) "Amateur Radio Operation in Band Caused no Interference to Measurements." Conclusion 10 on page 61.
2) "Out of Band Interference Not Significant." Conclusion 11 on page 61.
3) "measurement sites were chosen to be away from the location of potential interferers." Page 6 of Appendix A.
4) "should a passing mobile transmitter overload the preamplifier for a brief period, this event can readily be ascertained upon examining the recorded data. ... To date, only one data record has been identified in which such is the case." Page 6 of Appendix A.
5) "Additional photographs were made showing the PAVE PAWS waveforms in both the frequency and time domain to illustrate 1) normal operation of the radar, 2) the absence of in-band interference,..." Page 11 of Appendix A.
6) "It was determined that the relative amplitudes of the in-band Amateur Radio signals were well below the levels of the PAVE PAWS signals being measured." Page 17 of Appendix A.

A reader of BSL 2004b has every reason to believe that the peak power flux density measurements were, in fact, measurements of the PAVE PAWS radar.

A question about potential interference was raised during discussion of the test plan (BSL 2004a), to which BLS responded:

> "Yes, BSL is particularly concerned that the measurements not be corrupted by inband or out-of-band emissions. To this end, we have been conducting pre-test field evaluations of our measurement apparatus in order to determine the specifications needed for our bandpass filtering. On 16 and 17 December 2003 trial measurements were performed at 14 locations on the upper and lower Cape. We have identified not only the filtering requirements, but also the expectations for dynamic range of our system. The test system components will be swept for loss, linearity, and band-pass/reject characteristics. A serendipitous feature of a radar transmission is that it is "turned off" for more time than it is on. That is, there are ample opportunities to measure any extant interference to our radar measurements between pulses of the radar. Our power measurement instrumentation is sufficiently fast that non-pulsed energy in the measurements can be discriminated from the radar pulses. In addition to careful real-time monitoring of the spectrum with a spectrum analyzer while the measurements are taking place, additional review will be performed in the postprocessing of the data to insure PAVE PAWS measurements are not corrupted by in-band interference. At this time there is no need to conduct tests in which the radar is turned off on command." (BSL 2004a, Pg. 175)

In response to another question:

> "Similarly, any received spike-like emissions of the radar are dependent on the orientation of the observation point and a given beam-pointing angle. While spikes by nature are broadband, putting energy into a wide

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> spectrum at once, they are also by nature transitive and low in energy per frequency. These characteristics will make spike-related interference, if any, difficult to corrupt an average power measurement of an ambient emission; and If it does it will be readily identified." (BSL 2004a, Pg. 178)

Rather than explaining how the 2004 peak data was from potential interferers, the 2004 test plan and report repeatedly explain the measurements would not be subject to interference from other sources. In the explanation offered in the 2007 test protocol, no calculations or pictures of instrumentation displays were presented to support the hypothesis of an interferer. No interferers with power, gain, and distance from the measurement site necessary to produce these instantaneous peaks were identified. Nor was it explained how such interferers would produce instantaneous pulses that were so brief as to not corrupt the average signal measurements. Potential interferers would be broadcasting continuously (in the cast of broadcast transmitters) of for seconds (in the case of mobile communications), not millionth's of a second. Long signals from interferers as large as the peaks reported in 2004 would certainly have corrupted the average measurements, upon which the credibility of the entire NRC health assessment depended.

It is incomprehensible that the Air Force would have allowed other transmitters over a broad area emitting signals larger than the PAVE PAWS radar. Remember the amateur radio operators were forced to lower their power from 50 watts to 5 watts.

Furthermore, If the durations of the "instantaneous" values are not known, it cannot be concluded that they are brief or "instantaneous." This apparent self-contradiction should be resolved. BLS 2004b was, after all, a report of PAVE PAWS emissions, not emissions from unidentified, hypothetical interferers.

BSL continued to respond to this writer's concerns and defended their 2004 procedures:

> "To ensure we were not clipping our instrumentation, we observed the radar pulses on the spectrum analyzer for a period of time until we had discerned the probable maximum received pulse power. The instrumentation was set to accommodate that maximum, with additional headroom, while ensuring the noise floor remained at a usefully low level. If any clipping occurred in the instrumentation, as hypothesized by Mr. Young, it is not likely to have been from the radar pulses, based on our setup practices. Rather, because the instrumentation was broadband (30 MHz) and the peak power sensor was looking for instantaneous peaks, there is a possibility that apparent peaks may heve been detected that were higher than the peaks of the radar pulses." (BSL 2007a, Pg4)

The data files refute this claim. At test site #20, the Sandwich public library, 2.08 miles from the radar, the first measurement taken with a gain of 30 dB saturated the preamplifier with output of 24.74 dBm. The gain was then increased to 40 dB for the next five measurements yielding 24.81, 24.85, 24.64, 24.58, and 24.60 dBm! Not only

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does this ill advised increase in gain prove that clipping occurred, it suggests that sufficient attention was not always being paid to the resulting data being logged.

Comparison of 2004 to Previous Measurements Erroneous and Deceptive

The DSEIS states "The study also compared the measurements from the current survey [BSL 2004b] with those taken in 1978 and 1986. Overall, the previous studies' measurements appear to be generally higher than the current measurements." (AF 2008, p 4-5,6). The 2004 test report states "The 1986 measurements taken at three sites similar to 2004 locations were consistently higher than the 2004 measurements." BSL 2004b, p 36.

13
6.9 The 2004 measurements at sites similar to the 1979 and 1986 sites were all subject to the clipping instrumentation error and are not valid. In cases where this error occurs, the true power flux density is greater than reported. The data cannot be used to support the conclusions in the previous paragraph.

Furthermore, it is erroneous and deceptive to assert that 2004 measurements were less than 1986 measurements, the Scusset comparison being a counter-example.

In 2004, measurements were taken at two Scusset Beach Parking sites, #22 and #23, at a range of 2.6 miles. They were compared to a measurement at Scusset pier at a distance of 1.8 miles. Since power flux density varies as the inverse square of the distance, the base value at Scusset Beach Parking should be 48% of the values at the Scusset pier.

BSL 2004b p J3 notes of site #22 "Site near canal in shadow of canal electric power plant" and notes of site #23 "Unobstructed site in parking lot, in second row of [sic] facing east." BSL 2004b Table 2 gives a power flux density peak of 1.54 microwatts per square centimeter and average of -37.1 dB microwatts per square centimeter for site #22. Table 2 gives a power flux density peak of 15.0 microwatts per square centimeter and average of -24 dB microwatts per square centimeter for site #23. It was deceptive to compare the value of site #22 "in shadow of the canal electric plant" to the 1986 value for Scusset pier when a measurement at unobstructed site #23 was available. Note the peak values for Scusset Beach sites belong to the set of clipped values (0.15, 1.5, 15 microwatts per square centimeter) discussed above.

From Figure 1 we see that the peak power flux density for unobstructed site #23 exceeded the antenna pattern specified in AF 1979 by about 7 dB, a factor of 5. It should be pointed out that the Scusset pier site falls in the null between the first and second side lobes and should be very small.

Cape Cod Ewing's Sarcoma Cluster Cannot be Ignored

In 2002, 2003, and 2004, a dramatic increase in Ewing's sarcoma on Cape Cod occurred (Figure 5). The cases are found at two ensembles where higher PAVE PAWS emissions have been measured; the ensembles are separated by a high population density area shadowed from PAVE PAWS where lower emissions are found. The three cases in the

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Mid-Cape ensemble were diagnosed in 2003 and 2004. One case from the Mid-Cape ensemble and one from the Upper Cape were diagnosed the same month in 2004.

Most of the Ewing's cases have little or no terrain between them and PAVE PAWS. Valley locations or locations on the sides of hills away from PAVE PAWS are an exception. Only two cases have terrain interference, but the individual in one of these cases may lie in a particularly strong signal path, attended two schools in that path, and was employed as a lifeguard during recent summers with frequent outdoor exposure in a large open area with no terrain interference. Many of the Upper Cape cases live at high elevations (3 cases within 15 vertical feet of Scargo Tower) on a large plateau. Three Upper Cape cases lie at depression angles (the angle below the horizon of the center of the PAVE PAWS antenna) within 0.03 degrees of the peak of the first sidelobe of radiation from PAVE PAWS which is found at 0.4 degrees.

East of the Sandwich-Barnstable border, the land slopes gradually to sea level at the Bass River, the boundary of Dennis and Yarmouth. Hyannis, Yarmouth, and northern Centerville (communities of high population density) are in the shadow of the aforementioned high plateau. Not surprisingly, low signal strengths were reported by BSL in this area. No Ewing's cases were found in this shadow region.

East of the Bass River, the elevation again rises, and much of the area emerges from the shadow of the upper cape plateau. The path from PAVE PAWS now passes over the Great Salt Marsh of Barnstable, or Cape Cod Bay. Here the signal strength increases, even though the distance is much further. It is here that we encounter three more cases of Ewing's.

Two beams from the two faces of PAVE PAWS meet along the 106 degree radial. Near that line the beams widen. To improve the "peripheral vision," four times as many pulses are transmitted near that line. The exposure along that line is thus eight or more times that received by the general population (MITRE 2000). Sandwich Higit School, Dennis-Yarmouth Regional High School in South Yarmouth, and the Ezra H. Baker School in West Dennis lie near that line. A young man who attended Sandwich High School and who succumbed to Ewing's in January, 2007, attended Sandwich High prior to his diagnosis; a young woman who attended D-Y High (and Ezra Baker) succumbed to Ewing's in January, 2008. Both were diagnosed at the same clinic within days of one another, in December 2004. Both were accomplished athletes, used to performing with aches and pains, and whose diagnosis was delayed. This suggests that carcinogenesis in these two cases may have occurred at a time nearer to the earlier cases than date of diagnosis would suggest. Three cases occurred in 2003, and one in late 2002 (see Figure 5); the six cases were diagnosed over a 26 month period. Eight childhood cases have been identified by concerned citizens over a ten year period, and an additional case in 2005 has been identified by the Massachusetts Department of Public Health (MDPH 2007); there have also been adult cases.

MDPH 2007 included a report (BSL 2007b) on PAVE PAWS peak power flux density measurements at the homes and other places associated with the Ewing's cases. It is the

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opinion of this writer and several epidemiologists that the study was fatally flawed from the outset. Of greater concern is that the report ignored the fact that control sites measured in 2007 and 2004 had 40-300 times higher measurements in 2004 than 2007. At six sites, peaks measured in 2007 were less than averages measured in 2004. Peaks should be on the order of 6000 times averages.

Other Concerns

While we don't know their true value, the electrical field components published in 2004 are about 1/100 the value used in the electrophoresis technique commonly employed in DNA analyses for basic research and DNA identification. The mobility of DNA in cytoplasm is greater than in the gels used in DNA analysis. Typical cell dimensions are several orders of magnitude less than electrophoresis channels. Ewing's is the result of known translocation errors so any factor which can manipulate DNA should cause concern. Preliminary estimates by this author suggest that a strand of DNA may be moved 1/3 the width of a cell during a pulse. The circular polarization may produce an effect comparable to putting DNA strands in a blender. There is a need for basic research in this area. A comprehensive literature review of micronucleus assay studies was suggested in RFIAWG 1999 because of the relevance to carcinogenesis.

The radar exposure typically consists of two pulses 8 milliseconds long or three pulses 5 milliseconds long and continually repeated every 41.04 seconds, 24 hours per day, 365 days per year. However, the radar may be operated in an "enhanced search mode" where the repetition is repeated every 2.5 seconds, increasing the exposure about 16 times normal. Occasional operation in this mode, either for test purposes or in response to a perceived military threat (such as 9/11), is of special concern, and may explain the temporal distribution of the Cape Cod Ewing's sarcoma cluster in 2002-2005. The possible significance of 9/11 on the operation of this radar station should be taken seriously.

In 2002 another environmental impact statement (AF 2002) was prepared for an upgrade of PAVE PAWS computer hardware and software, but not a change in power or operational characteristics. This was termed the Service Life Extension Program or SLEP. Clearly, the advances in electronics hardware, and the inability to maintain outdated hardware made such an upgrade attractive.

It is entirely possible that the operating envelope of PAVE PAWS could be altered (for example by lowering the main beam elevation) relatively easily, and relatively quickly. The possibility has come with the qualifier that there was no incentive, as that would cause other operational difficulties (NRC 1979b p 58).

However, it is likely that the state of the art of phased array radar has advanced in the 25+ year life of this radar station. It is possible that opportunities for improved performance given the existing antenna array and power limitations have been identified. It is possible that the station was or is being used temporarily as a test platform for new control strategies.

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One strategy for controlling phased array radar is to generate multiple beams for multiple tasks or targets. This would likely come with a loss of the narrow focus of the radiation pattern. Protections originally provided to minimize exposure on the ground would likely be compromised.

Radar is vulnerable to outside interference (jamming) from any vehicle which could deliver a sufficiently controlled and powerful radar signal. Vehicles which may have this capability are in the U.S. fleet, and could be engaged in jamming and countermeasure experiments, exposing the Cape Cod population to bi-directional radiation exposure in excess of that we have been experiencing previously.

It is also possible that phased array radar could be used as a low-level electromagnetic pulse weapon. PAVE PAWS has been reported to have "shot down" a helicopter which strayed too close. The phased array technology is used in the "Active Denial" device, a HUMVEE mounted radar which burns human skin at a distance of 1500 feet.

Such reasonable speculation could have been replaced with hard data if the 1979 requests for continuous environmental monitoring had been honored.

Comments

It is this writer's professional opinion that the power flux density of the pulses at any point within the scanned sectors can be predicted from the specifications of the radar and the laws of electromagnetic wave propagation. The free space prediction was given in AF1979a and the ability to compute path losses was demonstrated in BSL 2004a.

It is this writer's professional opinion that the power flux density from the PAVE PAWS radar can be measured reliably. A diligent measurement program would include comparison of the measurements with predicted values, and an interpretation of those results.

It is this writer's opinion that the PAVE PAWS radar station has been given a "free pass" with respect to environmental monitoring in spite of requests from the community. Continuous monitoring would allow the exposed population to know whether or not the radar exposure is consistent with predictions.

Conclusions

14 The DSEIS is not responsive to the concerns of the scientific community and local community about potential health effects from the intense pulses emitted by the PAVE
6.6 PAWS radar.

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15 Peak measurements were made to support the DSEIS, but were ignored. Had they been analyzed, it would have been apparent that several exceeded the published specifications
6.9 for the radar, and that approximately half of both peak and average power measurements were corrupted by instrumentation error. We still do not know the true value of the human exposure to PAVE PAWS radar emissions. Further exposure predictions or epidemiologic analyses using this data are fatally flawed.

The goal of the EIS process is to assure the public that the proponent's activity can be conducted without harm to the environment. Reviewing the research supporting the Draft Supplemental Environmental Impact Statement shows levels of electromagnetic radiation, in spite of being under-reported due to instrumentation error, exceed previously
16 published specifications for the radar station. A statistically significant excess of Ewing's sarcoma has temporal and spatial relationships to the radar operation that was
6.10 missed in the epidemiologic study supporting the DSEIS. However, in the intervening three years there was ample opportunity to consider the Cape Cod Ewing's sarcoma cluster.

A final EIS which relies on this flawed research cannot be published.

Need for Further Investigations

1) A diligent review of the work reported by Broadcast Signal Lab, particularly the power flux density measurements, must be conducted by a credible independent third party.
2) An explanation must be provided as to when and why the PAVE PAWS specifications have changed.
3) A complete description of the radar operating modes and their resulting human exposure must be provided.
4) Environmental Impact reviews required by changes in specifications or operational characteristics which changed environmental exposure must be conducted.
5) BSL measurements of the peak and average values of power flux density at the 50 sites visited in 2004 must be replicated by a credible independent third party during the winter when vegetative cover is minimal.
6) Further research as described by the NRC in 1979 regarding enhanced exposure in buildings, such as the schools located in high exposure areas, must be conducted for frequencies in the 420-450MHz band.
7) An independent party should be asked to assess the possibility that the PAVE PAWS radar station has been used as a test platform for new control strategies, for multiple beam operation, for use as an electromagnetic pulse weapon, and for use in radar jamming and countermeasures experiments.
8) An independent party must assess potential for aiming the PAVE PAWS main beam below the 1 degree elevation where advantages of ducting may be realized. The technology available since this was last dismissed 30 years ago casts doubt that the previous conclusions are still valid.

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9) A program to conduct independent, continuous monitoring of the PAVE PAWS radiation must be established as has been done for other potential hazards in the environment. This must include instrumenting a fixed site and providing mobile equipment to identify "hot spots" or to investigate exposure at particularly significant sites, such as schools and beaches.
10) Finite Difference Time Domain (FDTD) modeling of anatomically well scaled models of humans in sizes from infancy through adulthood must be conducted. It is crucial that the complete characteristics of the radar field as experienced by humans be accurately modeled. This study must include postures of the fetal position and sitting, as well as standing. It must also identify enhancements due to multiple persons positioned at critical spacings.
11) An effort must be made to analyze the growth of Ewing's tumors so that bounds can be estimated for the time interval prior to diagnosis at which carcinogenesis may have occurred.
12) Possible etiologies associated with potential biologic effects in bones from PAVE PAWS radiation must be evaluated as possible causes of the Ewing's translocation error.
13) The continued research must take place with full public view, and that participation by interested parties must be allowed.

Sincerely,

Bernard J. Young, P.E.

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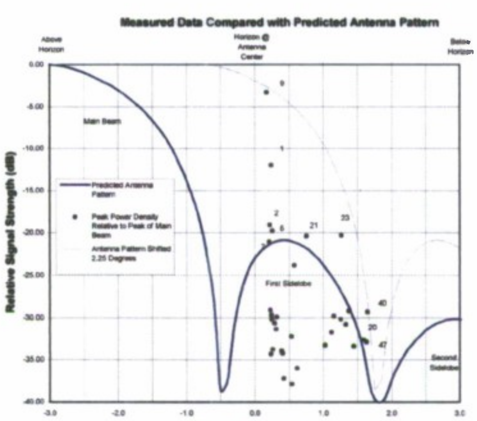

Figure 1: Measured peak signal strength relative to the peak of the main beam. Measurement site identification numbers are shown for sites exceeding predicted levels (AF 1979). Data above the antenna pattern is outside the specifications. The theoretical predicted antenna pattern has been arbitrarily shifted by 2.25 degrees so that all data falls within the envelope of the antenna pattern. Such a shift is a plausible cause for the higher signal strengths encountered.

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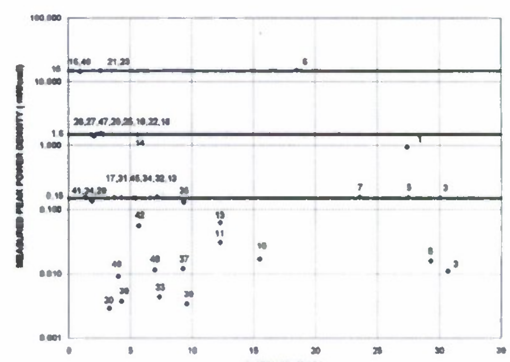

Figure 2: Semi-log plot of peak power measurements vs. distance from PAVE PAWS antenna, from BSL 2004b data reproduced here in Table 1. Numbers adjacent to data points identify the test site.

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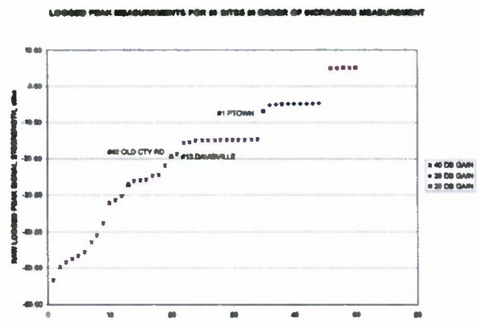

Figure 3. Peak signals from BSL data disk arranged in order of increasing value. The staircase effect and the gaps in between steps is an indication that the preamplifier was operated at too high a gain resulting in the amplifier saturation and measurement "clipping." For the flat steps, the sum of the value logged plus the gain is 25dBm, the maximum output of the preamplifier.

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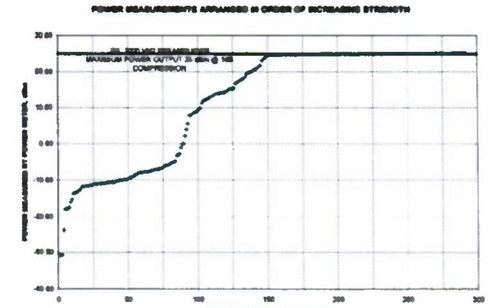

Figure 4. Measured power output form final microwave preamplifier arranged from smallest to largest. Of 292 measurements logged, 143 had the maximum output of the preamplifier. The true values are higher than reported.

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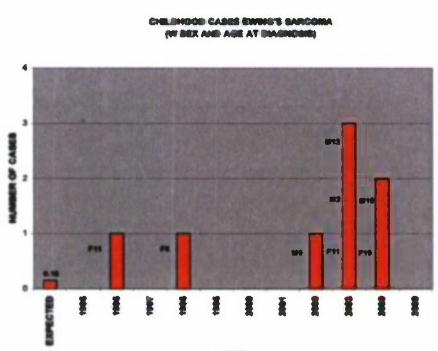

Figure 5: Histogram showing the temporal distribution of Ewing's sarcoma cases, the sex, and age at diagnosis. The expected occurrence is also shown.

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From:
Sent: Friday, August 01, 2008 3:37 PM
To: Neuman, Lynne E Civ USAF AFSPC AFSPC/A4/7P
Cc: Burnett, Barbara JS Civ 6 SWS/PA
Subject: Question related to PAVE PAWS SEIS

1
4.5 I have a question as to the repetition rate(Rep rate) in the tracking mode of PAVE PAWS. Is it the same as the basic 54 msec cycle of the system? I assume that it is, but wanted to check it out with you. I am interested in the rate for distant vehicles low on the horizon. I believe that the signal is a chirp.

I can be reached by phone on 508-430-1560. Please place me on the mailing list for the final SEIS, but I would hope to get an answer from you before then. Thank you.

Richard S. Perry, Ph.D.

-----Original Message-----
From: Burnett, Barbara JS Civ 6 SWS/PA <barbara.burnett@capecod.af.mil>
To: oceanperry@aol.com
Sent: Tue, 22 Jul 2008 11:44 am
Subject: RE: Pave PAWS public health Draft SEIS: e-mail attachments are same as color handouts I mailed you.

Good morning, Mr. Perry,
Glad to hear you received the report and e-mail. The color handouts I tucked in the front cover of your SEIS report are printouts of the attachments I e-mailed you, so you don't need to ask your kids to download them.

You're very welcome for the information. Thank you for calling to ask; I understand it's difficult to drive to evening meetings, and Bourne is a long drive from Harwich especially with summer traffic.

May I ask that you e-mail your questions about track mode to Lynne Neuman to be answered as part of the final SEIS? That's the process through which she's arranging for subject matter experts to be available to look at, and answer questions about the radar's public health impact. Her contact information is:

OA
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HQ AFSPC/A4/7PP
150 Vandenberg Street, Suite 1105
Peterson AFB, CO 80914-2370

Geological oceanography sounds like a fascinating career. I can only imagine the sights, experiences you've had with NOAA. Thanks for giving me a new vocabulary word, "multi-beam," meaning phased array.

Sincerely,
Barbara

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Document 10

Barbara J.S. Burnett, Community Liaison
6th Space Warning Squadron at Cape Cod Air Force Station
Tel: 508-968-3283, DSN 557-2283, <mailto:Barbara.burnett@capecod.af.mil>
Barbara.burnett@capecod.af.mil

From:
Sent: Tuesday, July 22, 2008 10:37 AM
To: Burnett, Barbara JS Civ 6 SWS/PA
Subject: Re: Pave PAWS public health Draft SEIS public comment thru 4Aug08. Mailed spiral-bound copy, and handouts 17July08.

Dear Barbara:
I received the report yesterday and your E-mail message this morning. It says something about attachments, but I haven't figured out how to get them out of the system(google). Perhaps my kids can help me out on that. Thank you very much for your help.

As to the rep rate in the tracking mode, there is a good description of the cycles of the system in Chapter Four of the National Research Council Report (P.39) under the heading "waveform generation". It indicates that the system goes through a series of 17 consecutive cycles of 54 msec each, then is silent during an 18th cycle of calibration. During each cycle there is a transmitting pulse(s) of up to 16 msec duration, then the remainder of the time is spent listening for the return echo and signal processing. In the search mode, the beams are constantly moving, so no one place gets more radiation than a typical FM station gives out.

It doesn't say anything, however, about the tracking mode. I assume that the system goes through the same 54 msec cycles, putting out signals of up to 16 msec duration and then listening for the return. The outgoing pulses during the2016 msec transmission are apt to contain a series of frequency changes known as a "chirp", with each frequency change being either higher or lower than the one before, much like stair steps. My question is whether these chirped signals are directed at the vehicle in each successive 54 msec cycle during the tracking, or is there a longer interval of several cycles between chirps. Logic indicates that it is sending out a chirped signal directed at the vehicle once during each successive 54 msec cycle. If you go out to look at the indicators showing electrical load in the powerhouse, you should see the power load increase significantly during the tracking mode.

The question could be answered easily by a tech who maintains the system, but not necessarily by someone who is watching the big screens, because the systme is designed to be totally automatic. You can reply by the internet or mail. My internet address of "   " derives from being a retired geological oceanographer, who spent most of my career working for NOAA. Because sonar and radar are of similar design, I am quite used to phased array systems and radio transmissions. In the oceanographic world, we call phased array systems "multibeam".

Thank you for all your help. I was sorry to have to hang up so soon, but my mobile phone needs a new battery, so the present one starts beeping at me after about 10-15 minutes of use. I check my e-mail everyday or so, and am usually home to get phone calls.

Richard B. Perry

2

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PUBLIC COMMENTS RECEIVED OUTSIDE OF THE COMMENT PERIOD

The following comments were received approximately 8 months after the public comment period ended (ended August 4, 2008). These comments are included as part of the official record for the Final SEIS for the Pave PAWS Early Warning Radar Operation, Cape Cod AFS, Massachusetts and were provided to the decision makers in accordance with 40 CFR Part 1503 for their consideration prior to completion of the ROD.

Document 11

From: Sherry Milham
Sent: Wednesday, April 01, 2009 10:23 AM
To: Neuman, Lynne E Civ USAF AFSPC AFSPC/A4/7P
Cc:
Subject: PAVE PAWS March 2009 EIS

Dear Ms Neuman,

I'm a medical epidemiologist who has been following the PAVE PAWS story since its inception (my CV is attached). I'd be very surprised if there were no detrimental health effects due to this antenna. There is another powerful government antenna in Massachusetts, a LORAN antenna on Nantucket Island. There are a lot of animal and human data suggesting that radio frequency radiation is carcinogenic. Looking at available cancer incidence data for Mass. counties and towns makes me even more suspicious about these antennas.

The National Cancer Institute state cancer profiles website: http://statecancerprofiles.cancer.gov/incidencerates/index.php shows that for the 14 Mass. counties 2001-2004, all races and both sexes, Barnstable (PAVE PAWS) and Nantucket (LORAN) counties have very high cancer incidence rates for total cancers and selected cancers. Nantucket and Barnstable rank 1 and 2 of the 14 Mass. counties for total cancers. Nantucket county ranks first of the 14 counties for all cancers, female breast cancer, colon/rectal cancer and prostate cancer. Being a small population county, data was not available for many uncommon cancers. Barnstable county ranked second of the 14 Mass. counties for all cancers, first for leukemia and urinary bladder cancer, second for brain cancer, malignant melanoma of skin, and prostate cancer, and third for female breast cancer.

The excellent Mass. Cancer registry city and town series: http://www.mass.gov/?pageID=eohhs2terminal&L=7&L0=Home&L1=Consumer&L2=Physical+Health+and+Treatment&L3=Diseases+%26+Conditions&L4=Cancer+and+Benign+Brain+Tumors&L5=Data+and+Statistics&L6=City+and+Town+Series&sid=Eeoh allows closer look at the towns around PAVE PAWS, and at Nantucket Island which is also a town as well as a county for the years 2001-2005.. The three towns around PAVE PAWS, Barnstable, Sandwich and Bourne each have a significant elevation of total cancers. Barnstable has a significant excess of malignant melanoma, pancreas and prostate cancer, and Sandwich has a significant elevation of malignant melanoma leukemia, prostate, and urinary bladder cancers. Nantucket Island has significant elevations of total cancers, malignant melanoma, female breast and colon/rectal cancer and prostate cancer.

Months ago, I suggested to the Mass. State Health Dept that they spot map these cancers by address at diagnosis to see if they congregate around the antennas. I have had no response,

It's ironic that that Air Force and others have spent millions and many years chasing after 14 Ewings sarcoma cases, when a general cancer epidemic has been staring them in the face.

in 4.26 the claim is made that "...no evidence of adverse health outcomes in animal or human studies...."
Here is my abstract of a $4.5 million rat study done at the University of
Washington on an US Air Force Contract in the mid-1980s. It presents strong evidence that low level, long term, radiofrequency radiation stimulates the immune system and is a potent carcinogen: Effects of long term low-level radiofrequency radiation exposure on rats. Kunz, LL, Chou CK, Guy AW. Prepared for USAF School of Medicine, Aerospace Medical Division (AFSC), Brooks Air force Base Texas 78235 USAFSAM TR-85-11

One hundred germ-free rats exposed to pulsed 2450 MHz circularly polarized microwaves at an average power density of 0.48 mW/cm2 (1) showed elevated T and B cell counts in mid-life (Figure 1 Attached)). Splenic lymphocytes responded in vitro to T and B cell mitogens with higher stimulation indexes in the exposed animals for 4 of 5 different mitogens. Also, 18 of 100 exposed rats developed cancer compared to 5 of 100 sham exposed controls. Nine of the 18 primary malignancies were present in the endocrine glands (adrenal, pituitary, thyroid and thymus) compared to 1 in the sham exposed rats. There also were 7 benign adrenal pheochromocytomas in the exposed rats compared to 1 in the controls. There were 36 metastatic cancers in the exposed rats compared to 18 in the sham exposed controls, with a striking excess of malignant lymphoma (17 in the exposed rats vs. 1 in the sham exposed animals). There were significantly more total non-neoplastic lesions in

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the exposed rats and in the organs (skin, brain, eye, lacrimal gland, liver) of the exposed rats than in the sham exposed controls.

On p S-6 The following statement is wrong: "The AFEB did not identify any evidence suggesting a cause-and-effect relationship between the county or town level elevated standardized rate ratios of disease in Massachusetts and the PAVE PAWS phased-array system. There was no immediate indication to support either initiation of new, or further analysis of existing epidemiological investigations of the association between radiofrequency energy emissions from the PAVE PAWS facility and any specific health outcome"

Best, Samuel Milham MD, MPH

Document 12

From: Sherry Milham
Sent: Wednesday, April 01, 2009 10:32 AM
To: Neuman, Lynne E Civ USAF AFSPC AFSPC/A4/7P
Cc:
Subject: Pave Paws EIS

Dear Lynne, My last E-mail got sent before I completed it. I'd like to add the following to my comments:
On p S-7 the following statement is also unbelievable:
"The evaluation concluded that there is currently no credible evidence for adverse
health effects associated with the operation of the PAVE PAWS radar system.
Rates for most of the cancers that initially led to concerns about possible adverse
health effects from PAVE PAWS radar exposure were found to be elevated on
Cape Cod prior to 1978 when the PAVE PAWS facility began operation"
Since the Mass. cancer registry didn't begin collecting data until 1982, how could cancer rates on the Cape be evaluated before 1978?

Sam Milham MD

Document 13

From:
Sent: Sunday, April 12, 2009 3:49 PM
To: Neuman, Lynne E Civ USAF AFSPC AFSPC/A4/7P
Subject: Comments on PAVE PAWS SEIS, 2009
Attachments: pave paws Final SEIS.doc

Dear Ms. Neuman,

Attached please find our comments on the Final Supplemental EIS for PAVE PAWS Early Warning Radar Operation Cape Cod Air Force Stations, Massachusetts. We request that you include these comments in the official legal SEIS process and documentation. We urge AF and MDA decision makers to re-read our previous comments that we have submitted throughout the numerous NEPA/EA/EIS/SEIS processes that began as far back as 1999 regarding the continued operation of PAVE PAWS on Cape Cod.

Cape Cod was an ill-chosen site for PAVE PAWS in 1979 due to the close proximity to a large population that has grown tremendously over the last 30 years. Cape Cod has a history of high cancer rates including the epidemic of Ewings Sarcoma that has yet to be explained. Given the AF and MDA's long-term plans for PAVE PAWS continued operation, it would be prudent to re-locate the Cape Cod PAVE PAWS operation to a remote location where residents would not be exposed to the phased array radiation that has not been adequately studied.

Sincerely,
Richard Judge
Former Sandwich Selectman

Sharon Judge

Document 13

April 10, 2009

Ms. Lynne Neuman
HQ AFSPC/A7PP
150 Vandenberg St. Suite 1105
Peterson AFB, CO 80914-2370
Fax: 719-554-3849
e-mail: Lynne.Neuman@Peterson.af.mil

RE: SUPPLEMENTAL EIS FOR PAVE PAWS EARLY WARNING RADAR OPERATION CAPE COD AIR FORCE STATION, MASSACHUSETTS

We are extremely disappointed in the EIS processes for the Cape Cod PAVE PAWS and resulting SLEP EA, Draft and Final Supplemental Environmental Impact Statement (SEIS). The Air Force (AF) reported in the media that they spent $6.5 million on the EIS/SEIS processes and AF funded studies. This was as waste of good taxpayer dollars that could have been spent on relevant time-domain measurements and analytical epidemiological studies that could have provided real evidence of safety or harm.

The AF took the NEPA regulations that were designed to allow a public voice in the process and spent millions of taxpayer dollars and man hours to circumvent and manipulate the NEPA process and minimize the public input and effectiveness. A fine example of this was that the public comments that were printed in the SEIS were minimized in size such that 4 one-page documents were printed on each page resulting in such small print that it is very difficult to read and much of the comments are lost.

The AF throughout the EIS processes and documents including the Draft and Final SEIS repeatedly minimized the extent of public concern over the long-term health effects of exposure to PAVE PAWS phased array radiation. In fact, a multitude of public officials including our MA federal delegation (Senators Kennedy, Kerry and Congressman William Delahunt) were extremely concerned, as were local elected officials and citizens. They were especially concerned that no studies had been done since the original EIS was completed in 1979. Senator Kennedy and the federal delegation in the late 1970's called for the original EIS and were still very concerned in the late 1990's to call for a new EIS.

The public and elected officials from the beginning of the new EIS processes which began in 1999 with the National Missile Defense (NMD) EIS Programmatic EIS and AF SLEP EA in 2000, called for an independent analytical epidemiological study using time-domain measurement data that included true-peak pulse measurement data. We wanted the epidemiological study to understand personal exposure in the home, work and school environments since people are not stationary and move around their community. We wanted true peak measurements as that is what Cape Codders are exposed to 24/7.

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We urged that the Silent Spring Institute that was already in place and had spent years doing analytical epidemiological work on the breast cancer incidence on Cape Cod carry out this work.

We expected an independent EIS process that would be done in a timely fashion that would provide the long-awaited studies and a process and resulting documentation that the public and elected officials could understand. This was not to be the case. The AF went ahead and broke the process down into a SLEP EA, and began what they insisted was an "iterative" process that would include multi-processes that the average citizen and elected officials could not follow or understand. This Final SEIS does not even mention that the Missile Defense Agency (MDA) formally the National Missile Defense Agency (NMD) did there own EIS process and supplement for PAVE PAWS. The MDA will be basing their decision on this AF SEIS whether or not to move ahead with their plans to upgrade and use the Cape Cod PAVE PAWS in the missile defense architecture.

There were multiple EIS processes going on at the same time by different agencies and it has been impossible for citizens and elected officials to understand and effectively participate in the various processes. In addition to the NMD EA and EIS processes and the AF SLEP EA process, the AF also did an EA for the Milstar System they added to the Cape Cod PAVE PAWS site and the Defense Satellite Communication System (DSCS) which was also added to the site.

The Scope of the SEIS process was very narrow especially due to the fact that the scoping process had been done so long ago in 2000 and 2003 before new data had come to light such as the Ewings Sarcoma epidemic on Cape Cod.

The AF and MDA dismissed the option to move PAVE PAWS without adequately studying this alternative. We had pointed out on numerous occasions that the Texas and Georgia PAVE PAWS had been disassembled and moved to a more remote location in Alaska. The AF announced their cost savings in a press release. The AF did not adequately investigate the option of a sea-based platform for PAVE PAWS and did not include it as an alternative.

We continuously pointed out throughout the various NMD/MDA and AF EIS processes in oral testimony at public meetings and hearings and in written comments that the Cape Cod community had grown extensively and there were people living and recreating within a mile of PAVE PAWS and that it should be moved to a remote location. This was especially important given the fact that the MDA also had long-term plans for the Cape Cod PAVE PAWS in their missile defense architecture.

The PAVE PAWS Public Health Steering Group (PPPHSG) was not independent. See our comments in the Draft SEIS that notes the AF (General Pavlovich) interfered in the public process. For instance the PPPHSG asked for time-domain measurements to be used in the study; however the AF's General Pavlovich sent a letter to the PPPHSG refusing to fund this request. The AF also insisted on a descriptive epidemiological study (vs. an analytical study).

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The PPPHSG administrative secretary and personnel were under AF direction/control. This control was a sticking point for the Barnstable County Commissioners who would not partner with the AF because they would not have the independence they required. For instance all mail received from the public, independent scientists, etc. was received and reviewed by the AF first (not the PPPHSG). There were also AF representatives on the PPPHSG that were very vocal and would often control the so-called public meetings.

The National Research Council (NRC) process was also not independent due to AF funding and control. Please re-read our comments in the previous EA, EIS and PPPHSG and NRC proceedings.

There was extreme AF interference in the silencing of AF researcher and medical doctor, Richard Albanese, MD throughout the EIS process and earlier when Dr. Albanese contacted the Massachusetts Department of Public Health with his medical concerns regarding PAVE PAWS. Dr. Albanese had been involved with the PAVE PAWS health issue since the 1970's. AF officials interfered in Dr. Albanese's presentation of his research to the NRC, his efforts in the AF's limited time-domain measurement effort and communication at public meetings including the PPPHSG as well as written communication. Dr. Richard Albanese is not mentioned once in the SEIS despite the fact that the MA federal delegation called for time-domain measurements to be taken based on the briefing they requested and received by Dr. Albanese on the research he lead on the Electromagnetic Health and Safety Program (EHS).

Numerous adverse actions were taken by AF management against Dr. Richard Albanese for speaking publicly as a private citizen on the PAVE PAWS issue. Dr. Albanese pointed out to officials and the public that a ground wave had been measured in the community surrounding PAVE PAWS but AF management denied this. The AF did not perform a data analysis of any of the AF's own time-domain measurement data. Dr. Albanese provided personally computed data to the NRC that was not included in the SEIS as well as his personal medical concerns that were also not included in the SEIS.

There is a fatal mathematical error in the data analysis of the BSL measurements of 2004. The resulting statistical data used by the AF in the SEIS as well as critical medical statistics and descriptive epidemiological data are fatally flawed as noted by leading epidemiologists.

The Air Force and Missile Defense Agency decision makers will be making their decisions on faulty information. There is still no evidence of safety more than 30 years after PAVE PAWS began operating that Cape Codders' health is not affected adversely affected by continuous long-term exposure to phased array microwave radiation from the Cape Cod PAVE PAWS.

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We urge you and the AF and MDA decision makers to re-read the comments we have provided in the Final SEIS (from our original documents in 1999 through the current SEIS documentation).

Thank you for the opportunity to comment.

Richard Judge
Former Sandwich Selectman

Sharon Judge

cc. President Barack Obama
Senator Edward Kennedy
Senator John Kerry
Rep. William Delahunt

Document 14

From: Bernard Young
Sent: Friday, April 10, 2009 2:22 PM
To: Neuman, Lynne E Civ USAF AFSPC AFSPC/A4/7P
Subject: RE: Comments, PAVE PAWS Final Supplement EIS
Attachments: 2009 04 10 PAVE PAWS- COMMENTS on FINAL SEIS.doc; PP19 9-59-26 AM.txt; SITE 19-1 JARVIS RD SANDWICH.xls

Dear Ms. Neuman:

Thank you for forwarding the PDF version of the subject SEIS.

I have yet to receive the paper copy I was expecting.

I am disappointed the public comments were shrunk to fit four pages into space for one. Some of the information they contain has been lost.

I have attached three files in response to the notice published in the Federal Register. They consist of a DOC file containing my comments, a TXT file from BSL, and an XLS spreadsheet recomputing the data contained in the TXT file and evaluating a systematic mathematical error.

Sincerely,

Bernard J. Young, P.E.

— On Mon, 3/30/09, Neuman, Lynne E Civ USAF AFSPC AFSPC/A4/7P
<Lynne.Neuman@PETERSON.af.mil> wrote:

> From: Neuman, Lynne E Civ USAF AFSPC AFSPC/A4/7P
> <Lynne.Neuman@PETERSON.af.mil>
> Subject: RE: Final Supplement EIS
> To: bjyoung716@yahoo.com
> Date: Monday, March 30, 2009, 11:31 AM
>
> Mr Young,
>
> The link is:
>
> http://www.peterson.af.mil/shared/media/document/AFD-090318-067.pdf
>
> You will also be mailed a hard copy.
>
> Regards,
> Lynne
>
> Lynne Neuman
> HQ AFSPC/A4/7PP
> 150 Vandenberg St, Ste 1105
> Peterson AFB, CO 80914
> Comm: (719) 554-6406
> DSN: 692-6406

4/21/2009

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Fax: (719) 554-3849

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-----Original Message-----
From: Bernard Young
Sent: Sunday, March 29, 2009 9:14 PM
To: Neuman, Lynne E Civ USAF AFSPC AFSPC/A4/7P
Subject: Final Supplement EIS

Ms. Neuman:

Please provide the correct address from which the public may download the subject document, Final Supplement Pave Paws Early Warning Radar Operation Project, Continued Operation of the Solid-State Phased-Array Radar System (SSPARS), also known as Pave, Phased Array Warning Systems (PAWS), Cape Cod Air Force Station, MA.

The address reported in the Cape Cod Times is for a 2006 letter from the PPPHSG to the Air Force.

Thank you.

Bernard J. Young, P.E.

4/21/2009

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Bernard J. Young, P.E.
REGISTERED PROFESSIONAL ENGINEER

August 3, 2008

Lynne Neuman
HQ AFSPC/A4/7PP
150 Vandenberg St.
Suite 1105
Peterson AFB, CO 80914-2370

Lynne.Neuman@Peterson.af.mil

Dear Ms. Neuman:

Please give these comments on the Final Supplemental Environmental Impact Statement March 2009 for PAVE PAWS Early Warning Radar Operation Cape Cod Air Force Station, MA, your careful consideration.

There is a mathematical error in the data analysis which continues to be widespread throughout the report on PAVE PAWS emissions, BSL 2004.

What Is Wrong?

An error in computing averages, median, and standard deviation results from inappropriately extending the mathematical property of *distributivity of multiplication over addition*. Distributivity is so fundamental is taken for granted; elementary and secondary students apply it long before they learn that it has a name. You will recognize it as intuitively obvious:

$$k\,(a+b+c\ldots) = ka+kb+kc+\ldots, \qquad (1)$$

where k, a, b, c, … are real numbers. It is valid in some other algebras, but it is not valid over the transcendental functions: sine, cosine, logarithm, to name a few.

For example,

$$\sin(a+b+c) \neq \sin a + \sin b + \sin c; \qquad (2)$$
$$\log(a+b+c) \neq \log a + \log b + \log c. \qquad (3)$$

In fact, one useful property of logarithms is

$$\log a + \log b + \log c = \log(abc). \qquad (4)$$

Now it is common in scientific fields which routinely analyze data ranging over several orders of magnitude, such as electronics and acoustics, to transform such data to the decibel scale, which is a logarithmic scale. There are two primary reasons for doing this. First, you can compress the data and see many orders of magnitude on a manageable graph. Second, adding decibels is equivalent to multiplying, and addition is more easily

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performed by man and computer than multiplication. The latter property is derived from equation (4) above.

The decibel transformation is

$$dB\ x = 10 \log x, \qquad (5)$$

where log is the common base ten logarithm.

The inverse decibel transformation is

$$x = 10\text{^}((dB\ x)/10) \qquad (6)$$

where "^" is the exponentiation operator, raising to a power.

These transformations are not distributive, because taking a logarithm or raising to a power not distributive.

It can be seen throughout BSL 2004, eg. Table 1, Page 7, that the average, median, standard deviation, minimum, and maximum of a set of decibel values are presented. This is readily done in a spreadsheet program which has functions to perform these tasks. However, these functions presume the arguments, the data on which they operate, are linear scalar quantities.

This error in not made consistently. For example, Table A6.2 from BSL2004, pages A35-36 show the six average power flux density measurements at each site, and their averages. The average values are correctly computed by converting the six individual decibel scaled measurements to their linear values before computing the average, and then converting that result back to a decibel scaled value. However, the standard deviation is computed with the decibel values.

How Bad is the Resulting Error?

In the case of a single decibel quantity, there is no error. The maximum and minimum functions return a single value without computation, so there is no error. The median function will return the correct decibel value for an odd number of members in the sequence, since a single number can be identified without computation for which the number of members of the set that are larger is equal to the number of members of the set that are smaller than the median value sought.

The standard deviation uses the average, so if the average is wrong, the standard deviation is wrong. The standard deviation also involves exponentiation (squaring). The usefulness of the standard deviation metric when applied to decibels values is dubious, since it yields unstable results, and any attempt to convert the standard deviation of decibel values to a linear scaled value is meaningless.

Given a set of decibel values, to properly compute the average one must apply the inverse decibel transform (6) to each member of the set to recover the linear scalar value, add the linear values, and divide by the number of values in the set. The operation of computing an average (arithmetic mean) is well understood. If the range between minimum and

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maximum of a set of decibel values is small, the error is small. If the range is large, as it is with most of the PAVE PAWS data, the error is large.

If one takes the average (arithmetic mean) of decibel scaled values and converts the result to a linear scale value, one gets the geometric mean. This result derives from equation (4) above. The geometric mean is always less than the arithmetic mean unless all values in a set are equal. Thus, taking the average (arithmetic mean) of decibel values is misleading.

This error is illustrated by considering a select set of 7500 data for Site 19, Position 1, 9:59:26, Jarves Rd., from the data disk delivered to Barnstable County Health Department with BSL 2004. The data logged at test time is contained in a text file and is attached herewith. I have imported that data into a spreadsheet and computed the average, median, and standard deviation of the decibel scaled data in the file and obtained the same results as entered in the text file. The average given at the bottom of the text file is -65.17 dBm (decibels relative to one milliwatt) and I confirmed that it is the average of the three columns (C, D, and E), 7500 points each, of decibel scaled values. I highlighted the results in yellow. I have added columns G, H, and I, converting decibel scaled values to linear values before averaging. Converting back to decibel scale yielded a result of -46.87 dBm, highlighted in green. The error results in under-reporting the average by -18.30 dBm, a factor of 1/67.57, highlighted in red. This is a significant error. It was repeated in 292 data files.

Peak Measurements

The inference is made that the "peak" measurements reported io BSL are brief. While one sample may be brief and consist of only 22 cycles, about half the values "measured" were nonetheless clipped, so we have no idea just how intense they were. This has not been refuted. No evidence is offered that these "peaks" were brief, or that they were encountered just once at each site. There is no evidence that they did not occur several times, or for a continuous for a substantially longer interval. To assume that only one brief 22 cycle occurred, and that it always coincided with a 22 cycle interval is wishful thinking.

Reference to the MDPH Report

To say that the MDPH report on PAVE PAWS and Ewing's sarcoma (MDPH 2007) is thoughtful and thorough is an uniformed lay opinion, is erroneous, and is of little value. Numerous environmental epidemiologists have described the MDPH effort as "fatally flawed." These concerns were first voiced immediately upon publication in December 2007, and have been recently communicated to the Secretary, Executive Office of Health and Human Services, Commonwealth of Massachusetts.

These flaws include matching the index and comparison testing sites on factors of distance and elevation, both related to emission levels, failure to estimate historical

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emission levels that may have been higher in the past, and possible interference when emissions were measured (a new explanation offered by BSL).

There are many factors built into the 2007 study which make the comparison (control) site measurements stronger than the index (Ewing's) measurements.

The comparison (control) site selection packed several sites at high elevations nearer to the radar than the nearest Ewing's case residence. Average, median, standard deviation, and minimum values of comparison sites were greater than for index (Ewing's sites). Only one comparison (control) was chosen further from the radar than the farthest Ewing's case, by only 0.5 miles out of 23.

Focusing on the average distance masks the fact that signal intensity diminishes as the square of the distance from the radar transmitter.

There is a vast area of Cape Cod where no Ewing's has occurred, and where no measurements were taken.

No histories were taken of the Ewing's cases which may have identified other locations where significant exposure may have occurred, including multiple residences and other schools.

Vegetative clutter (an attenuating factor more significant in summer, when the measurements were made, than in winter) exists for many of the Ewing's sites; clutter is less significant in several of the high elevation comparison (control) sites with the highest measurements.

The 2007 measurements were taken at ground level. Many of the index residences have second floor sleeping areas. The schools have two and three story classrooms. Near the ground a significant increase in signal strength with increasing elevation is to be expected (that is why TV antennas are mounted on chimneys). Measurements would be more sensitive to elevation at an index site than an exposed control site.

The measurement technique evaded the peak pulses measured in 2004, establishing a new peak metric about 1/100th of the peak levels reported in BSL 2004. The true intensity of those peaks was under-reported in 2004 due to a measurement error, even if that error didn't effect the 2004 average measurements. Had the correct average of the peaks reported in 2004 been computed, we would see that they are about 350 times higher than the peaks measured in 2007.

Whatever the cause, those Intense peaks of 2004 are part of the human exposure. The "Panel of Experts" (MDPH 1999) explained the importance of measuring peak data. No one was aware at that time that there are peaks above peaks. These larger peaks (averaged over 22 cycles) should have been accurately characterized as to intensity and duration during the 2007 measurements.

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Conclusion

In view of the fact that half of the peak values are underreported due to clipping, and the averages in the raw data files have been computed incorrectly, as has much of the tabulated data in BSL 2004, it is my opinion that the Air Force has not met its obligation to evaluate the potential health effects from PAVE PAWS radio frequency emissions. Futhermore, it is my opinion that to pursue the completion of the Environmental Impact process with data knowingly corrupt may be construed as arbitrary and capricious.

Sincerely,

Bernard J. Young, P.E.

Two attachments

References

BSL 2004. (Broadcast Signal Lab), A Survey of Radio Frequency Energy Field Emissions from the Cape Cod Air Force Station PAVE PAWS Radar Facility: Final Test Report, prepared for PAVE PAWS Public Health Steering Group by Broadcast Signal Lab, Medfield MA. 2004.

MDPH 2007, Evaluation of the Incidence of the Ewing's Family of Tumors on Cape Cod, Massachusetts and the PAVE PAWS Radar Station, Massachusetts Department of Public Health, December 2007.

MDPH 1999. Erdreich, Linda, Om P. Ghandi, Henry Lai, Marvin C. Ziskin, Assessment of Public Health Concerns Associated with Pave Paws Radar Installations. Report prepared for the Massachusetts Department of Public Health, November 1, 1999.

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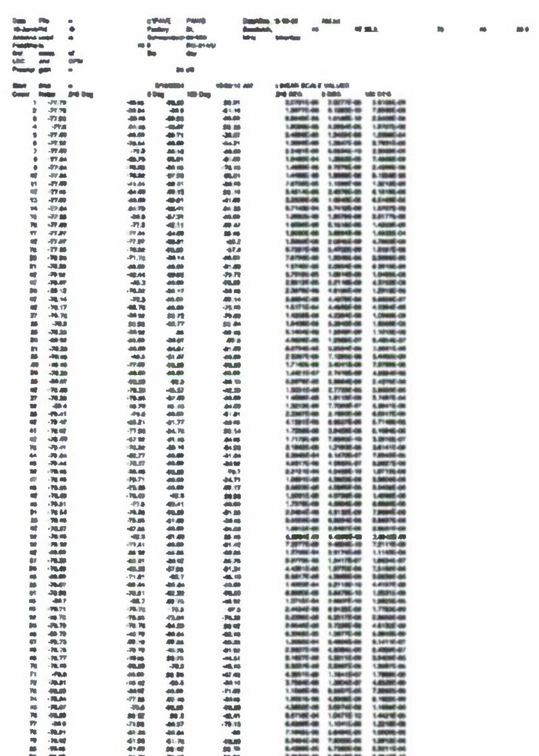

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APPENDIX A

NOTICE OF INTENT

[Federal Register: January 27, 2000 (Volume 65, Number 18)]
[Notices]
[Page 4406]
From the Federal Register Online via GPO Access [wais.access.gpo.gov]
[DOCID:fr27ja00-22]

DEPARTMENT OF DEFENSE

Department of the Air Force

Notice of Intent To Prepare an Environmental Impact Statement (EIS) for Actions To Sustain Operability of Air Force Space Command PAVE PAWS Radar Sites at Cape Cod Air Station (AS), Massachusetts (MA); Beale Air Force Base (AFB), California (CA); and Clear Air Station (AS), Alaska (AK)

Pursuant to the National Environmental Policy Act (NEPA) of 1969, as amended (42 U.S.C. 4321, et seq.), The Council on Environmental Quality (CEQ) Regulations for Implementing the Procedural Provisions of NEPA (40 CFR Parts 1500-1508), and Air Force policy and procedures (32 CFR Part 989), Air Force Space Command (AFSPC) intends to prepare an EIS for the Service Life Extension Program (SLEP) actions to modernize the facilities at the PAVE PAWS (Phased Array Warning System) radar sites located at Cape Cod AS, MA; Beale AFB, CA; and Clear AS, AK.

The current proposal includes replacements of electronic equipment and computer software in the PAVE PAWS Early-Warning Radar facilities. The EIS will assess all impacts as they relate to these replacements, including emission of radio-frequency energy. AFSPC will be the lead agency for the EIS. The Ballistic Missile Defense Organization has been invited to be a cooperating agency. AFSPC is planning to conduct public scoping meetings to determine the issues and concerns that should be addressed in the EIS. Notice of time and location of the scoping meetings will be made to public officials, agencies and announced in the news media in areas where the meetings will be held. For further information concerning the proposed replacements of electronic equipment and computer software in the PAVE PAWS Early-Warning Radar facilities at Cape Cod AS, MA; Beale AFB, CA; and Clear AS, AK, contact Mr. George Gauger, HQ AFCEE/ECA, 3207 North Road, Brooks AFB, TX 78235-5363.

Janet A. Long,
Air Force Federal Register Liaison Officer.
[FR Doc. 00-1976 Filed 1-26-00; 8:45 am]
BILLING CODE 5001-05-U

[Federal Register: July 22, 2002 (Volume 67, Number 140)]
[Notices]
[Page 47776-47777]
From the Federal Register Online via GPO Access [wais.access.gpo.gov]
[DOCID:fr22jy02-40]

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DEPARTMENT OF DEFENSE
Department of the Air Force

Air Force Space Command

AGENCY: Department of the Air Force, DoD.
ACTION: Amendment of the notice of intent to prepare an Environment Impact Statement for actions to sustain operability of Air Force Space Command early warning radar sites at Cape Cod Air Force Station (AFS), Massachusetts (MA); Beale Air Force Base (AFB), California (CA); and Clear AFS, Alaska (AK).

SUMMARY: The Air Force hereby amends its notice of intent to prepare an Environmental Impact Statement (EIS) for Service Life Extension Program (SLEP) action at the Early Warning Radars located at Cape Cod AFS, MA; Beale AFB, CA; and Clear AFS, AK, as published in 65 FR 4406, published 27 January 2000. The Air Force intends to prepare a Supplemental EIS to the 1979 EIS on the Operation of the PAVE PAWS Radar System at Otis AFB, MA. The Supplemental EIS will address concerns over the possible health effects from operation of the early warning radar at Cape Cod AFS. The Supplemental EIS will be prepared pursuant to section 1502.9(c) (2) of the Council on Environmental Quality regulations and will include, among other information, the results from ongoing studies and efforts that are addressing concerns related to radio frequency energy (RFE) from the radar. These studies and efforts include a National Research Council study; an RFE survey at Cape Cod, MA; an exposure assessment using the results of the RFE survey; a waveform characterization study; and a review conducted by the Armed Forces Epidemiology Board. The Air Force made the decision to prepare a Supplemental EIS following a review of the SLEP EIS process. The review was prompted by the decreasing availability of spare parts for the early warning radars and increasing concern that the radars were becoming unsupportable due to a lack of spare parts. Through the review process, which took into account comments received during public scoping meetings, the Air Force determined that public concerns centered around the possible health effects arising from operation of the radars, rather than from the proposed action of replacing outdated computer hardware and rehosting software. Replacing computer hardware and rehosting software will not change the amount or characteristics of the radio frequency energy being transmitted by the radar. Based on present calculations, which may change, the Air Force anticipates releasing a draft Supplemental EIS in 2004, approximately six months after the results from the last of the studies is scheduled to be published. The Air Force will prepare site-specific

environmental assessments (EAs) for the SLEP actions of replacing computer hardware and rehosting software at each of the three early warning radar sites. Notices will be published in local newspapers when the EAs are available for public review.

FOR FURTHER INFORMATION CONTACT: Mr. Robert Novak, HQ AFSPC/CEVP, 150 Vandenberg Street, Suite 1105, Peterson Air Force Base, CO 80914-2370, Fax 719-554-3849.

Pamela D. Fitzgerald,
Air Force Federal Register Liaison Officer.
[FR Doc. 02-18363 Filed 7-19-02; 8:45 am]
BILLING CODE 5001-05-P

APPENDIX B

SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT MAILING LIST

APPENDIX B

SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT MAILING LIST

This list of recipients includes interested federal, state, and local agencies and individuals that have expressed an interest in receiving the document. This list also includes the governor of Massachusetts as well as United States senators and representatives and state legislators.

ELECTED OFFICIALS

Federal Officials

U.S. Senate

The Honorable Edward Kennedy
United States Senator
2400 JFK Building
Boston, MA 02203

The Honorable John Kerry
United States Senator
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Boston, MA 02114

U.S. House of Representatives

The Honorable William Delahunt
Representative in Congress
146 Main Street
Hyannis, MA 02601

Representative Delahunt's Office
Attn: Mr. Mark Forest
146 Main Street
Hyannis, MA 02601

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Governor

The Honorable Deval Patrick
Governor of Massachusetts
State House, Room 360
Boston, MA 02133

State Legislature

The Honorable Demetrius Atsalis
State Representative
State House, Room 187
Boston, MA 02133

The Honorable Matthew C. Patrick
State Representative
State House, Room 540
Boston, MA 02133

The Honorable Jeffery D. Perry
State Representative
State House, Room 136
Boston, MA 02133

The Honorable Susan Williams Gifford
State Representative
State House, Room 540
Boston, MA 02133

The Honorable Cleon Turner
State Representative
State House, Room 540
Boston, MA 02133

The Honorable Therese Murray
State Senator
State House, Room 511-C
Boston, MA 02133-1053

The Honorable Ruth W. Provost
State Representative
State House, Room 26
Boston, MA 02133

The Honorable Robert O'Leary
State Senator
State House, Room 421
Boston, MA 02133-1053

The Honorable Eric T. Turkington
State Representative
State House, Room 473-F
Boston, MA 02133

Local Officials

The Honorable Catherine O'Bumpus
Town Selectman
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Falmouth, MA 02540

The Honorable Carol A. Cheli
Bourne Board of Selectmen
24 Perry Avenue
Buzzards Bay, MA 02532

The Honorable Ahmed Mustafa
Town Selectman
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The Honorable John Cahalane
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Mashpee, MA 02649

The Honorable Thomas Keyes
Town Selectman
19 Shaker House Road
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The Honorable Kevin Murphey
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The Honorable Wayne E. Taylor
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The Honorable Carey M. Murphy
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The Honorable Virginia Valiela
Town Selectman
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GOVERNMENT AGENCIES

Federal Agencies

Advisory Council on Historic Preservation
Executive Director
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Old Post Office Building
1100 Pennsylvania Avenue, NW
Washington, DC 20240

Center for Environmental Health and Injury Control
Centers for Disease Control
Attn: Director
1600 Clifton Road, NE
Atlanta, GA 30333

Department of Commerce
Office of Intergovernmental Affairs
Attn: Director
Commerce Building, Room 5414
Washington, DC 20230

Department of Health and Human Services
Office of Human Development Services
Attn: Director
200 Independence Avenue, SW, Room 324-F
Washington, DC 20201

Federal Aviation Administration
Attn: Director
800 Independence Avenue, SW
Room 939, FOB-10A
Washington, DC 20591

U.S. Department of the Interior
Office of Environmental Policy and Compliance
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Main Interior Building, MS 2340
1849 C Street, NW
Washington, DC 20240

U.S. Environmental Protection Agency
EIS Filing Section
Ariel Rios Building, Room 7241W1
1200 Pennsylvania Avenue, NW
Washington DC 20044

Regional Offices of Federal Agencies

Advisory Council on Historic Preservation
Eastern Regional Office
Attn: Director
Old Post Office Building, Suite 803
1100 Pennsylvania Avenue
Washington, DC 20004

U.S. Fish and Wildlife Service
Region 5
Attn: Chief, Division of Endangered Species
300 Westgate Center Drive
Hadley, MA 01035

U.S. Environmental Protection Agency
Region 1, New England
Attn: Regional Administrator
JFK Federal Building
Boston, MA 02203

U.S. Environmental Protection Agency
Region 1, New England
Attn: Timothy T. Timmerman
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Boston, MA 02203

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Sagamore, MA 02561-0428

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Missile Defense Agency
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Navy Annex
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Alexandria, VA 22202

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Brooks City-Base, TX 78235-5112

HQ AFSPC/A4/7PP
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Peterson AFB, CO 80914-4320

HQ USAF/A3S
1480 Pentagon
Washington, DC 20330-1480

HQ USAF/A7CIB
Crystal Gateway 1, Suite 1000
1235 Jefferson Davis Highway
Arlington, VA 22202

U.S. Army Space and Missile Defense Command
P.O. Box 1500
Huntsville, AL 35807-3801

U.S. Coast Guard
384 Woods Hole Road
Woods Hole, MA 02543

U.S. Coast Guard
Air Station Cape Cod
Attn: Commanding Officer
Otis ANG Base, MA 02542

State Agencies

Executive Office of Environmental Affairs
Attn: Ellen Roy Herzfelder, Secretary of Environmental Affairs
251 Causeway Street, Suite 900
Boston, MA 02114

Massachusetts Department of Conservation and Recreation
Attn: Commissioner
251 Causeway Street, Suite 600
Boston, MA 02202

Massachusetts Department of Environmental Protection
Attn: Commissioner
1 Winter Street
Boston, MA 02108

Massachusetts Department of Environmental Protection
Southeast Regional Office
Attn: Gary S. Moran, Regional Director
20 Riverside Drive
Lakeville, MA 02347

Massachusetts Department of Public Health
Attn: Paul Cote, Commissioner
250 Washington Street
Boston, MA 02108-4619

Massachusetts Historical Commission
State Historic Preservation Officer
Attn: Executive Director
220 Morrissey Boulevard
Boston, MA 02125

Local Government Agencies

Barnstable County Health Department
Attn: Director
Superior Court House, Box 427
Barnstable, MA 02630

Bourne Board of Health
24 Perry Avenue
Bourne, MA 02532

Falmouth Board of Health
59 Town Hall Square
Falmouth, MA 02540

Mashpee Board of Health
Town Hall
16 Great Neck Road North
Mashpee, MA 02649

Mashpee Board of Selectmen
Town Hall
16 Great Neck Road North
Mashpee, MA 02649

Mashpee Environmental Coalition
P.O. Box 274
Mashpee, MA 02649

Sandwich Board of Health
16 Jan Sebastian Drive
Sandwich, MA 02563

Wareham Board of Health
54 Marion Road
Warham, MA 02671

Libraries

Cape Cod Community College Library
Attn: Librarian
2240 Iyanough Road
West Barnstable, MA 02668-1599

Falmouth Public Library
Attn: Librarian
123 Katharine Lee Bates Road
Falmouth, MA 02540

Jonathan Bourne Library
Attn: Librarian
19 Sandwich Road
Bourne, MA 02532

Mashpee Public Library
Attn: Librarian
Steeple Street, Mashpee Common
Mashpee, MA 02649

Sandwich Public Library
Attn: Librarian
142 Main Street
Sandwich, MA 02563

U.S. Coast Guard Library
Bldg. 5205
Otis ANGB, MA 02542

OTHERS

Other Organizations/Individuals

BAE Services
Attn: Stephanie Syler
P.O. Box 305
Sagamore, MA 02561-0305

Cape Cod Coalition to Decommission PAVE PAWS
Attn: Sharon Judge
P.O. Box 150
Sandwich, MA 02563

Cape Code Commission
3225 Main Street
Barnstable, MA 02630

Mashpee Wampanoag Tribe
Attn: Shawn D. Hendricks Sr.
20 Black Brook Road
Mashpee, MA 02535

Wampanoag Tribe of Gay Head (Aquinnah)
Attn: Matthew Vanderhoop
Tribal Historic Preservation Officer
20 Black Brook Road
Aquinnah, MA 02535

Richard B. Perry, Ph.D.

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APPENDIX C

RADIOFREQUENCY REGULATIONS AND SAFETY STANDARDS

APPENDIX C

RADIOFREQUENCY REGULATIONS AND SAFETY STANDARDS

The assessment of human health and safety related to environmental exposure hinges on adhering to exposure limits recommended in scientifically based standards. The relevant primary exposure limits to protect health and safety regarding radiofrequency energy (RFE) are those developed by the Institute of Electrical and Electronics Engineers (IEEE) and adopted by the American National Standards Institute (ANSI). The IEEE standard was developed in 1991 and adopted by ANSI in 1992. The 1999 Edition (IEEE C95.1-1999) specifically modifies induced and contact current limits, but does not modify the exposure limits applicable to the general public. In addition to IEEE/ANSI, other organizations have published relevant limits, including state, federal, and international organizations.

C.1 UNCONTROLLED ENVIRONMENT/GENERAL PUBLIC EXPOSURE LIMITS FOR RADIOFREQUENCY ENERGY

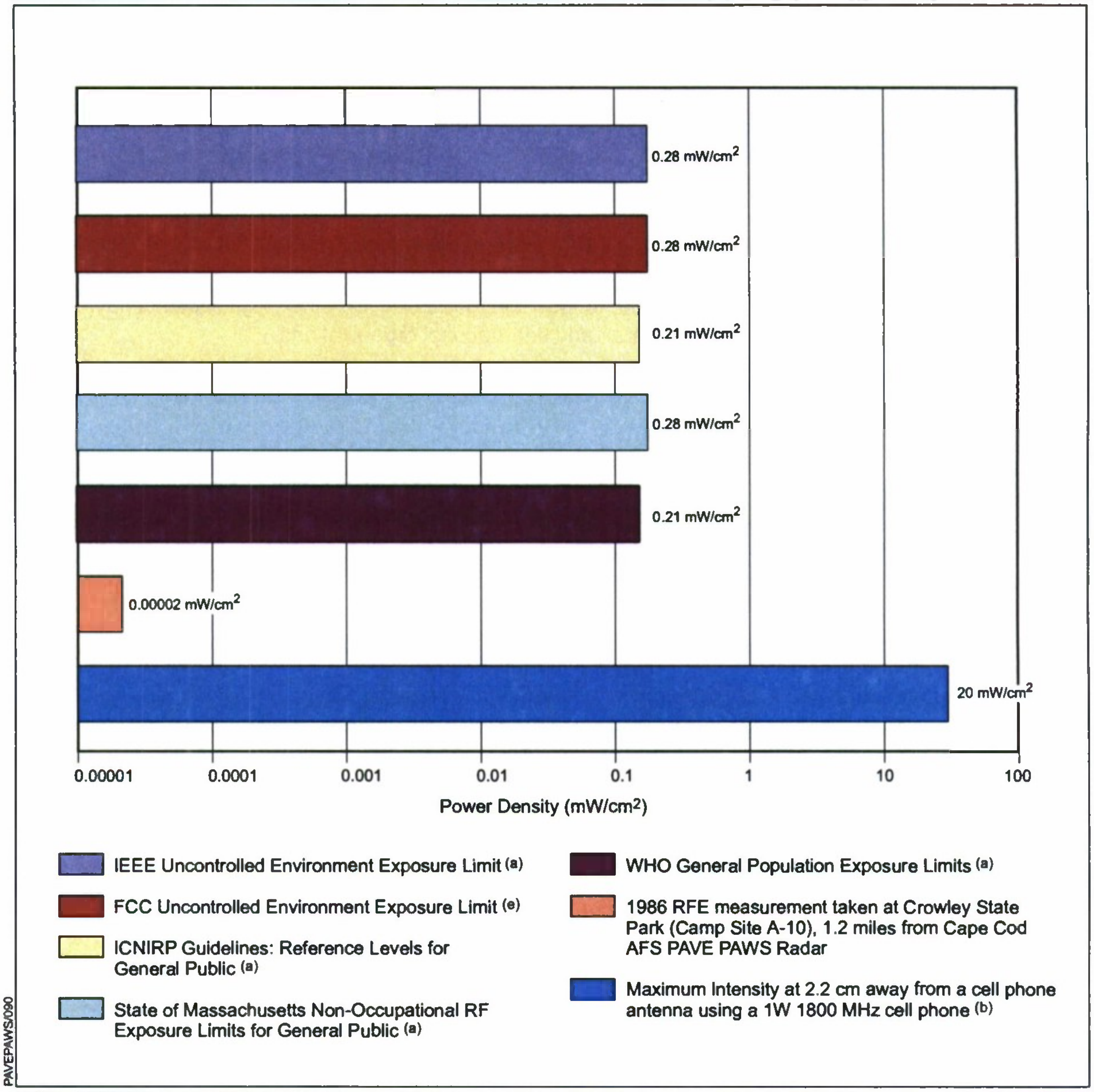
The standards for the human exposure limits to radiofrequency energy for the frequencies used by PAVE PAWS, 420-450 megahertz (MHz), are similar throughout the world. However, rationales differ for the magnitude of the safety factor, for the circumstances of exposure, for the nature of sensitive populations, and for the presumed health status of the individuals for whom the basic restriction (standard) is applicable (Erdreich and Klauenberg, 2001). Agencies and organizations that have promulgated exposure limits include IEEE/ANSI, United States Federal Communications Commission (FCC), World Health Organization (WHO)/International Commission on Non-Ionizing Radiation Protection (ICNIRP), United States Occupational Safety and Health Administration (OSHA), National Council on Radiation Protection (NCRP), Australia/New Zealand, Canada, and the United Kingdom's National Radiological Protection Board (NRPB). The exposure limits from several of these organizations are summarized in Table C-1 and illustrated in Figure C-1.

Table C-1. Radiofrequency Energy Limits for the General Public at 420-450 MHz

Organization	Applicable Frequency Range (MHz)	Derivation (mW/cm^2)	Exposure Limit at 420 MHz (mW/cm^2)[(a)]	Averaging Time (minutes)
IEEE, *(1999)*	300-3,000	f/1,500	0.28	30
U.S. FCC, *(1997)*	300-1,500	f/1,500	0.28	30
WHO/ICNIRP, *(1998)*	400-2,000	f/2,000	0.21	6
U.S. OSHA[(e)]	300-3,000	f/1,500	0.28	30
NCRP, *(1986)*	300-1,500	f/1,500	0.28	30
Aus/NZ, *(1994)*	400-2,000	f/2,000	0.21	6
Canada[(d)], *(1999)*	300-1,500	f/1,500	0.28	6
U.K. NRPB, *(1993)*	400-800	-	2.6[(b,c)]	15

Notes: (a) In the relevant frequency range, the lowest limit is for 420 MHz; therefore, only this limit is presented in this table.
(b) NRPB refers to these numbers as "investigation levels" and are measurement benchmarks for investigating whether compliance with basic restrictions (e.g., 0.4 W/kg) is achieved.
(c) This is not specific to occupational or general public exposures, rather it is based on the presence or absence of small children in the exposure environment.
(d) Health Canada.
(e) OSHA has adopted the IEEE exposure limits; (*e.g., U.S. EPA has adopted the FCC exposure limits*).

f = frequency in MHz
MHz = megahertz
mW/cm^2 = milliwatts per square centimeter



EXPLANATION

(a)	Frequency of 420 MHz
(b)	Source: Independent Expert Group on Mobile Phones, 2000.
FCC	Federal Communications Commission
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IEEP	Institute of Electrical and Electronics Engineers
MHz	megahertz
mW/cm^2	milliwatts per square centimeter
RF	radiofrequency
RFE	radiofrequency energy
WHO	World Health Organization

Comparison of RFE Measurements and Exposure Standards

Figure C-1

C.2 FEDERAL COMMUNICATIONS COMMISSION

The FCC is the agency responsible for regulating the use of electromagnetic (EM) spectral frequencies for broadcasting, transmitting, and telecommunications services. Table C-2 contains a listing of systems and applications regulated by the FCC.

Table C-2. Systems/Applications Regulated by the FCC

Experimental Radio Service	Wireless communications service
RF Devices	Radio broadcast services
Multipoint Distribution Service	Experimental/auxiliary/special broadcast and other program distribution services
Paging and Radiotelephone Service	Stations in the Maritime Service
Cellular Radiotelephone Service	Private land mobile, paging operations
PCS	Private land mobile, "covered" Specialized mobile radio
Satellite Communications	Amateur radio service
General Wireless Communication Service	Local multipoint distribution service

FCC = Federal Communications Commission
PCS = personal communication system
RF = radiofrequency

The FCC has developed regulations that specify what services may be provided and what systems may operate on certain frequencies across the EM spectrum (e.g., primarily in the RF and microwave radiation frequencies ranging from approximately 30 kilohertz [kHz] up to 300 gigahertz [GHz]).

In addition to regulating the use of EM spectral frequencies, the FCC has also adopted guidelines (47 Code of Federal Regulations [CFR] Parts 2.1 and 1.1310) to be used for controlling human exposure to RFE. First established in 1985, these guidelines were revised and updated on August 1, 1996. The FCC's Maximum Permissible Exposure (MPE) limits are based on exposure limits recommended by the NCRP and, over a wide range of frequencies, the exposure limits developed by the IEEE and adopted by the ANSI in 1992.

In reaching its decision on adopting new guidelines, the FCC carefully considered the large number of comments submitted in its rule-making proceeding, and particularly those submitted by the U.S. Environmental Protection Agency (EPA), the Food and Drug Administration (FDA), and other federal health and safety agencies.

The FCC's limits, and the NCRP and ANSI/IEEE limits on which they are based, are derived from exposure criteria quantified in terms of Specific Absorption Rate (SAR). The basis for these limits is a whole-body averaged SAR threshold level of 4 watts per kilogram (W/kg), as averaged over the entire mass of the body. Expert organizations have determined that potentially hazardous exposures may occur at levels above this threshold. The new MPE limits are derived by incorporating safety factors that lead, in some cases, to limits that are more conservative than the limits originally adopted by the FCC in 1985. Where more conservative limits exist, they do not arise from a fundamental change in the RFE safety criteria for whole-body averaged SAR, but from a precautionary desire to protect subgroups of the general population who, potentially, may be more at risk. The standards have been separated into two categories: Occupational/Controlled Exposure and General Population/Uncontrolled Exposure. The specifics of the standards are listed in Tables C-3 and C-4.

Table C-3. MPE Limits for Occupational/Controlled Exposure

Frequency Range (MHz)	Electric Field |E| Strength (V/m)	Magnetic Field |H| Strength (A/m)	Power Density (S) (mW/cm^2)	Averaging Time |E|^2, |H|^2, or S (minutes)
0.3 - 3.0	614	1.63	(100)[(a)]	6
3.0 - 30	1842/f	4.89/f	(900/f^2)[(a)]	6
30 - 300	61.4	0.163	1	6
300 - 1500[(b)]	-	-	f/300	6
1500 - 100,000	-	-	5	6

Notes: (a) Plane-wave equivalent power density.
(b) PAVE PAWS range 420-450 MHz.
A/m = amperes per meter
|E|^2 = square of electric field
f = frequency in megahertz
|H|^2 = square of magnetic field
MHz = megahertz
MPE = Maximum Permissible Exposure
mW/cm^2 = milliwatts per square cm
S = power density
V/m = volts per meter

Source: FCC, Office of Engineering and Technology (OET), *OET Bulletin 65: Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields*, Ed. 97-01, August 1997.

Table C-4. MPE Limits for General Population/Uncontrolled Exposure

Frequency Range (MHz)	Electric Field (E) Strength (V/m)	Magnetic Field (H) Strength (A/m)	Power Density (S) (mW/cm^2)	Averaging Time |E|^2, |H|^2, or S (minutes)
0.3 - 1.34	614	1.63	(100)[(a)]	30
1.34 - 30	824/f	2.19/f	(180/f^2)[(a)]	30
30 - 300	27.5	0.073	0.2	30
300 - 1500(b)	-	-	f/1500	30
1500 - 100,000	-	-	1	30

Notes: (a) Plane-wave equivalent power density
(b) PAVE PAWS range 420-450 MHz.
A/m = amperes per meter
|E|^2 = square of electric field
f = frequency in megahertz (MHz)
|H|^2 = square of magnetic field
MHz = megahertz
MPE = Maximum Permissible Exposure
mW/cm^2 = milliwatts per square cm
S = power density
V/m = volts per meter

Source: FCC, Office of Engineering and Technology (OET), *OET Bulletin 65: Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields*, Ed. 97-01, August 1997.

The occupational/controlled exposure limits apply in situations in which persons are exposed as a consequence of their employment, provided those persons are fully aware of the potential for exposure and can exercise control over their exposure. Limits for occupational/controlled exposure also apply in situations when an individual is transient through a location where occupational/controlled limits apply, provided he or she is made aware of the potential for exposure.

The general population/uncontrolled exposures apply in situations in which the general public may be exposed, or in which persons that are exposed as a consequence of their employment may not be fully aware of the potential for exposure or cannot exercise control over their exposure.

The FCC exposure limits are also based on data showing that the human body absorbs RFE at some frequencies more efficiently than at others. The most restrictive limits apply to the frequency range of 30-300 MHz, in which whole-body absorption of RFE by human beings is most efficient. This concept is illustrated in Figure C-2. At other frequencies, whole-body absorption is less efficient and consequently the MPE limits are less restrictive.

C.2.1 FCC Exposure Limit Safety Factors

Standard-making organizations have incorporated varying safety factors into their existing exposure standards, thus explaining the difference in exposure standards. The FCC has incorporated safety factors into the MPE limits based on a whole-body SAR of 4 W/kg. Consensus throughout the scientific community has established 4 W/kg as the threshold where thermal effects begin, resulting in observable bioeffects. The lowest whole-body average SAR that caused detrimental health effects in animal studies was found to be 4 W/kg. An exposure of humans to 4 W/kg for 30 minutes would result in a body temperature rise of less than 1 degree Centigrade (°C), which is considered an acceptable rise in body temperature.

The SAR is the rate of energy absorption per unit mass of an exposed object, or the basic RFE dosimetric quantity. The SAR is directly proportional to the following variables:

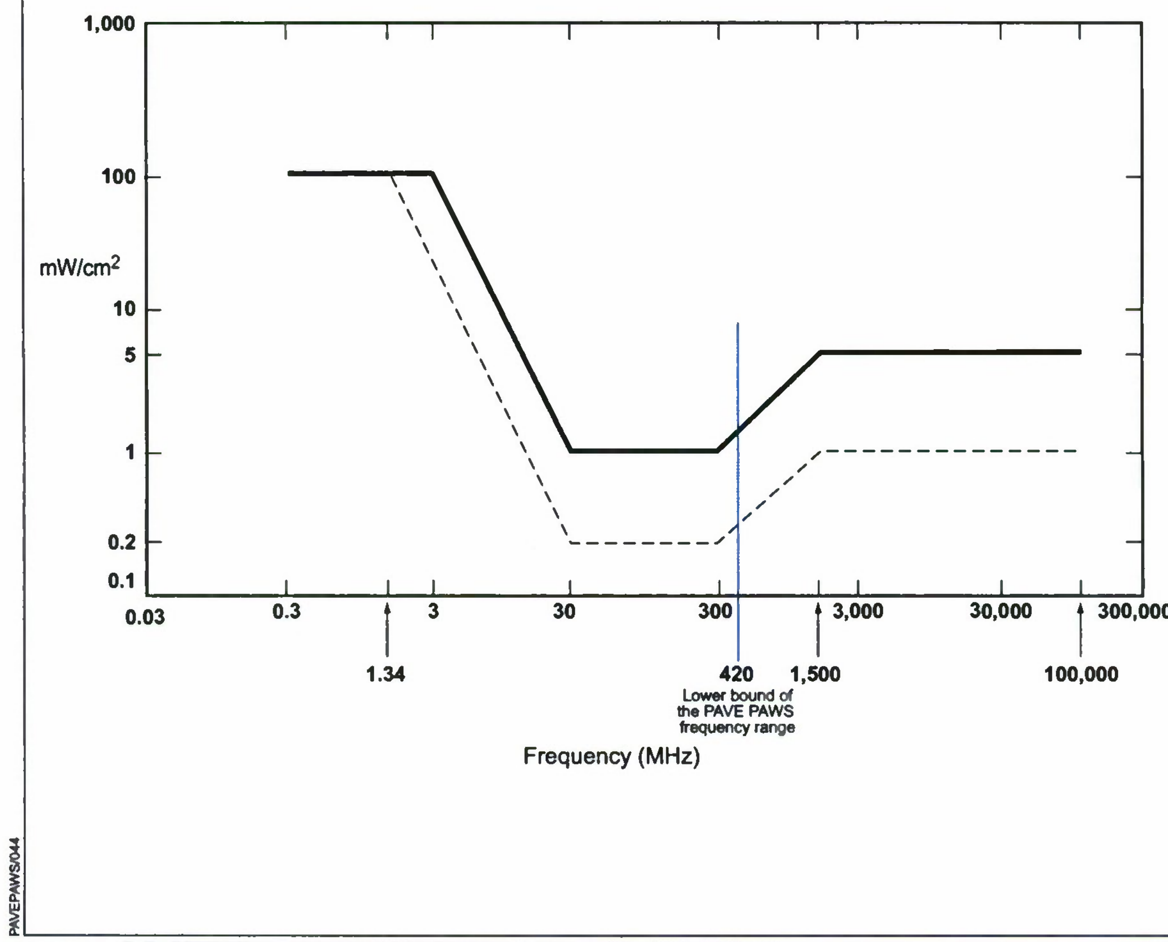
- Power density (S)
- Square of the electric field $|E|^2$
- Square of the magnetic field $|H|^2$
- Square of the induced current (I^2).

When exposed to RFE, the maximum SAR produced is 0.28 milliwatt per square centimeter (mW/cm^2) at a frequency of 70 MHz (|E| polarization). By comparison, the maximum aerobic power (heat conversion) generated by a healthy man during heavy exertion is approximately 16.7 W/kg (Pacific Northwest National Laboratory, 2001). Examples of ellipsoidal models used to predict SAR values are found in Figure C-3. These models show varying orientations for the multiple variables involved in the prediction of the SAR. Models such as the ones in Figure C-3 are often used in animal studies and human studies to predict SAR values for given RFE exposure scenarios. Variables such as frequency and polarization of the RFE field, size and shape of the exposed body, thermal conductivity of the body, and the surrounding environment/ground plane all contribute to the measured SAR.

However, in the absence of adequate knowledge concerning the mechanisms of interactions between radiofrequency (RF)/microwave energy and biological systems, and in light of the limitations inherent in the SAR, the following conclusions can be drawn (World Health Organization, 1981):

- SAR alone cannot be used for the extrapolation of effects from one biological system to another, or for the extrapolation of biological effects from one frequency to another

- Curves for exposure that produce equivalent SARs for a given body over the RF/microwave energy spectrum may be used to predict equivalent average heating, provided the data concerning heat dissipation indicate equivalent heat dissipation dynamics. Such curves cannot, however, be used as the only basis for predicting biological effects or health risks over the RF/microwave spectrum, since from current knowledge, it is not possible to state that equivalent average energy absorption rates for given radiation frequencies is associated with equivalent biological effects.



EXPLANATION

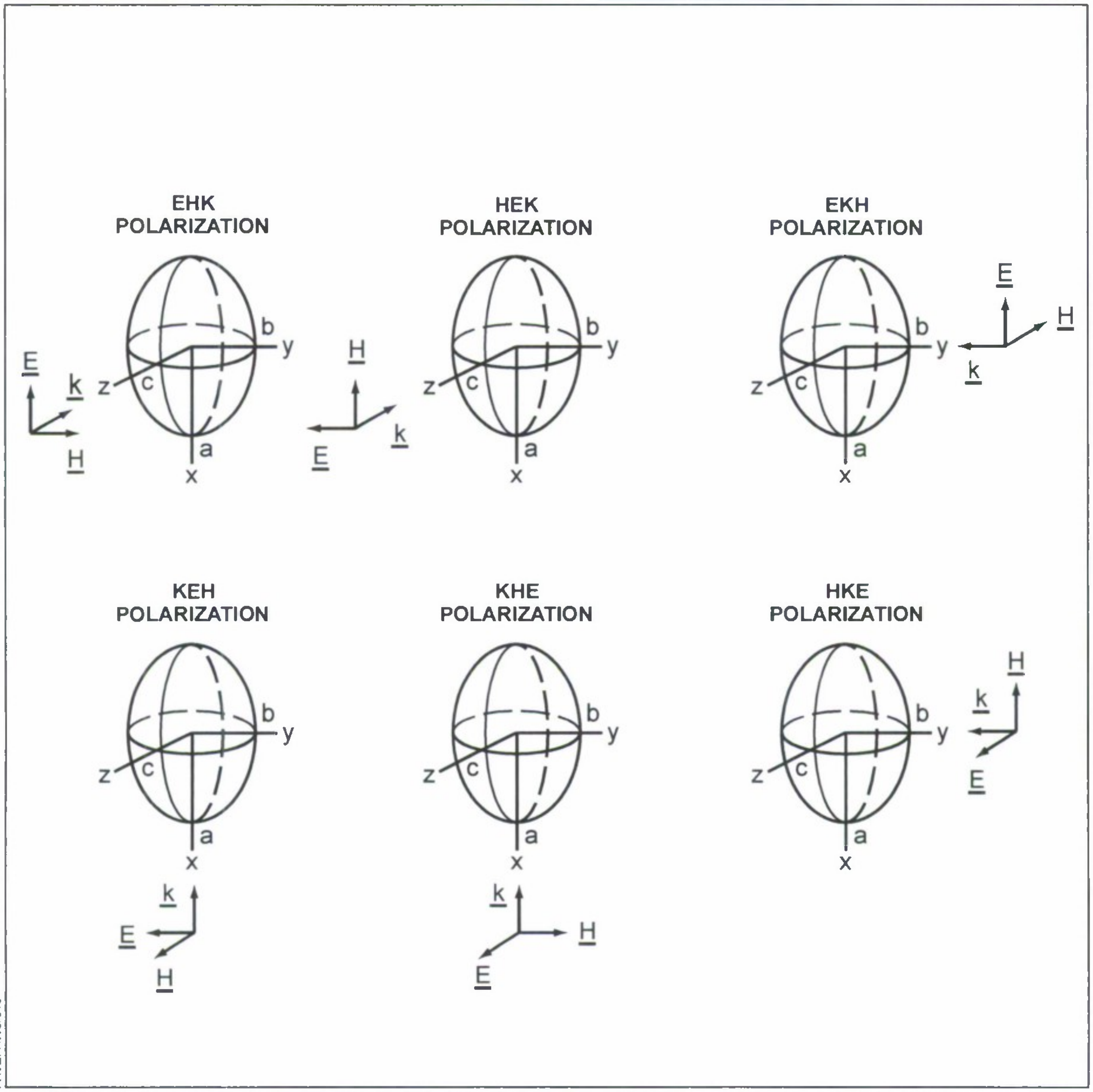
———	Occupational/Controlled Exposure
- - - - -	General Population/Uncontrolled Exposure
mW/cm^2	milliwatts per square centimeter
MHz	megahertz

Source: Federal Communications Commission, 1997.

FCC Limits for Maximum Permissible Exposure

Plane-wave Equivalent Power Density

Figure C-2



EXPLANATION

E	Electric Field Orientation
H	Magnetic Field Orientation
k	Orientation
a,b,c	Ellipse Lines
x,y,z	Coordinates
SAR	Specific Absorption Rate

Source: World Health Organization, 1981.

Ellipsoidal SAR Models with Multiple Orientations

Figure C-3

Based on the whole-body average SAR of 4 W/kg, the FCC adopted a limit of 0.4 W/kg as averaged over the whole-body as the *occupational/controlled exposure* SAR limit. This exposure limit thus incorporates a safety factor of 10 in order to allow for unfavorable, thermal, environmental, and possible long-term effects and other variables. However, the distribution of the absorbed energy in the human body can be very inhomogeneous and dependent on the RFE exposure conditions. In partial body exposure situations, depending upon the frequency, the absorbed energy can be concentrated in a limited amount of tissue, even though the whole-body average SAR is restricted to less than 0.4 W/kg. Therefore, the spatial peak SAR cannot exceed 8 W/kg as averaged over any 1 gram of tissue (defined as a tissue volume in the shape of a cube). Exceptions to this limit include the hands, wrists, feet, and ankles where the spatial peak SAR shall not exceed 20 W/kg, as averaged over any 10 grams of tissue (defined as a tissue volume in the shape of a cube). This is due to the fact that devices such as hand-held transmitting radios may exceed or cause a higher localized SAR in these body regions, but would not exceed the whole-body SAR.

Based on the whole-body average SAR of 4 W/kg, the FCC adopted a limit of 0.08 W/kg as averaged over the whole-body as the *general population/ uncontrolled exposure* SAR limit. This limit incorporates an additional safety factor of 5 above that for controlled exposure, for a total safety factor of 50, to allow for unfavorable, thermal, environmental, and possible long-term effects, and other variables. The spatial peak SAR cannot exceed 1.6 W/kg as averaged over any 1 gram of tissue (defined as a tissue volume in the shape of a cube). The spatial peak SAR for the hands, wrists, feet, and ankles shall not exceed 4 W/kg as averaged over any 10 grams of tissue (defined as a tissue volume in the shape of a cube).

C.2.2 Restricted Access and Warning Signs

Another aspect to the FCC exposure limits relates to accessibility to areas where high RFE levels may be present. Exposure may be limited by restricting access by means of erecting security fencing, posting warning signs, or locking out unauthorized persons in areas, where practical. There may be situations in which RFE levels may exceed MPE limits for the general population in remote areas, such as mountaintops or sparsely populated areas, which could conceivably be accessible but are not likely to be visited by the public. In such cases, if appropriate warning signs properly mark the area of concern, fencing or the erection of a permanent barrier may not be necessary. The FCC has adopted the RFE warning sign format produced by ANSI (ANSI C95.2-1982), and recommends the use of such signs; however, in some circumstances, long-lasting and clearly visible symbols are more important than the exact color used on the signage.

C.2.3 Summary

A brief overview of the FCC's regulations relating to RFE exposure has been presented above. The complete regulation can be examined by reading *OET Bulletin 65: Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields*, including Supplements A, B, and C. These documents are available in an electronic format through the FCC's website at http://www.fcc.gov/oet/rfsafety. Even though the FCC has promulgated their own regulations through the CFR, these regulations are based on the ANSI/IEEE C95.1-1992 (i.e., basic SAR and current limits) and NCRP exposure standards (i.e., MPEs and frequency range); therefore, these standards represent the intense scrutiny and peer reviewed findings from a multidisciplinary panel of experts.

Robert Brenner, Acting Deputy Assistant Administrator for Air and Radiation, U.S. EPA Office of Air and Radiation, wrote a letter to the FCC dated April 30, 1999, relating to the FCC RFE Guidelines and the role of other government agencies in the FCC rule-making process. Mr. Brenner stated:

> The FCC guidelines expressly take into account thermal effects of RF energy, but do not directly address postulated non-thermal effects, such as those due to chronic exposure. That is the case largely because of the paucity of scientific research on chronic, non-thermal health effects. The information base on non-thermal effects has not changed significantly since the EPA's original comments in 1993 and 1996. A few studies report that at non-thermal levels, long-term exposure to RF energy may have biological consequences. The majority of currently available studies suggest, however, that there are no significant non-thermal human health hazards. It therefore continues to be EPA's view that the FCC exposure guidelines adequately protect the public from all scientifically established harms that may result from RF energy fields generated by FCC licensees.

Based on the scientifically and regulatory-accepted standards-making process, the RFE exposure limits adopted by the FCC provide an acceptable level of protection to persons occupationally exposed to RFE and to the general population who may not be aware of potential RFE exposures within their surrounding environment. Even though these RFE exposure limits and regulations apply only to FCC-licensed facilities and transmitters, the rapid commercialization of the telecommunications industry brings the potential for the application of these regulations into the everyday lives of the general population.

C.3 THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS

The IEEE is a non-profit, technical professional association of more than 350,000 individual members in 150 countries. Through its members, the IEEE is a leading authority in technical areas ranging from computer engineering, biomedical technology, and telecommunications, to electric power, aerospace/ consumer electronics, and RF/microwave radiation.

The basis for the ANSI/IEEE C95.1-1999 standard goes back to the promulgation of ANSI C95.1-1982. In 1992, extensive revisions of the earlier standard were introduced into ANSI C95.1-1982 based on improved dosimetry that defined frequency-dependent limits on fields and power density. Also, the validity of the previously adopted SAR criterion of 4 W/kg as a basis for standard setting was questioned. A majority of the Risk Assessment Working Group agreed that the literature was still supportive of the 4 W/kg criterion, in addition to reaffirming the safety factor of 10 that yielded an SAR of 0.4 W/kg as the working basis for the MPE. Finally, a debate arose as to the need for two tiers of MPEs to distinguish occupational and general public exposures. In deliberations about the two-tiered system, ANSI concluded that no reliable scientific data exist indicating that:

- Certain subgroups of the population are more at risk than others
- Exposure duration at ANSI C95.1-1982 levels presents a significant risk
- Damage from exposure to EM fields is cumulative
- No thermal (other than shock) or modulation-specific sequelae of exposure may be meaningfully related to human health.

In the promulgation of ANSI/IEEE C95.1-1999 (includes the 1992 standard), ANSI/IEEE adhered to the scientific base of data in the determination of exposure levels that would be safe not only for personnel in the working environment, but also for the public at large. ANSI determined that no verified reports exist of injury to human beings or of adverse effects on the health of human beings who have been exposed to EM fields within the limits of frequency and SAR specified by previous ANSI standards, including ANSI C95.1-1982.

In ANSI/IEEE C95.1-1999, there are extensive modifications of the averaging time for determining permissible exposure. At the upper frequencies, these rules agree with soundly based averaging times derived from optical considerations. At the lower frequencies, new rules on induced currents have been introduced to prevent RFE shock or burns upon grasping contact with an object in an RF environment. For the 1999 revisions, research on the effects of chronic exposure and speculations on the biological significance of nonthermal interactions have not resulted in any meaningful basis for alteration of the standard.

In reaching their conclusion that existing research has not resulted in a meaningful basis for alteration of the standard, ANSI/IEEE selected an initial list of 321 papers as representative of the current state of knowledge on the many RFE bioeffects topics. The prime criterion governing the first selection was peer review before publication. Other selection criteria were publication date (with greater emphasis given to more recent publications on each topic), possible significance of findings (positive or negative) to human health, and relevance to concerns expressed by citizens groups. A final database for the standard comprised 120 papers.

Furthermore, in the continued support of the 4 W/kg SAR criterion, which marks the threshold for unfavorable biological effects in human beings, the IEEE cited: "in terms of human metabolic heat production, 4 W/kg represents a moderate activity level (e.g., housecleaning or driving a truck) and falls well within the normal range of human thermoregulation."

The IEEE C95.1-1999 RFE exposure limits are designed to protect specific exposure groups, thus the two separate exposure standards. The exposure limits have been separated into two categories: (1) Controlled Environments and (2) Uncontrolled Environments. The specifics of the exposure limits are listed in Tables C-5, C-6, C-7, and C-8.

The controlled environment exposure limits apply in situations in which persons are exposed as a consequence of their employment, provided those persons are fully aware of the potential for exposure and can exercise control over their exposure. Limits for controlled environments also apply in situations when an individual is transient through a location where controlled environment limits apply, provided he or she is made aware of the potential for exposure. Controlled environments would be the most likely areas where the induced and contact RF current limits would apply, as these measurements are primarily made in the near-field because far-field RFE levels are negligible.

Exposure associated with an uncontrolled environment is the exposure of individuals who have no knowledge or control of their exposure. The exposure may occur in living quarters or workplaces where there are no expectations that the exposure levels may exceed those in Table C-7, and where the induced currents do not exceed those in Table C-8.

C.3.1 Relaxation of Partial Body Exposure Limits

The adoption of IEEE C95.1, 1999 Edition brought the relaxation of the existing partial body exposure limits, with the exception of the eyes and testes. Compliance with the MPEs of Tables C-5, C-6, C-7, and

Table C-5. Maximum Permissible Exposure Limits for Controlled Environments[a]

Frequency Range (MHz)	Electric Field |E| Strength (V/m)	Magnetic Field |H| Strength (A/m)	Power Density (S) |E|-field, |H|-field (mW/cm^2)	Averaging Time $\|E\|^2$, $\|H\|^2$ or S (minutes)
0.003 - 0.1	614	163	$(100, 1 \times 10^6)$[b]	6
0.1 - 3.0	614	16.3/f	$(100, 1 \times 10^4/f^2)$[b]	6
3 - 30	1842/f	16.3/f	$(900/f^2, 1 \times 10^4/f^2)$	6
30 - 100	61.4	16.3/f	$(1.0, 1 \times 10^4/f^2)$	6
100 - 300	61.4	0.163	1.0	6
300 - 3000	-	-	f/300	6
3000 - 15,000	-	-	10	6
15,000 - 300,000	-	-	10	$616,000/f^{1.2}$

Notes: (a) The exposure values in terms of electric and magnetic field strengths are the mean values obtained by spatially averaging the squares of the fields over an area equivalent to the vertical cross section of the human body (projected area).

(b) These plane-wave equivalent power density values, although not appropriate for near-field conditions, are commonly used as a convenient comparison with MPEs at higher frequencies and are displayed on some instruments in use.

A/m = amperes per meter
$|E|^2$ = square of electric field
f = frequency in megahertz
$|H|^2$ = square of magnetic field
MHz = megahertz
MW/cm^2 = milliwatts per square centimeter
S = power density
V/m = volts per meter

Source: IEEE Standard for Safety Levels with Respect to Human Exposure to Radiofrequency Electromagnetic Fields, 3 kHz to 300 GHz, April 1999; IEEE Standard C95.1, 1999 Edition.

Table C-6. Induced and Contact Radiofrequency Currents (Controlled Environments)[a]

Frequency Range (MHz)	Maximum Current (mA)		Contact
	Through both feet	Through each foot	
0.003 - 0.1	2000 x f	1000 x f	1000 x f
0.1 - 100	200	100	100

Note: (a) It should be noted that the current limits given above may not adequately protect against startle reactions and burns caused by transient discharges when contacting an energized object.

f = frequency in megahertz
mA = milliamperes
MHz = megahertz

Source: IEEE Standard for Safety Levels with Respect to Human Exposure to Radiofrequency Electromagnetic Fields, 3 kHz to 300 GHz, April 1999; IEEE Standard C95.1, 1999 Edition.

C-8 is determined from spatial averages of power density or the mean squared electric and magnetic field strengths over an area equivalent to the vertical cross section of the human body (projected area) at a distance no closer than 20 cm from any object. Table C-9 summarizes the relaxation of partial-body exposures.

At low frequencies, the magnetic field limits have been relaxed relative to ANSI C95.1-1982. Models have been used to demonstrate that the new limits will ensure SARs less than 1/20 of those specified (i.e., 0.4 and 0.08 W/kg). For frequencies between 0.003 and 0.1 MHz (far below the frequencies used by PAVE PAWS), the induced current in controlled environments is limited to reduce the probability of reactions caused by induced currents that exceed perception thresholds for grasping contact with energized objects. For uncontrolled environments, the contact current is based on laboratory data on perception of currents at different frequencies in humans.

Table C-7. Maximum Permissible Exposure Limits for Uncontrolled Environments[(a)]

Frequency Range (MHz)	Electric Field $\|E\|$ Strength (V/m)	Magnetic Field $\|H\|$ Strength (A/m)	Power Density (S) $\|E\|$-field, $\|H\|$-field (mW/cm^2)	Averaging Time $\|E\|^2$, S, or $\|H\|^2$ (minutes)	
0.003 - 0.1	614	163	$(100, 1 \times 10^6)$[(b)]	6	6
0.1 - 1.34	614	16.3/f	$(100, 1 \times 10^4/f^2)$[(b)]	6	6
1.34 - 3.0	823.8/f	16.3/f	$(180/f^2, 1 \times 10^4/f^2)$	$f^2/0.3$	6
3.0 - 30	823.8/f	16.3/f	$(180/f^2, 1 \times 10^4/f^2)$	30	6
30 - 100	27.5	$158.3/f^{1.668}$	$(0.2, 940000/f^{3.336})$	30	$0.0636f^{1.337}$
100 - 300	27.5	0.0729	0.2	30	30
300 - 3000	-	-	f/1500	30	-
3000 - 15,000	-	-	f/1500	90000/f	-
15,000 - 300,000	-	-	10	$616000/f^{1.2}$	-

Notes: (a) The exposure values in terms of electric and magnetic field strengths are the mean values obtained by spatially averaging the squares of the fields over an area equivalent to the vertical cross section of the human body (projected area).

(b) These plane-wave equivalent power density values, although not appropriate for near-field conditions, are commonly used as a convenient comparison with MPEs at higher frequencies and are displayed on some instruments in use.

A/m = amperes per meter
$|E|^2$ = square of electric field
f = frequency in megahertz
$|H|^2$ = square of magnetic field
MHz = megahertz
mW/cm^2 = milliwatts per square centimeter
S = power density
V/m = volts per meter

Source: IEEE Standard for Safety Levels with Respect to Human Exposure to Radiofrequency Electromagnetic Fields, 3 kHz to 300 GHz, April 1999; IEEE Standard C95.1, 1999 Edition.

Table C-8. Induced and Contact Radiofrequency Currents (Controlled Environments)[(a)]

Frequency Range (MHz)	Maximum Current (mA)		Contact
	Through both feet	Through each foot	
0.003 - 0.1	900 x f	450 x f	450 x f
0.1 - 100	90	45	45

Note: (a) It should be noted that the current limits given above may not adequately protect against startle reactions and burns caused by transient discharges when contacting an energized object.

f = frequency in megahertz
mA = milliamperes
MHz = megahertz

Source: IEEE Standard for Safety Levels with Respect to Human Exposure to Radiofrequency Electromagnetic Fields, 3 kHz to 300 GHz, April 1999; IEEE Standard C95.1, 1999 Edition.

At frequencies above 6 GHz, the exposure in human tissue is quasi-optical and the SAR exclusion does not apply. At higher frequencies (i.e., greater than 15 GHz), it is known that penetration depth into tissue is much less than 1 cm and thermal time constraints drop to seconds. Conversely, below 0.1 MHz the SAR exclusion rule does not apply; in fact, limits on internal current density can substitute as the basis for exclusion. At these frequencies, the limits are meant to limit the internal current produced by the RF field in order to prevent shock or burns from the discharge of internal body current with an object. The radiating structure must be more than 2.5 cm from the body.

Table C-9. Partial Body Exposure Limits

Exposure Characteristics	Frequency (GHz)	Peak value of mean squared field	Equivalent power density (mW/cm^2)
Controlled Environment	$0.0001 \leq f < 0.3$	$< 20 \lvert\bar{E}\rvert^2$ or $20 \lvert\bar{H}\rvert^{2(a)}$	-
	$0.3 < f \leq 6$	-	< 20
	$6 < f \leq 96$	-	$< 20 (f/6)^{1/4}$
	$96 < f \leq 300$	-	40
Uncontrolled Environment	$0.0001 \leq f < 0.3$	$< 20 \lvert\bar{E}\rvert^2$ or $20 \lvert\bar{H}\rvert^{2(b)}$	-
	$0.3 < f \leq 6$	-	4
	$6 < f \leq 30$	-	f/1.5
	$30 < f \leq 300$	-	20

Notes: (a) $\lvert\bar{E}\rvert$ and $\lvert\bar{H}\rvert$ are the spatially averaged values from Table C-5.
(b) $\lvert\bar{E}\rvert$ and $\lvert\bar{H}\rvert$ are the spatially averaged values from Table C-7.
f = frequency in gigahertz
GHz = gigahertz
mW/cm^2 = milliwatts per square centimeter

Source: IEEE Standard for Safety Levels with Respect to Human Exposure to Radiofrequency Electromagnetic Fields, 3 kHz to 300 GHz, April 1999; IEEE Standard C95.1, 1999 Edition.

C.3.2 ANSI/IEEE Exposure Limit Safety Factors

Biological hazards commonly pose special difficulties to the formulation of safety factors. This is the case regarding the causal relationship between RF exposure levels and an observable biological effect. For some phenomena, the threshold concept may be accepted; however, the distribution of responses is inadequately known to formulate a moderately precise factor or margin of safety. A practical discussion of inference guidelines for risk management is included in the National Research Council's Committee on the Institutional Means for Assessment of Risks to the Public Health, *Risk Assessment in the Federal Government: Managing the Process*, Commission on Life Sciences. IEEE states, "It is the explicit recognition of the need to distinguish between 'science' and 'science policy' in the formulation of guidelines." The previous standard, ANSI C95.1-1982, invoked a safety factor of 10 on the threshold of 4 W/kg whole-body average SAR, but incorporated numerous "conservative assumptions" or implicit contributions toward "safety." The list of conservative assumptions included the following:

- The threshold selected itself (evidence of behavioral disruption) is not a defined hazard; rather it was assumed that chronic exposure under such conditions constitutes a health hazard
- The direct extrapolation from animal to man, arguably, is a conservative assumption given the demonstrably superior thermoregulation of man compared to the reference species
- The selection of the far-field, E-polarized "worst-case" exposure as the reference conditions (the SAR decreases markedly for other polarizations)
- The incorporation in one contour of the resonance frequencies (maximum absorption occurs at about 708 mHz for a standard man [about 175 cm in height]) for all size humans (the SAR falls off markedly for frequencies below resonance).

The collective impact of these "conservative" assumptions is to provide a degree of safety or freedom from hazard for a given human over time and space much greater than is implied by the explicit safety factor of 10. In the context of human thermoregulation, the impact of exposure to 0.4 W/kg is practically indistinguishable from the impact of normal ambient temperature variation, exposure to the sun, exercise, etc. The effect of the last two bullets above greatly reduces the likelihood that the exposure of a given human to the fields permitted under the standard will produce a whole-body average SAR of 0.4 W/kg, except at the individual's resonant frequency, oriented for E-polarization in the far-field. IEEE concluded that, for the ANSI/IEEE C95.1, 1999 Edition, an additional safety factor was justified only in an uncontrolled environment and then only for exposures that are penetrating or associated with complicating factors like effects from contacting metal objects. The existing safety factor, which is already very conservative, was unchanged by IEEE in the 1999 Edition.

In summary, the use of a safety factor presupposes the selection of a threshold for a hazard. The existing MPEs are based on the threshold for behavioral disruption with acute (short-term) exposures of experimental animals. The threshold selected was 4 W/kg and the explicit safety factor of 10 was applied to obtain a maximum permitted SAR (whole-body average) of 0.4 W/kg. In addition to this explicit safety factor, the MPE contains multiple conservative assumptions that constitute implicit or hidden contributions to a less precise, but much greater margin of safety. An extra safety factor is justified only for some exposures in an uncontrolled environment.

C.3.3 Restricted Access and Warning Signs

Revisions to the existing ANSI/IEEE C95.2-1988 standard include the expanded use of the well-known C95 symbol as well as the introduction of a symbol to discourage contacting metal surfaces that could result in undesirable contact currents. Otherwise, the existing signage and restricted access requirements around areas where potential exposure to RFE levels approaching or exceeding the MPEs continues to be emphasized in the revised ANSI/IEEE C95.2-1999, *Standard for Radiofrequency Energy and Current Flow Symbols*. Figure C-4 provides a graphical illustration of the advisory symbol for RFE.

C.3.4 Summary

Both ANSI and IEEE standards review policies require that each of its standards and/or guides be reviewed at 5-year intervals. Revisions to the previous ANSI/IEEE C95.1-1982 standard have resulted in the promulgation of C95.1, 1999 Edition, which contains updated scientific, peer-reviewed research in the area of RFE exposure and has based revised exposure limits (MPEs) on these data. IEEE standards are considered international; therefore, the input, scrutiny, and development of IEEE standards come from a diverse and multidisciplinary assembly of persons. Over the last 30 years, there have been attempts by the U.S. EPA, National Institute for Occupational Safety and Health (NIOSH), and the Occupational Safety and Health Administration (OSHA) to develop federal standards or guidance on safe RFE exposure, but all have failed. Federal agencies have primarily relied on the ANSI/IEEE C95 series of standards for the determination of safe exposure limits for RFE. An important factor in this process has been and is the existence of a Federal Policy, OMB A-119, mandating support of and participation by Federal agencies in the voluntary standards-setting process (OMB, 1993). In all, the credibility of the IEEE standards-making process has bestowed an international acceptance of IEEE standards, although other standards-making organizations have created their own RFE exposure standards (e.g., International Radiation Protection Association [IRPA]), resulting in a general consensus of exposure limits used today throughout the United States and many countries worldwide.

Radiofrequency Energy Advisory Symbol

Source: ICNIRP, 1998.

Figure C-4

C.4 INTERNATIONAL RADIATION PROTECTION ASSOCIATION AND THE INTERNATIONAL COMMISSION ON NON-IONIZING RADIATION PROTECTION

In 1974, the IRPA formed a working group on non-ionizing radiation, which examined the problems arising in the field or protection against the various types of non-ionizing radiation. At the IRPA Congress in Paris, France, in 1977, this working group became the International Non-Ionizing Radiation Committee (INIRC). In cooperation with the Environmental Health Division of the WHO, the IRPA/INIRC developed a number of health criteria documents on non-ionizing radiation as part of WHO's Environmental Health Criteria Programme, sponsored by the United Nations Environment Programme (UNEP).

At the Eighth International Congress of the IRPA in Montreal, Canada, in 1992, a new, independent scientific organization, the International Commission on Non-Ionizing Radiation Protection (ICNIRP), was established as a successor to the IRPA/INIRC. The functions of the Commission are to investigate the hazards that may be associated with the different forms of non-ionizing radiation, develop international guidelines on non-ionizing radiation exposure limits, and deal with all aspects of non-ionizing radiation protection.

Guidelines on high-frequency and 50/60 Hertz (Hz) EM fields were issued by IRPA/INIRC in 1988 and 1990, respectively, but are superseded by the 1998 ICNIRP *Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (up to 300 GHz)*. The 1998 ICNIRP RFE reference levels are listed in Tables C-10 and C-11.

According to ICNIRP, the occupationally exposed population consists of adults who are generally exposed under known conditions and are trained to be aware of potential risks and to take appropriate precautions.

According to ICNIRP, the general public comprises individuals of all ages and of varying health status, and may include particularly susceptible groups or individuals. In many cases, members of the general public are unaware of their exposure to EM fields. Moreover, individual members of the public cannot reasonably be expected to take precautions to minimize or avoid exposure. It is these considerations that underlie the adoption of more stringent exposure restrictions for the public than the occupationally exposed population.

The ICNIRP has established two types of exposure limits: Basic Restrictions, Reference Levels. Restrictions on the effects of exposure are based on established health effects and are termed basic restrictions. Depending on frequency, the physical quantities used to specify the basic restrictions on exposure to EM fields are current density, SAR, and power density. Protection against adverse health effects requires that these basic restrictions are not exceeded. Reference levels of exposure are provided for comparison with measured values of physical quantities; compliance with all reference levels given in the 1998 ICNIRP *Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (up to 300 GHz)* will ensure compliance with the basic restrictions. If measured values are higher than reference levels, it does not necessarily follow that the basic restrictions have been exceeded, but a more detailed analysis is necessary to assess compliance with the basic restrictions.

Because the body perceives/absorbs the RFE differently at different frequencies, the 1998 ICNIRP guidelines established basic restrictions for multiple frequency ranges for both the occupationally exposed and general public populations. The basic restrictions are listed in Tables C-12 and C-13. The basis for the revision of the 1988 and 1990 guidelines, and promulgation of the 1998 ICNIRP *Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (up to 300 GHz)* was a thorough

Table C-10. Reference Levels for Occupational Exposure to Time-varying Electric/Magnetic Fields (unperturbed rms values)

Frequency Range	|E|-field Strength (V/m)	|H|-field Strength (A/m)	B-field (μT)	Equivalent Plane Wave Power Density, S_{eq} (W/m²)
Up to 1 Hz	-	1.63×10^5	2×10^5	-
1 - 8 Hz	20,000	$1.63 \times 10^5/f^2$	$2 \times 10^5/f^2$	-
8 - 25 Hz	20,000	$2 \times 10^4/f$	$2.5 \times 10^4/f$	-
0.025 - 0.82 kHz	500/f	20/f	25/f	-
0.82 - 65 kHz	610	24.4	30.7	-
0.065 - 1 MHz	610	1.6/f	2.0/f	-
1 - 10 MHz	610/f	1.6/f	2.0/f	-
10 - 400 MHz	61	0.16	0.2	10
400 - 2000 MHz	$3f^{1/2}$	$0.008f^{1/2}$	$0.01f^{1/2}$	f/40
2 - 300 GHz	137	0.36	0.45	50

Notes: (a) f as indicated in the frequency range column.

(b) Provided that basic restrictions are met and adverse indirect effects can be excluded, field strength values can be exceeded.

(c) For frequencies between 100 kHz and 10 GHz, Seq, $|E|^2$, $|H|^2$, and B^2 are to be averaged over any 6-minute period.

(d) For peak values at frequencies up to 100 kHz (see Table 4 in the Standard, note 3).

(e) For peak values at frequencies exceeding 100 kHz (see Figures 1 and 2 in the Standard). Between 100 kHz and 10 MHz, peak values for the field strengths are obtained by interpolation from the 1.5-fold peak at 100 kHz to the 32-fold peak at 10 MHz. For frequencies exceeding 10 MHz, it is suggested that the peak equivalent plane wave power density, as averaged over the pulse width, does not exceed 1000 times the Seq restrictions, or that the field strength does not exceed 32 times the field strength exposure levels in Table 3.2-8.

(f) For frequencies exceeding 10 GHz, Seq, $|E|^2$, $|H|^2$, and B^2 are to be averaged over any $68/f^{1.05}$-minute period (f in GHz).

(g) No |E|-field value is provided for frequencies <1Hz, which are effectively static electric fields.

A/m = amperes per meter
$|E|^2$ = electric field
f = frequency in megahertz
GHz = gigahertz
$|H|^2$ = magnetic field
Hz = hertz
kHz = kilohertz
MHz = megahertz
rms = root mean square
S = power density
μT = microTesla
V/m = volts per meter
W/m² = watts per square meter

Source: 1998 ICNIRP *Guidelines for Limiting Exposure to Time-Varying electric, Magnetic, and Electromagnetic Fields (up to 300 GHz).*

Table C-11. Reference Levels for General Public Exposure to Time-varying Electric/Magnetic Fields (unperturbed rms values)

Frequency Range	|E|-field Strength (V/m)	|H|-field Strength (A/m)	B-field (μT)	Equivalent Plane Wave Power Density, S_{eq} (W/m²)
Up to 1 Hz	-	3.2×10^4	4×10^4	-
1-8 Hz	10,000	$3.2 \times 10^4/f^2$	$4 \times 10^4/f^2$	-
8-25 Hz	10,000	4000/f	5000/f	-
0.025-0.8 kHz	250/f	4/f	5/f	-
0.8-3 kHz	250/f	5	6.25	-
3-150 kHz	87	5	6.25	-
0.15-1 MHz	87	0.73/f	0.92/f	
1-10 MHz	$87/f^{½}$	0.73/f	0.92/f	-
10-400 MHz	28	0.073	0.092	2
400-2000 MHz	$1.375f^{½}$	$0.0037f^{½}$	$0.0046f^{½}$	f/200
2-300 GHz	61	0.16	0.2	10

Notes: (a) f as indicated in the frequency range column

(b) Provided that basic restrictions are met and adverse indirect effects can be excluded, field strength values can be exceeded

(c) For frequencies between 100 kHz and 10 GHz, Seq, $|E|^2$, $|H|^2$, and B^2 are to be averaged over any 6-minute period

(d) For peak values at frequencies up to 100 kHz (see Table 4 in the Guidelines, note 3)

(e) For peak values at frequencies exceeding 100 kHz (see Figures 1 and 2 in the Guidelines). Between 100 kHz and 10 MHz, peak values for the field strengths are obtained by interpolation from the 1.5-fold peak at 100 kHz to the 32-fold peak at 10 MHz. For frequencies exceeding 10 MHz, it is suggested that the peak equivalent plane wave power density, as averaged over the pulse width, does not exceed 1000 times the Seq restrictions, or that the field strength does not exceed 32 times the field strength exposure levels in Table 3.2-9.

(f) For frequencies exceeding 10 GHz, Seq, $|E|^2$, $|H|^2$, and B^2 are to be averaged over any 68/f1.05-minute period (f in GHz)

(g) No |E|-field value is provided for frequencies <1Hz, which are effectively static electric fields

A/m = amperes per meter
$|E|^2$ = electric field
f = frequency in MHz
GHz = gigahertz
$|H|^2$ = magnetic field
Hz = hertz
kHz = kilohertz
MHz = megahertz
S = power density
μT = microTesla
V/m = volts per meter
W/m² = watts per square meter

Source: 1998 ICNIRP *Guidelines for Limiting Exposure to Time-Varying electric, Magnetic, and Electromagnetic Fields (up to 300 GHz).*

Table C-12. Basic Restrictions for Time-varying |E|- and |H|-fields (up to 10 GHz)

Exposure Characteristics	Frequency Range	Current Density for head and trunk (mA/m^2)(rms)	Whole-body average SAR (W/kg)	Localized SAR (head and trunk) (W/kg)	Localized SAR (limbs) (W/kg)
Occupational Exposure	Up to 1 Hz	40	-	-	-
	1 – 4 Hz	40/f	-	-	-
	4 Hz – 1 kHz	10	-	-	-
	1 – 100 kHz	f/100	-	-	-
	100 kHz – 10 MHz	f/100	0.4	10	20
	10 MHz – 10 GHz	-	0.4	10	20
General Public Exposure	Up to 1 Hz	8	-	-	-
	1 – 4 Hz	8/f	-	-	-
	4 Hz – 1 kHz	2	-	-	-
	1 – 100 kHz	f/500	-	-	-
	100 kHz – 10 MHz	f/500	0.08	2	4
	10 MHz – 10 GHz	-	0.08	2	4

Notes: (a) Because of electrical inhomogeneity of the body, current densities should be averaged over a cross-section of 1 cm2 perpendicular to the current direction.

(b) For frequencies up to 100 kHz, peak current density values can be obtained by multiplying the rms value by 2½ (~1.414). For purposes of duration to the equivalent frequency to apply in the basic restrictions should be calculated as f = 1/(2tp).

(c) For frequencies up to 100 kHz and for pulsed magnetic fields, the maximum current density associated with the pulses can be calculated from the rise/fall times and the maximum rate of change of magnetic flux density. The induced current density can then be compared with the appropriate basic restriction.

(d) All SAR values are to be averaged over any 6-minute period.

(e) Localized SAR averaging mass is any 10 g of contiguous tissue; the maximum SAR so obtained should be the value used for the estimation of exposure.

(f) For pulses of duration tp, the equivalent frequency to apply in the basic restrictions should be calculated as f = 1/(2tp). Additionally, for pulsed exposures, in the frequency range of 0.3 to 10 GHz and for localized exposure of the head, in order to limit or avoid auditory effects caused by thermoelastic expansion, an additional basic restriction is recommended. This is that the specific energy absorption (SA) should not exceed 10 mJ/kg for workers and 2 mJ/kg for the general public averaged over 10 g of tissue.

E = electric field
f = frequency in hertz
GHz = gigahertz
H = magnetic field
Hz = hertz
kHz = kilohertz
mA/m^2 = milliamperes per square meter
MHz = megahertz
rms = root mean square
SAR = specific absorption rate
W/kg = watts per kilogram

Source: 1998 ICNIRP *Guidelines for Limiting Exposure to Time-Varying electric, Magnetic, and Electromagnetic Fields (up to 300 GHz).*

review of existing scientific literature related to short-term, immediate health effects (i.e., established effects). Regarding long-term effects of RFE exposure, ICNIRP concluded that available data are insufficient to provide a basis for setting exposure restrictions, although epidemiological research has provided suggestive, but unconvincing, evidence of an association between carcinogenic effects and long-term, low-level RFE exposures.

Table C-13. Basic Restrictions for Power Density (10 GHz to 300 GHz)

Exposure Characteristics	Power Density (W/m^2)
Occupational Exposure	50
General Public	10

Notes: (a) Power densities are to be averaged over any 20 cm^2 of exposed area and any $68/f^{1.05}$-minute period (where f is in GHz) to compensate for progressively shorter penetration depth as the frequency increases.
(b) Spatial maximum power densities, averaged over 1 cm^2 should not exceed 20 times the values above.
GHz = gigahertz
W/m^2 = watts per square meter

Source: 1998 ICNIRP *Guidelines for Limiting Exposure to Time-Varying electric, Magnetic, and Electromagnetic Fields (up to 300 GHz).*

Although the ICNIRP reviewed biological effects and epidemiological studies from a multitude of frequencies, the frequency range between 100 kHz and 300 GHz will be discussed here because of its relevance to PAVE PAWS. A discussion of biological effects associated with all frequencies evaluated for the purpose of the ICNIRP RFE exposure limits can be found in the 1998 ICNIRP *Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (up to 300 GHz).*

In their summary of the biological effects for frequencies between 100 kHz and 300 GHz, ICNIRP pointed toward the available experimental evidence that indicates that exposure of resting humans to EM fields for approximately 30 minutes resulting in a whole-body SAR between 1 and 4 W/kg yields a body temperature increase of less than 1°C. These data form the basis for an occupational exposure restriction of 0.4 W/kg, which provides a margin of safety for other limiting conditions, such as high ambient temperature, humidity, or level of physical activity.

C.4.1 ICNIRP Exposure Limit Safety Factors

There is insufficient information on the biological and health effects of EM fields (e.g., RFE) exposure of human populations and experimental animals to provide a rigorous basis for establishing safety factors over the whole frequency range and for all frequency modulations. Further, some of the uncertainty regarding the appropriate safety factor derives from a lack of knowledge regarding the appropriate dose metric (Repacholi, 1998). The following general variables were considered by ICNIRP in the development of safety factors for high-frequency fields.

- Effects of exposure to EM fields under severe environmental conditions (e.g., high temperature, high humidity) and/or high-activity levels
- The potentially higher thermal sensitivity in certain population groups, such as the elderly, infants and young children, and people with diseases or taking medications, that compromise thermal tolerance.

Based on the available scientific data that indicate an SAR of 4 W/kg is the threshold for the occurrence of harmful biological effects, ICNIRP has established a whole-body average SAR of 0.4 W/kg as the restriction that provides adequate protection for occupational exposures. Thus, the ICNIRP has incorporated a safety factor of 10 into the whole-body average SAR restriction. This is consistent with the whole-body SAR safety factor for occupational exposures adopted by other regulatory/standard-making organizations (i.e., IEEE and the FCC). For the general public, an additional safety factor of 5 was introduced, giving an average whole-body SAR restriction of 0.08 W/kg, again consistent with the whole-body SAR safety factor for general public exposures regulatory/standard-making organizations (i.e., IEEE and the FCC). The lower restriction for the whole-body SAR exposure for the general public takes into account the likelihood that the age and health status (e.g., infants, elderly) of the general population may differ from those of workers exposed to RFE occupationally.

The ICNIRP incorporated specific safety factors into the derivation of the reference levels for exposure of the general public by using various factors over the entire frequency range. These factors have been chosen on the basis of effects that are recognized as specific and relevant for the various frequency ranges. Generally speaking, the factors follow the basic restrictions over the entire frequency range. The safety factors for specific frequencies include the following:

- In the frequency range up to 1 kHz, the general public reference levels for |E|-fields are one-half of the values established for occupational exposures. This value was chosen to prevent adverse indirect effects for more than 90 percent of exposed individuals.
- In the low-frequency range up to 100 kHz, the general public reference levels for |H|-fields are set at a factor of 5 below the values set for occupational exposures.
- In the frequency range of 100 kHz to 10 MHz, the general public reference levels for |H|-fields have been increased compared with the limits given in the 1988 IRPA guideline. The 1988 IRPA guideline exposure limits were considered too conservative, because the |H|-field at frequencies below 10 MHz do not contribute significantly to the risk of shocks, burns, or surface charge effects that form the basis for limiting occupational exposure to |E|-fields in that frequency range.
- In the high-frequency range (10 MHz to 10 GHz), the general public reference levels for |E|- and |H|-fields are lower by a factor of 2.2 than those set for occupational exposure. The factor of 2.2 corresponds to the square root of 5, which is the safety factor between the basic restrictions for occupational exposure and those set for general public exposures. The square root is used to relate the quantities field strength and power density the whole-body SAR safety factor for general public exposures.
- In the high-frequency range 10 GHz to 300 GHz, the general public reference levels are defined by the power density, as in the basic restrictions, and are lower by a factor of 5 than the occupational exposure restrictions.
- For frequencies between ~0.3 GHz and several GHz and for localized exposure of the head, in order to limit or avoid auditory effects, the specific absorption from pulses must be limited (this concept is described in greater detail within the 1998 ICNIRP guidelines).

In Tables C-10 and C-11, different frequency break points occur for occupational- and general public-derived reference levels. This is a consequence of the varying factors used to derive the general public reference levels, while generally keeping the frequency dependence the same for both occupational and general public levels.

C.4.2 Restricted Access and Warning Signs

Although the ICNIRP does not specifically address these topics, they do provide recommended procedures relating to protective measures for occupational and general public exposure groups. ICNIRP states, "Protective measures must be implemented when exposure in the workplace results in the basic restrictions being exceeded." Protective measure recommendations include engineering controls (e.g., good safety design, interlocks, or similar measures); administrative controls (e.g., audible/visual warnings); and personal protective equipment (PPE) (e.g., protective clothing). PPE should be implemented as the last resort to ensure worker protection. With the exception of PPE, the same measures can be applied to the general public whenever there is a possibility that the general public reference levels might be exceeded. It is also essential to establish and implement rules that will prevent:

- Interference with medical electronic equipment and devices (including cardiac pacemakers)

- Detonation of electroexplosive devices (EEDs)
- Fires and explosions resulting from ignition of flammable materials by sparks caused by induced fields, contact currents, or spark discharges.

C.4.3 Summary

The development of international EM field standards requires a critical in-depth evaluation of the established scientific literature. The ICNIRP is the independent, non-governmental, scientific organization, comprising all essential scientific disciplines, which is qualified to assess health effects of exposure to EM fields and RFE. Based on this assessment, the ICNIRP has developed health-based exposure guidelines, free from vested interest. The ICNIRP guidelines can be accessed at http://www.icirp.de.

Various differences exist between the ICNIRP and IEEE RFE exposure guidelines/limits; for example:

- Each organization uses a different range of frequencies for establishing exposure limits
- Each organization uses different averaging times for frequencies greater than 10 GHz
- Each organization uses slightly different safety factors, including the basis for those safety factors
- ICNIRP establishes limits on magnetic flux density, whereas IEEE does not
- ICNIRP establishes restrictions to address the auditory effect, whereas IEEE does not
- At 420 MHz, the ICNIRP general public reference level of 0.21 mW/cm^2 is slightly lower than IEEE uncontrolled environment exposure limit of 0.28 mW/cm^2.

Although the specific exposure limits may differ, both organizations agree that the dosimetric limits or whole-body average SARs of 0.4 and 0.08 W/kg for occupational and general public exposures, respectively, are well-founded scientifically and provide conservative protection factors to both groups.

C.5 THE NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS

The NCRP has been active in the areas of radiation protection and measurements since its inception as The Advisory Committee on X-Ray and Radium Protection in 1929. It was originally established to represent all of the national radiological organizations in the United States on a collective, scientific basis and to serve, in essence, as the United States national analog of the International X-Ray and Radium Protection Committee which was created in July 1928 under the auspices of the 2nd International Congress of Radiology and, subsequently, evolved into the International Commission on Radiological Protection. The NCRP originally operated as an informal association of scientists seeking to make available information and recommendations on radiation protection and measurements.

With the vast increase in the use of radiation that took place in the 1940s and 1950s, the NCRP's program expanded significantly to meet the new needs and, subsequently, it was recognized that continuation of the informal mode of operation was inappropriate. As a result, the NCRP was reorganized and chartered by the U.S. Congress in 1964 as the National Council on Radiation Protection and Measurements.

The recommendations promulgated by the NCRP provide the scientific basis for radiation protection efforts throughout the country. Governmental organizations including the U.S. Nuclear Regulatory Commission (NRC), the Public Health Service, the U.S. EPA, and state governments utilize the NCRP's recommendations as the scientific basis of their radiation protection activities.

In 1982, ANSI promulgated a new revision to the 1966 exposure limits that incorporated recognition of substantial frequency-dependent variations in rates of energy transfer to the human body from an RF field. NCRP Report No. 86 adopts the 1982 ANSI exposure limits, with minor differences. NCRP Report No. 67, *Radiofrequency Electromagnetic Fields: Properties, Quantities and Units, Biophysical Interaction and Measurements*, 1981, was used in the basis for the development of the 1982 ANSI standard. The specific exposure limits are shown in Table C-14.

Table C-14. 1982 ANSI Radiofrequency Exposure Limits[a]

Frequency Range (MHz)	Equivalent Power Density[b] (mW/cm^2)	$(Electric Field)^2$ (V^2/m^2)	$(Magnetic Field)^2$ (A^2/m^2)
0.3-3	100	4×10^5	2.5
3-30	$900/f^2$	$4 \times 10^3 (900/f^2)$	$0.025 (900/f^2)$
30-300	1	4×10^3	0.025
300-1500	f/300	4×10^3 (f/300)	0.025 (f/300)
1500-100,000	5	2×10^4	0.125

Notes: (a) Measured equal to or greater than 5 cm from any object in the field and averaged for any 6 minute period.

(b) $(Electric Field)^2/1200\pi$ or $12\pi (Magnetic Field)^2$, whichever is greater.

A^2/m^2 = amperes squared per meter squared

ANSI = American National Standards Institute

f = frequency

MHz = megahertz

mW/cm^2 = milliwatts per square centimeter

V^2/m^2 = volts squared per meter squared

NCRP indicated that because of the multiplicity of interacting factors, exposure criteria must be established in a manner such that allowance is made for maximal amplification of biological effects as a result of field-object interactions. Furthermore, the criteria should take into account possible effects rising from unusual circumstances in either the external environment of the individual (e.g., ambient temperature and humidity) or the internal environment of the individual (e.g., hyperthermia, debility, and disease). The approach used by ANSI in establishing exposure criteria focused on the frequency dependence of the SAR, with particular emphasis on examination of the domain of resonant frequencies of human beings (i.e., 30-300 MHz) from small infants to large adults. According to NCRP, behavioral disruption appears to be the most statistically significant endpoint that occurs at the lowest observed SARs. In spite of marked differences of field parameters within the reviewed scientific studies, thresholds of behavioral impairment were found within a relatively narrow range of whole-body average SARs ranging from ~3 to ~9 W/kg. In contrast, the corresponding range of power densities was 8 to 140 mW/cm^2. Regarding the SAR limit, the 1982 ANSI standard specified a whole-body average SAR limit of 4 W/kg, and incorporated a safety factor of 10 into the limit resulting in a whole-body average SAR limit of 0.4 W/kg. The fundamental criterion of a whole-body average SAR of 0.4 W/kg averaged over any 6-min exposure period, arrived at by the NCRP in NCRP Report No. 86, did not differ from that chosen by ANSI. This value is proposed as a limit only for occupationally exposed individuals and, in contrast to ANSI, NCRP proposed lower limits of averaged exposure for members of the general public.

The reasons for a two-fold set of criteria presented by NCRP included:

- Individuals exposed in the workplace should be relatively well informed of the potential hazards associated with their occupation. Furthermore, these workers may have the opportunity to make personal decisions regarding their exposure, based on the relative risk as they perceive it.
- The population at large contains sub-populations of debilitated or otherwise potentially vulnerable individuals for whom there is inadequate knowledge to set firm exposure standards.
- The general population is much larger than the occupational population; therefore, the proportionate number of persons susceptible to potential harm can be greater unless exposure of the general population is lower.

Therefore, the NCRP recommends that there be an averaged exposure criterion for the general public that is set at a level equal to that of occupationally exposed individuals. Therefore, the whole-body averaged SAR for the general public for continuous exposure should not exceed 0.08 W/kg. The rationale for the reduction by a factor of 5 is based on the exposure periods of the two populations, rounded off to one digit (40 hours per week/168 hours per week [7 days x 24 hours/day] - ~0.2). For exposure of the general population, an averaging period of 30-min is recommended. The 30-min averaging period is responsive to some circumstances for the public at large, including transient passage by the individual past high-powered RF sources and brief exposure to civilian telecommunication systems.

The NCRP has established a committee to evaluate new and recent data relating to the biological effects of RF exposure, and evaluate the scientific validity of the existing NCRP exposure limits.

C.6 OTHER STANDARD-MAKING ORGANIZATIONS/FEDERAL AGENCIES

In addition to the regulatory agencies and standard-making organizations previously identified, other federal agencies have put forth RFE exposure limits, promulgated regulatory exposure limits for RFE, or presented papers/organized proceedings related to RFE exposure. These agencies/organizations include:

- American Conference of Governmental Industrial Hygienists (ACGIH)
- OSHA
- FDA
- Department of Defense (DOD)
- Federal Aviation Administration (FAA)
- Foreign Countries (International Community)
- States (Massachusetts).

C.6.1 American Conference of Governmental Industrial Hygienists

The ACGIH is an organization devoted to the administrative and technical aspects of occupational and environmental health. ACGIH is a professional society, not a governmental organization, which has established occupational exposure limits for multiple hazards, including RFE. In establishing occupational exposure limits, ACGIH has adopted the IEEE C95.1-1991 controlled environment MPEs (i.e., for occupational exposures). The *2000 Threshold Limit Values (TLVs) for Chemical Substances and Physical Agents, and Biological Exposure Indices (BEIs) Booklet* does not cite the adoption of the ANSI/IEEE C95.1, 1999 Edition; however, future editions of the TLV Booklet may adopt the revised standard. ACGIH does not address the issue of uncontrolled environments or general population exposure to RFE.

C.6.2 Occupational Safety and Health Administration

OSHA promulgated an RFE exposure standard, 29 CFR Part 1910.97, in 1966, which limited workers' RFE exposure to 10 mW/cm^2. The 1966 standard was ruled unenforceable by the courts because its language was not mandatory (it used the word *should* and not *shall*). OSHA has not replaced this regulation with updated versions. OSHA has agreed that use of updated ANSI/IEEE C95.1 standards, including that for warning symbols, is generally acceptable in a responsible RF safety program in the workplace. By its nature, OSHA is committed to the establishment of exposure limits for occupational purposes, not exposure limits for the general population. OSHA regulations can be accessed at http://www.osha.gov.

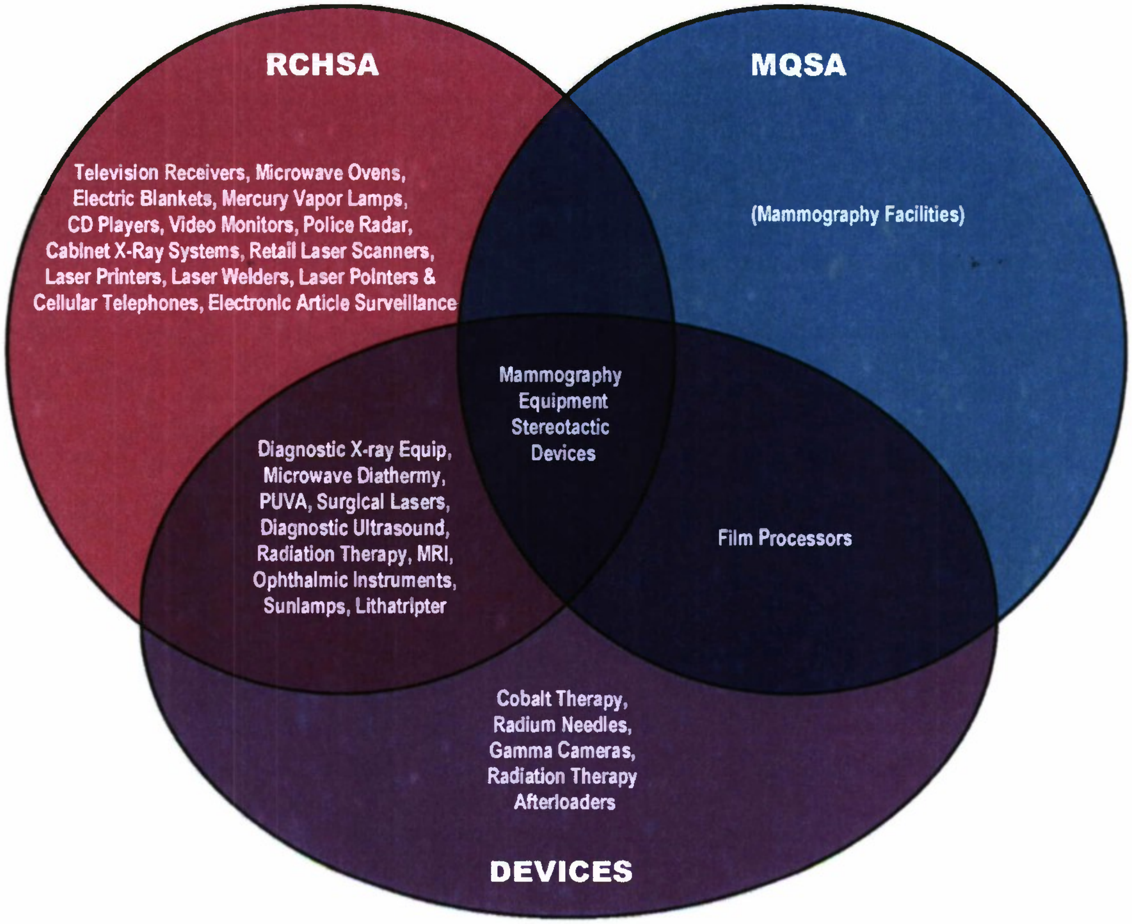
C.6.3 Federal Drug Administration

FDA has had a key role in the development of regulatory guidance related to RFE starting with the passage of the Radiation Control for Health and Safety Act of 1968. The performance standard for microwave ovens, which was developed by FDA, has long since become universally adopted throughout the world (5 mW/cm^2 at 5 cm distance from the unit). The FDA has also contributed to the work, at the committee level, of the ANSI/IEEE C95.1 standard. Recently, FDA has emphasized the need for new measures to control hazardous RF interference (RFI), especially when medical devices are involved. Figure C-5 illustrates the overlap of FDA enforcement authorities for radiation-emitting products.

C.6.4 Department of Defense

DOD has established standards regulating the use of RFE-emitting equipment and personnel exposure to RFE. The primary regulation governing DOD operations is Department of Defense Instruction (DODI) 6055.11, *Protection of DOD Personnel from Exposure to Radiofrequency Radiation and Military Exempt Lasers*, which incorporates the ANSI/IEEE C95.1-1991 standard. In addition to this standard, several of the individual branches of DOD (e.g., Air Force, Army, and Navy) have established regulations and standards governing exposure to RFE. The U.S. Air Force recently updated their previous RFE exposure standard designated Air Force Occupational Safety and Health Standard (AFOSH) 48-9, *Radio Frequency Radiation (RFR) Safety Program*, which incorporated the ANSI/IEEE C95.1-1991 standard. The U.S. Navy's Occupational Safety and Health Program, OPNAVINST 5100.19D provides guidance on RFE exposure and has incorporated the ANSI/IEEE C95.1-1991 standard into its own regulation. The U.S. Army's regulation, Army Regulation (AR) 40-1, *Health Hazard Assessments*, provides guidance on the assessment of health hazards including RFE exposure. AR 40-1 has incorporated the ANSI/IEEE C95.1-1991 standard.

Figure C-5. Overlap of FDA Enforcement Authorities (with examples of products)



Note: Not all of the devices listed above are RF/microwave energy emitters.

RCHSA	=	Radiation Control for Health and Safety Act of 1968
MQSA	=	Mammography Quality Standards Act of 1992
Devices	=	Federal Food, Drug, and Cosmetic Act, Chapter 5, Medical Devices

C.6.4.1 Restricted Airspace near Cape Cod AFS

Airspace restrictions have been identified near Cape Cod AFS, as designated by DOD and FAA, not to prevent occupational or inadvertent RFE exposure to military or civilian aircraft operators, respectively, but to prevent the inadvertent explosion of EEDs (i.e., weapon systems, ejection system rockets, or countermeasures) that maybe present on military aircraft (Figure C-6). EEDs are initiated electrically; therefore, stray EM energy (of which RF/microwave are forms of EM energy) could cause the accidental firing of these EEDs. Air Force Manual (AFMAN) 91-201, *Explosives Safety Standards* has established U.S. Air Force guidance related to EM energy exposure to EEDs.

EXPLANATION

- Region of Influence
- Restricted Area
- Military Operations Area (MOA)
- Class E Airspace Boundary
- Class C Airspace Boundary
- Airports/Airfields
- Private Airports/Airfields

0 2 4 8 Nautical Miles

Source: National Oceanic and Atmospheric Administration, 2000.

Airspace Restriction Cape Cod AFS

Figure C-6

C.6.5 Federal Aviation Administration

The FAA had adopted the most current RF/microwave energy exposure criteria published by the ACGIH and ANSI/IEEE C95.1-1991, as of the publication date of their internal radiation program in the FAA Occupational Safety and Health Program, *Order 3900.19B, Chapter 14*. In its adoption of ANSI/IEEE C95.1-1991, the FAA incorporated the distinction between controlled and uncontrolled exposure environments. The only difference is that the FAA has established the ANSI/IEEE C95.1-1991 uncontrolled environment exposure standards as "action levels", not as ceiling limits for exposure, for implementing the specific guidance in FAA *Order 3900.19B, Chapter 14*. In addition, the FAA established interim measures in 1997, prior to the update of FAA *Order 3910.3A*, in which RFE measurements would be quantified in existing/proposed sites for child care centers in the vicinity of FAA radar and communications facilities. This feature of FAA *Order 3910.3A* was devised solely by the FAA, not in response to regulatory requirements. The acceptance of the FAA radiation safety program by OSHA is documented in Figure C-7.

C.6.6 Foreign Countries (International Community)

RFE exposure standards from different countries have been as diverse as the countries themselves. The WHO generated a compendium of RFE exposure standards from nine countries (some of which no longer exist, principally the USSR and Eastern European countries) in 1981, in *Environmental Health Criteria 16: Radiofrequency and Microwaves*. These included:

- Australia (0.57 mW/cm^2 @ 420 MHz)
- Bulgaria (0.01 mW/cm^2)
- Canada (1 mW/cm^2)
- Czechoslovakia (0.001 mW/cm^2)
- East Germany (1,000 mW/cm^2)
- Poland (100 mW/cm^2)
- Sweden (1 mW/cm^2)
- United States (0.28 mW/cm^2 @ 420 MHz)
- Union of Soviet Socialist Republics (0.005 mW/cm^2).

Many of these countries used different rationales and included differing safety factors into their exposure standards, so no direct comparison is possible. Although several countries had very conservative exposure limits, these limits were possibly intended for political propaganda purposes (Eastern Block countries and Union of Soviet Socialists Republic) or based on different viewpoints and rationales. Several articles have been written recently regarding the very conservative exposure limits promulgated by the USSR and other Eastern Block countries, and their origins. As Yost (1992) has explained, differences between exposure limits "may be largely due to different viewpoints used in setting standards. In Russia, exposure limits tend to be set below the level at which any observable biological effect is found; in the U.S., exposure limits typically are set below the level of any harmful biological effects [within a margin of safety]." In addition, it should be noted that the guidelines in Russia were intended to apply only in nonmilitary situations (McRee, 1979). It has been postulated that "the Soviets, in practice allowed exposure above their guidelines, since they knew that it was not seriously hazardous" (Sliney and Cuellar, 1992). Furthermore, very recently, these guidelines were relaxed enormously. (Other aspects of invalid comparisons between Soviet and U.S. standards have been discussed by Osepchuk [1987].)

Figure C-7. OSHA Acceptance of FAA Radiation Safety Program

U.S. Department of Labor

Occupational Safety and Health Administration
Washington, D.C. 20210

Reply to the Attention of

SEP 21 1998

The Honorable Melissa J. Spillenkothen
Assistant Secretary for Administration
Department of Transportation
M-1, Room 10314
400 7th Street S.W.
Washington, D.C. 20590

Dear Ms. Spillenkothen:

The Occupational Safety and Health Administration (OSHA) has reviewed your document entitled Chapter 28: Radiation Safety Program," and believes that when implemented this doc- ument will provide equal or greater protection than 29 CFR 1910.97. Thus OSHA agrees that the Federal Aviation Administration (FAA) may use this standard in place of 29 CFR 1910.97 to regulate occupational exposure to radiation.

The exposure limits selected by FAA are well recognized and supported by the safety and health community as well as OSHA by reference (e.g. ACGIH TLV's and ANSI). Although more restrictive than the OSHA standards, complying with the selected consensus standards is feasible and will provide a more protective workplace. The selection of the more restrictive public exposure limits from the current ANSI C95.1 standard as an "action level" which determines when an RF Safety Program is necessary is particularly useful. Most importantly, the adoption of the most recently published ACGIH TLV's will ensure that the FAA program is not locked into outdated standards, in that limits are automatically updated with each update to the TLV's. Of course, full implementation of this program is key to providing the worker protection described.

Accordingly, the FAA is permitted by 29 CFR 1960.16 to prescribe and enforce more stringent permissible exposure levels or threshold limit values and may require more frequent monitoring of exposures without recourse to the approval procedures for alternate standards described in 29 CFR 1960.17. OSHA believes that the radiation program proposed by the FAA is more protective than the 1910 standard and agrees that FAA should adopt this as its radiation standard. Additionally OSHA will use this proposed standard to determine worker exposure to radiation and will not measure compliance against 29 CFR 1910.97.

Figure C-7. OSHA Acceptance of FAA Radiation Safety Program, continued

2

Please advise this office when full implementation is expected, so that we can apprise our compliance inspectors.

Sincerely,

Emzell Blanton, Jr.
Deputy Assistant Secretary

Many of the exposure limits are for the general population, although the averaging times differ significantly ranging from 30 minutes to unlimited (24 hours). Also, many of the exposure limits account for both continuous wave (CW) and pulsed energy waveforms, whereas the IEEE C95.1-1991 limits are not specific for either CW or pulsed waveforms.

C.6.7 State Regulatory Agencies (Massachusetts)

The regulations governing RF/microwave energy exposure in the State of Massachusetts are listed under the Department of Public Health or in Part 105, Section 122.000 of the Commonwealth of Massachusetts Regulations (CMR) (105 CMR Section 122.000). 105 CMR Section 122.000 parallels the FCC and ANSI/IEEE C95.1-1982 standards, with marginal differences in definitions. Table C-15 lists the occupational RF exposure limits for employees, as shown in 105 CMR Section 122.100, and Table C-16 lists the non-occupational RF exposure limits for the general public, as shown in 105 CMR Section 122.015.

Table C-15. Massachusetts Occupational RF Exposure Limits

Frequency Range	$\|\bar{E}\|^2$-field Strength $(V/m)^2$	$\|\bar{H}\|2$-field Strength $(A/m)^2$	Equivalent Plane Wave, Free Space Power Density (mW/cm^2)[(a)]
10 kHz – 3 MHz	400,000	2.5	100
3 MHz – 30 MHz	4,000 $(900/f^2)$	0.025 $(900/f^2)$	$900/f^2$
30 MHz – 300 MHz	4,000	0.025	1.0
300 MHz – 1500 MHz	4,000 (f/300)	0.025 (f/300)	f/300
1500 MHz – 100 GHz	20,000	0.125	5

Note: (a) Power density measurements are averaged over any 6 minute period.
A/m^2 = amperes per square meter
E = electric field
f = frequency in megahertz
GHz = gigahertz
H = magnetic field
kHz = kilohertz
MHz = megahertz
mW/cm^2 = milliwatts per square centimeter
V/m^2 = volts per square meter

Table C-16. Massachusetts Non-Occupational RF Exposure Limits for the General Public

Frequency Range	$\|\bar{E}\|^2$-field Strength $(V/m)^2$	$\|\bar{H}\|^2$-field Strength $(A/m)^2$	Equivalent Plane Wave, Free Space Power Density (mW/cm^2)[(a)]
300 kHz – 3 MHz	80,000	0.5	20.0
3 MHz – 30 MHz	800 $(900/f^2)$	0.005 $(900/f^2)$	$180/f^2$
30 MHz – 300 MHz	800	0.005	0.2
300 MHz – 1500 MHz	800 (f/300)	0.005 (f/300)	f/1500
1500 MHz – 100 GHz	4,000	0.025	1.0

Note: (a) Power density measurements are averaged over any 30-minute period.
A/m^2 = amperes per square meter
E = electric field
f = frequency in megahertz
GHz = gigahertz
H = magnetic field
kHz = kilohertz
MHz = megahertz
mW/cm^2 = milliwatts per square centimeter
V/m^2 = volts per square meter

105 CMR Section 122.000 exposure limits (both occupational and non-occupational) do not address the low frequency ranges that ANSI/IEEE C95.1-1991 does; therefore, induced currents within the body may not be factored into the establishment of limits as in ANSI/IEEE C95.1-1999. The regulation also states the use of warning signs in accordance with ANSI/IEEEC9122.12-1982, or subsequent revisions (i.e., ANSI/IEEE C95.2-1999).

C.6.8 The Precautionary Principle

The precautionary principle was first introduced in 1984 at the First International Conference on Protection of the North Sea. Following this conference, the principle was integrated into several international conventions and agreements including the Maastricht Treaty, the Barcelona Convention, and the Global Climate Change Convention. It has been implicitly incorporated into several U.S. environmental laws such as the Pollution Prevention Act of 1990. The precautionary principal is a concept of taking anticipatory action in the absence of complete proof of harm, particularly when there is scientific uncertainty. The principal states that action should be taken to prevent environmental damage when evidence from several studies combined, indicates actual or potential environmental harm (Tickner, 1997).

The precautionary principle asserts that decision-makers should act in advance of scientific certainty to prevent harm to humans and the environment. It is a concept to address limitations of current decision-making methods such as problems of cumulative effects and limitations of science. However, this concept provides few guidelines for policy makers, and fails to constitute an analytical framework for implementation. Although several frameworks for integrating the principal into environmental decision making have been proposed, no comprehensive, systematic structure for precautionary decision-making has been applied on a national or international level (Tickner, 1997).

With regard to RFE, scientific committees have concluded that the threshold for potential adverse biological effects occurs at exposures greater than 4 W/kg. Thresholds for workers with potential RFE exposure are set with a safety factor of 10, thus, 0.4 W/kg is used as a limit for workers around RFE. A safety factor of 50 is applied for individuals in public locations as an extra measure of safety; thus, limiting public RFE exposure to 0.08 W/kg. These safety limits for worker and public exposure to RFE are used in RFE standards adopted throughout the world including the United States, Europe, Japan, Australia, and Canada.

Establishing the more conservative safety limits do not arise from a fundamental change in the RFE safety criteria, but from a precautionary desire to protect specific groups of the general population (i.e., workers around RFE and general population) who may be at more risk. Complying with these accepted RFE safety standards constitutes compliance with the concepts of the precautionary principal.

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APPENDIX D

ELECTROMAGNETIC SPECTRUM

APPENDIX D

ELECTROMAGNETIC SPECTRUM

D.1 ELECTROMAGNETIC SPECTRUM

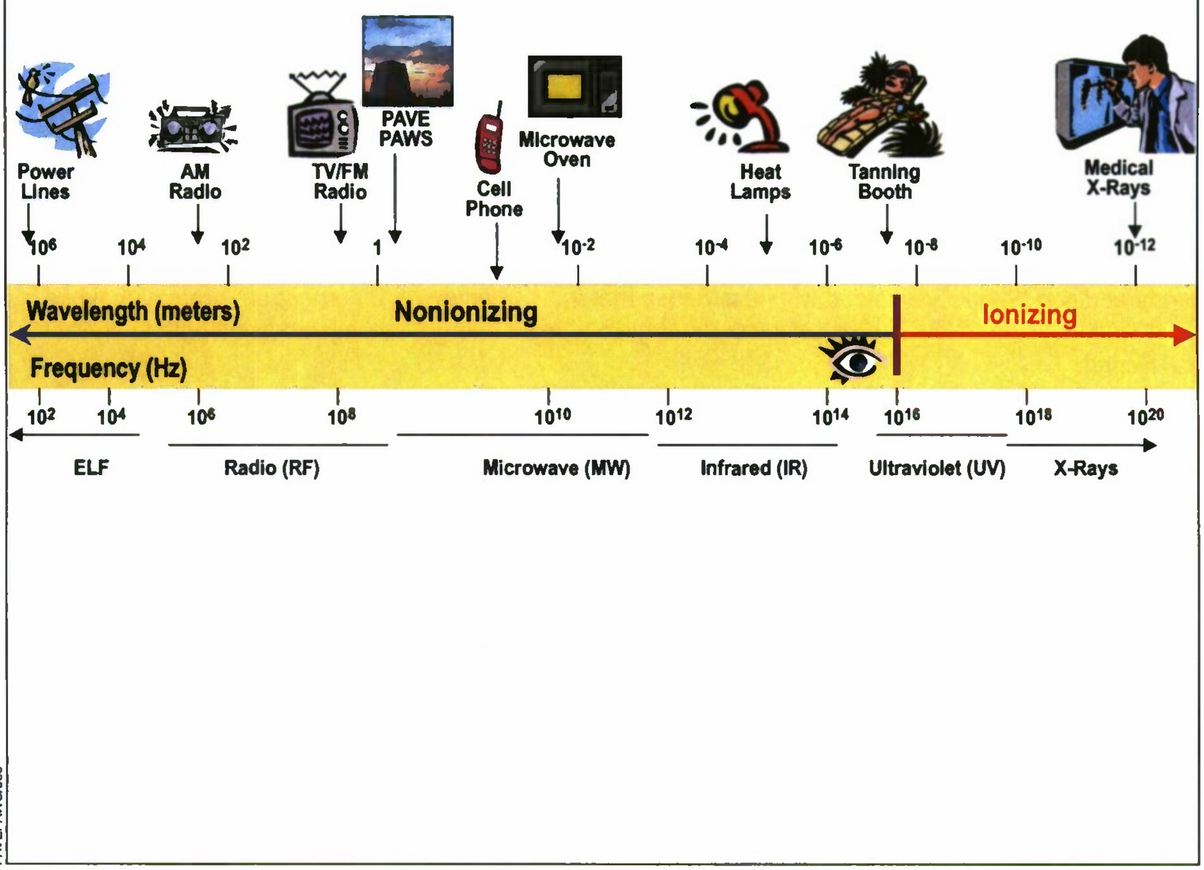
The electromagnetic (EM) spectrum refers to the many different types of radiation ranging from radio waves to gamma rays. The EM spectrum permeates the entire planet, either from naturally occurring EM sources, or from man-made EM sources. The types of EM radiation are classified according to their wavelengths/frequencies and the amount of energy they carry. An illustration of the EM spectrum and associated man-made sources of EM is shown in Figure D-1.

Figure D-2 represents the significant difference in wavelengths and, thus, energy levels from one end of the EM spectrum to another. Gamma rays have wavelengths on the order of millions of times shorter than those of visible light and radio waves have wavelengths billions of times longer than those of visible light. The shorter the wavelength or higher the frequency of the radiation, the higher the energy. Thus, several feet of concrete or steel shielding is needed to block gamma rays because the very short wavelengths can pass between molecular bonds. Radio waves with longer wavelengths cannot pass between molecular bonds and can be easily shielded with less dense materials. Within the EM spectrum are seven types of radiation that listed below in order of lowest energy to highest energy, or longest wavelength to shortest wavelength:

- Radio waves (RF)
- Microwaves (PAVE PAWS)
- Infrared radiation
- Visible light
- Ultraviolet radiation
- X-rays
- Gamma rays.

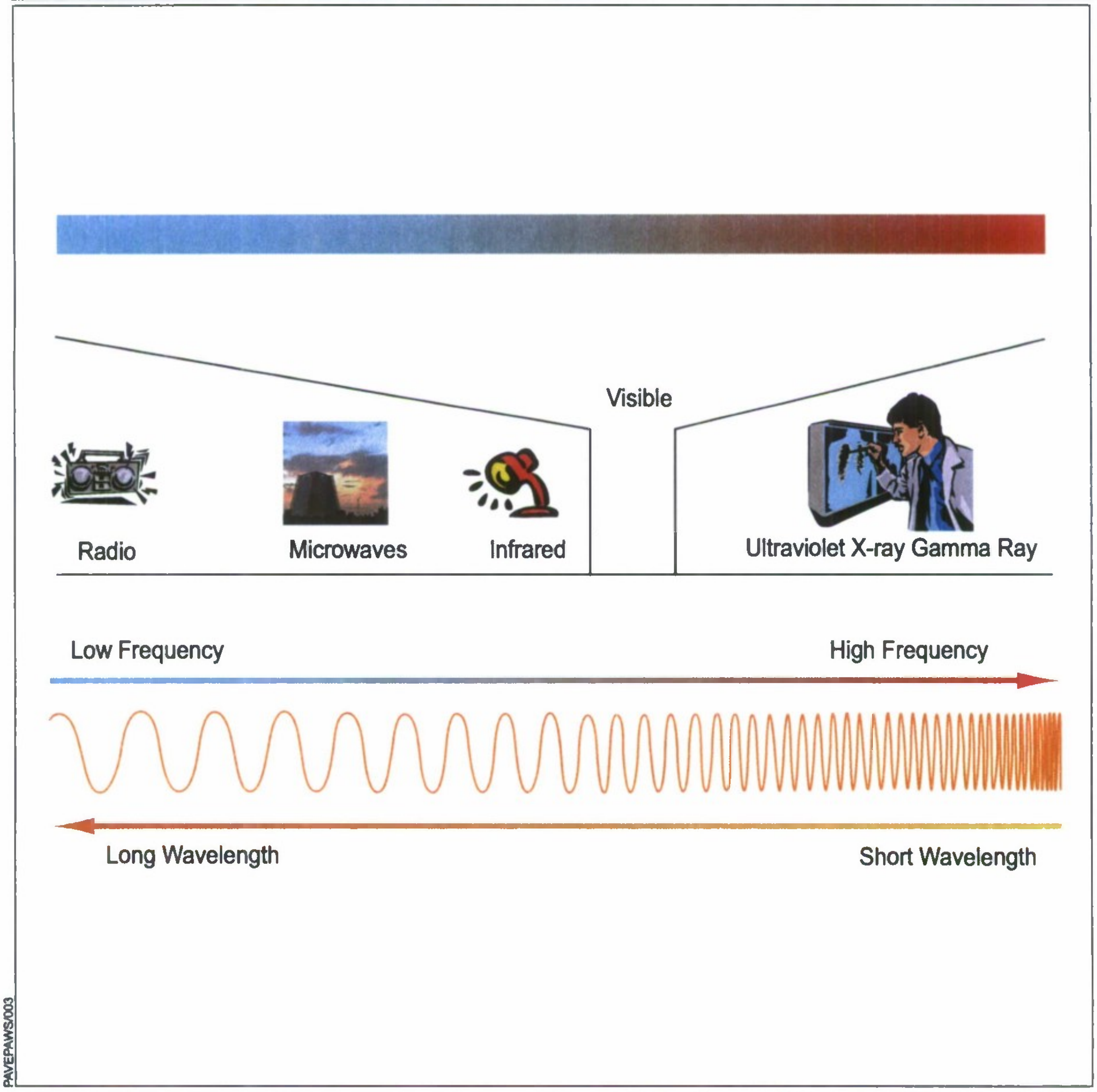
All EM radiation, except the wavelengths within the visible light spectrum, is invisible to the human eye. Some EM radiation, such as microwaves, can be sensed as a clicking sound resulting from thermoelastic expansion within the brain; infrared radiation can be sensed as heat. Of the seven listed, only X-rays and gamma rays constitute the ionizing radiation portion of the EM spectrum. These types of EM radiation have high energy levels capable of disassociating electrons from atoms or molecules, thus creating ions or charged particles. Non-ionizing radiation does not contain sufficient energy to ionize atoms or molecules.

Some organizations consider cosmic radiation, a type of ionizing radiation, to be the eighth type of radiation within the EM spectrum. This type of radiation originates in space, outside of the Earth's atmosphere, from stars, pulsars, and other luminous celestial bodies. Cosmic radiation consists of high-energy particles produced by all luminous objects within the universe. The sun, part of our solar system, is a major source of cosmic radiation that contacts the Earth's atmosphere. Secondary cosmic rays, formed by interactions in the Earth's atmosphere, account for approximately 45 to 50 millirems of the 360-millirem background radiation that an average individual receives in one year (U.S. Nuclear Regulatory Commission, 2001).



Electromagnetic Spectrum

Figure D-1



Wavelength Difference of the Electromagnetic Spectrum

Figure D-2

All EM radiation is composed of two components, an electric field and a magnetic field. These fields propagate outward from the EM source as waveform (similar to waves created by an object dropped into water) with the electric and magnetic field perpendicular (i.e., at right angles) to one another. Figure D-3 represents the waveform of EM radiation. These waves of EM radiation travel at the speed of light through a vacuum, and slightly slower speeds through more dense media (e.g., planetary atmosphere).

D.1.1 Radio Waves (Radiofrequency Radiation)

Radio waves or RF radiation is generally categorized as the lowest energy radiation within the EM spectrum. Some organizations designate separate subgroups within the RF category (e.g., Extremely Low Frequency [ELF] radio waves). Radio waves/RF radiation is characterized by:

- Long wavelengths (less than a centimeter [cm] to hundreds of meters)
- Low energy.

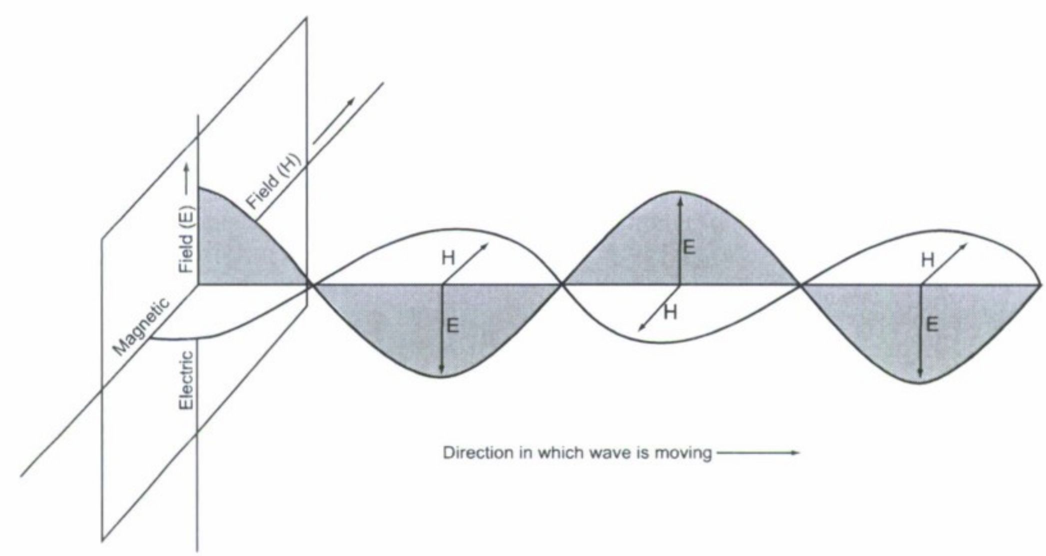
A Frequency Modulation (FM) radio station, at 100 on the radio dial, has a wavelength of about three meters; whereas an Amplitude Modulation (AM) radio station, at 750 on the radio dial, has a wavelength of about 400 meters. As indicated above, the shorter the wavelength or higher the frequency of the radiation, the higher the energy. Radio waves, with the longest wavelengths and lowest frequencies within the EM spectrum (see Figure D-2), have the lowest energy.

Radio waves, or RF, radiation falls within the category of non-ionizing radiation because it does not have the necessary energy to disassociate electrons from atoms or molecules. Radio waves are naturally produced on Earth and by celestial bodies/phenomena within the universe, including the sun.

Earth is constantly inundated with radio waves (RF radiation) from the sun and other natural objects in space. As the sun is a celestial source of RF radiation, other sources, such as the Earth itself and man-made sources of radio waves (RF radiation) collectively permeate everyday life. Although many man-made sources of RF radiation are the result of AM/FM radio transmissions, television transmissions, and radar operations, many more sources of man-made RF radiation exist within our homes, cars, and work places. Examples of these man-made sources of radio waves (RF radiation) and their respective frequencies are:

- Video Display Units (VDUs) (15-35 kilohertz [kHz])
- Garage door openers and alarm systems (~40 megahertz [MHz])
- Standard cordless phones (~40-50 MHz)
- Baby monitors (~49 MHz)
- Radio-controlled toy airplanes (~72 MHz)
- Radio-controlled toy cars (~75 MHz)
- Industrial equipment (RF sealers) (<100 MHz)
- Medical diathermy (<100 MHz)
- FM radio transmitters (88-108 MHz)
- Television (channels 7 to 13) transmitters (174-216 MHz).

The frequencies within the radio wave (RF radiation) range of the EM spectrum that present the most danger to human beings are those between 30 and 300 MHz. The celestial contribution of radio waves within this frequency range equals approximately 10 picowatts (pW)/square cm (cm^2) (World Health Organization, 1981). The reason this frequency range presents the highest degree of danger is that this frequency range represents the resonant-frequency domain for human beings from smallest child to tallest man, under both grounded and ungrounded conditions. This means that the human body absorbs the highest amount of RFE at these frequencies.



EXPLANATION

Radiofrequency/microwave energy is made up of an electric field (E) and a magnetic field (H). The fields are perpendicular to one another. These fields expand in a wave-like pattern as the energy propagates outward from its point-of-origin.

Electromagnetic Monochromatic Wave

Source: World Health Organization, 1981.

Figure D-3

D.1.2 Microwaves

Microwaves occupy the spectral region of the EM spectrum between radio waves and infrared radiation (see Figure D-1). Microwave radiation is often considered a subset of radio waves, although an alternative convention treats microwaves and radio waves as two spectral regions. The wavelengths of microwaves generally range from approximately 1 millimeter (the thickness of a pencil) to approximately 30 cm or 12 inches (see Figure D-2).

Microwaves fall into the category of non-ionizing radiation because they do not have sufficient energy to disassociate electrons from atoms or molecules. Microwaves are naturally produced here on Earth and by celestial bodies/phenomena within the universe. In 1965, two radio astronomers discovered the cosmic microwave background radiation, a diffuse radiation that emanates uniformly from all directions in the sky. The scientific consensus believes the cosmic microwave background radiation is the cooled remnant of the "Big Bang," or theorized creation of the universe.

As the universe itself is a source of microwave radiation, other sources such as man-made sources permeate everyday life. Even though many of the man-made sources of microwaves are represented by radars (e.g., Doppler/NEXRAD meteorological radars and air traffic control radars), other sources such as satellite communication systems (SATCOM) and wireless communications also operate in the microwave frequencies. In addition to these sources, a common household appliance, the microwave oven, operates in the microwave frequencies. Also, many police radars used to determine a vehicle's speed operate in the microwave frequencies. The PAVE PAWS radar system operates within the microwave frequency range of 420-450 MHz. Examples of man-made sources of microwaves and their respective frequencies are:

- PAVE PAWS (420-450 MHz)
- Taxi/industry/transport communications services (452.05-452.5 MHz)
- Ambulance/hospital radio communication services (467.95-468.175 MHz)
- Microwave ovens (2,450 MHz)
- Cellular telephones (~824-849 MHz)
- Aircraft telephones (894-896 MHz)
- New 900-MHz cordless phones (900 MHz)
- Digital audio broadcasts (1,435-1,524 MHz)
- Global Positioning Systems (GPS) (1,227 and 1,575 MHz)
- Personal communication systems (PCS) (1,755-2,290 MHz).

The primary hazard associated with microwaves is the heating of tissue, which can cause, other problems or bioeffects throughout the body. As in a microwave oven, microwaves heat tissue at the molecular level resulting in the heating of water within the system. The amount of microwave energy, which tissue has absorbed, and the penetration depth of the microwaves determine the degree of heating. Microwaves penetrate to different depths at different frequencies. For example, at 2,450 MHz, microwaves penetrate in muscle to a depth of 1.67 cm and fat to a depth of 8.1 cm (Cember, 1996). With regards to biological effects, the microwave frequencies above 10 GHz have increasingly small penetration depths in human tissue, thus they are closer to the way infrared and visible light interacts with biological tissue (e.g., quasi-optical). While at the human resonance frequencies (30-300 MHz), almost all of the RFE is absorbed deeply in the body, whereas in the so-called quasi-optical portion of the microwave frequency range (10-300 GHz), penetration depth in tissue is only a few millimeters.

D.1.3 Infrared Radiation

Infrared radiation (IR) is categorized as the wavelengths between the visible light and microwave ranges of the EM spectrum (see Figure D-1). IR has shorter wavelengths (see Figure D-2) and higher energies than radio waves and microwaves. IR is frequently separated into two categories:

- Near-IR
- Far-IR.

Near- and far-IR radiation refers to the regions that lie at each end of the IR spectrum, one near the microwave spectrum and the other near the visible light spectrum. IR is characterized by heat.

Any object that has a temperature above absolute zero (0° Kelvin [K] or -459.67°F) radiates IR. Even objects one may think of as being very cold, such as an ice cube, emit IR. Another example is hot charcoal, which may not give off visible light, but emits IR that humans perceive as heat. Human beings emit IR at a wavelength of ~10 microns (or 0.0000001 meter), as do all other warm-blooded mammals. IR falls within the category of non-ionizing radiation because it does not have sufficient energy to disassociate electrons from atoms or molecules. Although IR has a higher energy level than radio or microwaves. IR is naturally produced on Earth and by celestial bodies/phenomena within the universe, including the sun.

As the sun is a celestial source of IR, other sources, such as the Earth itself and man-made sources of IR, collectively permeate everyday life. Examples of these IR sources include:

- Television/electronics remote control devices
- Cafeteria food heat lamps
- IR lasers
- IR transfer ports on computers or calculators
- Fires
- Welding equipment.

IR is perceptible as a sensation of warmth on the skin. The increase in tissue temperature upon exposure to IR depends upon the wavelength, the total amount of energy delivered to the tissue, and the length of exposure. The far wavelength (far-IR) region of 5,000 nanometers to 0.1 cm is completely absorbed in the surface layers of the skin. The wavelengths within the IR range that present the most danger to human beings are those in the range of 750 to 1,500 nanometers (nm). This short wavelength (near-IR) region is capable of causing injuries to the cornea, iris, retina, and lens of the eye. The condition known as "glass blower's cataract," or "heat cataract," is the result of excessive exposure to IR/visible light from furnaces or similar hot bodies. This condition is an opacity of the rear surface of the lens in the eye.

D.1.4 Visible Light

Visible light consists of the wavelengths between the IR and ultraviolet ranges in the EM spectrum (see Figure D-1). Visible light has shorter wavelengths (see Figure D-2) and higher energies than radio waves, microwaves, and IR. Visible light is the part of the EM spectrum that we are able to view with the unaided eye. Visible light is the rainbow of colors, which coincide with the wavelength(s) of greatest intensity emitted by the sun. The wavelengths of visible light range from approximately 7.5×10^{-7} meters to 4.0×10^{-7} meters. Visible light is characterized by the following colors:

- Red
- Orange

- Yellow
- Green
- Blue
- Indigo
- Violet.

Visible light falls within the category of non-ionizing radiation because it does not have sufficient energy to disassociate electrons from atoms or molecules. Visible light is naturally produced on Earth and by celestial bodies/phenomena within the universe, including the sun.

As the sun and other celestial bodies/phenomena are sources of visible light, other sources such as naturally-occurring (non-celestial) man-made sources of visible light collectively permeate everyday life. Naturally-occurring (non-celestial) sources of visible light include lightning, the northern lights, and specific animals (e.g., fireflies, some deep ocean animals). Examples of man-made sources of visible light include the following:

- Incandescent light bulbs
- Fluorescent light bulbs
- Search lights
- Laser pointers
- Welding operations.

The primary hazard associated with visible light is potential damage to the unprotected eye as a result of exposure to extremely luminous sources of visible light. Although lasers are not limited to the frequencies of visible light, the primary hazard associated with optical lasers is damage to the unprotected eye. Unlike incandescent sources of visible light that radiate their light in all directions and frequencies, lasers emit a highly concentrated and coherent beam of light in the same direction and frequency, yielding light beams of high energy and intensity. Laser light may be concentrated within the eye to a degree that causes serious damage to the retina, whereas, a light-bulb cannot produce serious harm because the energy is unfocused.

D.1.5 Ultraviolet Radiation

UV radiation is categorized as the wavelengths between the visible light and X-ray ranges of the EM spectrum (see Figure D-1). UV has shorter wavelengths (see Figure D-2) and higher energies than radio waves, microwaves, IR, and visible light. UV radiation is frequently separated into three categories, according to wavelength:

- UV-A (315-400 nm)
- UV-B (280-315 nm)
- UV-C (100-280 nm).

Most UV radiation falls within the category of non-ionizing radiation because it does not have sufficient energy to disassociate electrons from atoms. UV radiation can be characterized by the biological effect each wavelength range has on the human body:

- UV-A is the wavelength range responsible for pigmentation of the skin, also called the ("black light region")

- UV-B is the wavelength range responsible for harmful effects to the human body and can cause a sunburn

- UV-C does not reach the surface of the Earth as it is readily absorbed by the air; however, some arc-welding operations produce UV-C that can have harmful effects on the cornea within the human eye.

UV radiation is produced by celestial bodies/phenomena throughout the universe, including the sun. As previously noted, most of the UV radiation does not reach the surface of the Earth as it is absorbed in the upper atmosphere by the ozone layer. However, as the ozone layer is depleted, increasing amounts of UV radiation can reach the Earth's surface, increasing the risk to humans. Man-made sources of UV radiation are also common. Examples of man-made sources of UV radiation are:

- Black light lamps
- Tanning salon sunlamps
- Arc-welding operations
- Fluorescent light bulbs (produced internally, but shielded by the glass bulb)
- Germicidal lamps.

Even though a small amount of UV radiation is healthy and contributes to the overall health of our skin, overexposure to sunlight or an excessive dose of UV radiation can be extremely detrimental to our health. UV radiation has two primary effects, dermatological and ocular. The dermatological effects produce immediate changes in the skin such as darkening of the cellular pigment, the occurrence of a sunburn, production and migration of melanin granules, and changes in cell growth in the epidermis. Long-term effects to the skin include decreased elasticity of the skin giving the appearance of premature aging and an increase in certain types of skin cancer, specifically melanoma.

Although a small amount of UV may not produce permanent injury to the eyes, increased exposure can cause significant damage to the eyes without discomfort during exposure. The development of corneal and conjunctival irritation may result from excessive exposure of the eyes to intense sunlight, or exposure to man-made sources such as arc-welding operations. Arc-welding flashes are the most common industrial exposure to UV radiation resulting in damage to the eye called "welder's flash".

D.1.6 X-rays

X-rays are categorized as the wavelengths between the UV radiation and gamma ray range of the EM spectrum (see Figure D-1). X-rays have shorter wavelengths (see Figure D-2) and higher energies than radio waves, microwaves, IR, visible light, and UV radiation. X-rays are frequently separated into two categories:

- Soft X-rays
- Hard X-rays.

The X-rays of longer wavelengths (i.e., near the UV boundary) or soft X-rays are less penetrating and may be shielded with thin layers of steel, whereas X-rays of shorter wavelengths (i.e., near the gamma ray boundary) or hard X-rays will penetrate several cm of steel. The X-ray region generally marks the transition from non-ionizing radiation to ionizing radiation. X-rays do possess the energy necessary to disassociate electrons from atoms or molecules. As a result, X-rays can produce significant damage to cellular/biological systems. In addition, ionizing radiation can produce mutagenic/teratogenic effects in biological systems, resulting in chromosomal and DNA changes to both existing and future generations.

X-rays are naturally-produced by celestial bodies/phenomena within the universe, including the sun. Man-made sources of X-rays are also common. Examples of man-made sources of X-rays are:

- Medical X-ray units (including dental)
- X-ray units used for non-destructive inspection of industrial welds/components
- X-ray lasers
- X-ray fluorescence (XRF) device used for lead-based paint inspections
- X-ray spectrometer used in chemical analyses
- X-ray diffraction device
- Transmission electron microscope
- Scanning electron microscope.

X-ray radiation is an external radiation source meaning x-rays originate outside the nucleus of an atom and are capable of ionizing molecules from a distance outside of the body. The brief, low-intensity exposure incurred during medical diagnostic procedures does not present a significant hazard. However, the effects of ionizing radiation exposure are cumulative, so the amount of radiation exposure received (if any) is measured. Multiple exposures combine to equal a potentially hazardous dose to the human body and its physiological systems. Ionization strips electrons from atoms and breaks their chemical bonds with other atoms. A simple molecular structure, such as water, will recombine after ionization; however, this is not the case in a complicated living cell. Ionization may give many possible atomic recombinations in living cells, including the onset of cancer. The rupture of a few bonds in the elaborate structure of the molecules of a living cell may have profound effects.

D.1.7 Gamma Rays

Gamma rays are generally categorized as the highest energy radiation within the EM spectrum (see Figure D-1), although some organizations consider cosmic rays to be higher in the EM spectrum than gamma rays. Gamma rays are frequently separated into two categories:

- Soft gamma rays
- Hard gamma rays.

Gamma rays of longer wavelength (i.e., near the X-ray boundary) or soft gamma rays are less penetrating, whereas gamma rays of shorter wavelengths (i.e., near the top of the gamma ray range) are more penetrating and energetic. With X-rays, gamma rays make up the ionizing radiation part of the EM spectrum. Gamma rays possess the necessary energy to disassociate electrons from atoms or molecules; therefore, gamma rays present a significant hazard to biological systems. As with X-rays, gamma rays can produce mutagenic/teratogenic effects in biological systems, resulting in chromosomal and DNA changes to both existing and future generations of people. Gamma rays present an external hazard, because with their short wavelength and high energy, they can easily pass through the body and cause damage to biological systems. Gamma rays are an internal source of radiation meaning they originate inside the nucleus of an atom. Gamma rays are produced during the radioactive decay or transformation of specific elements.

The decay process for ^{137}Cesium isotope emits a gamma ray when the intermediate isotope ^{137m}Cesium loses energy in reaching the stable ^{137}Barium (^{137}Ba) isotope. Gamma rays are produced by specific elements within the Earth and celestial bodies/phenomena within the universe, including our sun. Man-made gamma ray sources that are utilized include:

- Household smoke detectors
- Nuclear fission reactors
- Specific radiopharmaceuticals
- ^{226}Radium-coated dials on watches and compasses (outdated practice)
- Older model fueled-lanterns (e.g., specifically the mantel).

Gamma rays have similar qualities to X-rays and thus have similar harmful effects. Unlike X-rays, whose radiation originates outside the nucleus of an atom, gamma ray radiation originates inside the nucleus of an atom and is capable of ionizing molecules from a great distance outside of the body. Also like X-rays, ionizing gamma rays produce cumulative effects in biological systems and multiple exposures combine to create a potentially hazardous dose to the human body and its biological systems. With their extremely short wavelengths, gamma rays can pass completely through the body, resulting in internal damage to biological systems.

D.2 IONIZING RADIATION AND NON-IONIZING RADIATION

All regions of the EM spectrum below X-rays are categorized as non-ionizing radiation, while X-rays and gamma rays are categorized as ionizing radiation. Definitions of these terms are as follows:

Non-ionizing radiation cannot damage biological material through ionization. However, it can cause damage through other processes (e.g., photochemical reactions, heat-buildup). Non-ionizing radiation includes ultraviolet radiation, microwaves, radio waves, and low-frequency electric and magnetic fields. The SSPARS RFE emissions are a form of non-ionizing radiation.

Ionizing radiation refers to forms of radiation that can cause ionization in biological material and thus cause damage. Ionizing radiation originates from both natural sources (e.g., cosmic radiation, outer space, radon) and from man-made sources such as X-ray equipment and nuclear reactors.

A typical source of ionizing radiation is radioactive material. Naturally occurring radioactive materials such as uranium (^{238}U), radium (^{226}Ra), and radon (^{222}Rn) exist throughout the environment. Uranium and radium are found in subsurface rocks as ore and are actively mined, while radon is a gaseous decay product of uranium and seeps up through rocks to the surface. Radon can seep into basements and other subsurface structures or foundations and present a significant exposure hazard to the public. Ionizing radiation sources are in many households in the form of small radioactive sources (e.g., ^{241}Americium) in smoke detectors.

The primary difference between ionizing and non-ionizing radiation is the photon energy. The photon energy produced by a gamma ray emission from a naturally occurring radioactive ore, ^{238}U, is as high as 663 kilo-electron volts (keV) (i.e., 1 keV is 1,000 electron volt [eV]), while the photon energy of radio waves and microwaves corresponds to 4.1×10^{-10} eV at 100 kHz and 1.25×10^{-3} eV at 300 GHz. Therefore, the EM spectrum is easily differentiated by the categories of non-ionizing and ionizing radiation.

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APPENDIX E

ATTENUATION OF RADIOFREQUENCY ENERGY

APPENDIX E

ATTENUATION OF RADIOFREQUENCY ENERGY

E.1 NATURAL ATTENUATION

The PAVE PAWS radar is housed in a 32-meter high, three-sided building, in which two flat arrays of individual radiating elements transmit and receive radiofrequency (RF) signals generated by the radar. The two array faces are 31 meters wide and tilted back 20 degrees (°) from vertical. The active portion of the array resides in a circle 22.1 meters wide in the center of the array. Each radiating element provides 325 watts of power (U.S. Army Space and Missile Defense Command, 2000).

The RF signals transmitted from each array face form one narrow main beam with a width of 2.2°. Approximately 90 percent of the energy is contained in the main beam. The near-field region extends to 183 meters and the far-field region begins at 439 meters, with a transition zone in between. The exclusion area at Cape Cod AFS is at approximately 1,000 feet (305 meters) from the radar. The security fence at Cape Cod AFS is situated at approximately 150 feet (46 meters) from the radar face.

Persons on the ground or in buildings or residences are not subject to RF from the main beam. This is accomplished by restricting the lowest elevation of the main beam to three degrees above horizontal. The elevation of the main beam is still substantially above ground level even when the topography of the sites surrounding the radars is taken into account. The highest elevation in the vicinity of Cape Cod AFS is the road portion of the Sagamore Bridge at 275 feet. The bridge is approximately 8,370 feet (2,582 meters) from the radar (U.S. Air Force, 1979). At this location, the center of the main beam would be 149 meters above the ground, and the bottom of the beam width would be 101 meters above the ground. Software programming and redundant automatic interlocks combine to provide a triple-redundant system. Therefore, a simultaneous failure of three systems would be required to direct the beam outside the designated elevation.

The radar emits smaller amounts of energy outside the main beam, referred to as side lobes. The first side lobe is a concentric circle around the main beam, while the second and higher side lobes are narrow beams around the main beam. Energy contained in these side lobes progressively decreases with distance from the main beam and from the radar. The maximum power density of the first side lobe is 1/100 (1 percent) of the maximum power density of the main beam. The maximum power density of the second side lobe is only 1/1000 (0.1 percent) of the maximum power density of the main beam. Based on the radar set-up, only the side lobes intercept the ground. Additionally, the antenna beam is constantly scanning. As the beam scans away from the horizon, side lobes intersect the ground progressively farther from the main beam. Thus, side lobes with significantly lower energy intersect the ground. The result is that the vast majority of the energy emitted by the radar is directed upward, not at the ground. Furthermore, the radar is transmitting pulses only 18 percent of the time. The maximum possible use of the radar resource for combined surveillance and tracking activities is 25 percent and is the operating condition that produces the maximum possible power density.

Tables E-1 and E-2 summarize power densities in relation to distance from the PAVE PAWS site. The highest possible RF power density that could be produced at ground level in the near-field region, transition zone, and far-field region was calculated. These calculations apply to the worst-case scenario (e.g., the highest of the higher side lobe emissions, maximum power output). Calculations were based on modeling and, where available, spot measurements were used to confirm the reasonableness of the

Table E-1. Near-field and Transition Region Power Densities

Distance From Radar (meters)[a]	Current Calculated 30-minute Average Power Density (mW/cm^2)[b][c]
30	0.6
61	0.2
122	0.06
183	0.03
305	0.01

Notes: (a) Values and calculations from Cape Cod AFS have been averaged for the purpose of this table.
(b) Current calculations assume that both radar faces are operating with a 25 percent duty cycle. The duty cycle is divided between surveillance mode (11 percent) and track mode (14 percent).
(c) The current calculated power densities could be compared directly to the IEEE/ANSI standard of 0.28 mW/cm^2 at 420 MHz.
mW/cm^2 = milliwatts per square centimeter

Table E-2. Far-field Ground-Level Power Densities Calculated for Specified Locations

PAVE PAWS Sites	Distance from radar (meters)	Maximum calculated 30-minute average Power Density (mW/cm^2)[a]	Comparison to IEEE/ANSI Standard (0.28 mW/cm^2)	Maximum Peak Power Density per Pulse (mW/cm^2)[c]	Comparison to IEEE/ANSI Standard (6,300 mW/cm^2)	Maximum Peak Power Density per 100 ms (mW/cm^2)[c]	Comparison to IEEE/ANSI Standard (100.8 mW/cm^2)
Cape Cod AFS	439[d]	0.006640	42 times lower	0.1606	39,228 times lower	0.0514	1,961 times lower
	1,051[b]	0.000786	356 times lower	0.0226	278,761 times lower	0.0072	14,000 times lower

Notes: (a) The current calculations assume that both radar faces are operating with a 25 percent duty cycle. The duty cycle is divided between surveillance mode (11 percent) and track mode (14 percent).
(b) One of the nearest locations with likely opportunity for public exposure.
(c) The current calculations assume that the radar is operating with a maximum pulse width of 16 ms.
(d) On station, beginning of far field exposures.
mW/cm^2 = milliwatts per square centimeter

calculations (U.S. Army Space and Missile Defense Command, 2000). The results of these calculations were compared to the Institute of Electrical and Electronic Engineers (IEEE)/American National Standards Institute (ANSI) uncontrolled environment exposure limit. The standard applicable to the general public is for an "uncontrolled environment," which refers to the condition for most people who do not knowingly encounter RF fields in their work environment.

Based on the information found in Tables E-1 and E-2, the average RF power density values, in an area with potential public exposure, would be at least 42 times lower than the limit of the IEEE/ANSI standard on time-averaged power density. For distances in the far-field region, the power density falls off inversely with the square of the distance. For most public areas near these radars, the levels are lower by a factor of 100 or more. Limits specifically recommended by IEEE/ANSI for peak intensity of RF pulses would not be exceeded.

E.2 ATTENUATION OF RF FIELDS BY BUILDINGS AND RESIDENTIAL HOUSEHOLDS

External EM fields are attenuated (reduced) by reflections at exterior walls of buildings and by scattering and reflections inside buildings. Studies have been performed to determine the amount of attenuation of RFE provided by different types of buildings. The following results were found.

Multi-story office buildings provide an attenuation of approximately 17 decibels (dB) for radiofrequency energy (RFE) at 450 megahertz (MHz) (Smith, 1978), or a reduction factor of approximately 50. This attenuation was determined inside the building, at a distance of 15 meters from the outer wall. The attenuation would be less closer to the wall and greater farther from the wall. Attenuation is not linear; thus, it depends significantly on the interior design of the building (wall panels, partitions, ceilings, ductwork).

Commercial single-story concrete block buildings and single-family residences provide an attenuation of approximately 7 dB RFE at 450 MHz (Smith, 1978). An attenuation of 7 dB translates to a reduction factor, in power, of approximately 5. The formula for converting dB to a reduction factor (*rf*) is as follows:

$$rf = \text{alog}\left(\frac{a}{10}\right)$$

Where:

rf = reduction factor
a = attenuation, dB
alog = antilogarithm, $10^{(a/10)}$

Table E-3 shows the degree to which the power density would be reduced inside a single-family residence with an attenuation of 7 dB. Attenuation would be highly dependent on building materials and layout of the structure. It should be noted that electric and magnetic field attenuations converge at frequencies above 10 MHz. At these higher frequencies, scattering and reflection of both fields are similar (Smith, 1998).

E.2.1 Attenuation of RF Fields due to Shielding Alternatives

Shielding can provide additional attenuation of RFE emissions from the SSPARS. A barrier may be constructed in the path of the radar beam between the antenna face and the general population to absorb some of the RFE from the side lobes. The types of barriers that may be used are described below.

E.2.1.1 Attenuation of RF Fields due to Earthen Barriers.

The earth absorbs and reflects EM energy. The attenuation at 420-450 MHz is very high. Side lobe energy would be cut off or absorbed by the earthen berm and exposure would be reduced. The power that would penetrate directly through such a berm would be negligible compared to the power scattered and diffracted into the region shadowed from the radar by the berm (U.S. Air Force, 1979). Based on the concept of optical shadowing, the shielding factor available in this manner should exceed a ratio of 10:1 and might easily be as large as 100:1 (U.S. Air Force, 1979).

Table E-3. Calculated Power Densities Inside a Single-Family Residence

PAVE PAWS Site	Distance from radar (meters)	Maximum calculated 30-minute average Power Density (mW/cm^2)[(a)]	Comparison to IEEE/ANSI Standard (0.28 mW/cm^2)	Maximum calculated 30-minute average Power Density (mW/cm^2)[(a)] with 7 dB Attenuation	Comparison to IEEE/ANSI Standard (0.28 mW/cm^2)
Cape Cod AFS	439[(b)]	0.006640	42 times lower	0.001328	210 times lower
	1,051[(c)]	0.000786	356 times lower	0.0001572	1,780 times lower

Notes: (a) The current calculations assume that both radar faces are operating with a 25 percent duty cycle. The duty cycle is divided between surveillance mode (11 percent) and track mode (14 percent).
(b) On station, beginning of far field exposures.
(c) One of the nearest locations with likely opportunity for public exposure.
dB = decibel
mW/cm^2 = milliwatts per square centimeter

Using Equation 1, the attenuation of RFE by an earthen berm or barrier can be calculated based on the dielectric constant and conductivity of the berm (i.e., soil) (Table E-4). Although these two values differ with the type/characteristics of the soil, [Cooke and Gladwin, no date] cited the moisture content of soil as a critical parameter for the permeability of ground-penetrating radar (e.g., RFE).

$$A = 3.34t\left[\mu \sigma f\right]^{1/2} \qquad \text{Equation 1}$$

Where:

A = Attenuation, dB
t = Thickness, inches
μ = Relative permeability to copper
σ = Relative conductivity to copper
f = Frequency, MHz

Using Equation 1, one meter of soil would provide an attenuation of approximately 35 dB, or a reduction factor of approximately 3,160.

E.2.2.2 Attenuation of RF Fields due to Wire-Mesh Screens.

Metal screens can be used for effective RF radiation shielding. Mesh openings should be no more than 1/4 the wavelength in dimension. The screens or sheets must be electrically bonded to one another and the entire assembly grounded, otherwise fields will pass through the gaps. Table E-5 presents the attenuation of three wire screen shield alternatives.

Using the attenuation values in Table E-5, these values were applied to the existing power density measurements for the Cape Cod AFS SSPARS. The power densities would be attenuated to levels far below the applicable IEEE/ANSI exposure limit. As seen in Table E-5, screens with narrower openings provide a higher degree of attenuation than screens with larger openings.

Table E-4. Calculated Power Densities Past a 1-Meter-Thick Earthen Berm

PAVE PAWS Site	Distance from Radar (meters)	Maximum Calculated 30-min avg. Power Density without Berm (mW/cm^2)(a)	Comparison to IEEE/ANSI Standard (0.28 mW/cm^2)	Maximum Calculated 30-min avg. Power Density (mW/cm^2)(a) Past 1-meter Thick Berm with 35-dB Attenuation	Comparison to IEEE/ANSI Standard (0.28 mW/cm^2)
Cape Cod AFS	439(b)	0.006640	42 times lower	0.0000021	132,720 times lower
	1,051(c)	0.000786	356 times lower	0.0000002	1,124,960 times lower

Notes: (a) The current calculations assume that both radar faces are operating with a 25 percent duty cycle. The duty cycle is divided between surveillance mode (11 percent) and track mode (14 percent).
(b) On station, beginning of far field exposures.
(c) One of the nearest locations with likely opportunity for public exposure.
dB = decibel
mW/cm^2 = milliwatts per square centimeter

Table E-5. Attenuation Provided by the Wire Screen Alternatives

Wire Size (mil)	Size of Opening (inch)	Reduction Factor(a)	Attenuation (dB)(b)
10	0.0625	85,457.29	49.31
20	1	26.95	14.30
23	0.5	222.27	23.46

Notes: Based on a frequency of 435 MHz and a wavelength of 68.9 centimeter.
(a) (Cember, no date) Eq. 14.19.
(b) (Cember, no date) Eq. 14.48.
dB = decibel
mil = millimeter

As seen in Table E-6, an attenuation of 14.3 dB translates into a reduction factor of 27; therefore, the power densities were reduced by a factor of 27. Since the second side lobe is the primary source of ground-impacting RFE, a screen shield would predominantly affect the ground-level power densities resulting from the second side lobe. The second side lobe has a maximum power of 1/1000 the power of the main beam; therefore, with the wire screen in place, the second side lobe could potentially be reduced by a factor of 27,000 compared the main beam.

E.2.2.3 Attenuation of RF Fields due to Trees.

Trees are also effective for shielding RFE. Existing trees near the SSPARS at Cape Cod AFS undoubtedly contribute some degree of RFE shielding; however, the specific amount of shielding has not been previously investigated. The shielding effect by trees could be enhanced by the addition of suitable trees at appropriate locations (U.S. Air Force, 1979). Different trees may provide differing degrees of RFE shielding based on factors such as height, thickness, spread, and type of foliage. In addition, the seasonal condition of trees and their foliage may play a substantial role in the degree of RFE shielding; for example, trees that defoliate during the winter would provide less RFE shielding during that time. In contrast, during the summer when the foliage cover provided by trees was maximized, a higher degree of

Table E-6. Calculated Power Densities Past Wire Screen Shield

PAVE PAWS Site	Distance from radar (meters)	Maximum calculated 30-minute average Power Density (mW/cm^2)[(a)] in front of the wire-screen shield	Comparison to IEEE/ANSI Standard (0.28 mW/cm^2)	Maximum calculated 30-minute average Power Density (mW/cm^2)[(a)] past the wire-screen shield (20 mil wire, 1-inch opening)	Comparison to IEEE/ANSI Standard (0.28 mW/cm^2)
Cape Cod AFS	439[(b)]	0.006640	42 times lower	0.000246	1,134 times lower
	1051[(c)]	0.000786	356 times lower	0.0000291	9,612 times lower

Notes: (a) The current calculations assume that both radar faces are operating with a 25 percent duty cycle. The duty cycle is divided between surveillance mode (11 percent) and track mode (14 percent).
(b) On base, beginning of far field exposures.
(c) One of the nearest locations with likely opportunity for public exposure.
mW/cm^2 = milliwatts per square centimeter

shielding may result. Specific data from the Joint Spectrum Center (1981) indicated that the attenuation of radio waves by trees without leaves showed that the difference in loss was on the order of 4 to 6 dB within the 400-500 MHz frequency range. In addition to the Joint Spectrum Center's 1981 report, a study completed by the FCC showed an additional loss caused by leaves of 4.5 dB at 450 MHz. Therefore, combining data from both reports yields a potential attenuation of 8.5 to 10.5 dB (7 to 11 times reduction) during the summer months when leaves and foliage on trees are most prevalent.

Table E-7 provides data regarding the types of trees and the foliage porosity (foliage coverage) for the Cape Cod AFS SSPARS. Cape Cod AFS has a mixture of evergreen and deciduous trees that provide effective RFE shielding during the summer months due to their higher foliage porosity; however, several of the tree species have a porous foliage porosity during the winter months, which would provide less RFE shielding.

Table E-7. Tree Coverage Surrounding SSPARS Sites[(a)]

SSPARS Location	Category of Trees		Foliage Porosity[(b)]	
	Scientific Name	Common Name	Summer Months	Winter Months
Cape Cod AFS	*Pinus resinosa*	Red Pine	Moderate	Moderate
	Pinus rigida	Pitch Pine	Moderate	Moderate
	Pinus strobulus	Eastern White Pine	Dense	Dense
	Pinus sylvestris	Scotch Pine	Dense	Dense
	Quercus alba	White Oak	Dense	Porous
	Quercus coccinea	Scarlet Oak	Dense	Porous
	Quercus ilicifolia	Bear Oak	Moderate	Porous
	Quercus velutina	Black Oak	Moderate	Porous

Notes: (a) Source: (United States Department of Agriculture Internet site; http://plants/usda.gov, 2001).
(b) Foliage Porosity Definitions:
Porous = 0-33% coverage
Moderate = 34-66% coverage
Dense = 67-100% coverage

Using data from (Joint Spectrum Center, 1981) and (Federal Communications Commission, 2001), the attenuated power density for each SSPARS site was determined based on previous power density measurements (Table E-8).

Table E-8. Shielding Effects on Existing Power Density Measurements

PAVE PAWS Site	Distance from radar (Meters)	Maximum calculated 30-minute average Power Density (mW/cm^2)[(a)]	Comparison to IEEE/ANSI Standard (0.28 mW/cm^2)	Maximum calculated 30-minute average Power Density (mW/cm^2)[(a)] Past Leafless Trees with 5 dB Attenuation	Comparison to IEEE/ANSI Standard (0.28 mW/cm^2)	Maximum calculated 30-minute average Power Density (mW/cm^2)[(a)] Past Leafed Trees with additional 4.5 dB Attenuation	Comparison to IEEE/ANSI Standard (0.28 mW/cm^2)
Cape Cod AFS	439[(b)]	0.006640	42 times lower	0.00208	134 times lower	0.000743	375 times lower
	1,051[(c)]	0.000786	356 times lower	0.000246	1,139 times lower	0.000088	3,189 times lower

Notes: (a) The current calculations assume that both radar faces are operating with a 25 percent duty cycle. The duty cycle is divided between surveillance mode (11 percent) and track mode (14 percent).
(b) On station, beginning of far field exposures.
(c) One of the nearest locations with likely opportunity for public exposure.
dB = decibel
mW/cm^2 = milliwatts per square centimeter

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APPENDIX F

BIOEFFECTS OF RADIOFREQUENCY ENERGY

APPENDIX F

BIOEFFECTS OF RADIOFREQUENCY ENERGY

Major difficulties exist in assessing the potential health hazards to man from exposure to radiofrequency energy (RFE) or microwave energy because of the highly complex relationship between the exposure conditions and the energy absorbed. The absorbed dose and rate of energy absorption depend critically on such variables as frequency, power density, field polarization, the size and shape of the exposed subject, and environmental factors. This appendix summarizes available information regarding RFE/microwave bioeffects including scientific/peer-reviewed studies completed by both electromagnetic (EM) energy research organizations and scientists related to the biological effects resulting from the interaction of RFE/microwave energy with biological matter and systems. References cited in the discussions below are listed in Appendix G.

F.1 RFE/MICROWAVE ENERGY PROPERTIES

RFE is defined arbitrarily as EM energy in the frequency range of 3 kilohertz (kHz) to 300 megahertz (MHz), whereas the arbitrary definition of microwaves includes EM energy whose frequencies range from 300 MHz to 3,000 gigahertz (GHz). EM waves consist of electrical and magnetic forces that move in consistent wave-like patterns at right angles to one another. The short wavelengths in the microwave frequency bands, on the order of millimeters to centimeters, contrast sharply with the much longer wavelengths, on the order of tens to hundreds of meters, in the RF portion of the EM spectrum.

When EM energy passes from one medium to another, it can be reflected, refracted, transmitted, or absorbed, depending on the biological system and the frequency of the energy (World Health Organization, 1981).

RFE and microwaves are forms of non-ionizing radiation, whereas x-rays and gamma rays are forms of ionizing radiation. The difference between the two types of radiation lies in the amount of energy each radiation contains, which is called *photon energy*. The unit of measure for photon energy is the electron volt (eV) or million electron volts (MeV). The photon energy carried by microwaves (non-ionizing radiation), such as those produced by the solid-state phased array radar system (SSPARS), is approximately 1.24×10^{-4} eV, whereas the photon energy contained in gamma rays (ionizing radiation) is approximately 1.24×10^{6} eV (or 1.24 MeV) (World Health Organization, 1981). Thus, the photon energy differences between non-ionizing and ionizing radiation may be on a scale of 10 orders of magnitude. This difference represents the ability of ionizing radiation to disassociate electrons from atoms or molecules, thus creating ions or charged particles, whereas non-ionizing radiation does not contain the amount of photon energy necessary to ionize atoms or molecules. This is the reason ionizing radiation can significantly damage biological systems, resulting in cancer and other forms of disease.

F.2 BIOEFFECTS FROM PHASED-ARRAY RADAR SYSTEMS

Phased-array radar systems, such as PAVE PAWS, have begun to replace the ever-present and recognizable rotating radar dishes, such as those commonly seen at airports. As this transformation progresses, questions have arisen about the human health effects that result from exposure to RFE/microwave energy emitted from phased-array radar systems. Jauchem (1996) reviewed several studies in which research was performed on populations or specific biological systems exposed to the energy produced by phased-array radar systems. Goldsmith (1996) has suggested that there may be risks to populations located in areas close to these systems, including those at Skrunda, Latvia, and at

SSPARS sites. The Skrunda radar operates between 156-162 MHz with average power density measurements in the surrounding residential areas not exceeding 0.01 milliwatts per square centimeter (mW/cm^2) (Kalnins et al., 1996). The SSPARS at Cape Cod Air Force Station (AFS) operates between 420-450 MHz with average power densities (from the 1978 and 1986 measurements) several orders of magnitude below those from the Skrunda site (0.000061 mW/cm^2 or 163 times lower). Aschengrau and Ozonoff [1992] examined potential exposures to a number of environmental factors in relation to cancer incidence. They reported no association with RFE from the PAVE PAWS system at Cape Cod AFS, but indicated that the exposure data were inadequate. However, Malowicki (1981) and Everett et al. (1983) both concluded that SSPARS RFE does not present a hazard provided that personnel are excluded from the immediate area (the existing demarcated area in front of the radar faces). In compliance with both Federal Communications Commission (FCC) and Institute of Electrical and Electronics Engineers (IEEE) RFE exposure standards, restricted access areas have been demarcated around the antenna face of the SSPARS, thus preventing inadvertent occupational overexposure in radar workers. Further, no public access is permitted near the radar system(s).

F.3 PUBLISHED BIOEFFECTS STUDIES

Since the introduction of conventional radar approximately 50 years ago, there has been an increasing use of radar and other sources of EM energy throughout our civilization. These sources serve a variety of purposes such as telecommunications, industrial production, transportation safety, military activities, medical applications, and home/residential equipment. As the use of EM energy sources has increased, so has the research into potential biological effects from those sources. As early as the 1940s and 1950s, research had begun into potential biological effects from EM energy resulting from acute occupational exposures. According to the National Research Council, "Data from experiments on biological systems indicate that exposure to low-intensity microwaves can have effects. But, on the basis of most of the available findings, the known or suspected effects are reversible and are not associated with increased human morbidity or mortality." Several known effects of exposure to microwaves and EM energy have been studied and are well documented, although much of the research into bioeffects has failed to document a correlation between cause and effect. Some of the documented effects and bioeffects include the following:

- Auditory effect
- Thermal heating effect
- Lenticular (ocular) effects
- Cardiovascular effects
- Reproductive system effects
- Cutaneous (Skin) effects
- Central nervous system effects
- Behavioral effects
- Teratogenic (fetal malformation) effects.

A review of published studies related to these effects will be discussed in the following sections, along with the details of each individual study and its findings. Following the review of the documented effects, additional published bioeffects studies will be discussed.

F.3.1 Auditory Effect

Experiments with animals and human volunteers have shown that energetic microwave pulses cause a hearing sensation perceived as buzzing, clicking, hissing, or knocking depending on the pulse parameters (National Council on Radiation Protection and Measurements, 1986). The auditory effect can be evoked even by a single microwave pulse with an average power density below 0.1 mW/cm^2 (Puranen and Jokela, 1996). A review of existing literature related to the auditory effect, *Radiation Hazard Assessment of Pulsed Microwave Radars* by Puranen and Jokela, of the Finnish Center for Radiation and Nuclear Safety, was published in 1996. The review indicates that the microwave auditory effect is the only well-established specific effect, in realistic exposure situations, associated with pulsed microwave energy (Puranen and Jokela, 1996). Although some exposure standards are based on the threshold for the auditory effect (e.g., United Kingdom National Radiological Protection Board), existing exposure standards in the United States are not based on the auditory effect (e.g., IEEE). According to the IEEE standard, the auditory effect is not considered damaging or even annoying.

Another study of the microwave auditory effect, "*Auditory Perception of Radio-frequency electromagnetic Fields*", was completed by Chou and Guy (1982), in which they reviewed literature that described psychological, behavioral, and physiological as well as physical measurements pertinent to the microwave auditory effect. Chou and Guy (1982) concluded that the mechanism for the microwave auditory effect was thermoelastic expansion (the transformation of EM energy into acoustical energy), which was first proposed by Foster and Finch (1974). Microwave pulses impinging on the head initiate a thermoelastic wave of pressure in brain tissue that activates the inner ear receptors (cochlear) via bone conduction. This has now become the viewpoint supported by recent studies and the scientific community. Earlier studies by Frey (1961, 1962, 1963) provided the initial research into the microwave auditory effect (at the time it was referred to as a "phenomenon") and hypothesized that the effect was a result of the stimulation of the cochlea through electromechanical forces by air or bone conduction.

An additional study of the microwave auditory effect by Chou et al. (1985), "*Auditory Response in Rats Exposed to 2450 MHz Electromagnetic Fields in a Circularly Polarized Waveguide,*" documented the dose-response relationship of the microwave auditory effect in rats. Varying pulse durations were monitored in conjunction with the fixed duty cycle, peak power, and the pulse repetition rate. Chou et al. (1982), confirmed that the amplitude of the auditory effect decreased as the pulse width and incident energy densities decreased. These responses were similar to the data from guinea pigs (Chou and Galambos, 1979), except that the latency of the peak auditory effect was shorter in rats.

Another study of the microwave auditory effect, *Microwave Hearing: Evidence for Thermoelastic Auditory Stimulation by Pulsed Microwaves*, by Foster and Finch (1974) provided the initial hypothesis relating the microwave auditory effect to thermoelastic expansion that precipitates a pressure wave detectable by the cochlea within the ear. This research studied the transformation of EM energy to acoustic energy in a liquid by surface heating, which resulted in the propagation of waves (transients) through the liquid. Using this research as a basis, Foster and Finch (1974) developed their hypothesis about thermoelastic expansion, which has since been widely accepted as the mechanism for the microwave auditory effect.

In conclusion, the microwave auditory effect is the only well established biological effect, in realistic exposure situations, associated with pulsed microwave energy. The above cited studies indicate that the microwave auditory effect is the result of a thermoelastic expansion caused by the impinging of microwave pulses on the head, which results in a wave of pressure in brain tissue that activates the inner ear receptors (cochlear) via bone conduction. This results in the subject perceiving a buzzing, clicking, hissing, or knocking depending on the pulse parameters. As noted by the National Research Council (1979), the microwave auditory effect is a reversible effect and is not associated with increased human morbidity or mortality. Furthermore, many of these cited studies were carried out under conditions that were unrealistic exposure scenarios for the general public as many of the studies subjects were exposed to microwave energy levels exceeding the applicable general population standards set forth by IEEE. Although the IEEE standard is not based on the threshold for the microwave auditory effect, exclusion zones or restricted access areas near microwave sources prevent the general population from entering those areas where exposures may approach the threshold for the microwave auditory effect. Restricted access areas or exclusion zones around microwave sources are required by the IEEE standard; therefore, the IEEE standard does take into effect the auditory effect in this regard, not in the actual exposure standard. Puranen and Jokela (1996) indicated the microwave auditory effect can occur at power density levels as low as 0.1 mW/cm^2; however, this level is significantly above exposure levels confirmed by previous measurements (e.g., measurements were in the microwatts per cm^2 ($\mu W/cm^2$) range, which is 100 times lower than the lowest threshold of 0.1 mW/cm^2 for the microwave auditory effect) in the general population areas surrounding the SSPARS.

F.3.2 Hyperthermia/Thermal Heating

The absorption of microwave energy often results in an increase in temperature. The microwave oven (which commonly operates at a frequency of 2450 MHz), commonly found in residential dwellings, offers an example of heating resulting from exposure to microwave energy. Numerous biological and pathophysiological effects have been attributed to temperature increases in the tissue resulting from absorption of microwave energy. If the rate of increase exceeds the ability of the thermoregulatory system of the subject to dissipate heat, hyperthermia (i.e., temperature increase to a level that can cause harm) will occur, followed by injuries such as burns, hemorrhaging, tissue necrosis, and death (Cleary, 1978). The influence of environmental conditions on hyperthermia induced by microwave exposure can be summarized as follows:

- Increasing ambient temperatures and humidity enhance thermal stress
- Increased air velocity decreases thermal stress.

Multiple animal studies have been completed to research the thermal heating effect that results from tissue exposure to microwaves, including the type of energy produced by the SSPARS. One such study was *Thermal Effects of Single and Repeated Exposures to Microwaves* by Michaelson (1973). Specifically, Michaelson (1973) studied the effects of thermal heating on dogs exposed to microwave frequencies of 2.86 GHz, 1.28 GHz, and 200 MHz and a power density of 165 mW/cm^2. After approximately 30 minutes of exposure at this level, a body temperature increase of 1°C to 1.4°C was observed. Eventually, the thermoregulatory system of the subject was unable to dissipate the heat rapidly enough and the subject succumbed.

Another study by Michaelson (1971) explored the influence of environmental conditions on thermal response to microwave exposure. Michaelson (1971) revealed that at an ambient temperature above 40.5°C, the subject's thermoregulatory system can maintain a normal body temperature, but was not able to cope with an additional thermal load produced by microwave exposure. However, at a lower ambient temperature (11°C), after an initial period of adaptation, the microwave energy does not significantly affect the subject's temperature (Michaelson, 1973).

In another study by McLees and Finch (1973), in which rats were exposed to 24 GHz and 300 mW/cm^2, it was shown that body cover also affected hyperthermia. Subjects with and without hair succumbed within 15.5 and 18.5 minutes, respectively, indicating that clothing could be expected to enhance the thermal effects of microwave energy, unless such clothing shielded from, or reflected microwave energy.

Other studies have suggested that blood circulation was considered to be an effective system for distribution of the heat generated throughout the body (Michaelson, 1971), and the thermal effects of microwaves in animals were mainly considered in terms of 'volume heating'. However, using phantom models (human or animal models used to estimate the Specific Absorption Rate (SAR) or amount of absorbed RFE in the body), Guy (1971, 1974) and Johnson and Guy (1972) developed thermographic techniques and demonstrated convincingly very nonuniform deposition of microwave energy, expected to result in nonuniform deep body heating. In physiological terms, this means that absorbed energy may cause local thermal stimulation or gross effects on different organs depending on the exposure level.

In conclusion, the thermal heating associated with microwave energy is the primary effect from which other biological effects and phenomena arise. However, many of the cited studies have exposed subjects to RFE/microwave fields that were several orders of magnitude more intense than any the general population could ever be exposed to as a result of operating the SSPARS. Although thermal heating is a mechanism for the microwave auditory effect, Foster and Finch (1974) determined that the maximum tissue temperature increase per microwave pulse was only 10^{-5} degrees Celsius (°C) (or 1/10,000°), a minute temperature variance. As a result, the microwave energy exposure standards promulgated by IEEE and adopted in the United States are based on the threshold for damage to a biological system from thermal heating. The existing standards focus on the SAR, which is defined as the rate of energy absorption per unit mass of an exposed object. For human subjects, the average SAR for exposures in the far-field (e.g., a region of the microwave energy field in which the general population would be exposed to SSPARS microwave energy) may reach a peak in the frequency range of 30-200 MHz, depending on various factors associated with the specific exposure situation (Johnson et al., 1976; Durney et al., 1978, 1980). Currently, the whole-body averaged SAR exposure limit for occupational exposures is 0.4 W/kg, while the general population whole-body averaged SAR exposure limit is 0.08 watts per kilogram (W/kg). These values are based on the whole-body averaged SAR threshold level of 4 W/kg, as averaged over the entire mass of the body, above which expert organizations have determined that potentially hazardous exposures may occur (Federal Communications Commission, 1997). The exposure limits have a safety factor of 10 and 50, respectively, built into the occupational and general population exposure standards.

F.3.3 Lenticular (Ocular) Effects

The *Environmental Health Criteria 16: Radiofrequency and Microwaves*, published by the WHO (World Health Organization, 1981), has documented the results of extensive studies on the lenticular effects resulting from RFE/microwave energy exposure. Much of the information provided below has been extracted from the referenced studies in WHO (1981). Studies on the effects of microwave energy on the eyes were carried out as early as 1948 (Richardson et al., 1974). Most animal studies have been conducted on the New Zealand white rabbit because its eye is similar to the human eye (World Health Organization, 1981). In one of the very few investigations of chronic, low-level exposure of rabbit's eyes (2 mW/cm^2 for 8 hours/day, 5 days a week for 8-17 weeks at 2.45 GHz), ocular changes were not observed up to three months after termination of exposure (Ferri and Hagan, 1976).

Studies have also been completed to determine whether a difference in cataractogenic potentials exists for pulses and continuous wave energy. When the cataractogenic power density levels for continuous wave and pulsed energy were compared at a few frequencies, no differences in the threshold levels for cataractogenesis (cataract-forming) were found (Carpenter and Van Ummersen, 1968; Carpenter, 1969; Birenbaum et al., 1969; Williams and Finch, 1974; Weiter et al., 1975). Based on these studies, the average power density, not the peak power density, appeared to be the critical field parameter in cataract induction. The WHO concluded the following, based on the available literature, related to the effects of microwave energy on the eye:

- Above 500 MHz (PAVE PAWS operates between 420-450 MHz), opacities of the eye may be produced when power densities exceed 150 mW/cm^2, if the duration of exposure is sufficiently long.
- Although ocular injury has not been reported at frequencies below 500 MHz, its possibility cannot be excluded.
- Injury to the eye from microwaves appears to be predominately thermal in nature, temperature gradients within the eye and the rate of heating being two major factors in the stress that leads to injury. Non-thermal effects cannot be excluded, but they alone do not appear to be sufficient to produce effects in the eye, although they may provide a necessary mechanism of interaction.
- Pulsed and continuous wave energy with the same average power density level seem to possess the same potential for cataract induction.
- Cataracts can be produced by repeated exposures to subthreshold power density levels. For this cumulative effect to occur, the exposure levels have to be sufficiently high that a slight but persistent injury is not fully repaired before another exposure takes place. However, if the time between exposures is sufficiently long for repair to take place, cumulative damage is not observed.

In addition to the WHO (1981), the National Research Council (1979) has reviewed existing literature on the lenticular effects microwave energy has on the human eye. A study by Shacklett et al. (1975), in which possible microwave induction of lenticular changes in Air Force personnel was evaluated, no statistically significant differences were observed in the incidences of opacities, vacuoles, and Posterior Subcapsular Iridescence between 447 exposed subjects and 340 control subjects was identified. In similar studies, Appleton et al. (1972, 1973, 1975) examined 1,500 military personnel working with microwave producing equipment and concluded that there were no differences in lenticular opacities, vacuoles, or Posterior Subcapsular Iridescence between microwave workers and unexposed persons of similar ages.

A number of individual case histories of microwave induction of cataracts have been reported (Hirsch and Parker, 1952; Kurz and Einaugler, 1968; Shimkovich and Shilyeav, 1959), but in all cases the exposures were well in excess of 100 mW/cm^2 (i.e., measurements surrounding the SSPARS are many orders of magnitude lower). Another study, Cogan et al. (1955), of possible relevance to the SSPARS hints at a lessening of cataractogenic efficiency at the comparatively low frequencies used in the investigation of cataract induction (e.g., 200, 385, and 468 MHz).

Overall, many of the cited studies that concluded cataract formation was a result of microwave exposure did so based on study parameters that involved exposure rates (i.e., power densities) well above regulatory exposure limits and, in some cases, many orders of magnitude above the measured power densities surrounding the SSPARS. The National Research Council (1979) concluded that "considering the radiation frequency and expected power densities associated with PAVE PAWS, the possibility of induction of cataracts in exposed members of the public is very small."

F.3.4 Cardiovascular Effects

A review of studies relating to cardiovascular effects resulting from exposure to microwaves was completed by the National Research Council (1979). A study by Edelwejn et al. (1974), concluded that no serious cardiovascular disturbances had ever been reported in man or experimental animals as a result of exposure to microwave energy. However, Gordon (1970) claimed that prolonged exposure (e.g., microwave energy wavelengths of centimeters and millimeters, average power densities of 0.1 to 10 mW/cm^2) can produce marked disturbances in cardiac rhythm (bradycardia) and hypotonia (less than normal arterial tone). Although this study concluded that prolonged exposure to microwave energy did result in observable biological effects, Czerski and Siekierzynski (1974) reported that blood pressure of workers routinely exposed to power densities less than 1 mW/cm^2 did not differ significantly from that of unexposed control subjects.

Another review of studies relating to cardiovascular effects resulting from exposure to microwave energy was completed by WHO (1981). Functional damage to the cardiovascular system as manifested by hypotonus, bradycardia, delayed auricular and ventricular conductivity, and flattening of electrocardiogram (EKG) waves has been reported, by several former Soviet Union clinicians, to result from chronic exposure of workers to RFE fields (Gordon [1970, 1976]; Tjagin [1971]; Baranski and Czerski [1976]). Although these studies may have some relevance to an occupational exposure setting, the National Research Council (1979) states "the long-term, low-level intensity effects reported in some Eastern European publications have no discernable application to exposure conditions associated with the operation of PAVE PAWS." Furthermore, the National Research Council (1979) concluded that "the probability is very low that low-intensity microwave radiation has adverse cardiovascular effects on exposed humans."

Another review of literature (Jauchem, 1996) related to cardiovascular bioeffects in humans resulting from RFE exposure cited multiple studies and concluded that no obvious cardiovascular-related hazards existed from acute or long-term exposure to RFE at or below current exposure standards. One study, by Bortkiewicz et al. (1995), indicated "measurable effects in the heart rate variability and blood pressure parameters" in workers at AM broadcasting stations as compared with a control population; however, none could be assigned clinical significance. Data from the study indicated that measured parameters (i.e., EKG, heart rate, heartbeat duration, heart-rate variability, and blood pressure) did not significantly differ between the RFE-exposed and control groups. Djordjević et al. (1979), measured cardiovascular parameters in 322 radar workers (all exposed to pulsed microwaves) and a control group of 220 persons; no parameters differed between the two groups. Robertson and Michaelson (1985) reviewed epidemiological studies of humans exposed to RFE and concluded that no "identifiably serious" cardiovascular disturbances have been seen as a result of RFE exposure.

As cited by Jauchem (2000), Toler et al. (1988) studied the effects of chronic low-level microwave exposure on cardiovascular parameters in Spraque-Dawley rats. Exposure to pulsed 435 MHz (center frequency for the PAVE PAWS radar system) microwave energy 22 hours per day, 7 days per week, for 6 months resulted in no differences in heart rate and blood pressure between microwave- and sham-exposed animals. Estimated whole-body absorption rates ranged from 0.04 to 0.4 W/kg.

Another cardiovascular system related effect addresses the effect pulsed microwave energy may produce on cardiac pacemakers. Mitchell (1975) reported an extensive study on the interference of cardiac pacemakers from radar-like pulses, including those operating at frequencies of 450 MHz. Adverse effects to pacemakers, occurring as a direct result of EM interference, consist of the following:

- Pacemaker rate falls below 50 beats per minute (bpm)
- Pacemaker rate exceeds 125 bpm.

Mitchell (1975) indicated, that based on results from the study, the interference problems should be eliminated with design improvements in newer pacemaker models. However, older, susceptible pacemakers may be affected by exposure to PAVE PAWS energy fields, especially near the exclusion area (within Air Force controlled property, where no public access is possible). Furthermore, the National Research Council (1979) indicates that the scanning mode of the PAVE PAWS radar beam would be expected to induce only transient pacemaker interference, rather than a complete cessation of operation or a continual increase in rate exceeding 125 bpm.

In conclusion, effects to the cardiovascular system resulting from exposure to microwave energy have not been clearly explained and many studies have presented conflicting conclusions. Although some studies have shown an observable effect, the significance and causal-relationship cited by many of these studies have been refuted upon further peer review. Based on the advancement of medical science since 1975, current pacemaker models should not be significantly affected by RFE. In addition, the power densities cited by many of these studies were orders of magnitude higher than the measured energy levels surrounding the SSPARS; therefore, the applicability, and the attributed effects, of these studies to PAVE PAWS is unwarranted. This position is further supported by the National Research Council (1979).

F.3.5 Reproductive System Effects

Available information regarding the effects RFE/microwave energy has on the male and female reproductive systems is limited. Relevant information from WHO (1981) stated that reports of sterility or infertility from exposure to microwaves were questionable. No changes in the fertility of radar workers were found by Barron and Baraff (1958). Another study, Marha et al. (1971), attributed decreased spermatogenesis, altered sex ratio of births, menstrual pattern changes, congenital effects in newborn babies, and decreased lactation to the occupational exposure of mothers to RFE. According to the Marha et al. (1971) report, such effects occurred at power densities exceeding 10 mW/cm^2. Since these reported effects occurred at power densities several orders of magnitude above the measured power densities surrounding the SSPARS, it is doubtful that similar effects would be produced as a result of exposure to SSPARS energy. Furthermore, the Marha et al. (1971), study reported on females occupationally exposed (as a result of their employment and/or work function) to RFE; therefore, the plausibleness of these effects occurring in a general population exposure scenario is doubtful.

Jauchem [1996] cited several studies related to RFE/microwave exposure and reproductive system effects. One of these studies, Taskinen et al. (1990), concluded that microwave energy exposure did not significantly affect spontaneous abortion rates. Larsen (1991) found no significant associations between pregnancy outcome and exposure to high-frequency EM energy in the first month of pregnancy. A study by Ouellet-Hellstrom and Stewart (1993) indicated that "women who reported using microwave diathermy at the time of conception were at an increased risk of miscarriage..."; however, the odds ratio from this study was questionable, thus the existence of bias could not be ruled out. In addition, The International Commission on Non-Ionizing Radiation Protection (1998) summarized epidemiological studies of microwave exposures and concluded that "the studies yielded no convincing evidence that typical exposure levels lead to adverse reproductive outcomes or an increased cancer risk in exposed individuals." WHO (1981) cited Baranski and Czerski (1976) in their review of testicular damage and reduced spermatogenesis, specifically as a result of microwave exposure, and concluded that no serious effects should be expected at power density levels below 10 mW/cm^2.

Overall, studies have not confirmed a biologically significant causal-relationship between RFE/microwave exposure and detrimental effects to the human reproductive system. Although some studies have suggested that observable effects may be produced by exposure to RFE/microwave energy, the relevance of these studies to the exposure of the general population surrounding the SSPARS is remote because of the high power density levels used.

F.3.6 Cutaneous (Skin) Effects

A review of literature regarding the exposure of skin to RFE/microwave energy was completed by Heynick and Polson (1996), "*Human Exposure to Radiofrequency Radiation: A Review Pertinent to Air Force Operations.*" Studies were completed on both human (volunteer) and animal skin surfaces to determine what, if any, observable and detrimental effect(s) could be ascertained. Justesen et al. [1982] determined that a sensory adaptation occurs during longer skin exposures, versus shorter skin exposures, because the warmth sensation fades before the end of an exposure. Justesen et al. (1982), suggested that if this sensory adaptation is a general property of RFE-heating, it may account for the difficulty of rodents (from other RFE studies) to learn to escape from or avoid high levels of RFE.

Heynick and Polson (1996) concluded that the high threshold power densities for cutaneous perception of RFE found by Hendler (1963, 1968) and coworkers and by Justesen et al. (1982), particularly those at 2.45 GHz and 3.0 GHz (at which penetration is relatively deep), indicates that such perception may not occur at RFE power densities well above those in the current exposure guidelines. Therefore, the absence of such perception during RFE-exposure at such higher levels should not be taken as indicative of the safety of such exposures.

F.3.7 Central Nervous System Effects

A report, Jauchem (2000), presented at the 1999 NATO Research and Technology Organization (RTO) Human Factors and Medicine Panel (HFM) symposium on "*Countering the Directed Energy Threat: Are Closed Cockpits the Ultimate Answer?*" reviewed multiple studies performed by Western researchers and researchers in the former Soviet Union on effects to the human central nervous system from RFE exposure. Jauchem (2000) cited a human study (Reite et al., 1994), which used fairly low-level 27.12 MHz RFE with 42.7 Hz modulation (peak SAR of 0.1-100 mW/kg in brain) that had pronounced effects on sleep patterns, including a hypnotic effect. However, Röschke and Mann (1997) detected no difference in awake electroencephalograms of humans exposed to microwave energy from digital mobile radiotelephones (e.g., power density of 0.05 mW/cm^2). In another study, Herman and Hossman (1997) reviewed studies, including those using humans, and found no evidence that non-thermal microwave exposure related to mobile communication resulted in any neurological risks.

Former Soviet Union and Eastern European researchers described central nervous system effects in workers who manufactured, maintained, and operated RFE-generating equipment (Baranski and Czerski, 1976; Gordon, 1970; Sadchikova, 1974). These studies cited that long-term, low-level (less than a few mW/cm^2) exposures were reported to result in symptoms that were collectively described as a "microwave syndrome." The symptoms were relatively subjective and included irritability, sleepiness, difficulties in concentration, loss of memory, and emotional instability. Sadchikova (1974) showed that these symptoms were reversible after exposure was discontinued. Rayman (1995) noted that, although "radiowave sickness" (i.e., mentioned earlier as "microwave syndrome") has often been described in Eastern Europe, it has not been demonstrated in the West.

WHO (1981) cites multiple animal studies in which effects to the central nervous system, as a result of RFE exposure, were evaluated. Tolgaskaya et al. (1962), and Tolgaskaya and Gordon (1973) reported that brain hyperemia (i.e., abnormally large blood supply), pyknosis (i.e., cellular thickening), and vacuolization (i.e., formation of cavities within the cell protoplasm) of nerve cells were observed in rats repeatedly exposed for 75 days to microwave energy with wavelengths of 3 and 10 centimeters (PAVE PAWS microwave energy has wavelengths of 66.62-71.38 centimeters) at high power densities (40-100 mW/cm^2). These effects were less pronounced following exposures at 10-20 mW/cm^2 and with exposure to microwaves with a wavelength of 3 centimeters compared with wavelengths of 10 centimeters at the same power density. The effects were reversible, several days after termination of the experiment.

Although much of the literature on central nervous system effects may provide contradictory conclusions as to the resulting effect of exposure, the National Research Council (1979) determined that "whatever the effects of exposure on the human central nervous system are, it is not known whether the effects are deleterious to health." The National Research Council (1979) concluded that the effects of low-level exposure of the general population (members of the public), on the basis of available data and the known interaction mechanisms with biologic systems, would be reversible or transient; therefore, the possible exposure effects of PAVE PAWS should be restricted to transient, reversible functional alterations in the central nervous system that may or may not be perceived by the exposed individuals.

F.3.8 Behavioral Effects

Jauchem (2000) cited multiple animal studies that attempted to determine what, if any, behavioral effects resulted from exposure to RFE/microwave energy. D`Andrea and Cobb (1987) examined fixed-interval and reaction-time performance in Long-Evans rats exposed to 1.3 GHz microwave pulses. Significant effects were observed only at high average power levels that would cause tissue heating. D`Andrea et al. (1992), also found that localized exposure (1.3 GHz and peak power of 3.06 MW) to the heads of rhesus monkeys caused changes in performance of a vigilance task only at average SARs in the head of 16 W/kg or greater. The D`Andrea et al. (1992), study used a microwave frequency approximately 3 orders of magnitude greater than the SSPARS and a peak power approximately 5 orders of magnitude greater than that of the SSPARS system. D`Andrea et al. (1989a), investigated three distinct behavioral components in trained rhesus monkeys exposed to 1.3 GHz pulses at a peak power density of 132 W/cm^2; there were no significant changes in behavior. D`Andrea et al. (1989b), found no effect of high peak power microwave pulses at 2.37 GHz on vigilance performance in rhesus monkeys. Another study, D`Andrea et al. (1994), reported that 5.62 GHz high peak power microwave pulses (2.52 kW/cm^2) did not alter behavioral responses in rhesus monkeys any differently than exposure to conventional radar pulses (0.277 kW/cm^2) that produced equal whole-body average SARs. A study by Walter et al. [1995] investigated the possible behavioral effects of acute exposure to high peak power microwave pulses and showed no changes in a functional observational battery and a swimming performance test.

WHO (1981) cited multiple animal studies that attempted to determine what, if any, behavioral effects resulted from exposure to RFE/microwave energy. One study, Thomas et al. (1975), indicated that microwave energy was found to affect the behavior of rats conditioned to respond to multiple schedules of reinforcement. However, Roberti et al. (1975) did not find any difference in the spontaneous motor activity of rats after exposure to power densities ranging from 0.5-26 mW/cm^2. A study by Scholl and Allen (1979) indicated that exposure to continuous microwave energy (1.2 GHz and average power densities of 10-20 mW/cm^2) did not affect skilled motor performance in monkeys even when the animals were positioned for maximum energy deposition in the brain.

In conclusion, Cleary (1977) summarized that it is difficult to evaluate the significance of microwave-induced behavioral effects because of the general lack of quantitative correlation between thermal effects at low power densities and responses at the physiological or psychological levels of analysis.

F.3.9 Teratogenic Effects (Teratogenesis)

A review of literature regarding the teratogenic effects of RFE/microwave energy was completed by Heynick and Polson (1996), "*Radiofrequency Radiation and Teratogenesis: A Comprehensive Review of Literature Pertinent to Air Force Operations.*" Heynick and Polson (1996) cited multiple studies related to the promotion of congenital anomalies or teratogenesis as a result of exposure to RFE. One such study, Sigler et al. (1965), sought a possible relationship between the occurrence of Down's Syndrome ("mongolism") and presumed exposure of the fathers to RFE from radars during military service. Sigler et al. [1965], suggested that the fathers of the children with Down's Syndrome previously did have excess radar exposure or a larger proportion of military experience, although this suggestion was not supported as statistically significant. A follow-on study by Cohen et al. (1977) of the same group, with additional subjects, did not confirm the suggestions that the fathers had excess radar exposure or a larger proportion of military experience.

Other studies such as Peacock et al. (1971 and 1973), endeavored to assess whether the incidence of birth defects in Alabama could be associated with proximity of military bases. Peacock et al. (1973), concluded that the abnormally high number of fetal deaths "constituted evidence that the problem may be associated with radar." However, Burdeshaw and Schaffer (1977) reexamined the data from the Peacock et al. (1971 and 1973), studies with regards to Down's Syndrome and amended the conclusions to indicate negative findings and no statistically significant causal-relationship between Down's Syndrome and RFE exposure.

WHO (1981) drew conclusions related to the genetic (teratogenesis) effects to cells from exposure to microwave energy based on a review of existing literature at the time. These conclusions were:

- Chromosomal aberrations and mitotic alterations can be produced by microwaves at high power densities where thermal mechanisms play a definite role; however, there are many conflicting reports, and some doubts remain as to whether these effects can occur at lower power densities.
- Studies at the cellular and subcellular level are important for understanding basic interaction mechanisms. Chromosomal aberrations and mitotic alterations are potential early indications of biological changes and may reflect a response of specific tissue, but not genetic injury in the organism.
- Recent studies on cell proliferation and capacity to synthesize DNA indicate that power densities sufficient to produce thermal damage are necessary for effects to appear. This is shown by experiments comparing the effects of both water baths and microwave exposure. Exposure of animals to resonant frequencies (e.g., 2,450 MHz for mice) could be expected to induce effects at low power densities because a larger proportion of the incident energy is absorbed and converted to heat.

Heynick and Polson (1996) concluded that of the nine studies reviewed, collectively those studies provide no scientifically credible evidence that chronic exposure of mothers during pregnancy or of fathers to RFE at levels at or below the IEEE (1992) maximum exposure guidelines would cause any anomalies in their offspring. Furthermore, the National Research Council (1979) concurs saying "there is no evidence of significant microwave-induced genetic effects in humans."

F.4 BIOEFFECTS RELATED TO NON-HUMAN SPECIES

In an effort to evaluate the RFE teratogenesis in non-human species, multiple studies were conducted over the past several decades on non-human species such as insects and birds. These two groups were chosen for their termed "incubation" developmental stages, specifically, the pupae stage for many insects and the egg stage for avians (i.e., birds). These "incubation" stages provided a developmental stage in which to study the effect of RF exposure and an attempt to link any resulting teratogenic effects to RFE.

F.4.1 Published RFE Bioeffects Studies on Insects

Many studies to examine the RFE teratogenesis on insects, specifically the pupae of the darkling beetle (Tenebrio *molitor*) were completed in the 1970s (Heynick and Polson, 1996). In an early study, Carpenter and Livstone (1971) exposed single pupae to 10 GHz RFE for two hours at 17 mW/cm^2 (e.g., estimated SAR of 40 W/kg) or at 68 mW/cm^2 (SAR of 160 W/kg) for 20 or 30 minutes. As representative results, about 20 percent of pupae exposed at the lower RFR level developed into normal beetles; about 4 percent died and 76 percent had gross abnormalities. Approximately 75 percent of the pupae heated conventionally to the temperature reached at 17 mW/cm^2 developed into normal beetles, leading the authors to conclude that abnormal development of RFR-exposed pupae could not be explained as a thermal effect.

Lindauer et al. (1974) exposed groups of Tenebrio *molitor* pupae to 9 GHz continuous wave RFE at a level of 17.1 mW/cm^2 for two hours in an attempt to verify the findings of Carpenter and Livstone (1971). Although some RFR-related differences were significant ($p<0.05$), no clear dependence of effect on dose rate or total dose was found. Also, no significant differences in results were shown between pulsed and continuous wave RFE at the same average power density.

Liu et al. (1975) extended this work at 9 GHz and found significant teratogenesis for two hour exposures at power densities as low as about 0.17 mW/cm^2. In yet another study, Olsen (1981) exposed groups of Tenebrio *molitor* pupae to a standing-wave, 6 GHz field for varying time periods yielding a constant total dosage of 1123 Joules per gram (J/g). The results of the control experiment showed no morphological defects, in sharp contrast to the relatively large incidence of anomalies observed in control pupae by Liu et al. (1975). Olsen (1982) suggested the existence of a hyperthermia threshold of approximately 40°C for deleterious effects on Tenebrio *molitor* pupae.

Thus, Heynick and Polson (1996) point out in contrast with the findings of Carpenter and Livstone (1971), Lindauer et al. (1974), and Liu et al. (1975), the results of the various studies by Olsen (not all of the studies by Olsen that are cited by Heynick and Polson [1996] are reported here) and coworkers indicated that the deleterious effects of RFE on the darkling beetle were thermally based, and that non-RFE factors could have influenced the differences in findings in the prior studies.

F4.2 Published RFE Bioeffects on Avians

Byman et al. (1985) did a study related to the Glaser (1968) concept of the satellite power system (SPS). SPS is a satellite in geostationary orbit for converting solar power into microwaves (2.45 GHz) and beaming that power to a suitable site on the earth's surface, where the power would be received by an array of antennas and then transmitted to the population via conventional high-power lines. Power densities would vary from about 1 mW/cm^2 at the edge of the array to 233 mW/cm^2 at the center of the array. This study sought to determine whether bird nests on the receiving antenna array would be adversely affected by exposure to the RFE, specifically egg hatchability and embryo development. The Japanese quail (*Coturnix japonica*) was used as the test subject. Differences in egg-mass loss, hatchability, and chick weights did not vary significantly at an SAR of 12.5 W/kg and no abnormalities were observed. However, hatchability was much lower at an SAR of 50 W/kg and varied significantly.

Hamrick and McRee (1975) exposed eight 4x5 arrays of Coturnix *japonica* eggs to 2.45 GHz RFE at a level of 30 mW/cm^2 and an SAR of 14 W/kg, while a sham-exposed group was also used. The differences between the RFE and the sham-exposed groups were all nonsignificant except for hemoglobin, which was about 4 percent lower for the RFE exposed group than the sham-exposed group.

Various studies with Japanese quail eggs were carried out by McRee et al. (1975), Hamrick and McRee (1975), McRee and Hamrick (1977), Hamrick et al. (1977), Inouye et al. (1982), McRee et al. (1983), Byman et al. (1985), Gildersleeve et al. (1987), and Spiers and Baummer (1991). All of those studies were done with 2.45 GHz RFE, and the SARs ranged from 3.2 to 25 W/kg. The endpoints included hatchability, hatchling weights, viability, and the incidences of abnormalities. The findings showed no significant differences between RFE-exposed and sham-exposed eggs in any endpoints except when RFE-exposure raised internal egg temperatures by a few degrees above normal incubation temperatures. An important difference between RFE-exposure and maintenance of eggs at the same surface temperature by conventional means is the non-uniform spatial internal-temperature distribution in RFE-exposed eggs, with consequent higher local temperatures within them (Heynick and Polson, 1996).

Chicken and turkey eggs were also studied by Fisher et al. (1979), Saito et al. (1991), Braithwaite et al. (1991), Hills et al. (1974), Hall et al. (1982), and Hall et al. (1983). Collectively, the various studies on Japanese quail, chickens, and turkeys also yielded RFE-related effects ascribable to significant temperature increases in the exposed specimens (Heynick and Polson, 1996). No credence can be given to the results of a few of the studies because of inadequate methodology and/or dosimetry (Heynick and Polson, 1996).

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APPENDIX G

BIBLIOGRAPHY OF RADIOFREQUENCY ENERGY/MICROWAVE BIOEFFECT STUDIES

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RADIOFREQUENCY ENERGY/MICROWAVE BIOEFFECT STUDIES

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