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Report to Congressional Requesters

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NATIONAL WEATHER SERVICE

Sulphur Mountain Radar Performance

GAO/AIMD-99-7

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The Honorable Judd Gregg
Chairman
The Honorable Ernest F. Hollings
Ranking Minority Member
Subcommittee on Commerce, Justice,
State, and the Judiciary
Committee on Appropriations
United States Senate

The Honorable Barbara Boxer
United States Senate

In December 1994, the National Weather Service (NWS) began operating a Next Generation Weather Radar (NEXRAD) located on Sulphur Mountain in Ventura County, California. The radar was recently the focus of a study by the Rose Institute of Claremont McKenna College. The Institute concluded, among other things, that the location of the radar prevented it from performing its mission to provide accurate and timely information for warning of flash flooding in nearby communities and wind shear at nearby airports.

Given the issues raised by the Rose Institute, Senate report 105-48 requested that we review the findings in the Rose Institute report. As agreed with your offices, our objectives were to determine whether the Sulphur Mountain NEXRAD (1) can provide timely and accurate information for warning of flash floods[1] and (2) is intended to provide low-level data necessary to predict wind shear for Los Angeles International Airport.

Results in Brief

Since the Sulphur Mountain NEXRAD was commissioned in December 1994, the accuracy and timeliness of flash flood warnings has improved for Ventura and Los Angeles counties. From January 1992 through December 1994, 18 flash flood events were reported in Ventura and Los Angeles counties. There was no advanced warning for any of the 18 events. However, from January 1995 through February 1998, advanced warnings were issued for 17 of the 22 reported events; the average warning lead time for these was just over 2 hours. Although the Sulphur Mountain radar is not the only source of data on which flash flood warnings are issued, NWS

[1]NWS' Operations Manual defines a flash flood as a flood which is caused by heavy or excessive rainfall in a short period of time, generally less than 6 hours.

officials believe that the Sulphur Mountain NEXRAD is the primary reason for the increase in advanced warning lead time because it provides advanced warning of heavy precipitation, often before severe weather hits the California coast.

In addition, users of the Sulphur Mountain NEXRAD data told us that the information it provides is valuable, accurate, and timely. For example, officials from the Los Angeles County Department of Public Works, who are responsible for constructing, operating, and maintaining the flood control and water conservation facilities in Los Angeles County, told us that the Sulphur Mountain NEXRAD has significantly improved the quality and quantity of radar information they receive and that it is substantially more detailed, accurate, and timely than previous radars. In addition, the Director of Emergency Services for Ventura County considers the radar "to be an effective tool for identifying the appropriate level of response for county emergency services during inclement weather."

Despite the improvements in flash flood warning lead time and user satisfaction, NWS data show that the Sulphur Mountain NEXRAD is not consistently meeting its 96 percent availability[2] requirement. During the 30 months from October 1995 through March 1998, the Sulphur Mountain NEXRAD was available as required for 20 months; for the other 10 months, availability ranged between 79 percent to 95 percent. If the NEXRAD is not available as required, it increases the risk that NWS will not have the data it needs to accurately and quickly predict flash floods and other severe weather. NWS headquarters officials acknowledged the availability shortfalls and stated that they are monitoring the failure rates of parts and are attempting to reduce the failure rates or to more quickly replace the parts that fail most often. For instance, they told us that they are installing fans to keep the transmitter, a component that has been unreliable since the inception of the NEXRAD program, from overheating. In addition, NWS officials told us that they are working with different shipping companies to hasten the delivery of replacement parts.

Predicting wind shear at Los Angeles International Airport is not part of NEXRAD's mission. The Federal Aviation Administration (FAA) uses three different systems, either alone or in tandem, to predict wind shear at airports—Terminal Doppler Weather Radar (TDWR), Weather Systems Processor (WSP), and Low Level Wind Shear Alert System (LLWAS). TDWR is the "state of the art" wind shear detection system that is currently being

[2]System availability is defined as the time that a system is operating satisfactorily, expressed as a percentage of the time the system is required to be operational.

deployed at high traffic airports that experience severe weather. WSP is an enhancement to an existing air traffic control surveillance radar that is to provide FAA with 80 to 95 percent of the capability of TDWR. WSP is to be installed at high to moderate traffic airports that experience limited severe weather. LLWAS is a network of anemometers[3] that were originally installed in the 1970s. LLWAS is used to supplement TDWR at nine high traffic airports at greatest risk of severe weather and it is used at other airports that will not get TDWR or WSP—typically lower traffic airports. Los Angeles International Airport currently has LLWAS and since it is an airport designated as having high to moderate traffic and typically experiences limited severe weather, it is scheduled to get WSP in 2001.

Background

NWS began a nationwide modernization program in the 1980s to upgrade observing systems, such as satellites and radars, and design and develop advanced forecaster computer workstations. The goals of the modernization are to achieve more uniform weather services across the nation, improve forecasts, provide better detection and prediction of severe weather and flooding, permit more cost-effective operations through staff and office reductions, and achieve higher productivity. Four major programs are included in this modernization: NEXRAD, the Automated Surface Observing System (ASOS), the Next Generation Geostationary Operational Environmental Satellite (GOES-Next), and the Advanced Weather Interactive Processing System (AWIPS). NEXRAD, ASOS, and GOES-Next—commonly referred to as the observing systems—are operational, while AWIPS is scheduled to be deployed nationwide in June 1999.

Ongoing problems—both developmental and operational—have surrounded the modernization. For example, we have reported that the NEXRADs have not always been operating when severe weather threatened, and ASOS has fallen short of performance and user expectations.[4] We have made specific recommendations and testified numerous times over the past several years on these performance problems, developmental

[3]An anemometer is an instrument for measuring and indicating the force or speed of wind.

[4]Weather Forecasting: Radar Availability Requirements Not Being Met (GAO/AIMD-95-132, May 31, 1995) and Weather Forecasting: Unmet Needs and Unknown Costs Warrant Reassessment of Observing System Plans (GAO/AIMD-95-81, Apr. 21, 1995).

problems, and problems relating to cost and schedule.[5] As a result of its continuing problems, the NWS modernization has been included—both in 1995 and 1997—on our list of high-risk government programs.[6] Although NWS acknowledges that key problems confront the new systems, it has found that the new radars and satellites have improved forecasts and warnings.

As part of its modernization program, NWS plans to reorganize its field office structure from 256 offices (52 Weather Service Forecast Offices and 204 Weather Service Offices), to 121 Weather Forecast Offices (WFO). NWS field offices provide basic weather services such as forecasts, severe weather warnings (e.g., tornadoes, flash floods), warning preparedness, and, where applicable, aviation and marine forecasts. Warning preparedness includes coordinating with local emergency management, law enforcement agencies, and the media on notification of and response to severe weather events. It also relies on human observers to collect and report data on severe weather events.

NEXRAD: A Brief Overview

NEXRAD is a Doppler radar[7] system that measures wind velocity in severe weather, tracks storm movement and intensity, and generates data and imagery for forecasters and other users, such as air traffic controllers. There are 141 operational NEXRADs in the conterminous United States: 120 are operated by NWS and 21 are operated by the Department of Defense.[8] The system allows forecasters at each weather office to access radar information via dedicated and dial-up connections to neighboring radars. This information is very important for observing and tracking significant weather. The reported cost of the NEXRAD program was nearly $1.5 billion. NWS reports that the new radars have helped to increase the accuracy and

[5]See National Weather Service: Budget Events and Continuing Risks Of Systems Modernization (GAO/T-AIMD-98-97, Mar. 4, 1998), Weather Service Modernization: Risks Remain That Full Systems Potential Will Not Be Achieved (GAO/T-AIMD-97-85, Apr. 24, 1997), Weather Forecasting: Recommendations to Address New Weather Processing System Development Risks (GAO/AIMD-96-74, May 13, 1996), Weather Forecasting: NWS Has Not Demonstrated That New Processing System Will Improve Mission Effectiveness (GAO/AIMD-96-29, Feb. 29, 1996), Weather Forecasting: Improvements Needed in Laboratory Software Development Processes (GAO/AIMD-95-24, Dec. 14, 1994), and Weather Forecasting: Systems Architecture Needed for National Weather Service Modernization (GAO/AIMD-94-28, Mar. 11, 1994).

[6]High-Risk Series: An Overview (GAO/HR-95-1, Feb. 1995) and High-Risk Series: Information Management and Technology (GAO/HR-97-9, Feb. 1997).

[7]Doppler radar is used to determine the speed and direction of rain or snow particles, cloud droplets, or dust moving toward or away from the radar. The radar accomplishes this by sending out a pulse using a stable frequency and then measuring the changing frequencies as the distances between the radar and the object changes.

[8]FAA operates seven NEXRADs in Alaska, four in Hawaii, and one in Puerto Rico.

timeliness of warnings for severe thunderstorms, tornadoes, and other hazardous weather events.

In 1995, we reported that NWS did not know if its radars were meeting the availability requirement because it was not monitoring availability effectively. We recommended that NWS analyze and monitor NEXRAD system availability on a site-specific basis and correct any shortfalls in system availability that this analysis shows.[9] NWS concurred with these recommendations and began monitoring system availability on a site-specific basis. However, as we reported in our February 1997 high-risk report, not all NEXRADs were meeting the availability requirement.[10]

Each NEXRAD consists of three major subsystems—the radar data acquisition (RDA) subsystem, the radar product generator (RPG) subsystem, and the principal user processor (PUP) subsystem—and associated communications among these subsystems. Each NEXRAD includes about 400,000 lines of code for operating the radar, processing radar signals, generating and transmitting data, and displaying data products.

The RDA consists of a 10 centimeter wavelength Doppler weather radar that collects the raw data to, among other things, (1) measure wind velocity in severe weather, (2) provide improved estimates of precipitation amounts, and (3) track storm movement and intensity. The technology needed to perform this function includes an antenna, pedestal, radome (a dome-shaped covering to protect the antenna), transmitter, and receiver. Included in the RDA unit is hardware and software necessary for a variety of control functions, including signal processing, monitoring, and error detection, as well as archiving the radar data. A computer processes the radar signals to create digital data that can be further processed by the RPG.

The RPG includes all hardware and software necessary for turning the data into displayable data products. Specifically, the RPG provides real-time generation, storage, and distribution of products for users. It includes hardware and software required for system control; status monitoring; and error detection, archiving, and data processing.

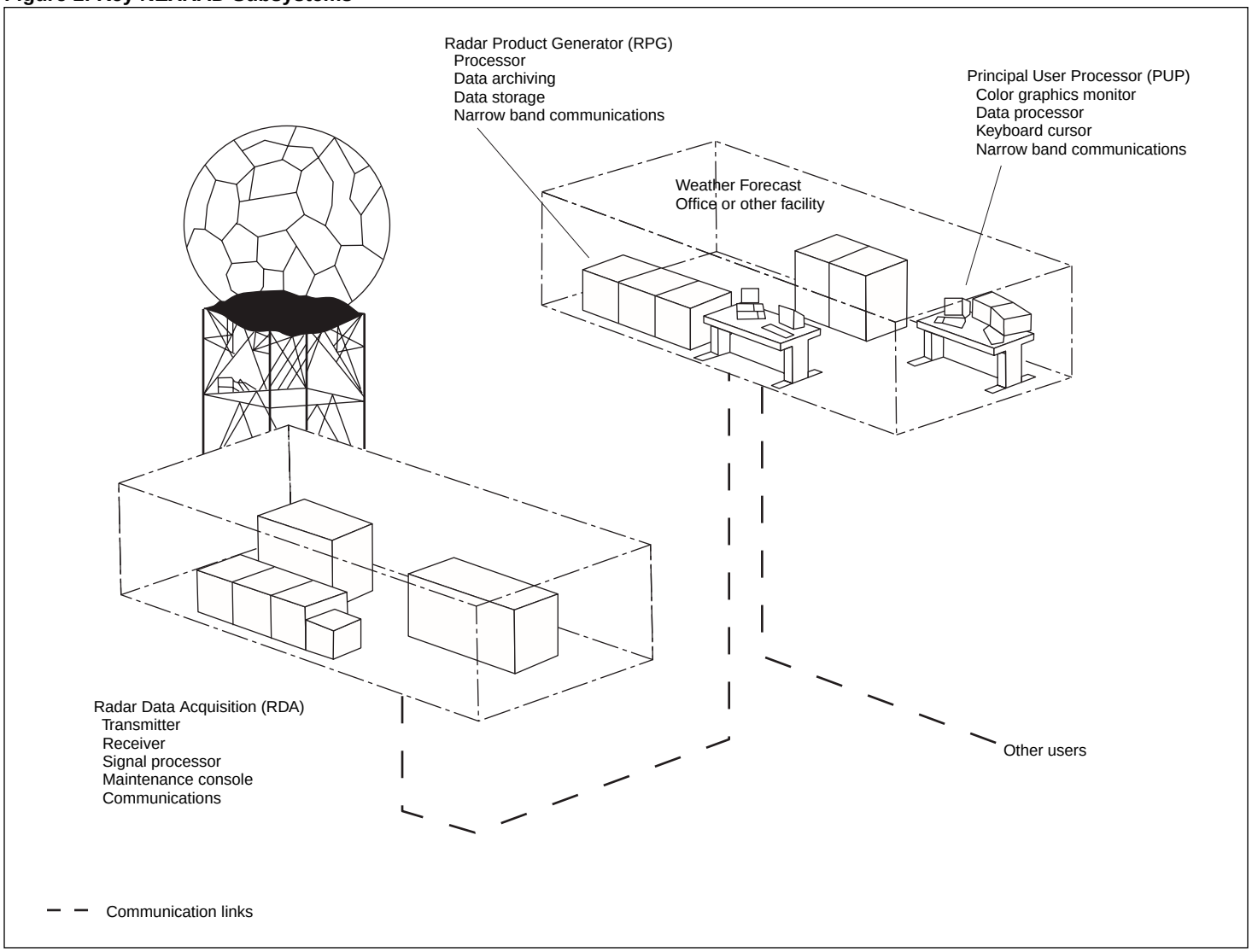
The PUP is a workstation that consists of the hardware and software required for the request, display, local storage and annotation, and distribution of products by forecasters. It also includes the hardware and

[9]GAO/AIMD-95-132.

[10]GAO/HR-97-9.

software required for local control, status monitoring, archiving, and communicating with other users. The PUP maintains a dedicated communication link to the RPG located on-site, and it routinely receives NEXRAD products. The PUP also has the capability to access data from RPGs at other NEXRAD sites. In addition, under an NWS administered NEXRAD information dissemination service, NWS has set aside four communications ports to allow access by commercial companies that provide data to other government agencies and the public. Figure 1 shows the key NEXRAD subsystems for a typical NWS weather forecast office.

Figure 1: Key NEXRAD Subsystems



Sulphur Mountain NEXRAD Overview

The Sulphur Mountain NEXRAD was delivered for installation during November 1993, tested from January 1994 through March 1994, accepted in March 1994, and commissioned in December 1994. It is located in southern Ventura County near the communities of Ojai and Sulphur Springs, controlled by the Los Angeles/Oxnard weather forecast office (WFO), and serves Los Angeles, Ventura, San Luis Obispo, and Santa Barbara counties. Prior to installation of this weather radar, no radar precipitation estimates were available for the Los Angeles area.

The Los Angeles/Oxnard WFO also uses radar images from NEXRADs located in Santa Ana, and Vandenberg and Edwards Air Force bases. According to Los Angeles/Oxnard WFO officials, the four NEXRADs cover the following counties or parts thereof:

Sulphur Mountain NEXRAD - eastern Santa Barbara County and offshore waters, Ventura County and offshore waters, western Los Angeles County and offshore waters.

Vandenberg Air Force Base NEXRAD - San Luis Obispo County and offshore waters, Santa Barbara County and offshore waters.

Santa Ana NEXRAD - eastern Los Angeles County and offshore waters.

Edwards Air Force Base NEXRAD - extreme northern Ventura County, northern Los Angeles County.

According to the National Weather Service, the offshore waters covered by these four NEXRADs are essential to obtain advance warning of storms as they approach the California coast. See figure 2 for the counties served by the Los Angeles/Oxnard WFO and the locations of the four NEXRADs used by this office.

Figure 2: Counties Served by the Los Angeles/Oxnard Weather Forecast Office and Locations of NEXRADs Used by This Office

Southern California Topography and Climate

Southern California has some of the steepest terrain in the United States. The steep mountains and the Pacific Ocean create ideal conditions for the

orographic enhancement of rainfall.[11] This terrain combined with the fact that the soil does not readily absorb moisture make the rivers in this area prone to flooding during heavy rains. NWS officials told us that the heaviest rains that produce flooding in this area occur in the winter and typically approach from the southwest.

Overview of the Rose Institute Study

When residents of the Upper Ojai Valley were informed that NWS was installing a weather radar system on Sulphur Mountain, they became concerned about the health effects of microwave radiation and asked the Rose Institute of State and Local Government at Claremont McKenna College to conduct a preliminary review of the issues.

In August 1997, the Rose Institute issued the report, The National Weather Service's Tower in the Upper Ojai: A Case History. The report's conclusions were:

- "The initial siting decision seems to have been made without full compliance with ordinary regulatory procedures; and the administrator of the National Weather Service has issued incorrect and misleading statements in defense of the selection of the site."
- "There is evidence that the Sulphur Mountain site prevents NEXRAD from performing its mission of accurate, timely warning of flash flooding in the San Gabriel mountain foothills, severe weather in the Basin or wind shear data for the Basin airports."
- "There is evidence that Sulphur Mountain radar fails to provide the low-level data necessary to predict wind shear and clear air turbulence for Los Angeles International Airport and the Burbank/Pasadena Airport on a timely basis."
- "Residents of the Sulphur Mountain area have been adversely affected, property values have dropped significantly, and the ability to sell property has virtually disappeared because of the presence of the radar. The National Weather Service has consistently refused to deal openly with the health issue raised by siting the radar in a residential area."

In November 1997, the NWS responded to the Rose Institute report and stated that it was "replete with misinformation concerning weather radars, weakly supported opinions, and several paradoxical conclusions."

[11]As moist air moves up a mountain slope, it is cooled and the moisture condenses forming clouds. If lifted far enough, precipitation occurs. The effect of precipitation forming simply from winds encountering mountainous terrain is called orographic precipitation.

Subsequent to that response, the Rose Institute issued another report in May 1998 that expanded on some of the issues raised in its November report, while also raising additional concerns, including whether the Sulphur Mountain NEXRAD coverage is needed since "ninety percent of the area that the Sulphur Mountain tower was installed to cover is covered by other NEXRAD stations."

Objectives, Scope, and Methodology

The objectives of our review were to determine whether the Sulphur Mountain NEXRAD (1) can provide timely and accurate information for warning of flash floods and (2) is intended to provide low-level data necessary to predict wind shear for Los Angeles International Airport.

To determine whether the Sulphur Mountain NEXRAD can provide timely and accurate information for warning of flash floods, we

- reviewed documentation on NEXRAD and interviewed NWS officials to determine what information NEXRAD provides that is used to issue flash flood warnings,
- interviewed NWS officials at the Los Angeles/Oxnard WFO to determine what other systems, in addition to NEXRAD, are used to issue flash flood warnings,
- reviewed flash flood events (this information was obtained from the Storm Data database located in Silver Spring, Maryland) and flash flood warnings (this information was obtained from the National Climatic Data Center located in Asheville, North Carolina) that occurred in Ventura and Los Angeles counties[12] from January 1992 through February 1998 to determine the accuracy and timeliness of flash flood warning lead times prior to and after the installation of the Sulphur Mountain NEXRAD [Note: In calculating the warning lead times, we used the initial flash flood warning in our analysis and excluded all flash flood warning extensions that were issued after the initial warning.]
- supplemented the flash flood event and warning data obtained from the Storm Data database and the National Climatic Data Center, respectively, with local flash flood event and warning information from the Los Angeles/Oxnard WFO since the national databases were incomplete,
- verified our analysis of the flash flood event and warning data with NWS Los Angeles/Oxnard WFO officials,

[12]Ventura and Los Angeles counties were selected because they are two counties that the Los Angeles/Oxnard WFO had responsibility for from January 1992 through February 1998 (from January 1992 to October 1993 the office was located in Los Angeles), and because they are the two primary counties that the Sulphur Mountain NEXRAD covers.

- compared the timeliness of the flash flood warning lead times to the requirement specified in Commerce's 1999 Annual Performance Plan,
- obtained and reviewed Sulphur Mountain NEXRAD availability data from the Engineering Management Reporting System for the period from October 1995 through March 1998 to determine if the Sulphur Mountain radar was meeting the 96 percent availability requirement,
- reviewed three flash flood events that occurred on February 3, 6, and 23, 1998, to determine how data from the Sulphur Mountain NEXRAD is used in combination with rain gage information to issue flash flood warnings, and
- interviewed the following users to obtain their views of the quality, timeliness, and utility of the Sulphur Mountain NEXRAD data: officials from the Flood Control Department of the Ventura County Public Works Agency; the Los Angeles County Department of Public Works; Point Mugu Naval Air Warfare Center; U.S. Army Corps of Engineers, Los Angeles District, Reservoir Regulation Section; Ventura County Sheriff's Department; the Assistant City Administrator from the Emergency Preparedness Division, City of Los Angeles; weathercasters from KCBS-TV and KCAL-TV; and the director of Fox Weather, a private meteorological service.

To determine whether the Sulphur Mountain NEXRAD is intended to provide low-level data necessary to predict wind shear for Los Angeles International Airport, we

- reviewed documentation that established NEXRAD's requirements,
- reviewed FAA documentation describing systems that predict wind shear at airports, including those systems at Los Angeles International Airport, and
- interviewed NWS and FAA officials.

We performed our work at the National Oceanic and Atmospheric Administration (NOAA) and NWS headquarters in Silver Spring, Maryland, and at the Los Angeles/Oxnard WFO in Oxnard, California. Our work was performed from February 1998 to September 1998, in accordance with generally accepted government auditing standards. The Secretary of Commerce provided written comments on a draft of this report. These comments are discussed in the "Agency Comments" section of this report and are reprinted in appendix II. In addition, FAA officials, including the Acting Product Lead for Wind Shear and Radar, provided oral comments on a draft of this report. FAA's comments are also discussed in the "Agency Comments" section.

Sulphur Mountain NEXRAD Has Contributed to More Accurate and Timely Flash Flood Warnings, but Is Not Always Available

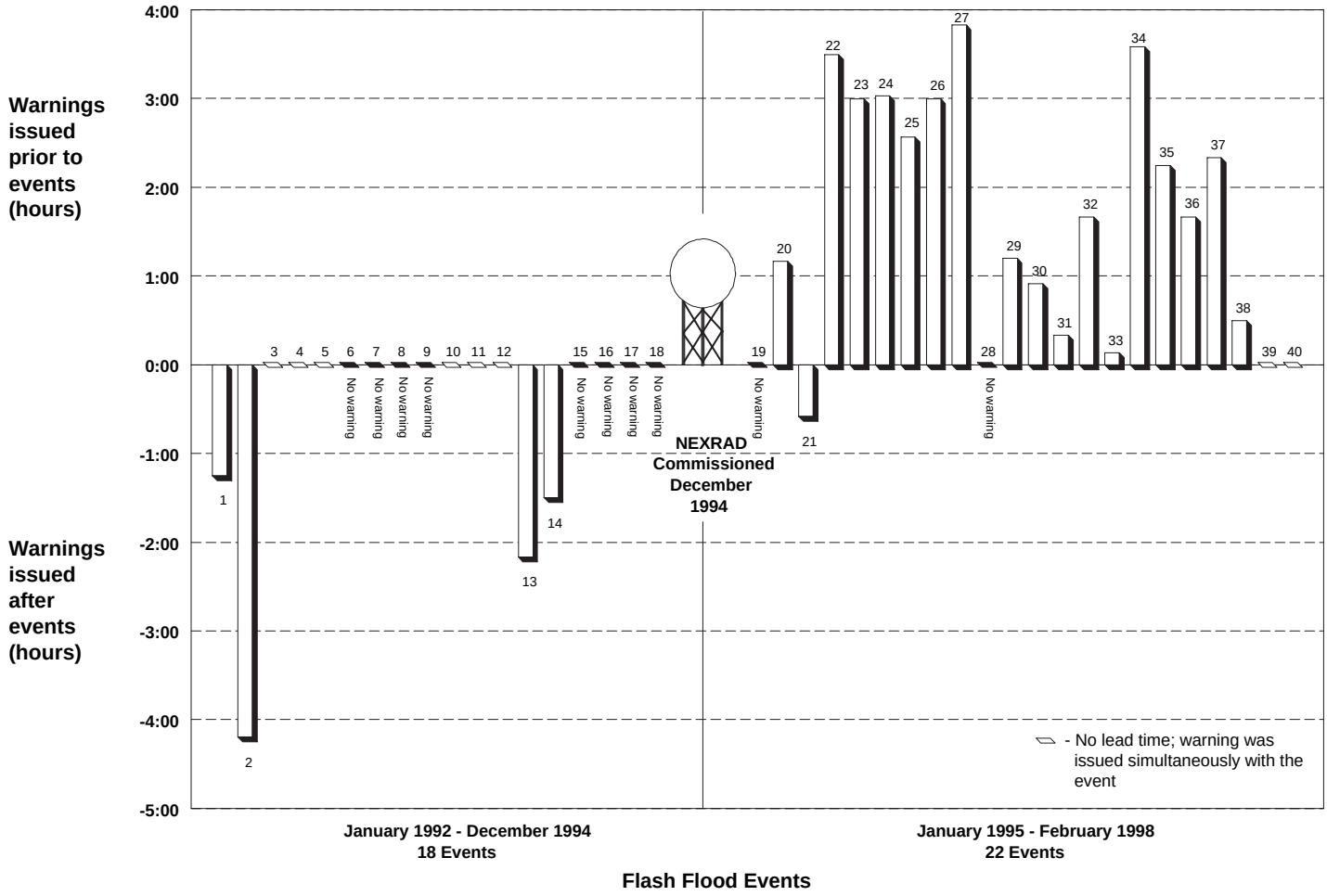
The accuracy and timeliness of flash flood warnings has increased in Los Angeles and Ventura counties since the Sulphur Mountain NEXRAD became operational in December 1994. Although other systems can contribute to the improved timing of the flash flood warnings, NWS officials believe that the system that is primarily responsible for improved flash flood warning lead times in Ventura and Los Angeles counties is the Sulphur Mountain NEXRAD. Users, in addition to NWS, also told us that they rely heavily on the Sulphur Mountain NEXRAD to alert the public to flash floods. Despite the improvements in flash flood warnings and overall user satisfaction, the Sulphur Mountain NEXRAD is not always available the required amount of time.

Accuracy and Timeliness of Flash Flood Warnings Has Improved Since Sulphur Mountain NEXRAD Became Operational

The Department of Commerce's Fiscal Year 1999 Annual Performance Plan specifies as one objective to "continue improving the timeliness and accuracy of short-term environmental predictions that have immediate impact on individuals and many sectors of the economy." It further states that for fiscal year 1999, the goal is to increase flash flood warning lead time to 42 minutes.

The accuracy and timeliness of flash flood warnings has increased in Los Angeles and Ventura counties since the Sulphur Mountain NEXRAD was commissioned in December 1994. From January 1992 through December 1994, 18 flash flood events were reported in Ventura and Los Angeles counties. There was no advanced warning for any of the 18 events. However, from January 1995 through February 1998, advanced warnings were issued for 17 of the 22 reported events; and the average warning lead time for these was just over 2 hours. For the 17 events, the warning lead time ranged from 8 minutes to 3 hours and 50 minutes, and exceeded the fiscal year 1999 flash flood warning lead time goal of 42 minutes for 14 of the 17 events. Figure 3 displays flash flood warning lead times for the 40 flash flood events that occurred in Ventura and Los Angeles counties from January 1992 through February 1998.

Figure 3: Warning Lead Time for Flash Flood Events for Ventura and Los Angeles Counties (January 1992 Through February 1998)



Source: Los Angeles/Oxnard WFO, Oxnard, CA; National Climatic Data Center, Asheville, NC; NWS Headquarters, Silver Spring, MD.

Concerning the five events since January 1995 that were not preceded by a warning, Los Angeles/Oxnard WFO officials stated that two of the events were incorrectly recorded as flash floods and two were flash flood warning extensions that were issued after the initial warning and, therefore, none of the four should be counted as missed events. According

to the Los Angeles/Oxnard WFO meteorologist-in-charge, one of the incorrectly recorded events was an urban flood event,[13] while the other was the result of a controlled water release into the Los Angeles River. However, because no documentation was provided to substantiate NWS' statements, we classified all five as missed events.

Another measure of accuracy is the number of false warnings that occurred. From January 1992 through December 1994, NWS data shows that there were three false flash flood warnings, while from January 1995 through February 1998, NWS data shows five false flash flood warnings. See appendix I for details on each of the 40 events listed in figure 3 (e.g., date of the event, time of the flash flood, time the warning was issued), as well as the dates of the false warnings.

Although NEXRAD is not the only source of data on which storms are tracked, Los Angeles/Oxnard WFO officials told us that the Sulphur Mountain NEXRAD is the primary reason for the increase in advanced warning lead time because it provides advanced warning of heavy precipitation oftentimes before severe weather hits the California coast. NWS officials told us that well before the NEXRAD imagery is used to issue a flash flood warning, forecasters use other sources of information to track storms as they approach the west coast, primarily high resolution satellite imagery from the GOES-Next satellites and detailed numerical models. However, as storms approach the counties covered by the Los Angeles/Oxnard WFO, the detailed imagery from the Sulphur Mountain NEXRAD is used to issue flash flood warnings, along with the neighboring NEXRADs (i.e., Vandenberg Air Force Base, Edwards Air Force Base, and Santa Ana).

NEXRAD estimates of precipitation rate and amount are extremely important for flash flood forecasting; however, NWS officials at the Los Angeles/Oxnard WFO told us that these estimates are not always exact and are supplemented with rainfall sensors and human observers. For example, radar reflectivity is affected by many factors, including precipitation growth, evaporation, and type; thus, the precipitation observed by the NEXRAD beam is not absolute and may not be exactly representative of that reaching the ground. Therefore, to improve NEXRAD precipitations estimates, Los Angeles/Oxnard WFO officials rely on "ground

[13]NWS' Operations Manual defines an urban flood event as flooding to streets and low-lying areas, such as railroad underpasses and urban storm drains. The manual states that urban flooding is mainly only an inconvenience and is generally not life threatening nor is it significantly damaging to property.

truth" that is provided by surface observation networks[14] and human observations.

Users Say Sulphur Mountain NEXRAD Provides Valuable, Accurate, and Timely Data

NWS officials and other users of the Sulphur Mountain NEXRAD data told us that the information it provides is valuable, accurate, and timely. NWS officials provided us with detailed case studies of three February 1998 El Nino-related flash flood events that show how the Sulphur Mountain NEXRAD imagery was used to issue flash flood warnings.[15] For example, on February 6, 1998, NWS issued a flash flood warning for southern Ventura and western Los Angeles counties at 8:35 a.m. based on the Sulphur Mountain NEXRAD information. At 8:40 a.m., the Sulphur Mountain NEXRAD showed heavy thunderstorms moving on shore near Ventura Harbor. By 10 a.m., rafts were needed to evacuate a mobile home park in Camarillo. As the storm moved eastward, a 20-foot sinkhole opened near Moorpark road in Thousand Oaks and mudslides closed the Pacific Coast highway in Malibu.

Eight of the nine other users of Sulphur Mountain NEXRAD data we interviewed told us that they are pleased with the information it provides, and that it was an important tool for performing their jobs accurately and timely. For example, officials from the Los Angeles County Department of Public Works, who are responsible for constructing, operating, and maintaining the flood control and water conservation facilities in Los Angeles County, told us that the Sulphur Mountain NEXRAD has significantly improved the quality and quantity of radar information they receive and that it is substantially more detailed, accurate, and timely than previous radars. An official from the Point Mugu Naval Air Warfare Center, who provides day-to-day forecasts during flight briefings to ensure the safety of aircraft, described the Sulphur Mountain NEXRAD data as "critical." The Director of Emergency Services for Ventura County considers the radar "to be an effective tool for identifying the appropriate level of response for county emergency services during inclement weather." The Los Angeles District Corps of Engineers, which manages water control projects in Southern California, including 10 Corps of Engineers reservoirs in the Los Angeles area that provide flood protection to downstream areas, said that data from the radar "has proven to be a very valuable water management tool." One user, the director of Fox

[14]These surface observation networks are referred to as the Automated Local Evaluation in Real Time (ALERT) network. The ALERT network uses remote sensors (i.e., rain gages) from various sources, including, privately owned companies, county flood control agencies, and the Automated Surface Observing System (ASOS) which transmit data to a central computer in real time.

[15]These three events occurred on February 3, 6, and 23, 1998.

Weather, a private meteorological service, said that the radar was less useful for Ventura County than for the Los Angeles area because it had not significantly improved his ability to provide precipitation estimates for his clients. NWS officials acknowledge that precipitation estimates are not always exact and therefore are supplemented with surface observation networks and human observers.

Several of the users also described specific incidents where data from the Sulphur Mountain NEXRAD was especially useful in informing the public and protecting lives and property. For example, the TV weathercaster for KCBS-TV used the radar during an intense storm on December 6, 1997, to track the storm and give people in Ventura County up-to-the-minute reports. With the data from the Sulphur Mountain NEXRAD, he was able to provide warnings to specific locations before the storm occurred. In addition, the program administrator of the Ventura County Sheriff's Department's Office of Emergency Services told us that 48 hours after the La Conchita landslide in March 1995, data from the Sulphur Mountain radar was used to provide a warning of another severe storm moving into the La Conchita area. The warnings, which were not available from other NEXRADs in the area, provided ample time to evacuate already deployed emergency services personnel, ground helicopters, and take other safety precautions.

Sulphur Mountain NEXRAD Is Not Meeting Availability Requirement

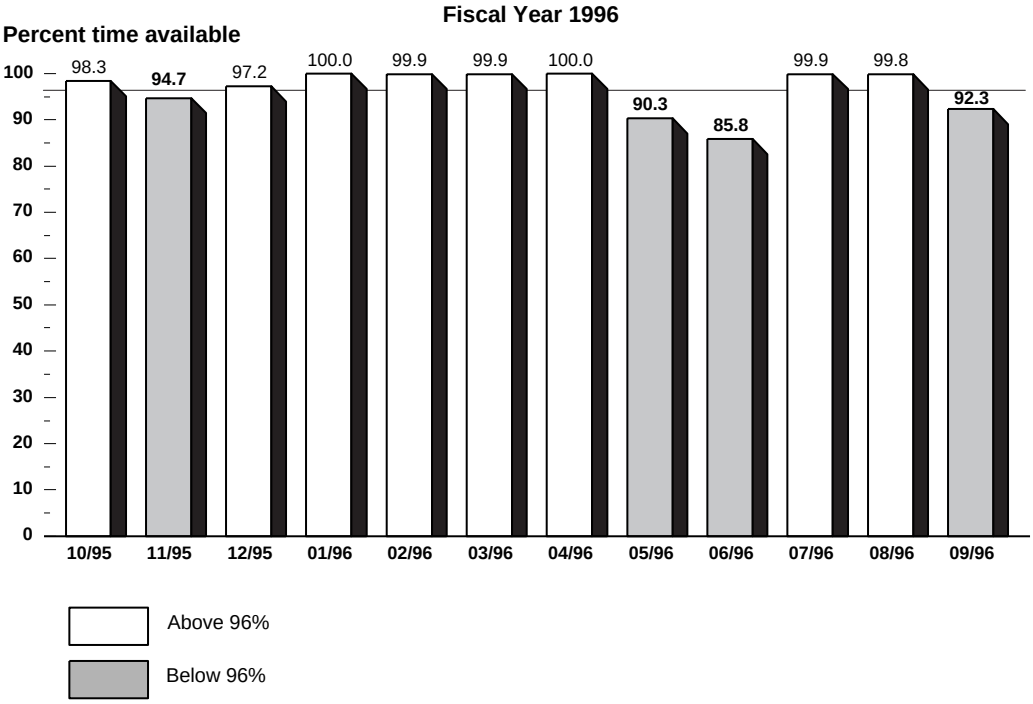
System availability is defined as the time that a system is operating satisfactorily, expressed as a percentage of the time the system is required to be operational.[16] NWS requires that each NEXRAD be available 96 percent of the time. We reported in May 1995 that according to NWS officials, the 96 percent requirement is based on an analysis that considered factors such as equipment reliability, staff costs, and spare part costs.[17] These officials stated that the additional costs (for example, redundant systems, spare parts, and additional maintenance technicians) associated with achieving availability above 96 percent were not worth the added benefits.

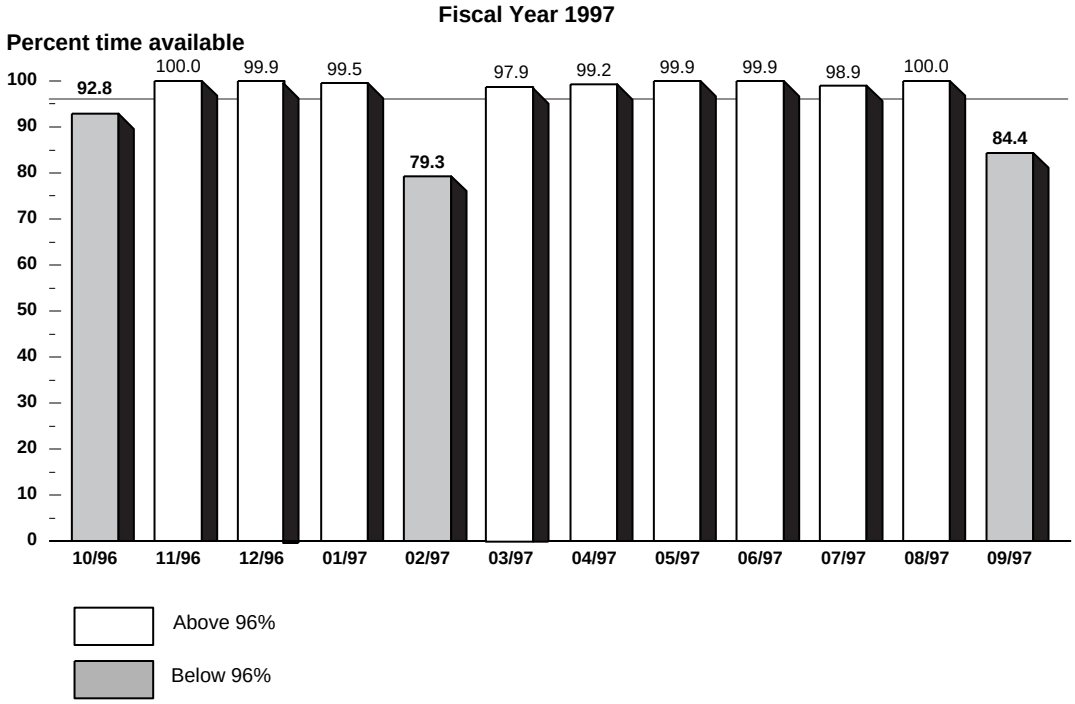
The Sulphur Mountain NEXRAD is not consistently meeting the 96 percent availability requirement. From October 1995 through March 1998, NWS' engineering management reporting system (EMRS) reports show that the Sulphur Mountain NEXRAD did not meet the 96 percent requirement for 10 of the 30 months reviewed. (See figure 4.)

[16]NWS refers to this percentage as service availability.

[17]Weather Forecasting: Radar Availability Requirements Not Being Met (GAO/AIMD-95-132, May 31, 1995).

Figure 4: Sulphur Mountain NEXRAD Availability Fiscal Years 1996, 1997, 1998 (Through March 1998)




Fiscal Year 1997
Percent time available
100
90
80
70
60
50
40
30
20
10
0
92.8
100.0
99.9
99.5
79.3
97.9
99.2
99.9
99.9
98.9
100.0
84.4
10/96
11/96
12/96
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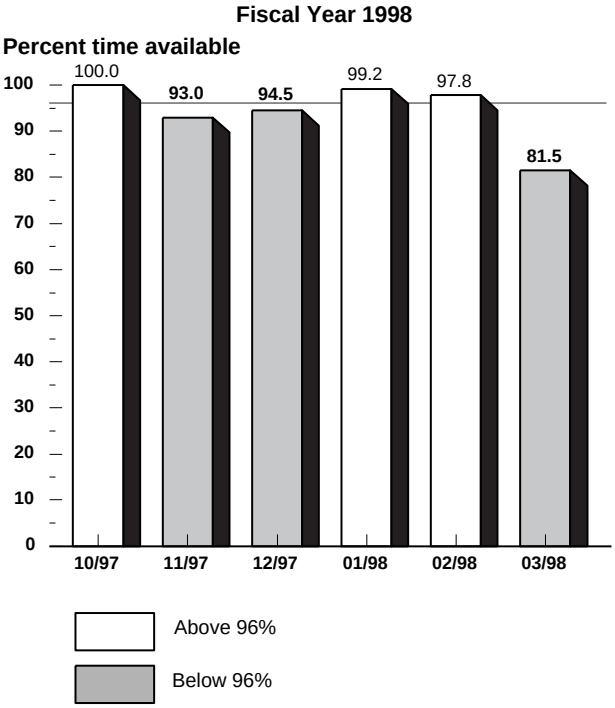
03/97
04/97
05/97
06/97
07/97
08/97
09/97
Above 96%
Below 96%



Source: NWS. We did not independently verify these data.

NWS officials from the Los Angeles/Oxnard weather forecasting office told us that the Sulphur Mountain NEXRAD is not consistently meeting the 96 percent availability requirement because of component failures and the time-consuming logistics process associated with fixing the failed components. If the NEXRAD is down for more than 28 hours in a 30-day month, the 96 percent availability requirement will not be met. The Los Angeles/Oxnard WFO technicians who troubleshoot outages and are responsible for making repairs told us that most of the outages associated with the months when the availability requirement was not met required ordering a part that was not on hand. They added that it usually takes at least 24 hours for the parts to arrive after they are ordered. The technicians told us that they strive to meet the 96 percent requirement, but that it is very difficult, considering that it takes 1 hour to get to the site from the Los Angeles/Oxnard WFO, time to analyze the problem, usually 24

hours to receive the needed part, 1 hour to get back to the site, and time to repair the NEXRAD.

The technicians told us that they have tried using other shipping companies to hasten delivery of replacement parts, but these efforts have not resulted in improved delivery times. The technicians also told us that deliveries of parts are sometimes delayed because some ordered parts are not in stock and some replacement parts have been defective. For example, in May 1996, when the NEXRAD's availability was only 90.3 percent, there was a 48-hour logistics delay because the required part was out of stock. In addition, the low availability reported in February 1997 occurred because the ordered part was defective.

Until the Sulphur Mountain NEXRAD consistently meets the 96 percent availability requirements, NWS risks not having the data it needs to accurately and quickly predict flash floods and other severe weather. NWS headquarters officials acknowledged the availability shortfalls and stated that they are monitoring the failure rates of parts and are attempting to reduce the failure rates or to more quickly replace the parts that fail most often. For instance, they told us that they are installing fans to keep the transmitter, a component that has been unreliable since the inception of the NEXRAD program, from overheating. They added that the NEXRAD program has a 6-year modification plan which, among other things, identifies deficiencies in hardware performance and reliability and prioritizes NWS' improvement activities. They are also attempting to stock those spare parts that fail frequently at each location; however, they added that their budget does not allow for a full set of spares at each location. In addition, NWS officials told us that spare part inventories at the National Logistics Supply Center have recently been bolstered to replenish those stocks that were below desired levels. Finally, NWS officials told us that they are working with different shipping companies to improve the shipping process.

NEXRAD Is Not Intended to Provide Data That Are Used to Predict Wind Shear at Airports

Although NEXRAD uses doppler technology that is capable of detecting changes in wind direction, such as wind shear and atmospheric conditions associated with tornadoes and other severe storms, the detection of low-level wind shear at airports is not part of the mission of the NEXRAD network, and it is not specifically designed to do that. FAA uses three different systems, either singly or in tandem, to predict wind shear at airports — Terminal Doppler Weather Radar (TDWR), Weather Systems Processor (WSP), and Low Level Wind Shear Alert System (LLWAS). Los

Angeles International currently has LLWAS and is scheduled to get WSP in 2001.

NEXRAD Was Not Designed to Detect Wind Shear at Airports

NEXRAD was originally designed to be a weather surveillance radar for general weather observation. It was not designed to detect wind-shear at airports. According to FAA officials, in the early 1980s, FAA studied whether NEXRAD could meet its requirements for detecting wind shear and microbursts.[18] The study concluded that NEXRAD could not produce timely warnings of wind shear or other low altitude phenomena at the required 1 minute update rate required by FAA.[19] NEXRAD information is updated every 5 to 6 minutes.

In addition to not being designed to detect wind shear at airports, NEXRADs are not located to serve airports. NEXRADs were located throughout the contiguous United States to optimize national coverage for general weather observation. On the basis of NWS', Department of Defense's, and FAA's collective mission needs and the Weather Service Modernization Act, which mandates that the Secretary of Commerce certify that there will be no degradation in radar coverage at the 10,000-foot level prior to closing, consolidating, automating, or relocating any of NWS' field offices, the three agencies negotiated the radars' locations to meet tri-agency radar coverage requirements.[20]

FAA Uses Three Systems to Detect Wind Shear at Airports

FAA uses three systems that are specifically designed to detect wind shear at airports. TDWR is the "state of the art" wind shear detection system that is currently being deployed at high traffic airports that experience severe weather. TDWR is a Doppler radar, typically located 8 to 12 miles from the airport, that is designed to detect wind shear, microbursts, precipitation, and storm motion. Its information update rates match the near real time requirement needed during aviation landings and departures.

[18]Wind shear is defined as a sudden change in wind direction that occurs at low altitudes, and a microburst is a form of wind shear.

[19]Because microbursts develop quickly and move rapidly, FAA requires 1 minute updates of radar information.

[20]The 10,000-foot level is significant because this is the elevation at which the coverage range of an individual NEXRAD is measured. The ascending radar beam loses its reliability about 125 miles from the radar. At this distance, the lowest part of the beam is approximately 10,000 feet off the ground. Therefore, each radar has a coverage diameter of 250 miles. The 250 mile cylinders were the basis for siting NEXRADs to ensure adequate national coverage.

WSP is a modification to FAA's air traffic control airport surveillance radar (ASR-9) that is to provide FAA with 80 to 95 percent of the capability of TDWR. WSP is to be installed at high to moderate traffic airports that experience limited severe weather. It adds a doppler processor to the ASR-9, giving it the capability to detect microbursts, gust fronts, precipitation intensity, storm cells and the motion of shifting gust fronts. A prototype WSP is installed in Albuquerque, New Mexico, and a production contract was awarded on September 14, 1998.

LLWAS is a network of anemometers that were originally installed in the 1970s. LLWAS is used to supplement TDWR at nine high-traffic airports at greatest risk of severe weather and it is used at other airports that will not get TDWR or WSP—typically lower traffic airports. Los Angeles International currently has LLWAS and since it is an airport designated as having high to moderate traffic that typically experiences limited severe weather, it is scheduled to get WSP in 2001.

Conclusions

The accuracy and timeliness of flash flood warning lead times has improved since the Sulphur Mountain NEXRAD was commissioned in December 1994. Although other systems, including the sophisticated network of ground sensors, have contributed to this improvement, NWS officials told us that the Sulphur Mountain NEXRAD is the primary reason for the improvement. NWS feedback on the NEXRAD's performance is consistent with that of other users, who find its data accurate, timely, and valuable.

However, the Sulphur Mountain NEXRAD is not consistently meeting its availability requirement, thus increasing the risk that NWS and other users will not always have the data needed to accurately and quickly predict flash floods and other severe weather. The risk is more serious in the winter months when Southern California experiences flash flooding. Until the Sulphur Mountain NEXRAD consistently meets the required availability requirement, lives and property are at increased risk. Consistent with our 1995 recommendation to correct shortfalls in NEXRAD system availability,[21] NWS headquarters officials told us they are taking steps to improve systems availability. However, as the Sulphur Mountain NEXRAD data show, these steps have not been sufficient.

[21] GAO/AIMD-95-132.

It was never the intent of the NEXRAD systems to provide detailed data used to predict wind shear at airports, and NEXRAD was not designed for this purpose. FAA uses other systems to perform this mission.

Recommendation

Since the Sulphur Mountain NEXRAD is not always available as required, we recommend that the Secretary of Commerce direct the NOAA Assistant Administrator for Weather Services to determine all the reasons why the Sulphur Mountain NEXRAD is not meeting the 96 percent availability requirement and to correct the problems so that the radar is available as required.

Agency Comments

In commenting on a draft of this report, the National Weather Service concurred with our recommendation and mentioned several key activities that are planned to improve radar availability. This written response is reprinted in appendix II. In addition, FAA officials said that the information presented in this report is accurate.

We are providing copies of this report to the Secretaries of Commerce and Transportation, the Director of the Office of Management and Budget, and interested congressional committees. Copies will be available to others upon request. If you have any questions about this report, please call me at (202) 512-6253, or Dave Powner, Assistant Director, at (202) 512-4348. We can also be reached by e-mail at *willemssenj.aimd@gao.gov* and *pownerd.aimd@gao.gov*, respectively. Major contributors to this report are listed in appendix III.

Joel C. Willemssen
Director, Civil Agencies Information Systems

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Abbreviations

AIMD	Accounting and Information Management Division
ASOS	Automated Surface Observing System
ASR	Airport Surveillance Radar
AWIPS	Advanced Weather Interactive Processing System
EMRS	Engineering Management Reporting System
FAA	Federal Aviation Administration
GOES-Next	Next Generation Geostationary Operational Environmental Satellite
LLWAS	Low Level Wind Shear Alert System
NEXRAD	Next Generation Weather Radar
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
PUP	principal user processor
RDA	radar data acquisition
RPG	radar product generator
TDWR	Terminal Doppler Weather Radar
WFO	Weather Forecast Office
WSP	Weather Systems Processor

Flash Flood Events and Warnings for Ventura and Los Angeles Counties From January 1992 Through February 1998[1]

Date	Time flash flood event occurred[a]	Time warning issued	Counties affected by event and/or warning	Warning lead time (hours:minutes)
(1) 2/10/92	1230 hours	1345 hours	Ventura /Los Angeles	–1:15
(2) 2/10/92	1600 hours	2012 hours	Los Angeles	–4:12
(3) 2/11/92	0959 hours	0959 hours	Los Angeles	0:00
(4) 2/12/92	0937 hours	0937 hours	Ventura /Los Angeles	0:00
(5) 2/12/92	1302 hours	1302 hours	Los Angeles	0:00
(6) 2/15/92	0545 hours		Ventura/ Los Angeles	No warning
(7) 8/13/92	0915 hours		Los Angeles	No warning
(8) 1/13/93	All day		Ventura/ Los Angeles	No warning
(9) 1/13/93	2110 hours		Ventura	No warning
(10) 1/18/93	0940 hours	0940 hours	Ventura/Los Angeles	0:00
(11) 2/8/93	All day	1115 hours	Ventura/Los Angeles	0:00
(12) 2/18/93	All day	1721 hours	Ventura/ Los Angeles	0:00
(13) 2/7/94	1500 hours	1710 hours	Los Angeles	–2:10
(14) 2/7/94	2100 hours	2230 hours	Los Angeles	–1:30
(15) 2/17/94	0740 hours		Los Angeles	No warning
(16) 2/20/94	0345 hours		Los Angeles	No warning
(17) 3/7/94	1645 hours		Los Angeles	No warning
(18) 3/24/94	1630 hours		Los Angeles	No warning
(19) 1/4/95	0930 hours		Ventura	No warning
(20) 1/4/95	1000 hours	0850 hours	Los Angeles	1:10
(21) 1/7/95	1700 hours	1735 hours	Los Angeles	–0:35
(22) 1/9/95	0300 hours	2330 hours	Ventura	3:30
(23) 1/10/95	0600 hours	0300 hours	Los Angeles	3:00
(24) 1/10/95	0717 hours	0415 hours	Ventura	3:02
(25) 1/10/95	0834 hours	0600 hours	Los Angeles	2:34
(26) 3/10/95	2150 hours	1850 hours	Ventura	3:00
(27) 3/10/95	2330 hours	1940 hours	Los Angeles	3:50
(28) 1/20/97	1352 hours		Los Angeles	No warning
(29) 2/3/98	0600 hours	0448 hours	Ventura	1:12
(30) 2/6/98	0930 hours	0835 hours	Ventura/Los Angeles	0:55
(31) 2/6/98	0930 hours	0910 hours	Ventura	0:20
(32) 2/6/98	1135 hours	0955 hours	Los Angeles	1:40

(continued)

[1] No flash flood events or warnings were recorded during 1996. Three false flash flood warnings were recorded prior to the commissioning of the Sulphur Mountain NEXRAD: 2/12/92, 2/15/92, and 2/8/94. Five false flash flood warnings were recorded after the commissioning of the Sulphur Mountain NEXRAD: 9/2/97, three on 12/6/97, and 2/3/98.

Date	Time flash flood event occurred[a]	Time warning issued	Counties affected by event and/or warning	Warning lead time (hours:minutes)
(33) 2/6/98	1038 hours	1030 hours	Ventura/Los Angeles	0:08
(34) 2/7/98	2040 hours	1705 hours	Ventura	3:35
(35) 2/7/98	2205 hours	1950 hours	Los Angeles	2:15
(36) 2/23/98	1115 hours	0935 hours	Ventura	1:40
(37) 2/23/98	1500 hours	1240 hours	Ventura/Los Angeles	2:20
(38) 2/23/98	1630 hours	1600 hours	Los Angeles	0:30
(39) 2/23/98	2255 hours	2255 hours	Los Angeles	0:00
(40) 2/24/98	0300 hours	0300 hours	Los Angeles	0:00

[a]The event and warning times are recorded using a 24-hour clock, e.g., 1400 hours is 2 p.m.

Comments From the Department of Commerce

THE SECRETARY OF COMMERCE
Washington, D.C. 20230

SEP 22 1998

Mr. Gene L. Dodaro
Assistant Comptroller General
Accounting and Information Management Division
United States General Accounting Office
Washington, D.C. 20548

Dear Mr. Dodaro:

Enclosed is a copy of the Department of Commerce's comments on the General Accounting Office's draft report entitled, "National Weather Service: Sulphur Mountain Radar Performance."

These comments were prepared in accordance with the Office of Management and Budget Circular A-50.

Sincerely,

William M. Daley

Enclosure

GENERAL COMMENTS:

We acknowledge the thorough work conducted by the General Accounting Office (GAO) in researching the complex issues in preparation of this report.

The National Weather Service is pleased to note that the GAO recognizes the critical importance of the WSR-88D (NEXRAD) radar in providing forecasters with the information necessary for the dramatic improvements in the accuracy and timeliness of flash-flood warnings. One of the reinvention goals of the NWS is to increase the average lead time provided for severe weather events. Clearly, this goal is being met with regard to flash-flood warnings in the Oxnard County warning area as the GAO report documents.

GAO RECOMMENDATION:

Since the Sulphur Mountain NEXRAD is not always available as required, we recommend that the Secretary of Commerce direct the NOAA Assistant Administrator for Weather Services to determine all the reasons why the Sulphur Mountain NEXRAD is not meeting the 96 percent availability requirement and to correct the problems so that the radar is available as required.

RESPONSE:

The National Weather Service concurs with the GAO regarding the importance of radar availability. Key activities planned to improve radar availability include modifications to several high-failure components in the transmitter, which will reduce radar down-time; remote maintenance terminals, which will provide for faster diagnosis and repair of problems; and the construction of Transition Power Maintenance Shelters, which isolate the radar from power interruptions, surges caused by lightning strikes, and substandard power quality. These and other planned major radar product improvement efforts also underway will take advantage of new and improved radar and computer technology to address evolving operational needs, to control life-cycle costs, and to improve system reliability and maintainability.

Major Contributors to This Report

Accounting and Information Management Division, Washington, D.C.

Keith A. Rhodes, Technical Director
David A. Powner, Assistant Director
Barbarol J. James, Evaluator-in-Charge
Robert D. Faggart, Information Systems Analyst

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