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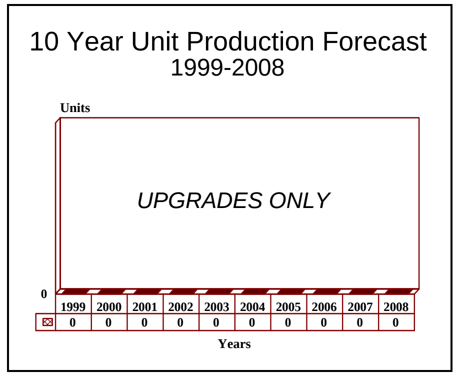
WSR-88D (NEXRAD) - Archived 8/2000

Outlook

- US production and installations complete
- Backbone of weather forecasting for FAA and DoD, as well as major weather science asset for National Weather Service
- A major part of many TV weather forecasts



Orientation

Description. The WSR-88D is a coherent Doppler weather radar. It is known as the NEXRAD (Next-Generation Weather Radar). WSR-88D is the official designation, standing for: Weather Surveillance Radar - 1988, Doppler.

Sponsor

Department of Commerce

National Oceanic and Atmospheric Administration

National Weather Service (NWS)

1325 East-West Highway

Silver Spring, Maryland (MD) 20910

USA

Tel: +1 310 713 0622

Fax: +1 310 713 1292

(Joint sponsor)

Contractors

Lockheed Martin Corp

Tactical Systems

1 Ridge Hill Road

Yonkers, New York (NY) 10710

USA

Tel: +1 914 968 2500

Fax: +1 914 968 2774

Concurrent Computer

106 Apple St

Tinton Falls, New Jersey (NJ) 07724

USA

Tel: +1 908 758 7000

(NEXRAD computer hardware)

Premier Microwave Co
33 New Broad St
Port Chester, New York (NY)
USA
Tel: +1 914 939 8900
(rf components)

Northrop Grumman Corp
Electronic Sensors & Systems Division
PO Box 17319
Baltimore, Maryland (MD) 7319
USA
Tel: +1 410 765 000
Fax: +1 410 993 8771
(Radar transmitters)

Status. In production, installations continue.

Total Produced. Through 1998, an estimated 160 systems had been produced and delivered. (120 National Weather Service, 22 DoD, 12 FAA, 6 support systems.)

Application. NEXRAD is part of a program to upgrade US weather forecasts and analysis to the National Weather Service, FAA, and US Air Force. It provides an advanced severe weather detection system covering the Continental US, Alaska, Hawaii and Caribbean. Some radars will be sited at USAF installations in the US and at selected USAF locations in Europe.

Price Range. National Weather Service places the cost of each WSR-88D at US$2.25-2.5 million each (excluding site costs).

Technical Data

	Metric	**US**
Dimensions		
Antenna diameter:	8.5 m	28 ft
Radome diameter:	12.2 m	39 ft
Tower height (to top of radome):	30.8 m	101 ft
Characteristics		
Frequency:	2.7 to 3.0 GHz	
Power:		750 kW peak
Polarization:	circular	
RF duty cycle:	0.0021 max	
PRF:		318 to 452 pps
Pulse Width:	1.57, 4.75 m sec	318 to 1304 pps
Antenna beamwidth:	0.89^{o} to 0.95^{o}	
Coverage:	360^{o}	
Elevation:	-1^{o} to +45^{o}	
Range Doppler		
(wind gust/velocity):	230 km	145 mi
Reflectivity (precipitation):	460 km	285 mi
Altitude:	70,000 ft (unambiguous Doppler)	

Receiver		
Dynamic Range:	95 dB	
Intermediate Freq.:	57.6 MHz	
Bandwidth (3dB):	0.79 MHz	
Processor		
Clutter canceler:	Infinite impulse response design	
Suppression:	30 to 50 dB	
Range sampling:	0.25 km	0.16 mi
Azimuth sampling:	1^o	
Velocity estimate accuracy:	1 m/sec	
Probability of detection		
Severe thunderstorm:	91%	
Maximum rain rate measured:	2.94 in/hr	
False alarm rate:	21%	

Design Specifications. Each NEXRAD system has four principal elements: an unattended Radar Data Acquisition tower; the transmitter/receiver and signal processor; the Radar Product Generator; and the Principal User Processing (PUP) terminals. All of the elements are linked via fiber optic cable or microwave transmission. The radar antenna is enclosed in a fiberglass skin foam sandwich radome. Stability is emphasized throughout the system, and is one reason for the radar's superior performance.

The WSR-88D is a fully coherent Doppler radar that was designed to provide accurate reflectivity measurement and its attendant information on spatial location and distribution. Signal processors extract three types of meteorological data from a returned signal. These are *volume reflectivity*, the *mean radial velocity* and the *spectrum width*. The volume reflectivity is expressed in terms of equivalent radar reflectivity (Ze); the mean velocity is the component of the reflected particle motion toward or away from the radar; and spectrum width is a measure of dispersion of radial velocities within the radar sample volume.

The radar uses very stable oscillators and signal sources to insure accuracy and fine discrimination in extracting the Doppler shift of returned signals. The transmitter signal is generated at a power level of a few hundred MW and amplified to 750 kW by intermediate solid-state devices and a klystron amplifier. The klystron is the only vacuum tube device in the system and features high gain (53 dB).

The center-fed parabolic antenna has a mainlobe one-way 3 dB beamwidth of 0.95^o. The receiver uses a frequency mixer to down-convert the received signal to an IF level for amplification, matched filtering and automatic gain control. A second frequency conversion provides synchronous detection that retains received signal amplitude and phase information. At this point, the signal is characterized by a power level equal to echo radar reflectivity and a frequency equal to the Doppler shift.

Meteorological quantities are calculated by a programmable single instruction multiple data (SIMD) processor. Multiple arithmetic units operate on data from different segments of the range sweep in lock step using the same set of instructions.

The radial component scatter motion and velocity dispersion in the radar sample volume (spectrum width) information provides meteorologists with a direct measure of important dynamic storm parameters and makes possible the recognition of severe storm features associated with the unique signature of velocity fields/ patterns.

Doppler radar technique allows the system to detect the movement of air masses. NEXRAD data processing algorithms are predictive and designed to forecast the development of microburst phenomena, project wind direction shifts, and track precipitation in detail. Unlike earlier weather radars, NEXRAD is not dependent on precipitation to determine the existence of weather activity. The system is sensitive enough to use Doppler processing of detected microscopic dust particles and insects to determine wind speed and direction.

The system uses three general purpose processors. A Radar Control Processor controls antenna pedestal control loops; controls and monitors the radar; and buffers the reflectivity, radial velocity, and spectrum width base data into wideband communications links.

The Radar Control Processor provides a standard set of data to the Products Processor. The Radar Product Generator uses a variety of sophisticated algorithms to produce 70 or more products to individual operators per their requests. This architecture eliminates conflict between operators trying to control the radar to perform specific tasks. Operators can operate with live data, recorded data for forecasting, and special data/variable studies for advanced meteorological studies and analysis.

The third processor is the Principle User Processor (PUP), which maintains local storage of the data for interactive display. The PUP provides detailed analysis and product generation with high-quality color graphics. It can also access data products from other NEXRADs in the network. The communications links can support up to 46 remotely located PUP workstations.

The PUP workstations are the heart of the analytical/weather science capability of NEXRAD. They are driven by 32-bit general purpose digital computers, i.e., 14.7K Whetstone/CPU (6.1 mps/CPU) expandable to three CPUs. The 24-megabyte semiconductor memory is expandable to 120 megabytes. The graphic display processor is a fixed point, 32-bit architecture, general purpose digital computer. The display system consists of dual 19-inch CRT high-resolution color graphics video monitors with resolution of 640 x 512 pixels, and a color graphic printer.

The graphic monitors display meteorological products together with background maps, and meteorological overlays (storm tracks, forecasts, tornado information, hail/severe weather outlines and data). The display system is interactive, permitting magnification of up to eight times, recentering, color control, and animation of up to 72 display frames.

Operational Characteristics. Besides vastly increasing the detail in which forecasters can analyze the atmosphere, NEXRAD significantly increases tornado warning lead time and enhances the detection and measurement of wind shear, severe turbulence, damaging winds, as well as hail storms. It is improving the ability to forecast the position and severity of thunderstorms and improve the ability to pinpoint threatened areas. It will also anticipate and forecast the formation of tornado conditions and has proven able to predict the development of full-fledged tornadoes.

The distribution and presentation of radar data allows for better use of available information and significantly decreases the number of erroneous forecasts and false alarms. Forecasters can better estimate the rainfall associated with flash-flooding and make more useful river level/flood forecasts. The data can also be used for water resource management as well as community safety projections.

NEXRAD has the ability to look "inside" storms and trace the detailed motion of winds the rate of precipitation. Algorithms and software developed during the course of the ten-year development are used to process the data. Raw Doppler radar returns are fed to the signal processor which produces data on radial velocities, reflectivity (for water content), and spectrum (turbulence measurement).

Two operational modes have been defined for NEXRAD to date. They are a CLEAR AIR mode and PRECIPITATION mode. The radar uses three scan strategies, with provisions for up to eight. The three distinct scan strategies are determined by the type of weather conditions involved and data analysis requirements. Elevation angle, prf, dwell time and filter bandwidths/sensitivity can be varied to ensure best radar operation for the type of weather present and analysis needed.

The NEXRAD data base is so extensive that more than 70 different weather data products can be produced. These products are available to TV and radio stations, commercial weather forecasting services and any other agencies needing up-to-date weather information. Data from different localities is transferable between stations.

NEXRAD generates radar based information rather than just manipulating raw data due to the embedded automation capability which is combined with sophisticated algorithms. These features allow weather forecasters to make maximum use of the radar's Doppler capability without an increase in either manpower or skill levels. Forecasters across the US are making routine use of NEXRAD. *NEXRAD Tru-Doppler, Doppler 4000, Doppler 9000*, these and other names for the radar video have become a standard part of most TV weathercasts. Some communities are making select NEXRAD products available live to everyone on the cable channel, and The Weather Channel includes NEXRAD video as part of its service.

A WSR-88D radar monitors an area of approximately 50,000 square miles. The creation of frequent, detailed wind profiles allows more accurate short-term forecasts to be made for meteorological conditions such as microbursts. It graphically portrays weather fronts and can identify clear air fronts and dry line conditions. This is a first for weather radars. Stored data is proving invaluable to weather scientists who can now go back and analyze in detail developing weather systems.

NEXRAD directly measures the winds within storms. This is a first, which is vital to forecasting tornadoes, damaging winds and damaging hail. NEXRAD has dramatically increased the US severe weather warning capability. It doubles the ability to detect of severe thunderstorms, has cut the severe thunderstorm warning false alarm rate from 70 percent to 24 percent, and increased tornado touch-down warning from an average of two minutes to 18 minutes. The probability of tornado detection increased from 50 percent to 96 percent.

The FAA is making extensive use of the NEXRAD network and the FAA assigned radars are being used as interim terminal sensors until a TDWR (Terminal Doppler Weather Radar) can be installed. The FAA WSR-88Ds are installed in locations that provide coverage of terminal areas. The radar's 360^{o} coverage does not provide the detailed look at approach and departure areas that the TDWR will, so it cannot be used instead of the special terminal radars. The TDWR data presentation is less extensive, but the specialized information is displayed at the traffic controllers' positions and is planned to be made available, via data link, to aircraft.

NEXRAD data from the entire network is being supplied to Air Route Traffic Control Centers. Two PUPs are installed at each ARTCC and the Central Flow Control Facility. Users can select a standard set of data products based on their needs. Data from a single NEXRAD is provided continuously based on the selection. Products sent continuously to the Center Weather Service Unit (CWSU) in the Air Route Traffic Control Center (ARTCC) are:

- Precipitation intensity for three altitudes
- Strata
- Storm cell location
- Storm movement
- Hail
- Mesocyclones
- Tornadoes
- Winds

Additional data can be obtained from other NEXRADs through dial-up requests.

Variants/Upgrades

At present there are no variants, although a few systems are single-channel transmitters, others dual. Growth plans include adding dual polarization capability and improved weak signal recovery.

The antenna already supports dual polarization, so a new polarization switch and increased signal and data processing is all that is needed for this enhancement. This would increase the accuracy of rainfall estimates, especially at high fall rates, and improve the ability to distinguish between rain and hail.

Weak signal recovery improvements will be possible with signal and data processing changes and associated increased processor capacity. This improvement would improve cloud detection and wind profiling beyond the planetary boundary layer. An April 1999 *Commerce Business Daily* announcement initiated a market search for a Doppler Weather Radar receiver replacement.

There are active plans to upgrade the Radar Product Generator (RPG) processor and the Radar Data Acquisition (RDA) unit. This will involve reconfiguring the RPG and RDA to a state-of-the-art, open-system architecture. This will replace the existing computer system to increase processing capacity and improve logistics supportability.

Ongoing software and algorithm upgrades will result from the analysis of recorded radar data. As the size of the database builds up, by association pre-event measurements with weather event history, the predictive potential of NEXRAD will be expanded.

Since NEXRAD was designed to provide information for weather scientists to interpret, the system is so sensitive that it sometimes generates false echoes from anomalous propagation. Although this is usually no problem for meteorologists, traffic controllers need to have these anomalies eliminated from their presentations. Designers are in the process of upgrading 407 of the current product generators so they have enough capacity to handle the additional processing demands.

Program Review

Background. Foul weather threatens and affects life daily. The old radars used by the National Weather Service, FAA and Department of Defense (such as the WSR-57 and WSR-74) were designed and deployed in the early 1960s. Because they are non-Doppler, they could only detect precipitation, and forecasters could only infer the impending or actual occurrence of severe weather. This often involved more intuition than science.

Maintenance was a major problem with the aging radars as they needed constant attention. When they failed, parts were either difficult to secure or needed to be reverse-engineered. The National Weather Service has had to purchase tubes from the former Soviet Union to bring several radars back on the air. Five operational radars were removed from inventory in 1981 just to support a depot overhaul program that would ensure a continuous rehabilitation program. There were not enough radars to support requirements and the data they provided was inadequate to meet today's needs.

The requirement for a new radar was recognized in the early 1970s. Technical experts appreciated the value of Doppler technology and began a program to procure an advanced weather radar. Upon the completion of a cross-organizational study by the Office of the Federal Coordinator for Meteorology in 1979, the Office of Management and Budget requested that the DoD join the National Weather Service and FAA in a program that was to become NEXRAD.

The Joint Doppler Operational Project, conducted in Norman, OK, in 1977-1979, clearly showed that NEXRAD would meet the requirement for an enhanced severe weather detection capability and established a baseline for system performance characteristics. NEXRAD provided the opportunity for cost savings through a joint effort. A cost estimate completed in 1981 by the Air Force showed that to develop its own capability, it would have to spend over US$400 million. Thus, NEXRAD provided the opportunity for the participating departments to fulfill common requirements by sharing developmental costs.

Design validation research and development began in 1983 and continued through the end of 1988. A contract was awarded in 1988 to begin developing both the hardware and software for the new weather detection and forecasting system. Prototype and developmental systems were installed at Norman, OK, and Kansas City, MO.

During 1989 and 1990, the NEXRAD became controversial. Delays and cost increases created a conflict between the contractor and the government. Controversy arose in 1989 as the result of an interim test and evaluation performed by the Air Force (AFOTEC) which noted such shortcomings as a complex computer design, a tendency to break down frequently, difficulty in executing repairs, and significant errors in describing the location of fast-moving storms.

However, the AFOTEC report also noted that the radar met user requirements for weather warning support because of the high resolution and accuracy of NEXRAD reflectivity-based products. The quality of the products allowed the users to accurately identify the location of relevant weather phenomena relative to air routes, making ATC advisories and improved aircraft route planning possible. It also provided timely terminal wind and low-level wind-shear advisories.

Early Weather Service statistical analysis showed that NEXRAD could accurately warn of storms 91 percent of the time during a 5.5 month test period (compared to the 59 percent rate then offered by the Weather Service). It demonstrated a reduction in the false alarm rate exceeding 50 percent.

According to Unisys Government Systems (which was broken out into Paramax Systems, then Unisys Defense Systems, and later purchased by Loral Defense Systems, which has become Lockheed Martin Tactical Systems), some of the shortcomings were due to the use of an outmoded range and velocity data correction technique that was replaced, with a marked improvement in results. Overall, designers felt that the problems stemmed more from the pre-production nature of the hardware, rather than an overall system fault. National Weather Service sources admitted that many of the problems came from ineffective coordination of requirements between the program participants.

In early 1990, the government agreed to buy 165 of the radars for a total contract value of US$359 million. At this point, even with the shortfalls revealed during the 1989 USAF testing, the program seemed to be on course. However, by late 1990 there was a six-month delay in deliveries of the ten limited production units.

By early 1991, congressional questioning of National Weather Service officials revealed that software delays had put the NEXRAD program 18 months behind schedule. There were suggestions that the NEXRAD program should be canceled and re-started with a new manufacturer. Unisys was asking that as much as US $250 million be added to the contract price for unanticipated costs, many traceable to a lack of coordination in software development.

In the fall of 1991, the Commerce Department and Unisys settled the dispute over extra costs. The government agreed to pay an extra US$56 million for added development and production costs. This cleared the way for the program to enter full-scale production and installation. The superior performance of the developed system was a major incentive to solving the problem and moving on.

In October 1991, the National Weather Service dedicated the first WSR-88D at its Sterling, Virginia, facility on the outskirts of Washington, DC. This was the first radar to provide data direct to an FAA Air Route Traffic Control Center (ARTCC). NEXRAD data would also be provided to a PUP at Andrews Air Force Base, the home of Air Force One.

The National Weather Service has plans to install up to 161 of the radars at 115 or more sites in the US. The FAA will install between seven radars at Alaska sites and four radars in Hawaii. One will be installed in Puerto Rico, with one to three more likely installed in the Caribbean. The Air Force has plans to install 30 WSR-88Ds at air bases. Base closings and mission changes are impacting the AF plans, especially in Europe and may make additional radars available to NWS and FAA users. Twelve other DoD installations are planned.

According to the National Weather Service, when their installations are complete, NEXRAD will provide 100 percent coverage east of the Continental Divide and 80 percent in the West. Political pressure from communities wanting tornado protection is impacting schedule details. Anytime there is a slip or delay with a pending installation, many communities are campaigning to have the radar diverted to their area.

In August 1992, figures from the National Weather Service in Norman, Oklahoma indicated the new WSR-88D weather radar exhibited a 90 percent probability of detecting severe thunder storms and an 86 percent probability of predicting tornadoes. The prediction accuracy of older equipment was 60 percent for thunderstorms and 40 percent for tornadoes. Average NEXRAD prediction lead time was eighteen minutes for tornadoes, a major improvement over the past average of two minutes warning.

In August 1993, Taiwan signed a contract worth US$4.77 million for delivery of one WSR-88D radar. This was of the first sale of a system outside the United States. The Central Weather Bureau of the Republic of China will install the radar near Taipei. Long-range plans include three more systems to provide earlier warning of typhoons and other severe weather.

The Air Force is using its developmental funding to create analysis techniques that make it possible to use NEXRAD data to improve the service's tropical storm tracking and intensity determination/projection ability. Planners are also going to develop a severe icing detection algorithm and automated hail prediction capability.

Air Force Development. The US Air Force is funding its efforts at US$400 million per year through the year 2001. The effort would exploit the capabilities available in the new radars through Project 2781, Weather Radar Technology, Program Element 0603707F, Weather Systems Advanced Development. Developments will be shared with NWS and FAA users.

In FY94, the service spent US$400,000 to develop techniques to locate storm fronts and correlating severe weather and observed wind fields. FY95 funding (US$400,000) was dedicated to developing and evaluating new severe weather quantification algorithms for tornado and hail detection as well as the relationship between precipitation structures and severe weather.

FY96 plans were to complete severe weather prediction software as well as an algorithm which could determine the location and intensity of weather fronts. Work on the development of lightning strike algorithms would continue. This was budgeted at US$400,000

In FY97, the Air Force budgeted US$400,000 to complete development of the lightning strike algorithms for use with the WSR-88D.

NEXRAD Used to Prevent Bird Strikes. The WSR-88D installed at Kunsan Air Base, South Korea has proven that it could be used to detect bird strike-hazards. Through the combined efforts of the 8th Operations Support Squadron's Airfield Operations Flight, the squadron's weather forecasters and the 8th Fighter Wing Safety Office, Kunsan's NEXRAD was used not only to watch for weather fronts, but also flocks of birds. According to the Air Force Pacific Forces News Service the driving force behind this innovative application was Senior Master Sgt. John Hoffman, chief of airfield management. Taking what he learned about NEXRAD at safety conferences while assigned to Air Mobility Command, he began implementing the program at Kunsan. "I knew the bird threat was really bad here – extremely hazardous," Hoffman said. "So I was able to take the ideas on NEXRAD from BASH (bird aircraft strike hazard) working groups and apply them here."

NEXRAD proved itself so sensitive that it could detect groups of birds. The radar would give airfield management personnel a screen full of red and yellow splotches where large flocks of birds could be threatening the wing's aircraft. "We've seen where NEXRAD will pick up as few as eight birds," Hoffman said. "You don't necessarily have to have that big of a mass."

During high-threat conditions, base operations personnel check the NEXRAD screen every 15 minutes; it usually comes up clear. But when a large flock of birds shows up on the screen, airfield operations spring into action. These actions can range from simple airfield advisories (called bird watch conditions) that warn pilots which areas to stay away from to avoid a possible bird strike, to more direct measures. Airfield personnel will often use audiotapes of birdcalls, loud firecrackers, and gas cannons to coax and scare the birds away from the airfield.

"What we did in the old days was find the birds by chance or luck," Hoffman said. "We relied on visual identification from the tower. But by the time we saw the birds, it would be too late. They'd already be over our airfield. With NEXRAD we see them as far as 15 miles out."

The positive effects that something like this can have on a safety program cannot be overstated, according to Senior Airman Timothy Larson of the airfield operations flight. Larson, one of the flight's members who watches the NEXRAD screen for birds, recalled a 1995 incident at Elmendorf Air Force Base, Alaska, in which 30 geese took down an E-3 Airborne Warning and Control System aircraft, killing 24 Air Force members. "If you hear the tape of that incident, it sends chills down your spine to realize how quickly something like that can happen," Larson said. "Just imagine hitting something as big as a watermelon at almost 500 mph. The results can be devastating."

Larson sees NEXRAD helping to keep incidents like that from happening again, in an Air Force that suffered 31,522 bird strikes from 1985 to 1997. Aside from the immense cost in lives lost, these bird strikes caused more than US$457 million in damage. Larson thinks NEXRAD can help change that. "The program works," Larson affirmed. "I can attest to that since I've seen it in action."

The next big test for Kunsan's NEXRAD will come in October, when the local crow population starts congregating over the base and its flightline. Huge flocks of crows can sweep through Kunsan area on a regular basis during October to March, turning the sky black. But through a stepped-up BASH program that includes better gas cannon placement, a deeper grass height that's unattractive to birds and drawing the flocks away from the airfield with truck-mounted speakers blasting birdcalls, the sky has remained mostly blue. Safety officials say NEXRAD helps in this cause.

Kunsan has suffered only one bird strike from the end of 1997 to May 1998 thanks to the energized BASH program that includes this innovative use of NEXRAD, said Capt. Gregg Lunsford, former flight safety chief in the 8th FW Safety Office. "Using NEXRAD makes our BASH program more proactive and preventive," Lunsford said. "Before when the birds just showed up, it wasn't preventive, it was reactive. NEXRAD is just another tool for prevention, not even letting the birds get close to the airfield."

While NEXRAD's ability to track large groups of birds has long been known, Kunsan is the first base to implement such procedures on a wide scale. Hoffman and Lunsford presented the wing's use of NEXRAD to both military and civilian aviation officials at a recent BASH conference hosted by the Air Force Safety Center at Kirtland AFB, N.M., where it was positively received.

"There was a lot of interest in what we were doing at Kunsan, both amongst the civilians there who have researched this and the military members also representing bases," Lunsford said. "There were some bases that were very interested because they have similar locales to ours. They sit on the water and have a lot of different types of birds."

Both Lunsford and Hoffman hope the success NEXRAD has had with the BASH program at Kunsan will be carried over to other bases. Already the Federal Aviation Administration is looking at use of NEXRAD in protecting commercial planes from bird strikes, and the Israeli government recently purchased three units for its own bird strike prevention programs.

"I think it has a place at Air Force bases with severe bird problems, ones that are on coasts where you have birds migrating to and from the sites," Hoffman said. "What NEXRAD effectively does is give us that extra tool to allow us to control the environment." (Courtesy of Pacific Air Forces News Service)

CINRAD Joint Venture. In August 1994, the Unisys China Company Ltd, a wholly owned subsidiary of Unisys Corporation in China, and the China Meteorological Administration have signed an MoU to establish a joint venture in China to develop and produce a new Doppler weather radar for use in China and to be marketed throughout the Pacific Rim. The new radar would be similar to the WSR-88D. The China New Generation Weather Radar (CINRAD) would be specifically tailored for the Pacific Rim area and would sell at a lower cost.

In another agreement, the Shanghai Meteorological Bureau signed a US$4.76 million contract with Unisys China Hong Kong for the delivery of a WSR-88D Doppler weather radar for installation in Shanghai in early 1996. The Shanghai radar would be identical to the US systems and installed on a 700 ft twin-tower complex built in downtown Shanghai by a Hong Kong developer. Data would be transmitted to the Shanghai Meteorological Bureau and serve as a baseline for developing the CINRAD system.

Weather and Radar Processor (WARP). The weather information currently provided to the air traffic controllers in the en route environment comes from either long range surveillance radars which are not well suited for this purpose or NEXRAD. NEXRAD weather information cannot be displayed on existing en route controllers' consoles because of digital versus analog and other compatibility issues. Additionally, the center weather service unit meteorologists do not have an integrated system for collecting and displaying multiple weather sensor inputs. The current weather system relies on human interpretation to integrate available information which is time consuming and inefficient.

The WARP system will collect, process, and disseminate NEXRAD and other weather information to controllers, traffic management specialists, area supervisors, pilots, and meteorologists. It will provide a mosaic of multiple NEXRAD images to the Display System Replacement so it can be displayed along with aircraft targets. This will improve the quality of weather information available to air traffic controllers, reducing accidents and air traffic delays. WARP will also provide the center weather service unit meteorologists with automated workstations which greatly enhance their ability to analyze rapidly changing, potentially hazardous weather conditions. WARP will ensure that the latest and best information is provided to all system users within the en route environment.

This project will be completed in three stages:

Stage 0 provides the commercial off-the-shelf and non-developmental item portions of WARP hardware and software as a leased, turn-key system that will replace the existing meteorologist weather processor with updated technology.

This stage includes 23 leased WARP systems; 21 to air route traffic control centers and two to the Air Traffic Control Command Center.

Stage 1/2 will develop the NAS interfaces necessary to provide NEXRAD data to controllers' consoles via the Display System Replacement project. This stage will use commercial off-the-shelf components to upgrade Stage 0 hardware. Stage 1/2 will also provide meteorologists with additional data and analysis tools in a single integrated workstation replacing the NEXRAD principal user processor. This effort is being conducted in parallel with Stage 0 and will take approximately two years to fully develop, test and implement.

It involves 24 FAA-owned WARP systems; 21 for air route traffic control centers and one to the Air Traffic

Control Command Center. One system will go to the William J. Hughes Technical Center and one to the contractor's plant for Stage 1/2 and 3 developmental testing and evaluation.

Stage 3 will develop additional NAS interfaces for cost effective weather data sharing and to facilitate a common situational awareness within the en route environment. Stage 3 implements upgraded National Weather Service gridded data and leverages the FAA's investment in aviation weather research with sensor and algorithm upgrades to the WARP system. Stage 3 provides a common source for distributing National Weather Service high volume models and enhanced weather displays for controllers on the Display System Replacement. Stage 3 involved software work only.

Market Search For Doppler Weather Radar Receiver Replacement. A Request For Information (RFI) from the US Department of Commerce/NOAA, National Weather Service (NWS) was published in an April 9, 1999, *Commerce Business Daily*. Officials were conducting market research for the replacement of portions of the analog microwave receiver in its NEXRAD Weather Surveillance Radar WSR-88D. The receiver acquires and converts the radar return from a coherent Doppler radar transmitter and provides digitized in-phase (I), quadrature (Q), and log channel signal components to the radar signal processing subsystem within the Radar Data Acquisition (RDA) system.

The existing receiver is encountering obsolescence of critical components. Additionally, the National Weather Service is conducting a planned evolution of NEXRAD technology including addition of polarization diversity which will require a second receiver channel. Replacement of portions of the current receiver with digital components is a means of addressing these issues. The purpose of this RFI is to gather information from digital receiver manufacturers relating to the availability of components in the commercial market.

The following are the salient characteristics of the existing receiver. The receiver channel consists of the following components: receiver protector, interference filter, low noise amplifier, pre-select filter, mixer (STALO), pre-amplifier, matched filter, automatic gain control, IF amplifier, phase detector (COHO), and analog to digital converter (A/D). The input RF range is from 2700 to 3000MHz. The intermediate frequency (IF) is 57.5491MHz. The input signal dynamic range is 93 dB minimum. The first mixer output signal power is -76dBm to + 19dBm. Output impedance (to A/D converter) is 50 ohms. A/D conversion rate: 600 kHz. The current receiver contains extensive automatic calibration state determination and built-in-test (BITE) diagnostics.

Desired features of replacement digital receiver subsystems are as follows. Noise Figure: less than 18dB. Input digital dynamic range: 105dB minimum. Signal input impedance: 50 ohms. Input signal carrier frequency (IF) 57.5491MHz. Input signal power -76 dBm to +19 dBm. A/D conversion rate: 600kHz minimum. Input COHO frequency: 57.5491MHz. Input COHO power: up to +27dBm. In phase and quadrature signal output: 18 bit, 2's compliment/18 bit custom code. I/Q amplitude imbalance: 0.25dB maximum. I/Q phase quadrature imbalance: ± 2° maximum. The custom output data must be compatible with the custom format to the signal processor which is as follows. The I and Q outputs are a custom code with the sign bit and 11 least significant bits sent serially. There is an additional 6 bit parallel output which is the automatic gain control (AGC) attenuator position information. This information is used by the signal processor prescaler to scale the data in accordance with the AGC attenuators.

The National Weather Service wants to replace as many of the current analog components of the radar receiver as practical, given the current state-of-the-art in digital receiver technology.

Program Status (as of 06/06/99)

	Delivered	Accepted	Commissioned
NWS	120	120	120
FAA	12	12	12
DOD	22	22	17
Total	154	154	149

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RDA   WFO             ASSOCIATED
SID   SID     AGENCY WFO        NAME                 DELIVER  ACCEPT   COMMISSION
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AHG   AFC     FAA    ANCHORAGE, AK (Nikisi)        04/21/95 06/27/95 12/01/97
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AKC	AFC	FAA	ANCHORAGE, AK (King Salmon)	05/25/95	09/15/95	12/01/97
APD	AFG	FAA	FAIRBANKS, AK (Pedro Dome)	06/06/95	08/12/95	03/20/97
ABC	AFC	FAA	ANCHORAGE, AK (Bethel)	07/06/95	11/03/95	10/03/97
ACG	AJK	FAA	JUNEAU, AK (Sitka)	05/23/96	08/29/96	08/27/97
AIH	AFC	FAA	ANCHORAGE, AK (Middleton Is)	06/02/96	09/01/96	09/08/97
AEC	AFG	FAA	FAIRBANKS, AK (Nome)	08/01/96	10/08/96	03/21/97
MXX	BMX	DOD	BIRMINGHAM, AL (Maxwell AFB)	11/25/92	02/18/93	05/03/94
EOX	BMX	DOD	BIRMINGHAM, AL (Ft Rucker)	09/13/93	11/08/93	
BMX	BMX	NWS	BIRMINGHAM, AL (Alabaster)	03/17/94	05/16/94	12/15/94
MOB	MOB	NWS	MOBILE, AL	06/09/94	08/08/94	04/03/95
HTX	BMX	NWS	BIRMINGHAM, AL (NE Alabama)	04/24/97	07/01/97	12/04/97
LZK	LZK	NWS	LITTLE ROCK, AR	12/30/92	03/06/93	06/15/94
SRX	TSA	NWS	TULSA, OK	02/27/97	05/08/97	08/22/97
IWA	PSR	NWS	PHOENIX, AZ	01/14/93	03/25/93	04/27/94
EMX	TWC	NWS	TUCSON, AZ	04/13/95	06/22/95	12/06/95
FSX	FGZ	NWS	FLAGSTAFF, AZ	08/10/95	11/08/95	05/22/96
YUX	PSR	NWS	PHOENIX, AZ	03/28/96	07/16/96	01/15/97
VBX	LOX	DOD	LOS ANGELES, CA	03/05/93	05/10/93	08/17/93
VTX	LOX	NWS	LOS ANGELES, CA (Ventura)	12/09/93	03/01/94	12/16/94
DAX	STO	NWS	SACRAMENTO, CA	12/16/93	02/12/94	12/06/94
MUX	MTR	NWS	SAN FRANCISCO BAY AREA, CA	02/03/94	04/09/94	05/03/95
BHX	EKA	NWS	EUREKA, CA	10/20/94	01/21/95	07/12/95
HNX	HNX	NWS	SAN JOAQUIN VALLEY, CA	01/12/95	03/30/95	09/27/95
EYX	VEF	DOD	LAS VEGAS, NV	03/02/95	05/26/95	09/04/96
NKX	SGX	NWS	SAN DIEGO, CA (San Diego)	12/29/95	03/15/96	09/13/96
BBX	STO	DOD	SACRAMENTO, CA	05/24/96	07/25/96	
SOX	SGX	NWS	SAN DIEGO, CA (Orange Cnty)	07/09/96	10/19/96	02/26/97
FTG	BOU	NWS	DENVER/BOULDER, CO	03/18/93	05/25/93	07/13/94
PUX	PUB	NWS	PUEBLO, CO	10/06/94	12/15/94	08/09/95
GJX	GJT	NWS	GRAND JUNCTION, CO	08/22/95	11/18/95	06/05/96
DOX	AKQ	DOD	WAKEFIELD, VA	10/30/92	01/11/93	02/08/93
MLB	MLB	NWS	MELBOURNE, FL	03/14/91	07/10/92	03/30/94
EVX	TAE	DOD	TALLAHASSEE, FL (Eglin AFB)	10/03/91	08/24/92	11/05/92
AMX	MFL	NWS	MIAMI, FL	02/11/93	04/12/93	04/20/95
TBW	TBW	NWS	TAMPA BAY AREA, FL	01/13/94	03/19/94	04/28/95
TLH	TAE	NWS	TALLAHASSEE, FL	12/01/94	02/16/95	08/01/95
JAX	JAX	NWS	JACKSONVILLE, FL	12/08/94	02/25/95	08/01/95
BYX	MFL	NWS	MIAMI, FL	04/20/96	07/04/96	11/05/96
JGX	FFC	DOD	ATLANTA, GA	10/28/93	01/10/94	02/28/94
FFC	FFC	NWS	ATLANTA, GA (Peachtree City)	04/28/94	06/27/94	02/24/95
VAX	TAE	DOD	TALLAHASSEE, FL (Moody AFB)	02/29/96	05/18/96	
GUA	GUA.WFO	DOD	GUAM, GU	10/27/92	02/05/93	09/16/93

HKI	HFO	FAA	HONOLULU, HI (Kauai)	06/24/94	10/27/94	12/01/97
HMO	HFO	FAA	HONOLULU, HI (Molokai)	02/08/95	05/03/95	10/16/97
HWA	HFO	FAA	HONOLULU, HI (Hawaii)	03/08/96	06/21/96	12/01/97
HKM	HFO	FAA	HONOLULU, HI (Kohala)	06/01/96	09/23/96	12/01/97
DMX	DMX	NWS	DES MOINES, IA	10/05/93	12/06/93	06/01/95
DVN	DVN	NWS	QUAD CITIES, IA	10/27/94	01/21/95	09/07/95
CBX	BOI	NWS	BOISE, ID	09/23/93	11/24/93	01/11/95
SFX	PIH	NWS	POCATELLO/IDAHO FALLS, ID	05/04/95	07/21/95	02/16/96
LOT	LOT	NWS	CHICAGO, IL	04/22/93	06/25/93	12/16/94
ILX	ILX	NWS	CENTRAL ILLINOIS, IL	03/30/95	06/15/95	01/03/96
IND	IND	NWS	INDIANAPOLIS, IN	06/04/93	08/19/93	05/23/95
IWX	IWX	NWS	NORTHERN INDIANA, IN	06/26/97	08/30/97	03/17/98
DDC	DDC	NWS	DODGE CITY, KS	12/12/91	11/06/92	04/01/94
ICT	ICT	NWS	WICHITA, KS	07/30/92	10/13/92	04/20/94

RDA SID	WFO SID	AGENCY	ASSOCIATED WFO NAME	DELIVER	ACCEPT	COMMISSION
GLD	GLD	NWS	GOODLAND, KS	08/27/92	11/19/92	04/26/95
TWX	TOP	NWS	TOPEKA, KS	03/27/93	06/08/93	01/10/95
LVX	LMK	NWS	LOUISVILLE, KY	07/23/93	09/30/93	11/29/94
HPX	PAH	DOD	PADUCAH, KY (Ft Campbell)	12/21/93	02/27/94	
PAH	PAH	NWS	PADUCAH, KY	11/17/94	02/09/95	09/13/95
JKL	JKL	NWS	JACKSON, KY	02/08/96	04/18/96	10/25/96
LIX	LIX	NWS	NEW ORLEANS/BATON ROUGE, LA	02/24/94	04/22/94	02/14/95
POE	LCH	DOD	LAKE CHARLES, LA (Ft Polk)	03/10/94	05/06/94	06/07/95
LCH	LCH	NWS	LAKE CHARLES, LA	03/17/94	05/02/94	05/11/95
SHV	SHV	NWS	SHREVEPORT, LA	03/23/95	06/09/95	10/04/95
BOX	BOX	NWS	BOSTON, MA	09/09/93	11/07/93	12/15/94
GYX	GYX	NWS	PORTLAND, ME (Gray)	10/21/93	12/17/93	05/04/95
CBW	GYX	NWS	PORTLAND, ME (Houlton)	06/15/95	09/05/95	02/08/96
DTX	DTX	NWS	DETROIT, MI	04/22/93	06/19/93	03/23/95
GRR	GRR	NWS	GRAND RAPIDS, MI	04/27/95	07/16/95	02/01/96
MQT	MQT	NWS	MARQUETTE, MI	05/18/95	08/12/95	02/01/96
APX	APX	NWS	NORTH CENTRAL LOWER MICHIGAN	11/02/95	02/03/96	08/07/96
MPX	MPX	NWS	MINNEAPOLIS, MN	07/07/94	09/23/94	11/01/95
DLH	DLH	NWS	DULUTH, MN	06/01/95	08/10/95	05/08/96
LSX	LSX	NWS	ST. LOUIS, MO	11/07/91	11/21/92	07/15/94
EAX	EAX	NWS	KANSAS CITY/PLEASANT HILL, M	09/24/92	12/08/92	02/28/95
SGF	SGF	NWS	SPRINGFIELD, MO	11/10/94	01/28/95	09/14/95
JAN	JAN	NWS	JACKSON, MS	01/22/93	03/29/93	02/01/95
GWX	MEG	DOD	MEMPHIS, TN	02/12/94	04/18/94	11/08/95
TFX	TFX	NWS	GREAT FALLS, MT	07/14/94	09/11/94	04/26/95

MSX	MSO	NWS	MISSOULA, MT	07/27/94	11/07/94	06/01/95
BLX	BYZ	NWS	BILLINGS, MT	08/24/95	11/10/95	04/01/96
GGW	GGW	NWS	GLASGOW, MT	10/05/95	12/16/95	08/15/96
MHX	MHX	NWS	MOREHEAD CITY, NC	10/14/93	12/17/93	05/04/95
RAX	RAH	NWS	RALEIGH/DURHAM, NC	01/27/94	03/25/94	07/06/95
LTX	ILM	NWS	WILMINGTON, NC	08/18/94	11/02/94	07/06/95
BIS	BIS	NWS	BISMARCK, ND	09/01/94	10/29/94	10/11/95
MVX	FGF	NWS	EASTERN NORTH DAKOTA, ND	10/19/95	01/11/96	07/03/96
MBX	BIS	DOD	BISMARCK, ND	10/19/96	11/22/96	08/11/94
UEX	GID	NWS	HASTINGS, NE	04/28/93	06/28/93	12/16/94
OAX	OAX	NWS	OMAHA, NE	04/22/94	06/12/94	07/19/95
LNX	LBF	NWS	NORTH PLATTE, NE	10/26/95	01/19/96	08/01/96
DIX	PHI	NWS	PHILADELPHIA, PA	07/16/93	10/02/93	02/09/95
FDX	ABQ	DOD	ALBUQUERQUE, NM	03/01/94	04/28/94	06/14/94
HDX	EPZ	DOD	EL PASO, TX	05/14/94	06/30/94	07/15/94
ABX	ABQ	NWS	ALBUQUERQUE, NM	05/16/94	07/01/94	08/03/95
EPZ	EPZ	NWS	EL PASO, TX	01/04/96	03/10/96	07/31/96
RGX	REV	NWS	RENO, NV	07/21/94	10/31/94	06/14/95
ESX	VEF	NWS	LAS VEGAS, NV	12/21/94	03/09/95	09/13/95
LRX	LKN	NWS	ELKO, NV	07/18/95	10/27/95	04/29/96
BGM	BGM	NWS	BINGHAMTON, NY	07/07/93	09/07/93	03/16/95
OKX	OKX	NWS	NEW YORK CITY, NY	07/16/93	09/23/93	01/26/95
ENX	ALY	NWS	ALBANY, NY	09/09/93	11/12/93	04/14/95
BUF	BUF	NWS	BUFFALO, NY	06/22/95	09/08/95	04/04/96
TYX	BTV	DOD	BURLINGTON, VT (TBD)	08/28/97	11/05/97	
CLE	CLE	NWS	CLEVELAND, OH	06/04/93	08/03/93	02/09/95
ILN	ILN	NWS	CINCINNATI, OH	05/21/94	07/17/94	06/01/95
TLX	OUN	NWS	OKLAHOMA CITY, OK (Norman)	05/24/90	08/06/92	02/28/94
FDR	OUN	DOD	OKLAHOMA CITY, OK (Altus, AFB)	09/06/91	09/10/92	09/21/92
INX	TSA	NWS	TULSA, OK	02/19/93	04/23/93	05/17/94
VNX	OUN	DOD	OKLAHOMA CITY, OK (Kegelman)	10/06/93	12/13/93	12/20/93
RTX	PQR	NWS	PORTLAND, OR	11/03/94	01/20/95	07/12/95
RDA	WFO		ASSOCIATED			
SID	SID	AGENCY	WFO NAME	DELIVER	ACCEPT	COMMISSION
MAX	MFR	NWS	MEDFORD, OR	07/20/95	10/20/95	04/30/96
PDT	PDT	NWS	PENDLETON, OR	11/09/95	02/01/96	07/31/96
PBZ	PBZ	NWS	PITTSBURGH, PA	05/20/93	08/30/93	01/19/95
CCX	CTP	NWS	CENTRAL PENNSYLVANIA, PA	06/18/93	10/01/93	04/06/95
JUA	SJU	FAA	SAN JUAN, PR	02/16/96	06/07/96	07/07/97
CAE	CAE	NWS	COLUMBIA, SC	11/16/93	01/28/94	06/01/95
GSP	GSP	NWS	GREENVILLE/SPARTANBURG, SC	01/26/95	04/08/95	03/07/96

CLX	CHS	NWS	CHARLESTON, SC	12/28/95	03/27/96	06/06/96
FSD	FSD	NWS	SIOUX FALLS, SD	10/01/93	12/10/93	10/18/95
ABR	ABR	NWS	ABERDEEN, SD	09/22/94	12/06/94	09/06/95
UDX	UNR	NWS	RAPID CITY, SD	09/28/95	12/15/95	07/03/96
NQA	MEG	NWS	MEMPHIS, TN	08/06/93	10/15/93	01/19/95
MRX	MRX	NWS	KNOXVILLE/TRI-CITIES, TN	06/30/94	08/27/94	06/22/95
OHX	OHX	NWS	NASHVILLE, TN	08/25/94	10/20/94	07/06/95
HGX	HGX	NWS	HOUSTON/GALVESTON, TX	01/16/92	06/12/92	03/23/94
AMA	AMA	NWS	AMARILLO, TX	11/30/92	02/12/93	03/15/94
GRK	FWD	DOD	DALLAS/FORT WORTH, TX (Ft Hd)	01/29/93	04/05/93	06/20/93
DYX	SJT	DOD	SAN ANGELO, TX	09/01/93	10/20/93	01/06/94
FWS	FWD	NWS	DALLAS/FORT WORTH, TX	11/10/93	01/27/94	12/15/94
LBB	LUB	NWS	LUBBOCK, TX	12/30/93	03/04/94	09/14/95
DFX	EWX	DOD	AUSTIN/SAN ANTONIO, TX (Lau.)	01/19/94	03/17/94	07/26/94
EWX	EWX	NWS	AUSTIN/SAN ANTONIO, TX	03/23/94	06/04/94	01/19/95
BRO	BRO	NWS	BROWNSVILLE, TX	01/05/95	03/25/95	09/28/95
MAF	MAF	NWS	MIDLAND/ODESSA, TX	02/03/95	04/23/95	09/26/95
SJT	SJT	NWS	SAN ANGELO, TX	01/17/96	03/28/96	07/31/96
CRP	CRP	NWS	CORPUS CHRISTI, TX	02/22/96	05/09/96	09/04/96
MTX	SLC	NWS	SALT LAKE CITY, UT (Elder Co)	08/09/94	11/15/94	06/01/95
ICX	SLC	NWS	SALT LAKE CITY, UT (Cedar Cty)	07/11/96	10/30/96	03/05/97
LWX	LWX	NWS	BALTIMORE, MD/WASHINGTON, DC	07/31/91	06/12/92	06/15/94
AKQ	AKQ	NWS	WAKEFIELD, VA	05/26/94	07/16/94	08/17/95
FCX	RNK	NWS	ROANOKE, VA	09/15/94	12/04/94	08/03/95
CXX	BTV	NWS	BURLINGTON, VT	06/06/96	08/27/96	03/06/97
ATX	SEW	NWS	SEATTLE/TACOMA, WA	01/06/94	03/21/94	02/10/95
OTX	OTX	NWS	SPOKANE, WA	11/30/95	02/24/96	07/30/96
MKX	MKX	NWS	MILWAUKEE, WI	08/02/93	10/18/93	09/26/95
GRB	GRB	NWS	GREEN BAY, WI	08/11/94	01/21/95	07/26/95
ARX	ARX	NWS	LA CROSSE, WI	11/22/95	02/16/96	09/04/96
RLX	RLX	NWS	CHARLESTON, WV	06/23/94	08/28/94	08/24/95
CYS	CYS	NWS	CHEYENNE, WY	04/16/94	06/10/94	11/01/95
RIW	RIW	NWS	RIVERTON, WY	06/29/95	09/09/95	04/10/96

Funding

US FUNDING

	FY97		FY98		FY99		FY00(req)	
	QTY	AMT	QTY	AMT	QTY	AMT	QTY	AMT
Facilities & Equipment (FAA)								
NEXRAD	-	0.0	-	3.0	-	4.9	-	6.9[a]
RDT&E (USAF)								

PE#0603707F

Wx Radar Technology	-	0.4	-	0.0	-	0.0	-	--

NOTE: Air Force Program Element 0603707F included funding for developing the ability to fully exploit NEXRAD capabilities. This effort ended in FY97, and the overall PE was to terminate in FY99.

[a] The Senate Appropriations Committee, in its FY00 legislation, recommended a US$2 million reduction in the FAA budget request, approving the FAA's requesting the National Weather Service and USAF to contribute to modifications which will address the anomolous propagation problem experienced by current systems.

(All US$ are in millions.)

Recent Contracts

Contracts over US$5 million)

Contractor	Award ($ millions)	Date/Description
Unisys	357.0	Jan 1989 – NEXRAD production phase award (50-DMNW-8-00032).
Unisys	359.0	Jan 1990 – Option exercised for additional contract for NEXRAD full production.

Timetable

Month	Year	Major Development
	1978	Joint Doppler Operation Project began, demonstrated that NEXRAD would satisfy requirements for an improved severe weather detection capability
	1980	NEXRAD program initiated
Oct	1982	NEXRAD Request for Proposal for prototype development
Jun	1983	Contracts awarded to Raytheon and Sperry to develop NEXRAD prototype hardware
	FY84	Full radar system development began
Jul	1985	Initial algorithms delivered to Joint Program Office
	FY86	Downburst wind detection algorithm was developed and tested. Evaluated storm severity indicators as solutions to validated severe storm warning requirements
Aug	1986	NEXRAD Initial Operational Test and Evaluation began
Dec	1987	Unisys awarded a US$60 million contract for 10 systems
	FY88	Preplanned algorithm improvements for hail, tornadoes, windshear, and turbulence developed. A precipitation prediction algorithm completed. Any algorithm deficiencies identified during IOT&E corrected. Preplanned product improvements and deficiency corrections (as identified in IOT&E) integrated into the system
Oct	1988	First NEXRAD installation completed, Norman, OK
	FY89	Completed NEXRAD tornado probability forecasting tool. Completed final phase

Month	**Year**	**Major Development**
		of IOT&E
	FY90	Completed NEXRAD hail-size forecasting tool and small-scale wind shear algorithm
Jan	1990	Option exercised and Unisys awarded US$359 million additional contract for NEXRAD full production
Oct	1991	NWS operational system installations began, first system dedicated at Sterling, VA
Aug	1993	Taiwan contracted for one radar
4Q	1993	WARP mission need statement approved
Aug	1994	CINRAD, US/China joint venture MoU
3Q	1995	WARP solicitation issued
2Q	1996	WARP contract award
	1996	Shanghai installation to be complete
Aug	1996	Scheduled completion of current deliveries
2Q	1997	Last site Operational Readiness Demonstration (ORD)
4Q	1997	WARP first Stage 0 ORD complete
1Q	1998	WARP Stage 0 last ORD complete
1Q	1999	WARM Stage 3 begin advanced weather product implementation
3Q	1999	WARP Stage 1/2 complete testing & evaluation
4Q	1999	WARP Stage 1/2 first ORD complete
2Q	2000	WARP Stage 1/2 last ORD complete
2Q	2004	WARP Stage 3 complete weather product implementation, F&E program ends

Worldwide Distribution

The National Weather Service, and FAA have installed their systems throughout the Continental **US**. The DoD has installed systems at 22 bases and commissioned 17.

There is the potential for foreign sales. **Canada** is interested from both an air traffic and weather forecasting standpoint. **Taiwan** will install one radar and has long-range plans for three more. A radar was ordered for **Shanghai**. **Singapore** and **Japan** have expressed an interest. **China** has plans to develop a variant of the WSR-88D for use in China and to be marketed around the **Pacific Rim**.

Forecast Rationale

NEXRAD has proven in operation that it can do even more than originally planned. As forecasters and weather science specialists worked with the WSR-88D, they continued to find new ways to apply the array of data products to new and varied prediction and analysis efforts. The radars are capable of predicting serious weather problems before they occur, and four NEXRAD Information Dissemination Service (NIDS) providers support the commercial distribution of the radar data to forecasters. Air Force efforts continue to develop advanced algorithms for the system to enhance military uses; and the Kusan Air Base application for bird strike prevention as a creative use of the WSR-88D's capabilities.

The major criticisms of the national and FAA weather system have been on problems distributing weather information, including NEXRAD data, to those who need it. NEXRADs were sought after by most communities in tornado- and thunderstorm-prone areas. And the major criticism leveled at the National Weather Service and FAA was concern over data distribution by the communications and processing system, not data production by the radars. This attention to and concern for the ability to distribute radar date reflects the value of NEXRAD outputs and predictions.

The National Severe Storms Laboratory, Norman, Oklahoma, conducted *Project Vortex*, which used NEXRAD storm predictions and indications that a tornado may be developing to send storm chasers to the area to deploy instrument pods to measure conditions inside the storms. This is one way the new radar is making it possible for weather scientists to gather actual storm data that would not have been possible without the NEXRAD's predictive capability.

Canada has expressed strong interest in the WSR-88 and planned to issue an RFP when funding became available. Taiwan became the first international sale of the NEXRAD systems, and Singapore and Japan are interested. The joint US/China development of the tailored CINRAD may move the system into the Pacific Rim in significant quantities. European ATC may be interested, but the crowded frequency spectrum on the continent could present a problem with procurement. There are questions about the value of NEXRAD versus European weather. Unless an area experiences heavy thunderstorm and tornado activity, a NEXRAD may not give enough payback.

The FAA relied on NEXRAD for terminal weather detection and forecasting service until Terminal Doppler Weather Radars (TDWR) were installed at many airports. Much of the original software algorithm development from NEXRAD was transferred to TDWR. WSR-88Ds that are provided special air traffic coverage used some TDWR-specific algorithms tailored for approach and departure windshear and mesocyclone detection/prediction. The terminal systems concentrate their coverage on airport approach and departure areas for hazardous wind shear and microburst conditions. NEXRAD was designed, and is sighted, to cover larger areas and are proving especially useful in weather analysis along en route airways.

Installation of NEXRAD systems was an ambitious plan with systems delivered at a rate of up to three per month. Because of experience with operational radars, some of the installations were rescheduled to put NEXRADs into service at some locations later than planned. Miami and the NWS Hurricane Center are examples. There were some problems with property acquisition, site development, and installations, further changing the actual installation/commissioning dates for particular systems.

Applications for NEXRAD could go beyond the systems which were called for by the original NEXRAD program, especially if a significant Canadian order develops, and other possible international sales come about. This market has been slow in developing, though, and the financial crisis in the Pacific Rim is impeding what was considered the most likely market. The high cost of installations and weather conditions are causing Canada to thoroughly evaluate the cost of a NEXRAD venture. In addition, potential users are finding out that to take full advantage of the capabilities of the WSR-88D requires an extensive and expensive weather information/data distribution system, not just the radar. Many potential users are finding it too costly to set up a full NEXRAD weather system. This is impacting the marketability of the radar.

Competition for European radar manufacturers can be expected on the Continent, especially in light of a desire for C-band equipment. This is especially true in Eastern Europe.

The Massachusetts Institute of Technology developed Growth and Decay Tracker software which uses Doppler radar data to project storm line movement. The software compares the location of data details to determine and predict movement. Demonstrations at the Dallas-Ft. Worth airport showed that the new system can predict short-term (10 min to 2 hr) storm front movement and position. Initial attention is on perfecting 30 minute projections, later expanding to 60 and eventually 120 min. The system appears to be particularly effective with lines of thunderstorms, not as effective predicting air mass storms.

Although the DFW NEXRAD was used for the March 1998 Terminal Convective Weather Forecast Demonstration, plans are to incorporate TDWR and ASR-9 inputs as well. More accurate predictions from this system will be particularly helpful as an input to decisions on actions like gate closures and runway changes. Making changes too early or too late can be expensive and create unnecessary delays in traffic flow.

If successful, the Growth Decay and Tracker will be added as a pre-planned product improvement to the Integrated Terminal Weather System (ITWS) being developed for the FAA.

Ten-Year Outlook

No significant production projected.

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