An Historical Look at NEXRAD

Radar, also known as radio detection and ranging, is one of the earlier technological developments that had a huge impact on the field of meteorology. Weather Surveillance Radar-1988, Doppler (WSR-88D) Next Generation Weather Radar (NEXRAD) has become a staple technology for the National Weather Service (NWS) to meet the needs of its mission in detecting severe atmospheric features such as tornadoes, hail, and snow squalls. This technology, first used by the military to detect the movement of objects such as planes and ships in WWII, is now used in real-time operations to detect the sorts of atmospheric phenomena that could impact public safety and property. Here we will discuss the historical family line of radars that eventually led to the development of NEXRAD used by the NWS today.

The British were actually the first to "develop radio-location, direction-finding devices that could locate thunderstorms" through the efforts of Sir Robert A. Watson-Watt around 1935. Then, in the U.S. from 1942-1944, the Massachusetts Institute of Technology's (MIT) Radiation Laboratory (Rad Lab) showed that weather could be detected on certain types of radars out to ranges of 150 miles and at different wavelengths. Because of this, the Army Air Forces Weather Service established a program for the use of weather radar. Most U.S radar research and development was conducted at MIT's Rad Lab during WWII. In addition, because there were air traffic control and harbor defense radars set up on the Atlantic and Pacific sides of Panama, scientists from the MIT Rad Lab were able to visit and determine the effects of the atmosphere and usefulness of radar in observing atmospheric phenomena. The early use of this first radar network for weather detection and surveillance led to the recognition of many basic features of storm structure and organization and helped to realize the value of this information for operational purposes. All of these factors really helped to spur the growth of radar meteorology as a science.

After WWII, the NWS, formally known as the Weather Bureau, obtained various aircraft radars from the Navy. Most of them were AN/APS-2F radars which stood for Airborne Radar and they were modified and put into operation around the U.S. at about 5 per year. These were then renamed Weather Surveillance Radar (WSR) -1s, -1As, -3s, and -4s. All of these radars were pretty much the same and differed by some controls and indicators. The first WSR was installed at Washington, D.C. National Airport on March 12, 1947 and on June 1, 1947 a second WSR was installed at a NWS office in Wichita, Kansas. The radar in Wichita proved its worth when it was used to help guide and aircraft threatened by severe weather into clear skies so it could land safely.

WSR radars were all beginning to show their value in similar circumstances as what became known as the U.S. Basic Weather Radar Network began to form and expand after 1947. This network consisted of the early WSR-series systems, air force, civil government and cooperative radars. Eventually radars were being developed specifically for meteorological use and one of the first was known as the AN/CPS-9 Storm Detection Radars, produced by Raytheon Manufacturing Company. The CPS-9's were actually acquired by the Army

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Air Forces Weather Service and installed at military bases all over the world. Studies and research models of the CPS-9 were also conducted by MIT Rad Lab, as well as by the Signal Laboratory.

As the NWS considered expanding their radar network in the 1950s, a few major severe weather events occurred and lead to the formation of the Texas Tornado Warning Network and the establishment of communications between the NWS offices and local public officials. The NWS agreed to operate and maintain WSR-1, -1A, -3, or -4s at their offices and to provide warnings to the public when confirmed sightings were made - establishing volunteer spotter networks. Today, a more formal spotter program called SKYWARN® is run by the NWS where volunteers are trained to identify and describe severe local storms. Since the program formally started in the 1970s, the information provided by SKYWARN® spotters, coupled with Doppler radar technology, improved satellite and other data, has enabled NWS to issue more timely and accurate warnings for tornadoes, severe thunderstorms and flash floods.

In 1953, a tornadic feature known as a hook-shaped echo was first detected by a radar near Champaign-Urbana, Illinois and a couple of months later, two additional recordings of these echoes were made in Waco, Texas and Worcester, Massachusetts.

The installation of the WSR radars was a joint effort between local, state and the federal government, as well as universities. A great example of the partnership between the weather service and the local community occurred on April 5, 1956 when a tornado watch was issued by a weather service office in Kansas City for a specific area around Bryan, Texas at about noon. By 2pm on April 5, 1956, the Texas A&M University radar began seeing hook-echoes and University meteorologists were able to call the Bryan Police Department and the College Station School District to let them know about the impending touchdown of tornadoes. The school district decided to keep their students in school a bit longer instead of releasing them at their normal dismissal and this probably saved numerous lives. As one of the first known tornado warnings based solely on radar detection, the value of this technology was becoming more visible to society as a whole.

Hurricanes became another driver for the installation of radars. Their design used a frequency known as S-band, which allowed for longer range and more power in detection. After some extensive hurricane-force wind damage and flooding from 5 hurricanes in 2 years from 1954-1955, the NWS developed a major budget proposal for Congress to improve its warning services for hurricanes and severe weather, which was quickly approved. The budget included funding for the design, procurement, installation, and staffing for what became the WSR-57 radar. Raytheon Manufacturing Company was selected as the prime contractor; 31 radars were ordered by the NWS and installed at already existing weather service offices beginning in 1959 in Miami, Florida and ending in the early 1960s. While the main purpose was to install these near coastal areas, eleven of them were installed in the Midwest to detect severe storms. Fourteen additional radars were purchased in the late 60s to expand the network east ofthe Rocky Mountains. It is also important to note that these newer installations were placed in locations where weather service offices did not already exist. The main focus was to space the radars out optimally for coverage and continuity with the already existing radars.

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Some of the major design specifications included an “improved ability to detect storms behind intervening rainfall as to observe hurricanes at great distances.” In 1963 the NWS began to standardize the performance of the WSR-57s through calibration techniques. The WSR-57 also had a near real-time telephone transmission line for data and eventually a dial-in capability was added to allow access by military, airline offices and television stations, providing radar data remotely. Remote access is still an important part of the radar network today.

As discussed above, the NWS had installed many conventional, non-Doppler weather radars around the country but eventually they had to consider the technology with which they should replace them due to the aging WSR -1s, -1As, -3s, and -4s. Spare parts were disappearing and the 1940s technology upon which they were designed was just no longer feasible. The Office of the Federal Coordinator for Meteorological Services and Supporting Research began releasing a Federal Plan for Weather Radars and Remote Displays which was used by Congress as a “single source for reviewing the overall Federal program in meteorological services and supporting research.” The 1969 edition indicated that the NWS intended to buy more modern local-warning radars to replace the WSR -1s, -1As, -3s, and -4s. By fiscal year 1976, the NWS received funding for 3 years to replace those older radars, and the replacements were manufactured by Enterprise Electronics, which became known as WSR-74C. Additionally, Enterprise Electronics also manufactured some WSR-74S radars, which were used to fill some remaining gaps for special hurricane and heavy precipitation detection on the S-band frequency.

When computer technology began to emerge in the 1960s, researchers were able to more efficiently process radar data and application software for their radars. Eventually more sophisticated algorithms and techniques were developed that were also expanded to operational radars and it led to an improved knowledge base for the weather forecasters who had come to rely on radar data to do their daily jobs. Color monitor technology was also introduced, which made it even easier for meteorologists to be able to recognize storm echoes and other features.

During this same time, the MIT Rad Lab had been looking at the use of the Doppler Effect to measure target velocities by radar as a potential measurement for wind speeds, but the development of pulse-Doppler technology for operational use took a while. In 1971, the first Doppler radar was installed at the National Severe Storms Laboratory (NSSL) in Norman, Oklahoma and in 1973 a second Doppler radar was installed at Cimarron Airport in Oklahoma – both were meant to study the morphology of storms and used S-band frequency. By 1976, the Department of Commerce (DOC), Department of Defense (DOD) and the Department of Transportation (DOT) formed the tri-agency Joint Doppler Operational Project (JDOP) to explore the benefits of Doppler radar observations. Doppler radar was considered the next upgrade over conventional radar (i.e. WSR-57, -74) because of its ability to “measure the phase difference between transmitted and received radar signals. The rate of change of the phase difference is directly proportional to the radial component of target motion relative to radar, which is known as the Doppler velocity. As Doppler radar scans horizontally, it measures both reflectivity and the component of target motion along the radar beam axis.” This method

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shows a more accurate detection of circulations associated with tornadoes and other significant weather. The JDOP conducted field tests for three years with the NSSL Doppler radars and an Air Force Geophysical Lab Doppler radar in real-time to test various processing and display capabilities. In 1979, they delivered a final report with recommended specifications for the tri-agencies.

The JDOP reported out seven basic findings for the use of Doppler radar. A few of them were: Doppler radar is superior to conventional radar and spotters/public reports; Doppler radar can distinguish between severe and non-severe thunderstorms at a longer range; the size of a warning area can be smaller and much more specific due to increased precision by Doppler radar; and average lead time for detecting storms before occurrence would be increased.

Finally, the NWS recognized the increased need for standardized training of radar operators since Doppler radar data was much different from conventional radar data. They specifically noted that operators would need an introduction to basic Doppler principles and meteorologists would also need to be able to interpret velocity data. As a result of this, the National Weather Service Training Center (NWSTC) located in Kansas City, MO developed various foundation courses and intensive short courses that eventually became a job requirement for forecasters who were hired by the NWS.

In mid-1979, the JDOP reported to the House Committee on Appropriations proposing that a "new weather radar called NEXRAD, which had Doppler capability, be integrated into a national system to meet the requirements concerning the location, intensity, and movement of hazardous weather activity to meet their agencies' missions." In this report, it was also noted that NEXRAD would be useful for more than just detecting the hazards of severe weather. The JDOP proposed that NEXRAD be useful for water resource management; it would also foster economic value when used by various industries such as private meteorologists, TV stations, and the airlines to name a few. There was also interest internationally for this type of data.

By late 1979, the Federal Committee for Meteorological Services and Supporting Research (FCMSSR) established a Joint Systems Project Office (JSPO) to run the planning, programming and management of development, procurement and installation of NEXRAD. With the establishment of the JSPO, key documents such as the joint operational requirements (JOR), NEXRAD technical requirements (NTR) and a research and development plan resulted. All of these fed into the JSPO Interim Operational Test Facility (IOTF) operations set up in Norman, OK to develop many of the concepts for what eventually was to become the WSR-88D. Beginning in 1982, contracts for concept development, validation and risk reduction were awarded and finally, after other various operational testing and evaluations, Unisys Corporation was selected as the NEXRAD contractor for full scale production in 1990.

The WSR-88D network that exists today is the result of a billion-dollar weather service modernization that began in the late 1980s into the early 1990s. NEXRAD was just one part of the modernization of observation technologies being incorporated to improve NWS services. In 1995, the National Research Council (NRC) stated that "based on an intensive 6-month study, their NEXRAD Panel of the National Weather Service

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Modernization Committee (NWSMC) arrived at a strong overall conclusion that weather services on a national basis will be improved substantially under the currently planned NEXRAD network." It took almost eight years from when the first WSR-88D system installation near Norman, Oklahoma in 1990 to last operational WSR-88D installment in northern Indiana in 1997. It is important to note that all agencies (mainly NWS, DOD, and FAA) that have weather radar programs are using the same radar systems and this has allowed for substantial cost savings in sharing new algorithms or other improvements as they are developed. Today, there are now 159 operational NEXRAD radar systems deployed throughout the United States and at selected overseas locations. Radar technology and its application to the atmospheric sciences have revolutionized our ability to 'see' the weather. By the 1990s, the NWS was finally able to provide a substantial amount of warning time for severe storms to the public in a more consistent manner throughout the entire United States through the use of Doppler radar technology. Finally, the current upgrade of the WSR-88D weather radars with dual polarization is the next stage of improvements for storm detection and the provision of warnings that will continue to assist our forecasters in the protection of life and property for the citizens of the United States.

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Andrea J. Bleistein
NOAA External Affairs