Upgrade of Storm Warnings Paying Off

The National Weather Service's early experience with the radar at the heart of its ongoing $4.4 billion modernization shows that it is improving severe weather warnings dramatically

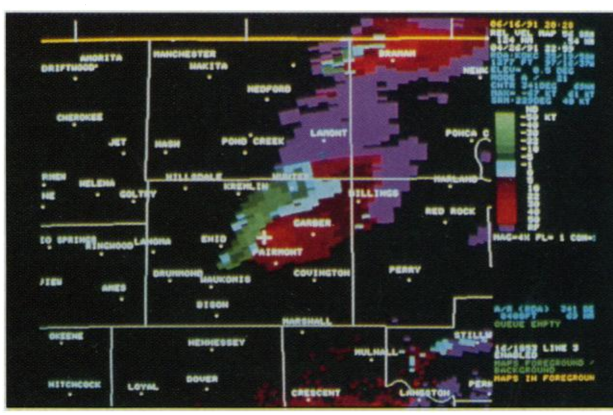
On 11 May last year, weather forecasters at the National Weather Service's (NWS) office in Norman, Oklahoma, peered into the heart of a storm bearing down on the small Oklahoma town of Kingston. They didn't like what they saw: Swirling wind patterns that indicated the storm was likely to spawn tornadoes. The forecast office alerted Kingston's civil defense director, who gave the order to sound warning sirens. Twenty minutes later, a tornado ripped through the town.

Twenty minutes to take shelter is no run-of-the-mill tornado warning; it's a radical improvement over what could have been done just a few years ago. Indeed, it would have been nigh impossible if the forecasters were relying on visual sightings of funnel-shaped clouds—the traditional way of triggering a warning, which may give several minutes notice but all too often none at all. Instead, the Oklahoma forecasters were seated in an office 150 kilometers from the storm they were tracking, eyeballing a radar screen splashed with color. "In past years with that same kind of storm, the local civil defense director would be asking why we couldn't have issued a warning," says Dennis McCarthy, who is meteorologist-in-charge (MIC) at the Norman office. But this time, "there were no more than minor injuries from flying glass."

The keystone of the stunningly successful Kingston warning was a state-of-the-art machine called the Next Generation Radar, or NEXRAD, that can look deep inside violent weather to get a picture not only of heavy precipitation, which conventional radars can do, but also the winds that shape and sustain violent storms. The Norman forecasting center was equipped with NEXRAD 2 years ago in the first step of a sometimes controversial $4.4 billion upgrade of the NWS's forecasting capabilities that is expected to revolutionize warnings of the 10,000 violent thunderstorms, 5000 floods, and 1000 tornadoes that strike the United States each year.

The upgrade is long overdue: The NWS's existing radar network dates back to the 1950s and is rapidly deteriorating. Vacuum tubes are still a crucial commodity in the NWS, notes Ron L. Alberty of the NEXRAD Operational Support Facility in Norman, and the repair of some radars has waited on parts from the sole remaining supplier—in the former Soviet Union. The full modernization will require the successful implementation of many components besides NEXRAD and some of the new technology has hit snags (see sidebar), but according to a major review just completed by NWS meteorologists, NEXRAD is proving to be a winner.

Indeed, after NEXRAD has been operating for almost 2 years at several sites—30 of the eventual 116 radars have been deployed—it is receiving glowing reviews. "It's incredible what we can see," says McCarthy. "We see things we always knew were there but couldn't see." In addition to curiosities like flocks of bats and smoke from fireworks, forecasters are detecting snow where conventional radar shows clear air, signs that seemingly innocuous storms are turning violent, and sometimes even tornadoes themselves. "It's been outstanding," agrees Bart Hagemeyer, MIC at the NWS's Melbourne, Florida, office. "It's exceeded our expectations." These testimonials must be sweet music to the ears of NWS officials, for the heavy reliance on NEXRAD in the modernization plan was initially criticized by some meteorologists who questioned whether the technology was up to the job, and argued that the planned number of radars would not provide adequate coverage of the United States.



NWS

Bad day in Oklahoma. The juxtaposed red and green of the NEXRAD radar's display reveal the winds blowing away and toward the radar, a signature of swirling, severe storms.

Scoping the wind

NEXRAD's technological edge comes from developments in the 1970s that greatly expanded radar's vision of the world. Conventional radars developed during World War II bounce microwave signals off raindrops, hail, and sometimes snow and measure the signals' round-trip travel time and intensity. The resulting images on a radar scope told forecasters where the precipitation was falling and something about how much there was. But the information provided few clues to which storms were particularly severe—those that produce 2-centimeter or larger hail and winds above 90 kilometers per hour.

That's where NEXRAD comes in. Not only does it measure the travel time and intensity of reflected signals but also the shift in their frequency due to their reflection from precipitation blowing in the wind. That Doppler shift translates into a wind velocity toward or away from the radar that is then displayed on a color-coded screen where the forecaster—with a computer's help—can search out severe thunderstorms, incipient tornadic storms, cold fronts, gust fronts, and the other boundaries in the atmosphere that tend to generate violent weather. NEXRAD also has an advantage over the old radars in having a greater useful range and having two to six times the resolution so as to produce a sharper picture of the weather.

Since installation beyond Norman began a couple of years ago, the Doppler NEXRAD's radically different outlook on the weather has been producing plenty of case histories that illustrate its virtues. Paul Polger and his NWS colleagues in Silver Spring, Maryland, recount several in their evaluation of NEXRAD's early performance, to be published in the *Bulletin of the American Meteorological Society*. On 24 April last year, forecasters at the NWS forecast office outside Washington, D.C., in Sterling, Virginia, were tracking low-topped thunderstorms coming out of West Virginia 100 kilometers northwest of Washington. Before Sterling's NEXRAD was installed, such storms revealed few clues to distinguish which were producing dangerous weather, leading forecasters to issue many warnings that failed to pan out. But with NEXRAD, some of the storms showed clear signs of severe conditions: large amounts of water, automatically tallied from the top to the bottom of a storm by the radar, and regions of weak radar echoes presumably cleared of water by intense updrafts, the

So Many Promises to Keep

The Next Generation Radar (NEXRAD) may lead to dramatic improvements in severe weather warnings (see main story), but the modernization and reorganization of the National Weather Service (NWS), scheduled to be completed by 1998, has several crucial components intended to make U.S. weather forecasters the most proficient and economical in the world. Not all aspects of modernization have been progressing smoothly.

■ **Next Generation Radar Network.** Development of the $850 million NEXRAD radar network hit a temporary snag when the NWS and the contractor, Unisys, haggled over putative cost overruns. Thirty radars have begun operating since installation began in January 1992, and the startup rate will soon hit four per month, according to Louis Boezi, deputy assistant administrator for modernization at the NWS. A few glitches in the hardware and the software are still being worked out, but all 116 NWS radars are expected to be installed by early 1995.

NWS

NEXRAD. These dome-enclosed radars are spreading nationwide.

■ **Automated Surface Observing Systems.** The ongoing installation of $118 million worth of automated sites will replace human observers at about 450 sites and add 450 new sites. The ASOS installations will report atmospheric pressure, temperature, wind direction and speed, visibility, cloud ceiling heights, and type and intensity of precipitation—and, unlike human observers, they will do it on a nearly continuous basis. But some pilots as well as human observers have complained that ASOS doesn't measure some weather elements, such as freezing rain, needed for safe flight operations, or improperly measures others, especially visibility and cloud heights. The NWS is rushing a freezing rain detector into test trials this winter, and it argues that some traditional manual observations are now covered by other sensors, such as the lightning detection system that now blankets the country. Problems with visibility and ceiling may prove trickier to resolve because ASOS differs from humans in the way it makes its observations; it looks in just one direction, not around the whole sky. Control tower personnel may have to pick up part of that job.

■ **Geostationary Operational Environmental Satellite.** The next GOES is scheduled to be launched in April 1994, now that instrument performance problems have been resolved. It will carry instruments that simultaneously return advanced visible and infrared cloud images and more precise atmospheric soundings. Both types of data aid warning of severe weather and floods and short-range weather forecasts.

■ **Improved computer forecast models.** Early next year the NWS's National Meteorological Center (NMC) in Camp Springs, Maryland, takes final delivery on a new Cray 90 supercomputer that will be five times as fast as the Cray YMP-8 it replaces. That added speed will allow NMC to upgrade its full suite of forecast models that guide local forecasters in formulating predictions. It will also allow a high-resolution model that should greatly improve predictions of precipitation. An improved hurricane forecast model will for the first time predict a storm's intensity as well as its track. Computer forecasting will be ratchetted up again in 1996 with the arrival of the next generation of supercomputer.

■ **Advanced Weather Interactive Processing Systems.** The $450 million AWIPS is billed as the nerve center of the modernized weather forecast office. In order for the forecaster to take full advantage of the increasing torrent of data, AWIPS must integrate and analyze the data, superimposing regional data and satellite images, for example, on the weather map produced by the NMC supercomputer. Then AWIPS must assist the forecaster in composing forecasts and warnings. Installation is scheduled for 1996 to 1998, later than anyone would like. And its schedule is still vulnerable to budget constraints.

■ **Reorganization.** To take advantage of the long reach of NEXRAD and the power of computerized communications and analysis, the NWS will be reorganizing its field offices and slimming down. Fifty-two Weather Service Forecast Offices and 197 smaller Weather Service Offices will coalesce into 116 Weather Forecast Offices with staffs that are more professional. The exact size of those staffs is still much debated. The NWS is aiming for a lean, economical unit with perhaps eight or 10 meteorologists, and its employees' union is arguing that's too lean. Once NWS has some of the new offices up and running, it should be able to base a final decision on their performance.

–R.A.K.

sort that lead to big hail. All the severe weather warnings from Sterling on that storm were verified by eyewitness accounts of either wind damage or large—2.5-3.7-centimeter—hail.

Another NEXRAD feature came into play on the 4th of July last year near St. Louis as the weather turned ugly late in the day. NWS forecasters had already successfully issued a warning to residents in the path of a severe thunderstorm and a weak tornado when, around 7:00 p.m., NEXRAD automatically alerted them to rainfall totaling 7.5 to 10 centimeters in 1 hour over nearby St. Clair County, Illinois. They issued a flash flood warning for the county; the town of Freeburg later reported flash flooding with water up to 1.5 meters deep.

NEXRAD has proved equally adept at helping forecasters avoid crying wolf. On 28 April 1992, the Norman forecast office had successfully issued a warning half an hour ahead of a storm dropping large hail 150 kilometers to the northwest. Two hours later, a pilot reported a funnel cloud in the same storm. But NEXRAD showed only weak rotation of the storm as a whole—a sign that it was not likely to produce a tornado. Usually it's only when the rotation is strong—giving the storm stability and time to intensify—that tornadoes appear. Forecasters ignored the eyewitness account and, relying on their new technology, declined to issue a tornado warning. No confirmed tornadoes were ever reported from that storm.

Polger and his colleagues have plenty of statistics to support these anecdotes. Overall, Norman's false alarm rate is down to less than 20%, while Sterling's dropped from 60% before NEXRAD to 30%. At Norman, where forecasters have the most experience with NEXRAD, the probability that severe weather will be detected has reached 90% while the national, non-NEXRAD average is about 60%. For five forecast offices other than Norman, a measure of warning skill that takes into account both the probability of detection and the false alarm rate nearly doubled after the arrival of NEXRAD. Warning lead times have improved, too. In the pre-NEXRAD era, warnings of 5 to 10 minutes were considered very good, say Polger and his colleagues. The Norman office's average lead time for severe weather warnings is about 15 minutes.

Critics of NEXRAD's implementation, principally the NWS Employee's Association, had argued that Doppler radar does not have enough useful range to fill in between sites, which are planned to be about 400 kilometers apart. Experience so far, at least according to the Silver Spring NWS group's statistics, suggests that such fears are unfounded, however. Considering warnings out of Norman, none of the measures of warning skill—detection, false alarms, or lead times —changed significantly with increasing distance from the radar, right out to 240 kilometers.

That is not to say that NEXRAD is omniscient; it has its blind spots. One is distant heavy weather that in effect hides behind weather that is closer in. Radar reflections may actually arrive from the distant storm, but NEXRAD—or any other radar—cannot say whether they were emitted recently and came from close by or were sent earlier and are just arriving from a great distance. On 6 August, such range-folding initially hid from the Sterling NEXRAD, which was 200 kilometers away, the severe storms that eventually generated 17 tornadoes near Petersburg, Virginia. Four persons died and 200 were injured when a tornado sliced through a Wal-Mart store without warning.

During congressional hearings last spring on the NWS modernization, such inevitable shortcomings prompted Robert Ryan, WRC-TV meteorologist in Washington, D.C., and president of the American Meteorological Society, to voice a word of caution. Ryan noted that weather forecasting will always have its limitations, no matter how spectacular the advances. NEXRAD will never catch every severe thunderstorm or tornado. Heavy snowstorms will still surprise forecasters and the public. And improved hurricane forecasts will continue to be hard to come by. "Our future challenge...may be as much educating the public as to our scientific limitations," he said, "as it is detailing our present accomplishments."

–Richard A. Kerr

GENETIC DISEASES

Copper Clues Clarify Metabolic Puzzle

When researchers told a recent psychiatric genetics meeting in New Orleans* that they had identified a gene for a disease that destroys the liver, the announcement wasn't really out of place. The illness is Wilson's disease, a disorder that can mimic symptoms of schizophrenia and other neurological disorders and place misdiagnosed patients in psychiatric wards. It can also kill people, if untreated, and identifying the gene means there is now a prospect of a genetic test that would lead to treatment with drugs before any symptoms even appeared.

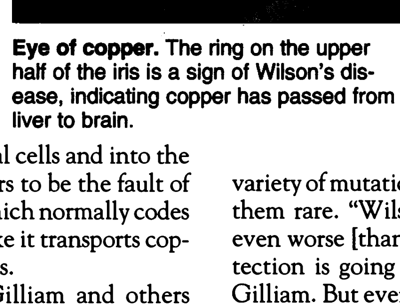
Striking 30 in every million people, Wilson's disease is a rare, inherited illness that stems from an abnormal buildup of copper in many organs. The buildup causes brain damage, and in the liver, where the buildup is most dramatic, copper toxicity ravages the organ and, without a transplant, causes death by early adolescence.

Researchers have long wondered why Wilson's patients are unable to get rid of excess copper, and in New Orleans, psychiatric geneticist T. Conrad Gilliam of Columbia University may have provided an answer. He reported that a team he led had found mutations that may account for the problems in copper transport. Gilliam cautions, however, that the gene may be susceptible to so many mutations that those wishing to develop a reliable genetic screening test could face a formidable challenge. The discovery's most immediate benefit may be to basic research, helping to clear up the biological mystery of copper transport. "Learning about these defects will tell us how the body moves copper from one part of the body to another molecularly," says geneticist George Brewer of the University of Michigan Medical Center, who has also been pursuing the gene.

* *1993 World Congress on Psychiatric Genetics, New Orleans.*

The search for the Wilson's disease gene began in earnest in 1985, when genetic linkage studies of families prone to the disease placed the gene on chromosome 13. To home in further, Gilliam's group this year developed a physical map of nine "microsatellite" markers, short repetitive sequences of DNA, that spanned the region. By examining the DNA of 115 Wilson's disease families, Gilliam's group could determine which markers were inherited most frequently by those with the illness. That data indicated the gene was associated with two markers on a stretch of chromosome 13 less than 200,000 base pairs long.

But the scientists couldn't get any closer without a candidate gene. Then, in January, three other groups independently reported in *Nature Genetics* on a gene involved in another rare, fatal, copper-related illness: Menkes disease. Menkes' patients suffer from copper "starvation" in which all the copper-dependent enzymes in the body shut down, leading to progressive brain damage and vascular defects. Dietary copper in these patients apparently cannot travel out of intestinal cells and into the bloodstream. That appears to be the fault of mutations in the gene, which normally codes for a protein that looks like it transports copper across cell membranes.



NATIONAL CENTER FOR THE STUDY OF WILSON'S DISEASE

Eye of copper. The ring on the upper half of the iris is a sign of Wilson's disease, indicating copper has passed from liver to brain.

It seemed clear to Gilliam and others that Wilson's disease might result from a defect in a simliar transport protein, so his group began looking in the suspect region on chromosome 13 for stretches of DNA that might match the Menkes gene. At the same time, Gilliam mentioned this effort to Rudolph Tanzi, a neurologist at Massachusetts General Hospital who, as part of his work on Alzheimer's disease, was screening genes that appeared to code for metal-binding proteins. And Tanzi, it turned out, had located one such gene—right on chromosome 13.

After talking with Gilliam, Tanzi quickly compared his candidate gene to the gene for Menkes disease and found the encoded amino acids were 76% identical. Next, Gilliam and his colleagues showed that Tanzi's gene indeed lay in the suspect region on chromosome 13. Moreover, the investigators found that the RNA produced by the gene is expressed most vigorously in the liver. And finally, Gilliam, Tanzi and their colleagues returned to the genetic data from the Wilson's families, looking for mutations in the gene that could affect the function of what is apparently another copper-transport protein. So far, the researchers have found four mutations that show up only in Wilson's patients and not in unaffected relatives.

But they also learned these mutations account for much less that 50% of their cases. That indicates that Wilson's disease, like cystic fibrosis, is caused by a large variety of mutations in a single gene, many of them rare. "Wilson's disease is going to be even worse [than cystic fibrosis]. Carrier detection is going to be really difficult," said Gilliam. But even if the identification of the gene for Wilson's disease doesn't turn into a clinical blessing, teasing out the gene's workings, along with those of the Menkes gene, should help clear up some mysteries behind the body's molecular metalworks.

–John Travis