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THE NATIONAL WEATHER SERVICE SEVERE STORM PROGRAM: YEAR 2000[1]

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1.0 Introduction

Weather affects the lives of almost each and every American citizen on a daily basis. It affects the way people dress and even the way they plan their daily activities. Hazardous weather has a profound effect on not only the citizens, but also the Nation's economy. The 1,000 tornadoes, 5,000 floods, 10,000 severe thunderstorms, and several tropical cyclones that are recorded in the United States annually continue to take hundreds of lives and cause property damages approaching 10 billion dollars. It is little wonder that today's National Weather Service (NWS) is considered every American's first line of defense against a wide variety of weather types.

The NWS, with its beginnings in the Army Signal Corps in 1870, has undergone almost continuous change since its inception. A part of the change has been due to advances in the science, while other changes have occurred due to rapidly moving technology. The present day structure of the organization is about 25 years old and makes extensive use of labor intensive programs to fulfill the agency's basic mission. The Nation's weather radar network is primarily composed of radar's employing 1950's technology. The agency continues to sample the atmosphere using manual surface observations and radiosondes carried aloft by balloons. The agency's nationwide computer network, known as Automation of Field Operations and Services (AFOS), has less computer processing power than many people have in their homes. The bottom line is that in its present configuration the NWS is not able to (1) keep up with the ever increasing demand for service, (2) readily incorporate advances in the science into operations, (3) take advantage of vastly improved technology, and (4) make the most effective use of the agency's limited human resources.

In order to take full advantage of the computer age and make optimal use of available resources, the NWS is embarking on a major modernization effort to lead the agency into the 21st century. Over the next decade new technologies as well as a shift to a predominantly professional workforce will cause unprecedented change in the operations of the NWS.

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It is the intent of this paper to provide the reader with an overview of how severe weather operations will be conducted in the year 2000. The overview includes a description of the new technology, its impact on services, and the operational concepts under consideration for the year 2000. It is not the intent of this paper to provide information on the management activities of the agency or transition plans as the new technology is implemented.

2.0 Integrated Warning Function

Before embarking on the discussion of the new technology and field operations, a brief overview of the structure, of the overall warning program is in order. Even though the NWS is planning major changes in technology and operational structure the core mission of the agency remains unchanged. The NWS will continue to provide severe weather and flood warnings to the American public using the concept of an integrated warning system (Leik et al., 1981).

An integrated warning system for severe storms and floods as operated in the United States consists of three basic elements. These are as follows:

a. Forecast/detection.

b. Dissemination.

c. Warning Response.

The NWS meteorologist is integrally involved in each of the elements today and will continue to be in the future. The planned technology and associated operational changes provide the forecaster with an opportunity and tools to improve service within each of the elements. In fact, the basic elements will be linked together in a much closer fashion than is possible with today's technology and operational structure.

3.0 Modernization and Operational Changes

Within the context of modernization, discussion will be centered around the new technology that should be in place at all NWS offices by the year 2000. The operational changes in the NWS will be discussed separately, but the reader must realize that these changes are dependent on the successful implementation of new technology.

3.1 Modernization

The NWS modernization project can be subdivided by function into two separate topics. These are the technology needed to better sense the state of the atmosphere, and that technology required for processing, assimilating, and analyzing the vast array of data available to the NWS forecaster. The automation planned will no doubt significantly affect the decision-making process in the warning program. The anticipated impact of automation on decision making within the NWS by the year 2000 is depicted in Figure 1. Even though the agency will rely heavily on the new technology, the human element will continue to be our most important resource. The next few sections will present short descriptions of the new systems planned for implementation over the next decade.

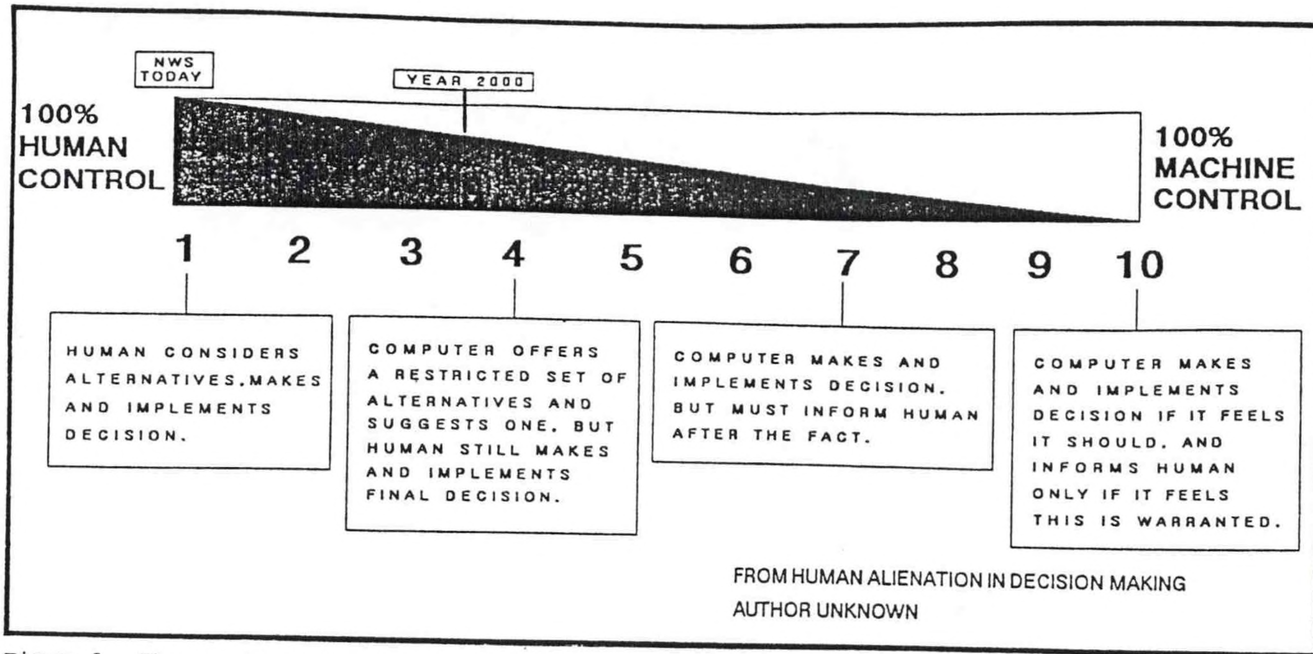

Figure 1. The spectrum of automation in decision making with the impact on NWS warning operations by year 2000 indicated.

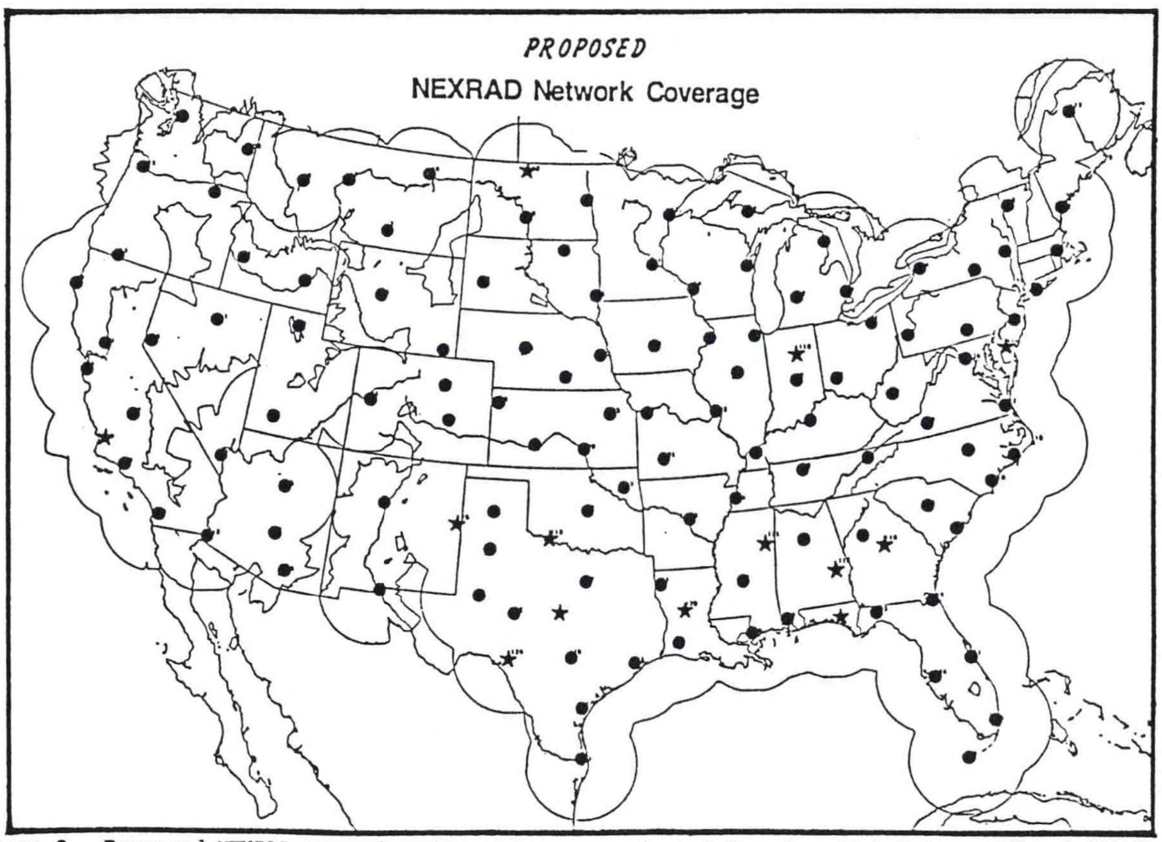

Figure 2. Proposed NEXRAD network radar coverage as planned for the mid-1990's. Stars indicate DOD supplemental sites; circles show NWS network sites.

3.1.1 Next Generation Radar (NEXRAD)

NEXRAD is being developed to provide the three sponsoring agencies -- the Department of Commerce (DOC), the Department of Defense (DOD), and the Department of Transportation (DOT) (NEXRAD, JSPO, 1986) -- with a wide array of weather information in support of their basic missions. The NEXRAD system, with its Doppler capability and automatic data processing equipment, will provide the principal users (DOC, DOD, and DOT) and other users, including those external to the government, with a marked improvement in their ability to predict and subsequently detect hazardous weather phenomena.

The NEXRAD will be deployed at 114 NWS sites in the contiguous United States beginning in late 1989 continuing through 1994. Selected NWS offices will also receive supplemental radar data from 18 DOD NEXRAD sites in real-time. The proposed network radar coverage along with the DOD supplemental radar installations is shown in Figure 2. The coverage shown is current as of September 1, 1987.

The NEXRAD system includes the hardware and software necessary to process the received radar signal and convert it to a high data rate stream of digital radar base data for reflectivity, velocity, and spectrum width which has been decluttered, dealiased, and range unfolded. The digital base data are then passed via a high speed communications link to a subsystem that generates radar products for the forecaster.

This subsystem is composed of the digital computer hardware, firmware, and software necessary to produce NEXRAD products in real-time. These products can then be displayed for the user, using the Principle User Processor (PUP) workstation. The workstation is composed of the digital computer hardware, software, and displays necessary to view, evaluate, and time-lapse, or use any other manipulation necessary to fully utilize the radar information contained in the product.

A major enhancement in operational capability of NEXRAD is that it will provide users with real-time meteorological analysis produced by the system. This provides each user with a set of radar data products tailored to support the user's warning and forecast responsibilities.

As one might suspect, the NEXRAD system will be providing the NWS meteorologist with a myriad of products designed to enhance severe weather operations. The overall impact on the warning program will be to increase the lead time for warnings while at the same time reducing the size of the warning area to that area most likely to observe severe weather.

In a typical operational scenario during a severe weather episode, the forecaster would detect an outflow boundary from previous thunderstorms using the combined shear product. This allows the forecaster to anticipate the subsequent development of severe thunderstorms along the boundary. As thunderstorms develop, the meteorologist is able to analyze the severe potential of each storm using automated analysis products, such as Vertically Integrated Liquid Water (VIL), severe weather probability, hail index, mesocyclone, and tornado vortex signature (TVS). If the forecaster desires additional information to consider before issuing a warning, the storm structure algorithm provides an alphanumeric product showing storm characteristics.

Once the meteorologist has determined the storm to be severe, a warning can be issued for an area depicted by the output of the storm tracking algorithm. Using the current and past positions of the storm centroid, this algorithm computes the future track of the storm out to one hour. In today's warning program, warnings are generally on a county basis. In the future, the capability will exist to issue warnings for a specific area based on the extrapolated storm track. Figures 3a and 3b illustrate the severe storm warnings of today compared to those that should be possible in the future.

The flash flood warning program will also be enhanced by NEXRAD. Not only will the meteorologist have access to rainfall mapping of various durations but also a flash flood potential algorithm that will provide assistance in the decision-making process for flash flood warnings. The algorithm will compare the NEXRAD estimated rainfall and future rainfall based on the forecast track and intensity to the flash flood guidance values for a particular basin. This will assist the NWS forecaster in issuing more site-specific and timely flash flood warnings.

The hurricane program will also benefit from NEXRAD. At the present time, local action statements are issued by NWS offices stating observed local conditions, preparedness requirements, and information obtained from advisories. NEXRAD will enable the meteorologist to estimate the winds and rainfall as well as the occurrence of tornadoes as individual spiral bands approach the coast. Therefore, information concerning the local conditions that are likely to be encountered can be disseminated to local officials and citizens alike.

3.1.2 Automatic Surface Observation System (ASOS)

Another important part of the modernization is improving the surface observation system. The surface observation program is of paramount importance to the NWS severe weather program.

Surface observations provide the forecaster with precise information concerning the state of the atmosphere at or near the earth's surface. Today, the surface observation program is still largely manual and labor intensive.

The NWS and the Federal Aviation Administration (FAA) are planning a surface observation network consisting of 1,000 ASOS units. The NWS will deploy approximately 250 units and the FAA up to 750 units. Current plans call for completion of the project by the end of 1994.

The severe weather program is heavily dependent on surface observations today and will remain so in the future. The surface analysis is used extensively to detect boundaries on which thunderstorms may develop and mesoscale high and low pressure systems that may initiate convection. Today's surface observational network produces information available for analysis on an hourly basis. However, the meteorologist needs much more frequent surface data (15-minute intervals) in order to facilitate timely detection of the development of mesoscale surface pressure systems. This, in turn, enables the forecaster to

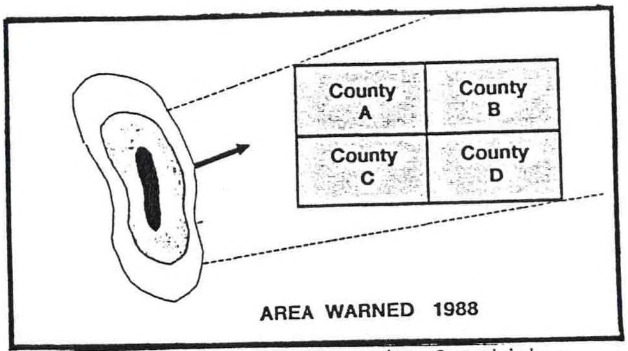

Figure 3a. Depiction of counties for which a warning would be issued (stippled area) using current NWS technology.

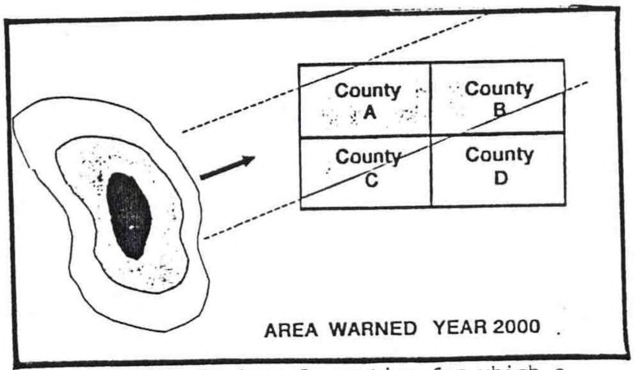

Figure 3b. Depiction of counties for which a warning would be issued (stippled area) using technology in the year 2000.

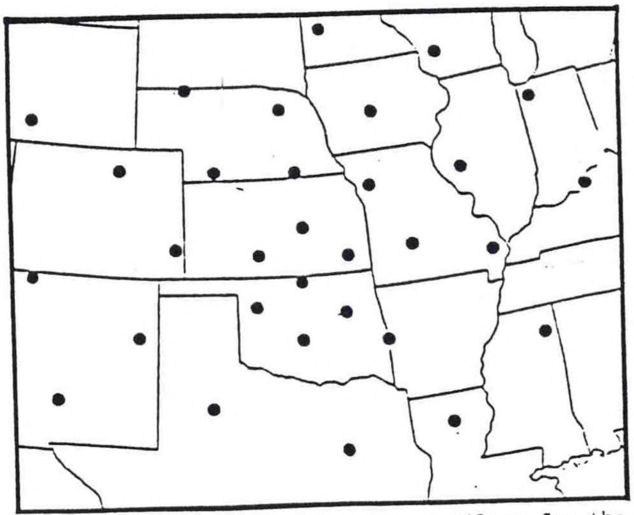

Figure 4. Planned locations of profilers for the NOAA/NWS profiler demonstration network.

anticipate severe weather and/or flash flood occurrence. It is expected that the automated surface observations will be most valuable to the field forecaster in the 0-6 hour time period.

3.1.3 GOES-NEXT

In support of the NWS Severe Storm Program, there will be a continuing need for a geostationary satellite system as we have today. However, pressures for more accurate and timely severe weather forecasts will subsequently produce a requirement for improved satellite weather data. GOES-NEXT (NOAA, 1983) is being designed to meet the future demand for better quality satellite data. At the present, it is anticipated the GOES-NEXT will be operational in the early to mid-1990's.

The next generation satellite system is designed to provide improved imaging capabilities for use in mesoscale analysis and forecasting. Some of the planned improvements include greater spatial resolution, improved IR temperature sensitivity, more accurate earth location, and improved atmospheric sounding capability.

In certain situations, the GOES-NEXT will provide the meteorologist with initial indications of the rapid development of convection. This will be especially important in the mountainous west where NEXRAD coverage is severely restricted by terrain features. The improved temperature sensitivity for earth surface temperatures will allow NWS forecasters to accurately determine the position of surface boundaries, such as dry lines that neither the NEXRAD or ASOS will adequately detect. Subsequently, using the GOES-NEXT imagery, the forecaster could more precisely delineate the formative areas of convective activity than is possible today.

A valuable tool in today's flash flood program is the ability to estimate rainfall amounts in data-sparse areas from satellite imagery. With improved earth location capability and greater IR temperature sensitivity, the satellite-derived rainfall estimates will be much more useful in flash flood prediction than those generated today.

Another valuable aspect of GOES-NEXT is the ability to produce satellite-derived atmospheric soundings at frequent intervals. This feature will enable the meteorologist to locate areas of decreasing stability enhancing the ability to predict and subsequently alert the public as to the potential of severe storms.

3.1.4 Profiler

According to Shapiro (1986), the major advances in our understanding of atmospheric processes and subsequent improvements in weather forecasting have resulted from technological advances in atmospheric observing systems and data processing systems. In recent years, a technological barrier to advancing our understanding of synoptic-scale and mesoscale atmospheric processes stemmed from the unavailability of temporally continuous, detailed vertical-resolution profiles of wind velocity, temperature, and moisture. This is due to the fact that the rawinsonde continues as the backbone of the NWS upper air observing network, providing soundings twice a day, with a spatial resolution of 500 km between release sites. The recent development of UHF/VHF radar wind profiling as a means for obtaining operational temporally continuous measurements of the atmosphere's motion provides forecasters with a very real opportunity for improved prediction of both synoptic-scale and mesoscale weather systems.

Another aspect of the NWS modernization effort is to deploy a network of profilers across the Nation. The initial demonstration network of 30 profilers is expected to be in place over the central region of the United States by 1992. This will comprise the NOAA Wind Profiler Demonstration Network (Figure 4). Pending successful demonstration, it is anticipated that additional profilers will be deployed in other regions of the country from 1992 through the year 2000.

The use of wind profiler data will allow forecasters to have access to a four-dimensional perspective of the atmosphere. This, in turn, will be used for continuously updating regional-scale and mesoscale numerical models as well as operational analysis in real-time.

The wind profilers will enable forecasters to monitor areas of convergence, divergence, and vorticity over time. This will be very important for forecasting the development and magnitude of convection in the 6- to 12-hour time period. Additionally, the profiler network will have the capability of detecting the formation of nocturnal, low-level jets (common place over the central U.S.) and other types of subsynoptic-scale features that are difficult to detect using the conventional radiosonde network.

3.1.5 Dissemination Systems

The dissemination systems of the future are not as well defined as the other systems discussed in this paper. However, the concepts concerning the amount, type, and modes for disseminating severe weather information in the future are recognized as an integral part of modernization efforts. When discussing dissemination, three basic paths of information delivery emerge as critical to the agency's mission. These are:

a. Information distributed to Emergency Management Officials.

b. Information distributed directly to the general public.

c. Information to the media and the private sector meteorologists.

It is quite likely that by the year 2000 each of these groups will receive information on severe weather from a different type of delivery system. For example, emergency management officials may well receive severe weather information in a graphical mode directly from the AWIPS system. On the other hand, the general public will probably receive warning information from NOAA Weather Radio (NWR) which will employ digital voice technology and site-specific warning capability. The private sector and media will receive their information through high speed data links with the AWIPS system. There is little doubt that the technology in place by the year 2000 will provide the NWS with a much faster and more efficient means of disseminating weather information.

3.1.6 Central Guidance

The computational resources at NMC are expected to increase by a factor of 100 over the present day system within two generations of computers. Beyond the 1995-2000 time frame, NMC expects to provide guidance to NWS field offices for the mesoscale out to 30 hours using a 40 km, 30 level nested model covering the U.S. and coastal waters. For periods from 36 hours to 10 days, a global 75 km, 30 level model with advanced physics will be used. The improved model physics should include a detailed diurnal cycle; surface physics; advanced convection and large scale precipitation parameterization; new atmospheric variables, such as ozone, cloud, liquid, and ice coverage; better topographic features and new initialization schemes.

The enhanced computer capability will provide more flexibility in running various forecast models. The amount of data available and faster computers could allow models to be run four times a day rather than two or, perhaps, on call if technically possible.

3.1.7 Advanced Weather Interactive Processing System (AWIPS)

In the year 2000, NEXRAD, GOES-NEXT, ASOS, profilers, and mesoscale data collection networks will provide a continuous flow of billions of bits of meteorological data into each NWS office. The meteorologist could quickly be overwhelmed by the myriad of data displays that could be available. Should this result, the value of this perishable data would be diminished. As stated previously, the present day AFOS system does not have the capability of processing the vast array of data that will be available for the NWS meteorologists by the year 2000. Therefore, the NWS is designing AWIPS to serve this purpose.

AWIPS is in the design stage at this point in time. However, several pilot projects, namely PROFS (Program for Regional Observing and Forecasting Services), VDUC (Vas Data Utilization Center), and CSIS (Computerized Storm Information System), are being used to gain experience for planning and developing the AWIPS system. There are two other projects, DARRRE (Denver Area Risk Reduction Requirement Experiment) and PROTEUS (Prototype Real-Time Operational Test, Evaluation, and User Simulation) which are being designed for use in testing various operational concepts in real-time.

AWIPS will provide both NWS field offices and national center personnel with a modern interactive system capable of (1) assimilating the diverse new data sets and integrating them with each other as well as conventional data, (2) supporting warning and forecasting decision-making processes, and (3) facilitating the dissemination of weather products. The expanded capability of AWIPS will enhance the forecaster's ability to analyze, detect, predict, and monitor phenomena, such as severe thunderstorms, heavy precipitation, tornadoes, heavy snow, etc. The AWIPS system is being designed to also receive, process, and store a vast array of hydrological data for use in the NWS river forecast program. Figure 5 shows a conceptual diagram of the AWIPS system and its interaction with the other planned systems.

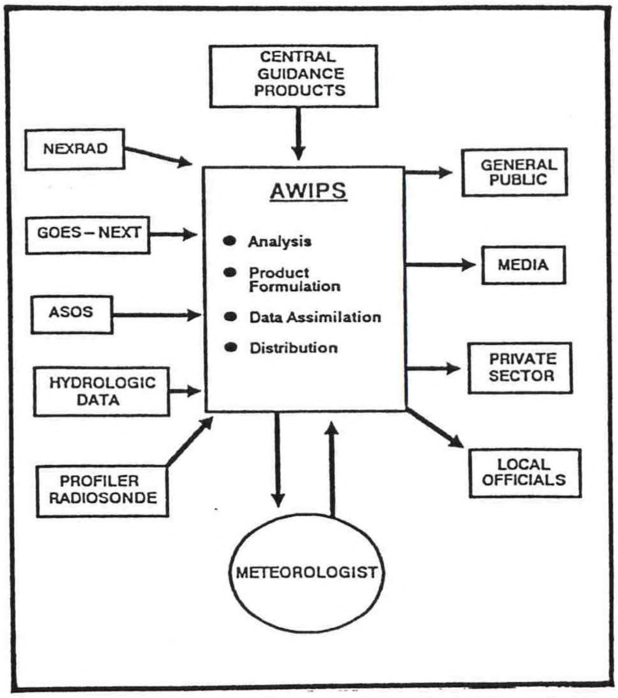

Figure 5. Conceptual depiction of AWIPS and its interface with other components of the modernization.

PROPOSED SEVERE WEATHER PRODUCT SUITE

	SOURCE	CONTENT	LEAD TIME (Hrs)	SCALE	INTENDED USE
CONVECTIVE OUTLOOK	SELS	PROBABILITY	6-36	SYNOPTIC	INTERNAL COORDINATION
READY	SELS WITH LCL ADAPTATION*	PROBABILITY	2-12	SYNOPTIC SUB-SYN	CIVIL DEFENSE PUBLIC AWARENESS
SET	FIELD OFFICE	PROBABILITY	1-3	SUB-SYN MESOSCALE	PUBLIC AWARENESS CIVIL DEFENSE
GO	FIELD OFFICE	YES/NO	0-1	MESOSCALE	PUBLIC ACTION
STATEMENTS	FIELD OFFICE	EVENT/REPORT	0		PUBLIC AWARENESS/ ACTION

* GOAL IS FOR THE FIELD OFFICES TO ISSUE THIS PRODUCT IN THE POST-1995 PERIOD.

Figure 6. Proposed operational concept of the NWS severe storm program for the year 2000.

When AWIPS becomes operational in the mid-1990's, the NWS forecaster will have the ability to utilize all of the available data for severe weather operations. The forecaster will analyze the situation by viewing displays containing integrated data sets from many different sources. The forecaster will also have decision trees, output from local flood warning systems, etc., to aid in the decision-making process during a warning situation. Once the decision to warn is made, AWIPS will assist the meteorologist in coordinating with adjacent NWS offices and disseminating the information to users in the most desirable format. AWIPS will have the ability to generate and transmit graphic warning messages to local officials and, at the same time, provide an alphanumeric warning message to NOAA Weather Radio for digital to voice transmission and access for other users. This technology frees up the meteorologist to maintain a continuous weather watch without being distracted by other duties. As can be readily seen in Figure 5, AWIPS is the essential element in the modernization for maintaining and improving the integrated warning system.

3.2 Operational Changes with the Modernization

Some changes in NWS field operations are required in order to gain the maximum benefit from the new technology. Therefore, an integral part of improving the NWS severe weather operations by the year 2000 will be transitioning of the field operations in a way that allows the NWS forecaster to best use the available technology. The primarily paraprofessional workforce of today will become a predominantly professional workforce by the year 2000.

The vast array of data that will be received from NEXRAD and augmented by that from GOES, ASOS, and profilers gives individual offices a unique data set that is of mesoscale proportions. Since most hazardous and destructive weather elements, such as tornadoes, severe thunderstorms, and flash floods, occur with mesoscale weather systems, the NWS forecaster must be able to concentrate on the subsynoptic-scale atmospheric processes. The office of the NWS of the 1990's will have characteristics that are different from those of today. A major difference will be 24-hour-a-day coverage by a staff of professional meteorologists at all offices. Also, the field office of the future will have on site the most complete data in existence for its particular area of responsibility.

It is planned for the severe weather watch function to be shifted from the National Severe Storms Forecast Center (NSSFC) to the field office. However, NSSFC will take on even greater responsibility in the restructured NWS. NSSFC will strengthen its role as a center for mesoscale guidance to t he field using the critical mass of expertise available. Another function of NSSFC will likely be one of coordinating the severe weather forecast program. Although coordination units are planned within the field structure, NSSFC will likely assume the responsibility for the overall severe weather coordination function.

Other programs, such as those pertaining to flash floods and winter storms, will function similar to the severe weather program. However, decisions have not been made at this time as to the type of coordination needed or locations from which guidance will be generated.

Within the scope of the hurricane forecast program, the National Hurricane Center (NHC) will function as a regional forecast center for the tropical cyclone program as they do today. However, beginning in 1988, NHC will assume the forecast responsibility for the eastern Pacific Ocean, formerly Weather Service Forecast Office San Francisco's responsibility.

4.0 Severe Weather Operations Concept for the Year 2000

The technology that should be available and subsequent operational configuration were discussed in the previous sections of this paper. In this section, an operations concept will be developed using the NWS of the 1990's as the basis. However, the following comparison should be kept in mind while reviewing the proposed operations concept. In today's NWS severe weather operations, the meteorologist generally detects the phenomena and then issues a warning. For future operations, the goal of the NWS will be to forecast the occurrence of the event.

The NWS severe weather operations of today is composed of a two-level system for providing information to users. These two levels are known as the "Watch" and "Warning." However, several groups studying the NWS warning program (including the National Science Foundation) have recommended a three-level warning system. For the sake of simplicity, this hierarchy of products will be referred to as "READY," "SET," and "GO." Now let's take a quick look at the three levels and the purpose and information provided for each one. (Figure 6 shows a matrix representation of this concept.)

4.1 "READY" Level

In the year 2000, the meteorologist will use guidance from regional subsynoptic-scale models along with AWIPS-generated analyses using ASOS, GOES-NEXT, and profiler data at the "READY" level. This information is designed to notify emergency management officials and sensitize the general public to the fact that a certain level of threat from severe weather exists, or will exist, in a particular area. The lead time for this level may range from two to 12 hours. Initially NSSFC will supply the "READY" information.

However, it is recognized that the local office with its unique data base will issue this product(s) after all the new technology has been deployed at NWS field offices.

4.2 "SET" Level

The NWS forecaster will use NEXRAD, GOES-NEXT, ASOS, and profiler-based mesoscale analyses generated by AWIPS in the "SET" level.

The "SET" level of information is intended to alert emergency management officials, as well as the general public, to the possibility of severe weather in the next 1-3 hours. This time frame, depending on the type of event, is expected to be sufficient for necessary preparatory actions to be performed. The "SET" information, which is based on regional scale analysis and statistical techniques, will be issued by the local field office.

4.3 "GO" Level

The meteorologist must rely, for the most part, on NEXRAD produced information at the "GO" level.

The "GO" information will be the primary warning product(s) of the future. This product will define the areas in which severe weather exists or is imminent. This product will be based on mesoscale analysis and/or actual detection of the phenomena. The time frame for the "GO" product will be generally less than one hour.

4.4 "CONVECTIVE OUTLOOK"

Another product, "CONVECTIVE OUTLOOK," would not be considered a fourth level of information. However, it would serve a useful purpose as part of the NWS severe weather program. Issued by NSSFC, the "CONVECTIVE OUTLOOK" would serve as mesoscale guidance for field offices as well as strong coordination mechanism. The "CONVECTIVE OUTLOOK" should discuss the possibility and magnitude as well as areal extent of convection over particular areas during the following 6-36 hours.

It is important to note the overlap in lead times associated with the "CONVECTIVE OUTLOOK" (6-36 hours), "READY" level (2-12 hours), and "SET" level (1-3 hours). This is intentional to underscore the uncertainty of actual lead times. The goodness of scientific techniques and the combined skill of the NWS forecasters will dictate lead times with the target lead times of each type of information evolving with time.

5.0 Summary

The information that was presented in this paper was a brief overview of the relationship of the overall modernization of the NWS to future severe weather services. It was not possible due to length constraints of this paper to provide detailed descriptions of the new technology and changes in field configuration. However, it should be quite apparent to the reader that unprecedented changes are planned over the next decade with an exciting future on the horizon. Once the automation is in place, the NWS meteorologist will be able to concentrate most of his/her forecast skill on the subsynoptic-scale weather systems (i.e., 0-36 hour time frame), with computers providing, for the most part, those forecasts beyond 36 hours. Having both a mesoscale data base and a smaller area over which to forecast, each field office should significantly improve the forecast and subsequent warning programs for those phenomena that have the most adverse effect on the American people.

6.0 Acknowledgements

I would like to thank my dedicated NWS colleagues of the Office of Meteorology and Office of Systems Operation for their diligent work in gathering information, preparing the figures, and typing the manuscript for this paper. Much of the information used in this paper was obtained from internal documents prepared by the Office of Systems Development, NEXRAD Joint System Program Office, and Transition Program Office. The efforts of all involved are greatly appreciated.

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