The NWS has extended the public comment period for the Weather-Ready Nation Roadmap through Friday, August 3, 2012. Please e-mail your comments on the Roadmap to NWS.Roadmap@noaa.gov

Dear Colleague:

The NWS Strategic Plan, *Building a Weather-Ready Nation,* anticipates the services needed by our increasingly weather-sensitive society for the next two decades, projects what science and technology may provide to meet these needs, and creates an unconstrained vision for a Weather-Ready Nation. Version 1.0 of this *Weather-Ready Nation Roadmap* is our first public draft of steps needed to make this vision a reality.

The *Roadmap* comprises four plans: Business, Services, Workforce, and Science and Technology. These plans are critical elements serving as inputs for the implementation effort.

We will revise the *Weather-Ready Nation Roadmap* over time to include feedback from both internal and external stakeholders. We also remain committed to open dialogue every time we propose specific changes in our products and services.

The National Academy of Sciences (NAS) is currently conducting a study that will identify major lessons of the previous NWS Modernization and Associated Restructuring effort and advise us on how to apply these lessons to the future. Version 2.0 of the *Roadmap* will incorporate the NAS study recommendations.

Thank you in advance for your comments on and inputs to this document. To incorporate your feedback into Version 2, please send comments by July 18, 2012 via the input form at https://apps.weather.gov/wrn/comments.php.

Sincerely,

Dr. John "Jack" L. Hayes
NOAA Assistant Administrator for Weather Services
and Director, National Weather Service
National Oceanic and Atmospheric Administration

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Executive Summary

America has become an increasingly weather-sensitive Nation, creating growing needs for better environmental information to safeguard life and protect livelihoods. More modern and integrated services from the National Oceanic and Atmospheric Administration (NOAA) and NOAA's National Weather Service (NWS) play a central part in meeting these growing needs in partnership with the whole weather enterprise.

The devastating impacts of extreme events can be reduced through improved readiness. NOAA's National Weather Service is transforming its operations to help America respond. NOAA's Next Generation Strategic Plan establishes a long-term goal of a Weather-Ready Nation, as part of a broader vision of resilient ecosystems, communities, and economies. NOAA's Weather-Ready Nation is about building community resilience in the face of increasing vulnerability to extreme weather and water events. In the end, emergency managers, first responders, government officials, businesses, and the public will be empowered to make faster, smarter decisions to save lives and protect livelihoods.

To achieve the vision of a *Weather-Ready Nation*, the agency has developed this sustainable Roadmap that lays the foundation for future NWS services. With today's increasingly complex environmental, societal, technological, and economic challenges, NWS must continually remain agile and flexible to achieve its mission to meet society's changing needs.

This Roadmap creates a practical guide to making the vision of a Weather-Ready Nation a reality. The United States has had 14 weather-related events that caused damages of a billion dollars or more in 2011 – a new record. At the same time, the current U.S. (and global) economy is placing enormous pressure on Federal budgets. The contrast between these growing societal needs and uncertain budgets makes this Weather-Ready Nation (WRN) Roadmap especially challenging: the agency needs a practical approach to building a Weather-Ready Nation that can adapt to our changing society. To manage high-impact events more effectively in the future, this Roadmap will guide the agency – and its customers – in the direction of a Weather-Ready Nation.

The WRN Roadmap comprises four sections: Business, Services, Workforce Evolution, and Science and Technology (S&T), each of which outlines the key activities and milestones the agency must achieve to implement its Strategic Plan through the year 2020. Each section of the Roadmap contains a series of underlying concepts that will enable a more Weather-Ready Nation. These concepts are summarized in **Figure ES-1. Figure ES-2** provides a snapshot of the Roadmap.

The Business Plan defines NWS' strategic business and operating goals. Strategic business objectives can be thought of as high-level, enduring principles that shape operation of the agency. The Services Plan outlines this framework, and also addresses emerging needs for NWS services to incorporate a better understanding of social and physical sciences. These emerging needs, as well as the growing demand from users for Impact-Based Decision Support Services (IDSS) and information usable by emerging and collaborative service sectors, require an innovative service approach that facilitates flexibility and agility across a wide spectrum of users. The Workforce Evolution Plan lays out a framework for the evolution of the NWS workforce – the agency's most important asset – as NWS enhances IDSS, extending NWS' capability to provide services that are superior to those provided today. Finally, the S&T Plan addresses the improvements and advances in science and technology needed to generate and deliver environmental information to realize NWS' vision of a Weather-Ready Nation.

Figure ES-1: Key Underlying Concepts of the NWS WRN Roadmap

Roadmap Section	Key Concept
Services	• Provide more complete integration into the National Incident Management System and the National Response Framework. • Improve integration of social science into NWS products and services. • Develop the Emergency Response Specialist (ERS) function to enable IDSS for rapidly evolving, high-impact weather. • Rapidly deploy from across NWS to support response to local and regional high-impact threats. • Establish an overarching capability of foundational datasets to form a Common Operating Picture (COP) to better support the weather enterprise. • Develop and refine an Impacts Catalog to document thresholds for high-impact weather. • Seamlessly link climate and weather through IDSS to support regional and local decision-making. • Leverage test beds and proving grounds to streamline infusion of new science and technology. • Partner with entities across the weather enterprise to improve communications and dissemination for high-impact events.
Workforce Evolution	• Adapt current suite of staffing profiles and skill sets to fully address emerging IDSS requirements. • Provide the requisite training to ensure that personnel are fully versed in IDSS and the COP. • Shift from product-focused service to interpretation and consultation. • Incorporate social science principles into day-to-day operations, including effective communication.
Science &Technology	• Provide comprehensive situational knowledge • Enhance the Forecaster Decision Support Environment (FDSE) capability • Improve coupled, computer-generated Earth system predictive guidance • Communicate on-demand, reliable, quantified, and comprehensible forecast confidence information • Provide agile, scalable, cost-effective data processing, management, and dissemination • Streamline and expedite symbiotic research to operations (R2O) and operations to research (O2R) activities
Business	• Be sustainable. • Be flexible and agile. • Increase value to the Nation.

Figure ES-2: NWS WRN Roadmap

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Introduction

In June 2011, National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS) published their Strategic Plan to guide the agency over the coming decades. *The NWS Strategic Plan: Building a Weather-Ready Nation* is aligned with NOAA's Next Generation Strategic Plan and is the result of a collaborative effort by NWS employees and the NWS Employees Organization (NWSEO), NOAA and NWS management, and NWS partners in the public, private and academic/research sectors. The vision of the document is to build a Weather-Ready Nation, one where society is prepared for and responds to weather-dependent events. The NWS Strategic Plan was built upon six goals:

NWS Strategic Plan Goals	
Goal 1	Improve weather decision services for events that threaten lives and livelihoods
Goal 2	Deliver a broad suite of improved water forecasting services to support management of the Nation's water supply
Goal 3	Enhance climate services to help communities, businesses, and governments understand and adapt to climate-related risks
Goal 4	Improve sector-relevant information in support of economic productivity
Goal 5	Enable integrated environmental forecast services supporting healthy communities and Ecosystems
Goal 6	Sustain a highly skilled, professional workforce equipped with the training, tools, and infrastructure to meet our mission

This Roadmap will guide the agency towards achieving each of the above goals through advancements in four areas: Services, Workforce, Science and Technology, and Business. The WRN Roadmap will examine each of the four areas in detail and provide broad guidelines and recommendations on how to steer the agency towards these goals over the coming years. Each of the following sections relates to one (or more) of the NWS Strategic Plan Goals.

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1. Services Plan

As NWS works to fulfill the vision of a Weather-Ready Nation, its diverse portfolio of service capabilities will become more focused on a framework approach that will enable the agency to provide the foundational information and IDSS needed. The Services Plan outlines this framework and addresses emerging needs for NWS services to incorporate a better understanding of social and physical sciences.

Key Term	Definition
IDSS	NWS' provision of tailored, relevant information and interpretative services to enable core partners' decisions when weather, water, or climate has a direct impact on the protection of lives and livelihoods.
Emergency Response Specialist	Operational personnel proficient in both production and delivery of decision support, including remote, on-scene services, as required by government decision-makers.
Impacts Catalog	Identifies high-impact thresholds of NWS' core partners.
Test Bed	A test bed focuses on testing a capability for scientific integrity and reliability.
Proving Ground	The proving ground will test the utility of the capability in actual operations.
Common Operating Picture	A repository of digital, extensible environmental data and forecasts, where all types of information are integrated and related to each other to facilitate their full use.

1.1. Underlying Service Concepts

As NWS works to fulfill the vision of a Weather-Ready Nation, the agency's services will be tied together by a number of underlying concepts and related activities, as shown below.

Underlying Service Concepts

- *More completely integrate into the National Incident Management System and the National Response Framework.*
- *Improve integration of social science into NWS products and services.*
- *Develop the ERS function to enable IDSS for rapidly evolving, high-impact weather.*
- *Rapidly deploy across NWS to support response to local and regional high-impact threats.*
- *Establish an overarching capability of Foundational Datasets to form a COP to better support the weather enterprise.*
- *Develop and refine an Impacts Catalog to document thresholds for high-impact weather.*
- *Seamlessly link climate and weather through IDSS to support regional and local decision-making.*
- *Leverage test beds and proving ground to streamline infusion of new science and technology.*
- *Partner with entities across the weather enterprise to improve communications and dissemination.*

1.1.1. Integration into NIMS and the National Response Framework

NWS will integrate into the National Incident Management System (NIMS), as directed by Homeland Security Presidential Directive (HSPD)-5, *Management of Domestic Incidents,* in providing its services for high-impact weather.

In addition, NWS will integrate into the interagency agreements contained within the National Response Framework (NRF), and more broadly within Presidential Policy Directive 8 related to national preparedness.

NIMS and the National Response Framework

NIMS and the NRF are companion documents designed to improve the Nation's incident management and response capabilities. While NIMS provides the template for the management of incidents regardless of size, scope, or cause, the NRF provides the structure and mechanisms for national-level policy on incident response. Together, NIMS and the NRF integrate the capabilities and resources of various governmental jurisdictions, incident management and emergency response disciplines, nongovernmental organizations, and the private sector into a seamless national framework for domestic incident response.

1.1.2. Improved Integration of Social Science

The social and behavioral sciences have created a growing body of knowledge about how humans interpret, understand, and use information in making decisions. NWS will increasingly leverage this body of knowledge in planning and delivering all NWS products and services, with a special focus on high-impact decision-making by core partners.

End-to-end social science integration starts with improving the agency's understanding of core partners' weather information needs and of weather information's effects on core partners' decision-making. It also involves quantifying uncertainty by communicating forecast confidence and risk information for better decision-making. This will involve not only new types of weather products but also more intuitive ways of presenting NWS information, including better, more user-friendly graphics. Social science will also help quantify the societal and economic benefits NWS brings to the Nation, allowing the agency to plan better programs, measure outcomes and improve performance, set targets for future improvements, prioritize investments, and communicate the Return on Investment (ROI) to the general public.

1.1.3. Emergency Response Specialists

Extreme weather threats require rapid, effective decisions by those entrusted with public safety. NWS' support of the decision-making process requires an increasing emphasis on decision assistance, while maintaining accuracy and timeliness of the agency's products and services. NWS' workforce will be trained and ready to provide such services to meet the increasing needs of government decision-makers when events such as Deepwater Horizon and the Alabama tornadoes of 2011 threaten lives and livelihoods.

Ultimately, NWS envisions that operational personnel at all field offices, national centers, regional headquarters, and national headquarters will receive training in IDSS. Training will include understanding of user information needs, production of user-friendly products and services, and communication of uncertainty and risk, so the NWS workforce will be prepared to deliver decision support services on demand.

NWS also envisions that some personnel in each office will receive advanced training and that NWS will create Senior ERSs – a group of NIMS-trained forecasters in diverse disciplines, who will serve as the first responders working on-site or remotely with core partners during a significant environmental event. Using the proven Incident Meteorologist (IMET) service approach built on NIMS management principles, NWS will provide impact information in rapidly changing response environments. Senior ERSs will be able to quickly bring together multiple offices and skills from across NOAA to provide credible, robust services to affected communities. For some events, NWS needs to be able to support a government response structure that may transition from a local to a regional event as the scope of the impact becomes better known. Increasingly, the first responders and the top government officials need the same information to respond effectively together. NWS must be able to effectively operate an organized, scalable response as the needs of the government officials become known. As the situation demands, ERSs will be embedded with core partners to enhance support during impact events and to better understand the context of the event and its impacts. ERSs will be equipped with tools necessary to conduct effective in-person, on-scene decision support.

1.1.4. Rapid Deployment

Given the range of events that threaten local and regional communities, NWS needs to be prepared to proactively address surge support situations in local NWS offices in the event of high service demand or high-impact weather events. For example, during the Deepwater Horizon oil spill, core partner requirements surged. While NWS met the core partners' requirements, the agency was forced to draw personnel from across the Nation in an ad-hoc, reactive fashion to meet the demand. Proactive concepts enabling rapid deployment are needed to streamline and accelerate the augmentation of impacted offices to meet critical service needs. This concept needs to leverage ERSs, but may also involve other skills required at another location (e.g., electronic technicians, IT support, and administrative support). These deployed personnel will be trained to meet the growing demand for decision support and to ensure continuity of operations.

1.1.5. Foundational Datasets

Core partners require easily accessible, interoperable data, available anytime and anywhere. This requirement demands more robust dissemination and decision support capabilities across a spectrum of current and emerging technologies.

NWS will work to complete the transition to digital services based on two fundamental concepts: the 4-Dimensional Data Cube and the Common Operating Picture (COP). Increasingly, complex data and information developed by users for their own decision support systems require a digitized set of NWS foundational data as an input.

NWS will implement the Data Cube, a digital repository of *all* publicly produced weather, water, ocean, seismic, climate, marine, and space weather information. Since this information will be accessible by all, the data will need to be accessible in interoperable formats and include all metadata. NWS will continue to work in partnership with the weather enterprise as the agency develops the Data Cube.

A portion of the Data Cube will contain NWS' best answer as to the current and forecast state of the environment – the COP. This subset of the Data Cube will represent "the official forecasts and observations" from NWS. Digital information within the COP will drive all NWS services and provide a foundation for the entire weather enterprise for delivering consistent weather, water and climate information.

The concept of foundational datasets enables the vision of services integration. While specific service areas will still exist, customers of NWS information will be able to assemble products and services from the foundational data themselves. Weather information may be combined with water or climate information to provide a specific product. In addition, NWS will continue to work internationally to promote the availability, exchange, and use of relevant data in the Data Cube, including those of other NOAA line offices, Federal agencies, and international information systems promulgated by the World Meteorological Organization, the International Council for Science, and others.

1.1.6. Impacts Catalog

NWS will undertake the development of an Impacts Catalog to support its increasing focus on decision support services. The Impacts Catalog will identify high-impact needs of NWS' core partners at multiple levels. High-impact events need not be catastrophic or widespread to have a significant impact on a local community or sector. The Impacts Catalog will contain summaries of the impacts of environmental events on society, and will be used to focus NWS forecasters on issuing forecasts and warnings critical to minimizing those impacts. WFOs and RFCs will lead NWS' effort to develop local Impacts Catalogs, while specific national centers will develop Impacts Catalogs for specific governmental service sectors.

Key Concept

When a forecast in the COP meets or exceeds the thresholds captured in the Impacts Catalog, both forecasters and the affected core partners will be alerted to the potential of a high-impact event. This alert will enable either party to initiate or request IDSS.

1.1.7. Seamless Climate, Weather, and Water Information

NWS users require information that span time periods from minutes and hours to years. NWS will work across NOAA's line offices to deliver seamless climate and weather information based on NOAA's best science and technology to meet the full spectrum of decision-making needs.

Key Concept

When a weather event begins to unfold, NWS ERSs will proactively support core partners throughout the event and well into the recovery phase.

Climate predictions and outlooks extend from about 2 weeks out to a year or more, and can provide an indication of potential impacts on infrastructure, agriculture, commerce, and health. These predictions and outlooks support not only traditional preparation, but also policy decision-making for mitigation and adaptation considerations. NWS field offices will play a significant role in engaging users, identifying regional and community needs, and working with NOAA's other line offices to develop and deliver climate information and decision support that will allow communities to adapt to and mitigate changing climate conditions.

Examples of climate-weather linked information needed for strategic decision-making include:

- Seasonal predictions of major spring flooding in 2011 delivered in January 2011 enabled the Federal Emergency Management Agency (FEMA), regional and local emergency managers, and communities to plan and prepare for flooding that plagued the Mississippi, Missouri, and Ohio River Basins from late March through May.
- Two-week predictions of prolonged, excessive heat allow regional and national health agencies to better prepare communities with advanced educational campaigns and positioning of supplies.
- Two-week outlooks indicating the potential for major winter storms, combined with 5- to 7-day forecasts of storm track and intensity enable air and surface transportation agencies to plan their response.

1.1.8. Pilot Projects, Test Beds, Proving Ground, and Simulation Training

NWS, as a science organization, continually enhances its science and technology capabilities to meet the Nation's needs. NWS must develop faster means of testing and fielding new capabilities as a way to meet these needs and reduce risk and cost prior to implementing new technology solutions.

NWS will continue to leverage test beds and develop an NWS Operations and Services Proving Ground. Test beds will continue the focus on assessing a capability for scientific integrity and reliability; the proving ground will assess the utility of the capability in actual operations. NWS envisions this proving ground capability will draw from across NWS, academia, core partners, and the weather enterprise in simulation, verification, and validation of new service capabilities before implementation decisions are made. To evaluate key concepts in the WRN Roadmap, NWS is embarking on a series of Pilot Projects, using the "build a little, test a little, field a little" paradigm. Results from the Pilot Projects will be communicated rapidly across the NWS, used to refine the concepts in the Roadmap, and used to define the WRN Execution Plan. Initially, six Pilot Projects will be rolled out, as described below:

Weather-Ready Nation Pilot Projects

National Weather Service Operations Center *– One-stop shop for IDSS to Federal agency-level partners, national situation awareness, and logistical planning*

Regional Operations Center *– One-stop shop for IDSS to regional-level government partners, regional situation awareness, and logistical planning*

IDSS in an Urban Environment *– High-impact decision support for transportation concerns, homeland security, and large event safety for multi-state/multi-jurisdiction partners*

IDSS in a Coastal Environment *– High-impact decision support for marine transportation, HAZMAT, tropical weather, thunderstorms, and flooding concerns*

Integrated Environmental Services *– Enabling improved IDSS for sensitive ecosystem, public health, water, and air quality concerns*

Mesoscale Meteorology Science to Operations *– Infusion of cutting-edge mesoscale meteorology research findings into IDSS operations*

1.1.9. Partner with the Weather Enterprise to Improve Communications and Dissemination

To counter the threat posed by extreme weather, NWS must communicate its forecasts and warnings quickly and effectively before, during, and after a high-impact weather water or climate event to reach as broad an audience as possible.

Emerging and rapidly changing wireless, social media, and other consumer technologies, paired with the services afforded by the COP, offer broader communications and dissemination capabilities for the entire weather enterprise. In this context, NWS will develop an enterprise-wide dissemination strategy to meet internal and external services requirements.

NWS' close partnerships with the weather enterprise in general, and especially with electronic media and other information providers in America's weather and climate industry, will continue to be an important element of the NWS communication and dissemination strategy. The agency collaborates with the electronic media during high-impact events to help develop a shared understanding of threats and avoid confusion that delays decision-making. NWS supports America's weather and climate industry by providing foundational data needed to meet the specialized needs of clients across a broad spectrum of the U.S. economy.

The Nation's early-warning system will continue to evolve through the public-private partnerships in which the COP powers a multitude of technologies, such as wireless, text messaging, and social media; and Federal programs such as the Integrated Public Alert and Warning System (IPAWS) add to enterprise capability. Different components of the weather enterprise lead in different technologies, but all work together to ensure that critical NWS information reaches the public in as many ways as possible.

1.1.10. Emerging Sector Needs and Integrated Environmental Services

Research continues to show the interwoven nature of the Earth's environment, and how interdependencies of weather, water, and climate impact the health and sustainability of the environment. A multidisciplinary approach is necessary to better understand, analyze, and forecast our Earth-atmosphere system. This involves creating environmental forecasts by combining NWS expertise on weather, water, and climate with expertise in other NOAA Line Offices and core partners. Built upon a foundation of multi-disciplinary science and technology, new and enhanced collaborative services will better leverage the strengths and assets of government agencies and partners to deliver seamless and transparent "Summit to Sea" integrated environmental services.

> **Key Concepts**
>
> - *Integrated environmental services offer NOAA and our partners, new opportunities to address increasingly challenging issues that affect our society.*
> - *NWS information can be better used as a key input into NOAA's ecological forecast systems, and into the capabilities of the weather enterprise. Growing consortia in water and climate will build partnerships that strengthen NOAA's role.*

The Data Cube and COP combine NOAA's environmental data and information and make it readily available for use with complementary information from other Federal, state, and local partners. Decision-makers will have ready access to a more robust and integrated suite of environmental data through the Data Cube. This expanded and integrated suite of geo-referenced environmental information will better provide a stronger foundation to support a spectrum of service sectors, such as hazard mitigation and resiliency, floodplain and coastal zone management, ecosystems, agriculture, climate, water supply, transportation, energy, water quality, and human health.

1.2. Impact-Based Decision Support Services

NWS' transformation to a culture of IDSS will enable NWS to accomplish its strategic goal of improving weather decision services for events that threaten lives and livelihoods. This is the overarching paradigm from which NWS will achieve its vision of building a Weather-Ready Nation.

> **Key Concept**
>
> *NWS must strive to understand:*
>
> - *What events have a high impact on its customers*
> - *How and what weather affects customers' key decisions*
> - *How to communicate uncertainty to decision-makers*

Effective IDSS will require an increased emphasis on production of accurate, high-quality forecast information, complemented by personnel trained to communicate that information to core partners. NWS forecasters will generate products and services from the foundational datasets of the Data Cube and COP. The information found in these sources, combined with a suite of products geared with specific formats for specific dissemination needs, will provide the foundation for IDSS.

Many NWS offices have already carried out decision support in their respective areas of responsibility. However, the intent is to move IDSS beyond the patchwork of offices conducting decision support and into the framework that defines how NWS conducts business as an agency.

Local communities have decision support needs – or safety and economic impacts – that are unique to their area. They are the first responders, and they must provide necessary planning and take appropriate precautionary actions. To be most effective, the local relationship should evolve and grow, where NWS sends staff members to work in the core partners' offices to better understand their mission, or vice versa. The key will be to listen and observe the decision-making process of core partners first, and then design and integrate NWS information to help them make better decisions. ***The goal is to become so much a part of the core partners' operation that they would not consider making a weather-sensitive decision without consulting with NWS.***

Impact events require close coordination and collaboration among NWS and NOAA offices and between NWS and core partners for a period of time. This coordination usually requires a response from multiple layers of government working together to mitigate societal impacts. NWS must begin providing IDSS long before a weather event impacts the area, throughout the actual event, and afterward while communities recover. Government agencies may form special task groups or emergency centers to manage these events.

To support a Weather-Ready Nation, NWS will provide IDSS to its core partners for high-impact events through the following activities:

- Developing and communicating a better understanding of the value of improved weather, water, climate, and space weather information.
- Making NWS' information indispensable to decision-makers at the international, national, regional, and local levels, particularly when life and property are at stake, by providing accurate, timely, and focused IDSS.
- Participating directly in decision-making processes fundamental to the role of government. NWS also participates in public policy decisions in the context of the agency's climate service role.

High-Impact Events

No standard, nationwide criteria define a high-impact event. It may impact millions of people or one sector, and it may vary in timing or location. It is any weather-related event that significantly impacts safety, health, the environment, economic productivity, or homeland security, such as:

- *Tornadoes, hurricanes, and tsunamis*
- *Persistent drought*
- *Thunderstorms in a congested airspace*
- *Rains that trigger flooding and cause agricultural runoff, leading to harmful algal blooms and dead zones*
- *Geomagnetic storms that disrupt energy distribution and communication systems*
- *Snow squalls at rush hour*
- *Toxic chemical release in a populated area*
- *An above-average hot day*

In providing IDSS, NWS will also seek to maintain existing and develop new trusted relationships with a variety of core partners and stakeholders from local to international levels. NWS information, as well as information leveraged from capabilities across NOAA, can be delivered to these core partners and stakeholders to help them mitigate the weather's negative impacts on society and enhance its positive ones. NWS' success depends on its ability to help decision-makers make more informed decisions.

1.2.1. IDSS Operations Concept

IDSS requires an NWS response that is adapted to suit each event and each user's decisions. The IDSS operations concept relies on highly trained and certified ERSs as the first line of defense, bolstered by an ability to escalate the response by drawing upon other NWS and NOAA resources. The incident response program of the future will encompass multiple disciplines and allow NWS personnel to respond appropriately to the type and level of any incident in the United States. Specialists within NWS will be specifically trained and certified to provide the decision-maker with the decision support required for more complex incident types. These ERSs will serve core partners remotely using cutting-edge technologies, and can deploy as embedded consultants with core partners, including Federal agencies and multi-agency command and coordination centers. The ERSs will leverage the Data Cube and the COP to query, display, or manipulate data relevant to the core partner and the needs of the incident response. These NWS ERSs will be widely available to Federal, state, and local communities for environmental incident decision support. The Workforce Evolution Plan fully describes the overall concept of NWS personnel in an IDSS framework.

> **IDSS Operations**
>
> - *NWS will understand and focus on determining what is high impact*
> - *NWS will better understand what and how weather impacts a decision from the core partner's perspective*
> - *NWS will communicate forecast uncertainty in understandable terms*

NWS will also staff Regional Operations Centers (ROCs) and the NWS Operations (Ops) Center with ERSs. The combined local, regional, and national ERS resources, in addition to other skill sets as needed, form a Rapid Deployment Team that can be used regionally or nationwide to respond to elevated incidents.

1.2.1.1. Local Response

WFOs and RFCs will lead the effort in providing IDSS at the neighborhood level. IDSS response at the local level will be coordinated across NWS using the Incident Command System (ICS) planning cycle.

> **Key Concept**
>
> *Local offices will evolve from product generators to expert decision support resources. They will incorporate societal impacts to assist local community decision-makers and the public by focusing equally on production and IDSS.*

NWS will evolve from a paradigm where the forecaster generates products based on static definitions toward a services model where the forecaster works closely with core partners to recognize their needs and provide expertise to community decision-makers. Local offices will continue to place a high priority on developing strong relationships with local core partners and community leaders to enable this paradigm. For example, forecasters will recognize the potential threat of impact based on the Impacts Catalog several days out and proactively begin alerting and informing the appropriate local community decision-makers using two-way communication tools adopted by NWS users. Information will continue to flow as the event approaches and after it occurs, and if necessary, in the post-event recovery phase.

Social scientists and storm surveys/assessments suggest that simple text products are not sufficient to convey the threat of a pending event; people often seek additional information or confirmation after receiving notification rather than taking immediate action. The traditional product-centric suite suffers from its limited ability to convey complete information, often encompasses too wide a threat window, and is subject to widely varied interpretation. To enhance the completeness of information, NWS will develop future products from foundational datasets, with a focus on social science inputs and testing and evaluation both at test beds and the NWS Operations and Services Proving Ground. Examples are a combination of text, graphics, and imagery. To support improved decision support, services need to evolve to real-time, interactive communication of information, forecast, and risks that aids community decision-makers.

Forecasters at the local level will retool their production capabilities to emphasize a more robust capability to provide IDSS. The S&T Plan details an approach to the forecast process to enable this evolution. As the focus shifts away from production and toward IDSS for local decision-makers, the Weather Forecast Office (WFO) will manage and deploy ERSs to meet the needs of the community. With a staff trained in NIMS principles and personnel dedicated to IDSS, each WFO and RFC, serving as NWS' neighborhood service center, will have the ability to provide on-demand support to core partners.

WFOs and RFCs will maintain an IDSS watch function using alerts that originate from the Impacts Catalog, cross-referenced against the COP, and that inform both the WFO and the core partners when potential impacts may occur. These alerts will enable on-demand IDSS. Local office management will maintain responsibility for managing the initial NWS response to the community within the office's service area. An Emergency Response Specialist will respond from the local WFO within minutes of notification of an incident. This response may be provided remotely or on-site.

Key Concept

As part of improved decision support, services need to evolve to real-time, interactive communication of information, forecast, and risks that aids community decision-makers.

Local decision support provided at this level can be characterized as follows:

- The impact of this response rarely spans more than a few offices due to the unique nature of the impact. Many local community decision-makers consider these local impacts most critical to their community. A wildfire affecting a community would be an example.
- The services that the local community requires are often a unique mixture of data, information, and one-on-one communication, and the local office serves as an environmental expert resource to the community.
- The trust developed at this level is critical for local communities to respond effectively to potential high-impact events. Ongoing relationships build that trust. The community then trusts that NWS will be there to support them and that NWS information is reliable and useful.

Once initial community response is established, NWS will manage additional response from the regional or national levels as needed.

1.2.1.2. Regional Response

While many incidents start locally, the response needed can quickly escalate beyond the community level. The affected NWS regional headquarters will stand up a ROC to address the next level of planning within NIMS. As incident responses become more complex, the community response will escalate accordingly. This escalation will be coordinated using the NIMS planning process involving the local office, as well as ROCs, RFCs, the NWS Ops Center, and the national centers. For example, the local wildfire cited in the previous section could quickly escalate into a fire that threatens a much larger area and exceeds the capability of the local office.

Regional Operations Centers

ROCs, staffed with ERSs, activate during events requiring an elevated NWS response. ROCs have the capability to run 24x7 if required to support regional core partners and local offices. They maintain situational awareness of activities and impacts within the region, track local office IDSS efforts, and facilitate information management of regional impact events to the NWS Ops Center.

The goal of the ROC is to enable IDSS at the local level, and to serve as an additional resource for local offices during high-impact events. Each ROC accomplishes the following duties in support of IDSS:

1. Each ROC works with regional- and state-level core partners, in a role analogous to the WFO in communities, to build relationships, consolidate and refine Impacts Catalogs, and align NWS IDSS capabilities to regional core partners.

2. The ROC provides IDSS to regional- and state-level core partners. In this capacity, decision support that the ROC provides assists key regional groups, such as FEMA, the U.S. Army Corps of Engineers (USACE), the U.S. Geological Survey (USGS), the U.S. Environmental Protection Agency (EPA), and other Federal- and state-level agencies, in making decisions related to response. ROC IDSS will lead to more pre-disaster declarations, and after an event, proactive post-disaster IDSS will support FEMA Regions as they receive requests for assistance after an event.

3. In support of local offices during a contingency response, each ROC plays a role analogous to that of an Emergency Operations Center (EOC) function in the NIMS framework. The primary support the ROC provides to the field offices during an elevated incident include:
   a. Assignment of an NWS Incident Lead
   b. Jurisdictional oversight of IDSS services provided by local offices
   c. Provision of equipment and personnel as requested by the responding offices
   d. Coordination of regional response activities with other NOAA/NWS offices
   e. Submission of required situation reports to the NWS Ops Center

Using the NIMS planning process, the ROC works in conjunction with local offices involved with the response, and the NWS Ops Center, to complete these functions:

1. In close coordination with other ROCs, the NWS Ops Center, and the National Fire Weather Operations Coordinator (NFWOC), each ROC manages deployment schedules of Emergency Response Specialists from and within their area.
2. Each ROC helps to allocate resources to re-establish operations (continuity of operations).
3. The ROC provides 24x7 support when needed and assumes the role of the EOC within NIMS. The ROC assigns personnel where they are needed for as long as they are needed.

1.2.1.3. National Response

NWS has resources to leverage on occasions when an incident grows beyond the local and regional levels of response, or when an incident starts immediately at a national or international response level.

When an incident grows beyond the local and regional levels of response, or when an incident starts immediately at a national or international response level, the NWS has a national IDSS response capability within Headquarters. The NWS Operations Center (NWS Ops Center) is an operational component of headquarters, and is physically staffed with ERSs. The NWS Ops Center serves as a central contact point for all NWS information gathered from the community level to the international level. In addition, the NWS Ops Center will work collaboratively with NOAA's National Ocean Service (NOS), Office of Response and Restoration (OR&R) National Hazards Response Center, to coordinate NWS participation and NOAA's response. Personnel have appropriate security clearances to handle classified information.

In addition to this group, the NWS Ops Center will leverage capabilities across NWS by managing a matrixed structure that maintains nationwide vigilance over high-impact events. Key functions of the NWS Ops Center group include:

- Anticipate, plan, and communicate extreme high-impact events in partnership with ROCs and NCEP.
- Collect, consolidate, and forward reports from NWS resources deployed to national partners (the Department of Homeland Security's National Operations Center (NOC), FEMA's National Response Coordination Center (NRCC), Centers for Disease Control (CDC) operations) to ensure consistent information management and situational awareness.

- Manage information about national impact events collected from ROCs and NCEP. All information flows through the NWS Ops Center, which in turn provides briefings and situation reports to NWS/NOAA/Department of Commerce leadership.
- Provide a one-stop reporting capability for ROCs and field offices. Existing infrastructure of multiple reporting requirements for systems, services, outages, and personnel are streamlined into one common protocol.

The National Centers for Environmental Prediction (NCEP) also plays a key role in partnership with WFOs and RFCs, and for providing IDSS to national- and international-level core partners, and also for providing IDSS for incidents that require a national-level perspective. NCEP maintains an IDSS functionality that responds quickly to requests from other NWS offices and from core partners. During events of a multi-regional, national, or international scope, NCEP Emergency Response Specialists provide IDSS in close coordination with the NWS Ops Center, and with the involvement of the appropriate ROCs. This approach ensures continuity of message and service.

National Centers for Environmental Prediction (NCEP)

- *Central Operations*
- *HPC: Hydrometeorological Prediction Center*
- *SPC: Storm Prediction Center*
- *SWPC: Space Weather Prediction Center*
- *CPC: Climate Prediction Center*
- *AWC: Aviation Weather Center*
- *EMC: Environmental Modeling Center*
- *NHC: National Hurricane Center*
- *OPC: Ocean Prediction Center*

Many of the above centers also provide international support.

NCEP offers expertise in IDSS across many disciplines. The Hydrometeorological Prediction Center (HPC) focuses on Quantitative Precipitation Forecasts (QPFs) and snowfall, SPC on severe convective weather and fire weather, NHC on tropical weather in the Atlantic and eastern Pacific, OPC on open-water concerns, SWPC on space weather and related impacts, CPC on climate IDSS, and AWC on national aviation IDSS. Other NCEP units such as EMC and NCEP Central Operations focus more on the production aspect of the COP and Data Cube, ensuring the quality and timeliness of information needed for all levels of the agency to facilitate both production and IDSS.

Internationally, the Pacific Region ROC serves the agency's IDSS needs for aviation, marine, and tropical cyclone information covering portions of the southern, central, and western Pacific. NWS' Tsunami Warning Centers focus on IDSS for tsunamis in their areas of responsibility, and the International Tsunami Information Center supports capacity development and education globally. In addition, the Volcanic Ash Advisory Centers (VAACs) will continue to provide volcanic ash advisory services to meet international aviation requirements.

1.2.1.4. Management of NWS Response at All Levels

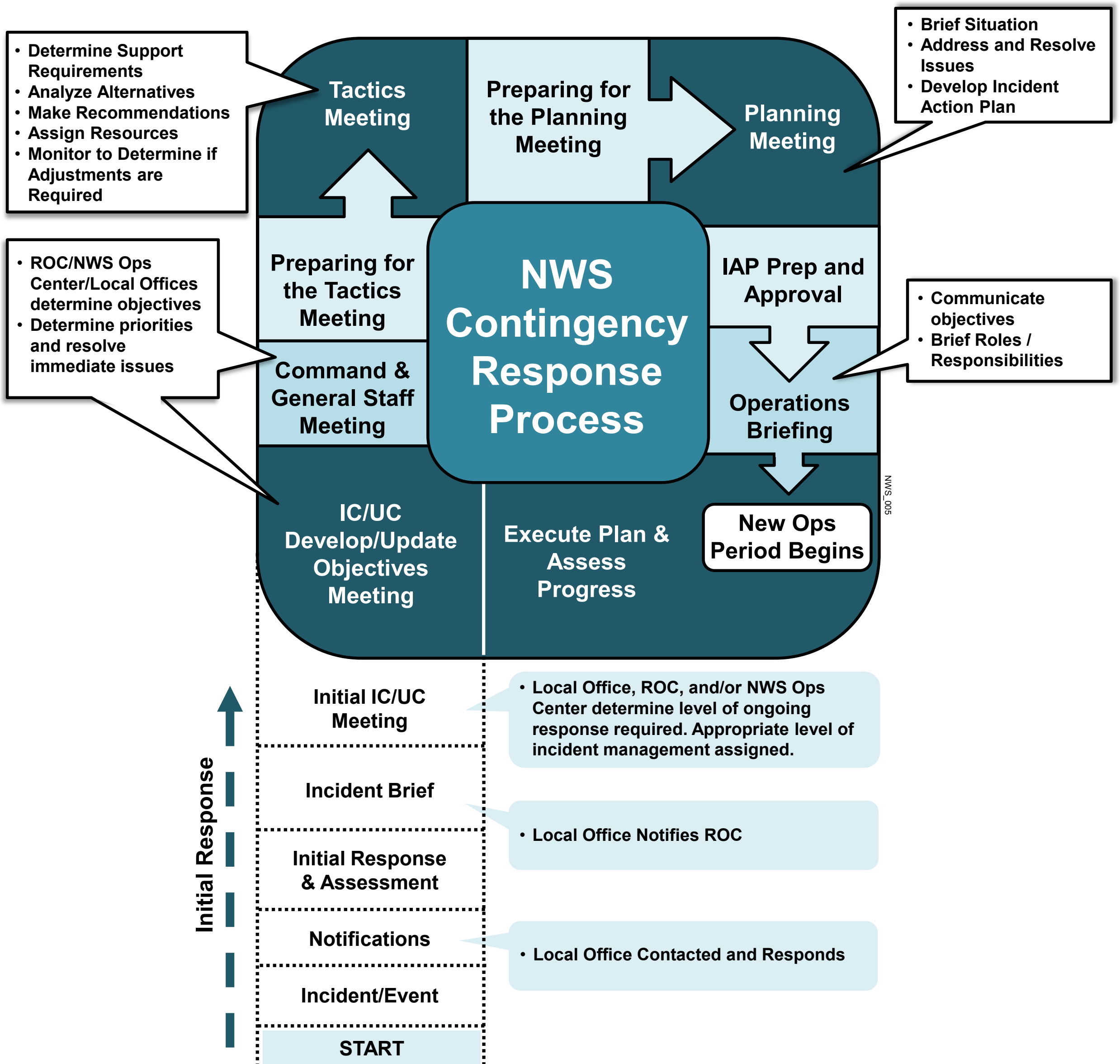
Escalation of contingency response will evolve as NWS adopts the "Planning P" component of ICS (see **Figure 1-1**), which enables a cycle of continuous planning and adjustment within an incident's operational period. Working closely with Incident Command, NWS resources will ramp up or draw down based on the needs of the core partner(s) requesting NWS services.

Scenario: Local to Regional/National Response Planning Cycle

An accident occurs at a coastal petrochemical plant. Weather support from the WFO or RFC is requested, including wind information and possibly dispersion model runs for the incident. The incident is not contained, and a tropical storm is forecast to approach the area. The plant is also located along a river that could easily be contaminated.

NWS utilizes the "Planning P" to effectively manage its response and match NWS resources to core partner needs, using an operational period and methodology that coincides with the core partner's own approach in managing the incident.

Figure 1-1: Incident Response Process – the ICS "Planning P"



*** PRE-DECISIONAL** DRAFT DOCUMENT*

1.2.2. Key Activities to Evolve IDSS

NWS project managers will assume responsibility for, and execute, the specific activities summarized in **Figure 1-2**.

Figure 1-2: Activities to Evolve IDSS

Short-Term 1-2 Years	Mid-Term 3-5 Years	Long-Term 5+ Years
Design, develop, and launch the NWS Operations and Services Proving Ground	The National Weather Service Training Center and Warning Decision Training Branch develop training capabilities; begin to conduct simulation training for Emergency Response Specialists	Access point to the COP is realized, which fully enables complete IDSS provision ERSs/Senior ERSs show core partners how to interact with the COP
Define and develop IDSS training program to certify ERS	Develop IDSS toolkit from evolving COP capability	NWS Ops Center, ROC, and local offices provide IDSS at all levels
Define concept; plan and execute NWS Ops Center pilot	Implement remaining NWS Ops Center structure	NWS is full partner with National Ocean Service/OR&R in the NRF; long-term IDSS missions are reimbursable under interagency agreements
Define concept; plan and execute Regional Operations Center Pilot Projects	Formally staff ROCs and standardize ROC operations in conjunction with NWS Ops Center/ROC/local operations concept	ERSs and Senior ERSs realized across the agency
Define concept; plan and execute local office ERS Pilot Projects	Based on results of the Pilot Projects, assess IDSS needs by office; develop possible staffing models	Determine best staffing model and execute
Identify expansion of NWS IMET program concepts to a new NWS IDSS program that is nationwide, is multi-disciplinary, and represents the agency's ERSs, who can serve on different types of incidents	Execute these concepts into NWS IDSS program	Assess these changes
Identify changes to NWS Directive system to reflect high-impact events based on societal impacts and the growth of the "local science expert" component of services	Execute these changes to NWS Directive system	Assess these changes
Develop implementation plan for NWS WRN Roadmap	Execute implementation plan	Assess the implementation plan

1.3. Common Operating Picture

Key Concepts

- *Technological advances will allow NWS to transmit and display digital and graphical forecast information on previously unheard-of scales.*
- *The forecast process will produce the COP, a repository of digital, extensible environmental data and forecasts, where all types of information are integrated and related to each other to facilitate their full use.*
- *NWS' COP capability will enable all users to pull consistent information and assemble it in a manner that meets their needs.*

Technological advances will allow NWS to transmit and display digital and graphical forecast information on previously unheard-of scales. The sheer volume of information coming in will require that NWS overhaul its methods of generating forecast information. This will enable NWS to take full advantage of improving numerical model guidance in support of core partners and the public.

The forecast process will produce a Common Operating Picture (COP), a repository of digital, extensible environmental data and forecasts, where all types of information are integrated and related to each other to facilitate their full use. The COP will serve as NWS' single authoritative source for observations and forecasts, and will represent the "best information" NWS has on the environment. Quality-controlled observational data will be found within the COP. Forecast data will include the deterministic forecast, as well as the forecast confidence that will be refined to better enable the development of scenarios (most likely, worst-case) for use in IDSS. Additional forecast information on the climate scale (at least a year into the future) will also be included to facilitate IDSS on seasonal projections of weather such as hurricanes, severe weather, winter weather, and flooding. This climate-scale information will also facilitate IDSS. Information within the COP will be supplied in industry-standard formats directly compatible with users' own systems, thus allowing NWS information to be directly used to manage decisions, resources, and mitigation within users' own decision support systems.

As the COP evolves, an additional capability could be the inclusion of environmental data from other NOAA line offices, which would produce a single, NOAA-wide environmental data repository.

The concept of "one-size-fits-all" products is evolving to the provision of forecast information in a format that allows forecast elements to be saved and geo-referenced. This is in contrast to today, where NWS sends text products that the agency itself has to decode to use more broadly in IDSS. NWS production work will serve as building blocks in user systems, as well as within NWS systems, to facilitate fully formatted information for those who need a finished product. All NWS products will be produced from the COP. IDSS will be provided from the COP and the broader Data Cube. Since all NWS offices will produce their content from the COP, customers on all scales will get a consistent message.

The concept of this system combines improved spatial and temporal resolution in guidance models with state-of-the-art techniques to create a high-quality starting point for the forecast cycle. This starting point facilitates a more collaborative forecast for the COP with considerably less effort from forecasters at the local level. Forecasters will also receive feedback on impacts (from the Impacts Catalog, described in Section 2.2.6) to focus production attention where it is needed the most. This heightened focus will serve to produce the maximum amount of lead time and spatial precision possible from NWS information.

1.3.1. Quantification and Communication of Forecast Confidence

The COP will contain not only the "best" or "single-value" forecast, but also information related to the uncertainty inherent in the single-value forecast; this information will be quantified in probabilities, the language of uncertainty. IDSS demands will drive an increase for the need of uncertainty measures in forecasts and observations. The probabilistic forecasts must be scientifically calibrated to enable users to make effective decisions and mitigate risk. Single-value forecasts must be accompanied with uncertainty information in a form users can readily understand.

IDSS requires NWS to provide community decision-makers with as much lead time as possible for potentially high-impact events, to allow them time to plan and prepare. These community decision-makers are tasked to better anticipate and manage resources in these evolving economic times.

1.3.2. Activities to Evolve the Forecast Process

NWS will assign project management responsibilities and execute the specific activities summarized in **Figure 1-3**.

Figure 1-3: Activities to Evolve the Forecast Process

Short-Term 1-2 Years	Mid-Term 3-5 Years	Long-Term 5+ Years
Collaboration with research enterprise to develop next-generation forecast process	Deploy initial Data Cube and COP services; COP represents next-generation National Digital Forecast Database (NDFD) and meets service requirements for NextGen Initial Operating Capability (IOC)	Warn-on-forecast is evaluated and placed into service for severe local storms
Complete transition of digital services to finish the NDFD	All NWS legacy text products and web forecast products are formatted from the COP instead of local databases	Finalized Data Cube and COP are deployed and meet service requirements for NextGen IOC
Forecasters transition to focus on modifying NDFD grids for high-impact events (initial “forecaster-over-the-loop” effort)	Develop and test tools to enable rapid grid modification	Tools are deployed

1.4. Integrated Environmental Services

Research continues to show the interwoven nature of the Earth’s environment, and how interdependencies of weather, water, and climate impact the health and sustainability of the environment. A multidisciplinary approach is necessary to better understand, analyze, and forecast the Earth-atmosphere system. This involves creating environmental forecasts by combining NWS expertise on weather, water, and climate with expertise in other NOAA line offices and core partners. Built upon a foundation of multi-disciplinary science and technology, new and enhanced collaborative services will better leverage the strengths and assets of government agencies and partners to deliver seamless and transparent “Summit to Sea” integrated environmental services.

The Data Cube and COP will combine NOAA’s environmental data and information and make it readily available for use with complementary information from

Key Concepts

- *Integrated environmental services offer NOAA and our partners new opportunities to address increasingly challenging issues that affect our society.*
- *Through integrated environmental services, NWS information can be better used as a key input into NOAA’s ecological forecast systems, and into the capabilities of the weather enterprise. Growing consortia in water and climate will build partnerships that strengthen NOAA’s role.*

other Federal, state, and local partners. Decision-makers will have ready access to a more robust and integrated suite of environmental data through the Data Cube. This expanded and integrated suite of geo-referenced environmental information will better provide a stronger foundation to support a spectrum of service sectors, such as hazard mitigation and resiliency, floodplain and coastal zone management, ecosystems, agriculture, climate, water supply, transportation, energy, water quality, and human health.

1.4.1. Water

Managers and decision-makers in all sectors of water resources require more integrated information and services to adapt to uncertainty associated with increasing stresses due to climate and land use change, economic development, population growth, regulation, and competing demands for limited resources. Water is a powerful force. It cultivates our food, supports our economies and livelihoods, and provides avenues for transport. Water also presents challenges: too much, too little, too fast, or poor quality can spell disaster.

From 1955 to 2008, floods in the United States caused more than $252B (in 2008 dollars) in damages. Flood waters transport contaminants, while droughts increase contaminant concentrations, both adversely affecting water quality. Water quality impacts human health and the health of rivers, lakes, and coastal estuaries. Poor water quality can lead to compromised water supplies, closed beaches, harmful algal blooms, coral reef destruction, fish kills, and widespread death of marine wildlife.

The nature and potential impacts of water-related issues vary across the United States. The amount of rain falling in the heaviest downpours has increased approximately 20 percent on average in the past century, with the largest increases in the wettest places. This has been especially noteworthy in the Northeast, where the number of days with very heavy precipitation has increased by more than 50 percent during the past 50 years. In contrast, observations show that extended dry periods have become more frequent in the Southwest over the past several decades.[1]

To address these growing societal issues, future water resource services will leverage the digitized geo-referenced information found in the Data Cube and COP, system interoperability and data synchronization resulting from the implementation of the Integrated Water Resources Science and Services (IWRSS) consortium, a National Water Center (NWC), IDSS, and emerging science and technology including the Community Hydrologic Prediction System (CHPS) and the Hydrologic Ensemble Forecast Service (HEFS).

Key Concept

Future water resource services will leverage digitized geo-referenced information in the Data Cube and COP, and the implementation of the IWRSS consortium.

[1] Intergovernmental Panel on Climate Change, 2007.

1.4.1.1. Integrated Water Resources Science and Service

> **Key Concept**
>
> *IWRSS will unify and leverage each stakeholder agency's expertise to improve water resource forecasts, understand how water moves across the land and rivers, and facilitate creative and informed decisions.*

Water issues are inherently multi-disciplinary. The NWS predicts where, when, and how much water will come from the skies as rain or snow and move through the rivers and streams. Moreover, NOAA provides services for the U.S. coastal and marine systems that receive water from the land and rivers as it flows back to the sea. NOAA line offices are coordinating their research to operations (R2O) activities in support of improved freshwater resource management. Closing gaps in this coordination requires a seamless integration of data, information, and services through a common operating framework across agency boundaries. Establishing this framework will require system interoperability and data synchronization between NOAA and its Federal partner water agencies. Toward that end, in 2011 NOAA signed a Memorandum of Understanding and subsequently launched a new partnership called IWRSS with USGS and USACE. Other agencies will be added as this partnership evolves. This new business model for interagency collaboration will facilitate expanded and routine sharing of technology, science, models, information, and best practices to more effectively leverage each agency's investment in water resource services.

Through IWRSS, NOAA and Federal partner water agencies will implement a broad and integrated system to serve as a reliable and authoritative basis for next-generation adaptive water-related planning, preparedness, and response activities. Improved and expanded services will support high-impact events and routine high-value decisions. IWRSS integrates services at the national, regional, and local levels.

The National Water Center (NWC) is a primary catalyst to achieve the IWRSS strategy and can be thought of as the "Nerve-center of IWRSS". The NWC will become the first-ever U.S. center for water forecast operations, research and collaboration across Federal agencies. This will enable the NWS, in partnership with other Federal agencies, to provide emergency managers and the public with detailed maps that show explicit locations and impacts of flooding for faster and more effective evacuations. It will also support the development of new forecasts for water supply and availability, helping communities become more resilient to floods. The center will deliver a new generation of information and services to mitigate water-related disasters, inform routine decision-making about water, and address competing demands for increasingly limited water availability.

1.4.1.2. Regional Level – River Forecast Centers

> **Key Concept**
>
> *RFCs will evolve into regional WRFCs to facilitate IWRSS partnerships and provide enhanced water resource services.*

The critical water intelligence information produced by the NWC will enable today's RFCs to fully leverage the capabilities of CHPS and HEFS to serve as regional Water Resources Forecast Centers (WRFCs) within their respective geographic regions. The concept of the River Forecast Center (RFC) will evolve from a river forecast service center to a forecast service center for river water resources. The WRFCs, working in collaboration with the NWC, will focus the facilitation of IWRSS partnerships at the regional level, provide an expanded suite of water resource forecasts and information, ensure data and forecast consistency, provide regional-level water resources IDSS, and strengthen regional coalitions.

1.4.1.3. Local Level – WFOs

WFOs will serve as water resources extension agents at the community level. WFOs will execute water resources IDSS as a part of their neighborhood IDSS mission. As with NWC and the WRFCs working collaboratively at the regional level, the WFOs will facilitate IWRSS partnerships at the local level, provide an expanded suite of water resource forecasts and information, ensure data and forecast consistency, and strengthen local partnerships. Information and services to be provided by WFOs include:

> **Key Concept**
>
> *WFOs will serve as water resources extension agents at the community level, working with WRFCs to execute IDSS as part of their neighborhood mission.*

1. Provide warning and hazard information services tied to IDSS efforts.
2. Utilize geo-referenced inundation maps showing forecasted spatial extent and depth of flooding.
3. Engage core partners and stakeholders.

1.4.2. Climate Services

NWS' community presence facilitates NOAA's efforts to identify and address the climate-related needs of decision-makers. Forecasters serve as a key resource to link climate to water and weather services by providing scenario-based forecasts; participating in tabletop exercises for various scenarios; and ultimately responding to the event before, during, and after it occurs to provide a holistic approach to IDSS.

> **Key Concept**
>
> *ERSs will serve as a key resource to link climate to water and weather services to help the Nation address environmental impacts.*

Demand continues to increase for climate information. This results from the heightened awareness of potential impacts from climate variability and change. A better informed public demands better NWS information, including data and their potential applications and limitations. NWS' challenge is to communicate more effectively to a nonscientific audience. An expanded training and outreach effort will be critical to NWS' goal of reaching an expanded public and will equip the NWS workforce to understand climate's impacts on society. Climate change has an impact on ecosystems, livelihoods, the environment, and health. Data stewardship will be one of the agency's highest priorities as NWS continues to be the Nation's unbiased broker of climate observations and data.

1.4.2.1. Framework for Climate Services

NWS will enhance a framework for state-of-the-art approaches to dissemination of comprehensive environmental information. This framework for climate services will work within the COP and Data Cube, and will help provide linkages between climate, water, and weather services. This framework, working within the S&T Plan's priority capability of R2O, will provide the mechanism for:

- Transitioning to operations of appropriate capabilities
- Developing applications that draw on operational systems and research advances to respond to societal needs for information
- Ensuring that observational systems are assimilated into research, operations, and products
- Leveraging and augmenting the existing service delivery infrastructure for provision of decision support services and decision support assistance to the Nation

- Coordinating the gathering of user requirements and consolidation of user feedback to ensure effective incorporation into all efforts, including those provided by the framework for climate services.

Outreach and education will play a key role in establishing this framework within the COP and Data Cube. NWS will also use the Partners Exchange Program (PEP) to better incorporate operational insights from the weather enterprise into NWS policy and planning processes.

1.4.2.2. Regional and Local Climate Services

Key NWS resources will align to provide IDSS and foundational information services to core partners at various levels. Climate services provided by NWS represent a comprehensive approach using many different resources across NOAA to meet customer needs. Existing NOAA climate programs, as well as NOAA and other Federal agencies' research programs, will be critical to the foundational dataset needs. Existing mechanisms across the Federal Government will play critical roles in outreach, education, and delivery of this information to core partners.

NCEP, ROCs, and local offices will work collaboratively to address the climate needs of national, regional, and local customers. ROCs and RFCs will champion the bridging of local climate needs and services with the national level, and ensure seamless services between the various components of NWS, NESDIS, the NOAA Office of Atmospheric Research, Regional Climate Centers, and other groups such as state climatologists and local academia.

Ultimately, NWS ERSs will serve as a conduit into the wealth of climate information available to assist core partners in decision-making. Local climate services that link climate to water and weather services will be a critical component of IDSS. For example, establishing conditional climatology based on El Niño Southern Oscillation (ENSO) phase for number of tornado days and number of significant tornadoes in the North Central United States will allow users to anticipate most likely convective activity, provide warning during years when enhanced preparedness may be needed, and answer questions from core partners regarding potential activity in a season. Tools such as the Local Climate Assessment Tool (LCAT) will be critical to providing this capability.

Scenario-based forecasts will enable ERSs to work collaboratively with core partners to run exercises based on scenarios. These exercises will ultimately enable NWS and core partners to learn about potential impacts and each other's capabilities. Thus, when an event unfolds, IDSS based on weather and water forecasts will benefit from this prior work and allow for more effective decision-making on the part of core partners.

1.4.2.3. Climate Observations and Data Services

Climate observations and data services will evolve from being product-centric to information-centric, and will allow users to tailor historical information to meet their specific needs. Data that span spatial and temporal scales will be provided in industry-standard formats through the Data Cube and the COP. The information-centric approach will allow users to view information (e.g., maps and graphs) for their unique data and format requirements at their preferred time and space scales. NWS will continue to rely on partnerships with the National Climatic Data Center (NCDC) and the Regional Climate Centers to archive and preserve data for use in monitoring ongoing climate perspectives.

1.4.3. Ecological Forecasting

Ecological forecasts – the prediction of the impacts of physical, chemical, and biological change on ecosystems and their components – are at the cornerstone of NOAA's ability to protect lives and livelihoods, enhance economic security, and meet its stewardship mandates. The American public and coastal managers are increasingly demanding early warning of environmental changes and related impacts to protect lives and livelihoods, promote coastal community resilience, and sustain ocean and coastal environments and their economic benefits.[2]

NOAA's National Ocean Service (NOS) leads the agency's integrated environmental services. NWS plays a supporting role with NOS and other line offices and agencies to bring an enabling infrastructure to the ecological forecasting process, and provides capabilities to predict physical parameters that support ecological forecasts. Equally important is NWS' service delivery infrastructure, which features a broad network of offices that can disseminate local and regional ecological forecasts. In coordination with various Federal and state and local agencies and the ecosystem research and management communities, NWS can enable comprehensive and integrated environmental predictions. These leverage existing operations (i.e., numerical modeling) to produce forecast guidance and field offices to enhance user engagement and service delivery.

Today, many organizations rely on NWS data and hydrometeorological, model-derived information for ecological forecasts, but this information is not well applied to biological and ecosystems management or routinely used for the protection of oceans and human health. NWS data and information are often difficult to locate and integrate with the relevant biological or biogeochemical models and tools of the user communities. The COP will seamlessly integrate weather, water, ocean, and climate data over broad spatial and temporal scales to enable ecological forecasting and innovative applications for improved ecosystem management. Increased emphasis on IDSS will support the correlation of ecological forecasting services to better decision-making (e.g., closing or opening of beaches or fishing grounds, optimized use of fertilizers and pesticides, or coastal and marine spatial planning). NOAA line offices can leverage NWS' IDSS capabilities to share their public service announcements with the public, related to eco-alerting and health support services. This type of sharing will be commonplace in the IDSS-driven services of the future.

An Example of Eco-Alerting

The following eco-alert was provided by one of our NOAA partners and transmitted through NWS dissemination channels:

"State health officials would like to remind residents that paralytic shellfish poisoning, or PSP, is an ever-present danger in locally harvested shellfish – including clams, mussels, cockles, and oysters. PSP can cause a tingling sensation in your lips and fingertips, followed by numbing of your arms and legs, and in some cases can lead to death. Anyone experiencing these symptoms should seek immediate medical care. Remember, PSP cannot be cooked or cleaned out of shellfish, but commercially grown shellfish is tested and considered safe."

[2] E.T. Cloyd, A.P. Leonardi, D.L. Sheurer, E.J., Turner, and the NOS Modeling Prioritization Group, "Establishing National Ocean Service Priorities for Estuarine, Coastal and Ocean Modeling: Capabilities, Gaps, and Preliminary Prioritization Factors," NOAA Technical Memorandum NOS NCCOS 57, June 2007, http://www.cop.noaa.gov/ecoforecasting/workshops/MPP_finalreport_0107.pdf.

1.4.4. Activities to Evolve Integrated Environmental Services

Figure 1-4 contains examples of activities NWS will undertake to evolve environmental services.

Figure 1-4: Activities to Evolve Integrated Environmental Services

Short-Term 1-2 Years	Mid-Term 3-5 Years	Long-Term 5+ Years
Water Services		
IWRSS to stand up a flood inundation mapping team	Demonstrate IWRSS flood inundation mapping	Full IWRSS flood inundation mapping for high-impact watersheds
Nationwide implementation of the Community Hydrologic Prediction System (CHPS) at all 13 RFCs	Demonstrate IOC for the National Water Center	Fully functioning National Water Center
Demonstrate the Hydrologic Ensemble Forecast Service (HEFS)	Nationwide implementation of the HEFS	National, regional, and local offices provide expanded river forecast confidence information to support IDSS and routine high-value information for decision-makers
Climate Services		
Expand the amount of data available to the public through NWS web pages in partnership with the NCDC and the Regional Climate Centers	Provide tools to WFOs and RFCs that will better handle the processing of historical weather data in order to streamline the ingest and quality control of the data	Fully integrate historical weather data in the operational process including use of GIS to better visualize the data
Introduce LCAT for NWS local climate studies in response to user needs	Develop local climate impact expertise in NWS local offices utilizing LCAT	Integrate LCAT into IDSS operational process
Enhance climate services by developing climate-related outreach brochures and “smart charts”	Develop a pool of relevant climate resources for use at local, regional, and/or national levels, which can also be used for educational purposes	Link IDSS operational routine with rich pool of climate outreach resources
Formalize the NOAA/NWS collaborative efforts with the Department of Energy (DOE)	Provide NWS wind climatology forecasts and training tools for DOE use	Incorporate emerging sector needs in delivery of NWS climate services
Make health warnings and alerts in conjunction with the release of routine NWS weather, water, and climate products	Close collaboration with the health community will result in the development of IDSS tools, such as an Impacts Catalog of climate indicators that are known to cause adverse health conditions	Decision-makers in the health community will better plan for and minimize risk to people and communities by incorporating NOAA weather, water, climate, and environmental observations, predictions, and data early in their decision-making process

1.5. Emerging and Collaborative Service Sectors

Key Concept

NWS' underlying service concepts, when implemented, will enable greater collaboration with emerging Arctic, space weather, aviation, surface transportation, renewable energy, and public health service sectors.

The underlying service concept of NWS information in foundational datasets enables integration of NWS services across a broad spectrum of emerging and collaborative services sectors.

In these areas, NWS will be the pre-eminent source of foundational data, and complement these data with decision support services to enable integration of this information for sectors including the Arctic, space weather, aviation, surface transportation, renewable energy, and public health. NWS will develop partnerships between the private sector and other government agencies to provide the most efficient service delivery to these emerging sectors.

1.5.1. The Arctic

Key Concept

The Arctic region is vulnerable and prone to rapid change. NWS foundational datasets and IDSS will enable a future where the global implications of Arctic change are better understood and predicted.

The Arctic has profound significance for climate and functioning of ecosystems around the globe. The region is vulnerable and prone to rapid change. Increasing air and ocean temperatures, thawing permafrost, loss of sea ice, and shifts in ecosystems are evidence of widespread and dramatic ongoing change. Critical environmental, economic, and national security issues are emerging, many of which have significant impacts for human lives, livelihoods, and coastal communities.

NWS foundational datasets and IDSS will enable a future where the global implications of Arctic change are better understood and predicted. The changing NWS service model focusing NWS resources on IDSS will better support the need for products and services related to the rapid changes being experienced in the Arctic. The following areas present opportunities for service improvement within the Arctic.

1.5.1.1. Sea Ice Forecasts

Improving sea ice forecasts and new seasonal prediction services in partnership with NOAA line offices will fill a critical gap in marine weather and climate services. Improved services will benefit communities, management of protected marine resources, and operations and navigation through these waters as marine transportation and industry use expands. Multi-decade sea ice projections are required for infrastructure planning, ecosystem stewardship under rapidly changing conditions, and projection of global climate impacts forced by changes first occurring in the Arctic. The ability to better predict changes in sea ice, and its linkage to hemispheric weather patterns, is necessary to achieve improvements in weather and climate forecasts for the Arctic and northern mid-latitude regions.

1.5.1.2. Strengthened Foundational Science and Understanding

An enhanced and integrated set of environmental observations is required to track changes to the Arctic across the land, in the atmosphere, and in the ocean, including physical indicators, biological responses, and social and economic impacts. Rapid integration, interpretation, and dissemination of this information in near-real time are required. Water-level information and forecasts are necessary for coastal community hazard resilience. Increased areas free from sea ice in the autumn allow new wave and storm surge impacts to develop.

1.5.1.3. Enhanced National and International Partnerships

Arctic services are best accomplished by sharing data at multiple levels – with universities and researchers, with other Arctic countries, and with non-Arctic countries possessing capabilities in the Arctic. NOAA must continue to expand these relationships through partnerships and formal bilateral / multilateral arrangements, increasing both its interagency and international partnerships to improve the accuracy, timeliness, and coverage of forecasts.

1.5.2. Space Weather

Advanced technologies that increasingly empower the global economy and national security, such as GPS-enabled precision positioning, navigation and timing, satellite-based telecommunications, spatial reconnaissance and financial services, and smart generation and distribution of electric power, are vulnerable to the adverse impacts of extreme space weather. NOAA and NWS are designated as the Nation's official source for space weather alerts, watches, warnings, and advisories for the civil sector.

Effects of Space Weather

In its most extreme forms, such as the famous Carrington solar flare and subsequent geomagnetic storm of September 1859, space weather has the demonstrated potential to cause trillions of dollars in economic losses and stress the fabric of our modern, advanced technology-based civilization. NWS exploits the propagation time for space weather disturbances to traverse the 93 million miles from the Sun to the Earth. The resulting information enables customers to take precautions to safeguard their critical assets and ensure the continuity of operations of their systems.

NWS will engage partners in the National Aeronautics and Space Administration (NASA), USGS, the National Science Foundation, the Department of Defense, and academia to continue its efforts to provide IDSS to educate core partners and the public on the impact of space weather to society. It is envisioned that NWS' space-weather services will eventually evolve into a consortium of Federal partners, like IWRSS for water services. Advances in space weather prediction and impact communication will evolve via the Space Weather Prediction Center's collaboration with the various Federal, academic, and private sector entities involved with the space industry and will benefit from experience and lessons learned in the traditional atmospheric science disciplines. Through these partnerships, foundational information and IDSS will be enabled by a suite of Sun to Earth numerical forecast models that will form the basis for future probabilistic ensemble forecasts of space weather conditions.

Space weather datasets will become a part of the COP and used in conjunction with Impacts Catalogs to alert local offices of IDSS needs for space weather impacts. Education and outreach effort will better train Emergency Response Specialists to correlate space science to impacts, such that useful IDSS can be provided to community decision-makers. Space weather data will be migrated onto the new AWIPS II software analysis and distribution architecture to allow seamless access and display of data between NCEP Centers and WFOs. Public awareness of space weather and knowledge of its potential impacts on critical infrastructure is growing in proportion to the customer base. WFOs will be increasingly called upon to provide basic guidance on the space weather outlook to their constituencies.

1.5.3. Aviation

Weather plays a significant role in aviation and traffic flow management: it has an estimated impact of $3B/year on the American public.[3]

The total cost of domestic air traffic delays to the U.S. economy in 2007 was as much as $41B (in 2007 dollars), including $19B in raised airline operating costs and $12B worth of passengers' time. Delayed flights cost the airlines and customers an additional $1.6B in fuel (740 million additional gallons of jet fuel at an assumed wholesale price of $2.15 per gallon in 2007). In addition, an estimated $10B was lost by industries that rely on air traffic for supplies or customers, such as food services, lodging, general retail, and ground transportation.[4]

Aviation weather services provide the Federal Aviation Administration (FAA), the weather enterprise, and the general and commercial aviation communities with critical forecasts and other decision support services to ensure the safe and efficient movement of aircraft across the National Airspace System (NAS). NWS' aviation support comprises Traffic Flow Management (TFM), Terminal Area Forecasts, and General Aviation Support.

NWS, through its WFOs, the Aviation Weather Center (AWC), the Alaska Aviation Weather Unit (AAWU), the Center Weather Service Units (CWSUs), and other operational units, provides a variety of weather information and products to support the FAA in operating the NAS and performing TFM. This is both a legal requirement and mission responsibility for NWS. NWS has a base budget that funds aviation-related activities in the WFOs, AWC, and the AAWU; the FAA reimburses NWS for the CWSUs.

The FAA estimates that 70 percent of delays in the NAS are caused by weather. Thunderstorms, icing, turbulence, low ceilings, and reduced visibility are among the most hazardous weather phenomena. NWS is working collaboratively with the FAA to develop near-term IDSS requirements whose fulfillment may decrease weather-related aviation impacts. In addition, enhanced decision support will enable more efficient surface transportation.

1.5.3.1. NextGen

As part of its support to the FAA, NWS is aligning its services with plans for the Next Generation Air Transportation System (NextGen), the wide-ranging initiative to transform the air traffic control system, of which weather is only one piece. As an air transportation network that stresses adaptability, NextGen enables aircraft to immediately adjust to changing factors such as weather. By 2025, all aircraft and airports in the NAS will be connected to the NextGen network and will continually collaborate in real time to improve efficiency and safety. To achieve NextGen's goals, NWS must improve its integration of weather information into FAA decision support systems. NWS currently works in partnership with the FAA to ensure that its IDSS:

- Incorporates requirements into the NextGen 4-D Weather Cube
- Enhances its en route and local terminal support to the FAA
- Focuses IDSS support to key FAA partners in the Golden Triangle (New York, Chicago, and Atlanta)

The FAA's commitment to developing and implementing NextGen will eventually result in changes to the fundamental operational concepts for managing the flow of air traffic in the NAS. In particular, the relationship between weather information and operational decisions will evolve as aviation requirements

[3] Joint NWS-FAA Traffic Flow Management Requirements Working Group.

[4] U.S. Congressional Joint Economic Committee, "Your Flight Has Been Delayed Again," Washington, DC, May 2008, available at: http://jec.senate.gov/public/?a=Files.Serve&File_id=47e8d8a7-661d-4e6b-ae72-0f1831dd1207.

and weather technology mature. As the main source of weather information for the NAS, NWS must evolve its services to meet the emerging requirements of the FAA's TFM mission. NWS is designing its services around those requirements dynamically from the digital database, as opposed to creating new manually generated products.

1.5.3.2. Traffic Flow Management

Weather plays a significant role in aviation and traffic flow management: it has an estimated impact of $3B/year on the American public.[5]

The total cost of domestic air traffic delays to the U.S. economy in 2007 was as much as $41B (in 2007 dollars), including $19B in raised airline operating costs and $12B worth of passengers' time. Delayed flights cost the airlines and customers an additional $1.6B in fuel (740 million additional gallons of jet fuel at an assumed wholesale price of $2.15 per gallon in 2007). In addition, an estimated $10B was lost by industries that rely on air traffic for supplies or customers, such as food services, lodging, general retail, and ground transportation.[6]

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1.5.4. Weather Impacts on Mobility and Productivity

Weather events can reduce mobility and the effectiveness of traffic signal timing plans. On roads with traffic signals, speed reductions can range from 10 to 25 percent on wet pavement, and 30 to 40 percent on snowy or slushy pavement. Average arterial traffic volumes can decrease by 15–30 percent, depending on road weather conditions and time of day. Travel time delay on roads can increase by 11–50 percent, and start-up delay can increase by 5–50 percent depending on the severity of the weather event.[7]

Key Statistics

- *Rain can decrease average freeway speeds up to 16 percent.*
- *During adverse weather, average travel time delay increases by 14 percent in Washington, DC, and by 21 percent in Seattle. WA.*

It has been estimated that 23 percent[8] of the nonrecurrent delay on highways across the Nation is due to snow, ice, and fog. This amounts to an estimated 544 million vehicle-hours of delay per year. Rain – which occurs more frequently than snow, ice, and fog – leads to greater delay.

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[5] Joint NWS-FAA Traffic Flow Management Requirements Working Group.

[6] U.S. Congressional Joint Economic Committee, "Your Flight Has Been Delayed Again," Washington, DC, May 2008, available at: http://jec.senate.gov/public/?a=Files.Serve&File_id=47e8d8a7-661d-4e6b-ae72-0f1831dd1207.

[7] Lynette C. Goodwin, "Weather Impacts on Arterial Traffic Flow," Mitretek Systems, Inc., December 24, 2002, http://ops.fhwa.dot.gov/weather/best_practices/ArterialImpactPaper.pdf; Lynette C. Goodwin and Paul A. Pisano, "Weather-Responsive Traffic Signal Control," http://ops.fhwa.dot.gov/weather/resources/publications/fhwa/ite04sprwxrespsigcon.doc.

[8] Source: Department of Transportation, "How Do Weather Events Impact Roads," http://ops.fhwa.dot.gov/weather/q1_roadimpact.htm.

NWS' IDSS will assist community decision-makers in mitigating road impacts, and will emphasize closer working relationships with Federal, state, and local DOTs to better identify and prepare for surface transportation impacts. NWS will also ensure the availability of this critical information through the COP to allow other components of the weather enterprise to meet the needs of their customers.

1.5.5. Renewable Energy

NWS has a role to play in fostering the development of renewable energy in this country through public and private sector partnerships, the operation of in-situ and remote observations, numerical modeling, and foundational weather, water and climate predictions.

As NWS works with core partners and the energy industry to define and refine its models, NWS recognizes that cooperation, not competition, with private sector and academic and research entities best serves the public interest and best meets the varied needs of specific individuals, organizations, and economic entities. The essence of this partnership is an understanding of respective roles and responsibilities and how they complement each other. This includes government having a taxpayer-funded responsibility to provide basic information, while creating the conditions for private sector entities to maximize their ability to serve their constituencies. Accurate foundational forecast data will prove vital to ensuring the cost-effectiveness and viability of the continued development of renewable energy capabilities.

Key Concept

Regarding renewable energy and the private sector, NWS can appropriately assume the role of an "honest broker," receiving and protecting proprietary data from industry for use in improving the accuracy of foundational weather forecasts.

1.5.6. Public Health

The Health and Human Services' Department's CDC is responsible, in part, for monitoring environmental conditions that may result in risks to human health across the Nation and regions of the United States. Through its headquarters, CDC uses weather, water, and climate products to attempt to identify areas of potential future health risk (such as excessive heat, flooding precipitation, or airborne diseases such as swine flu or dengue fever). NWS and CDC must collaborate to ensure a mutual understanding of each agency's respective areas of expertise and their impacts on one another's end users. NWS will expand IDSS in collaboration with the weather enterprise and public health sector partners for persistent events, such as extreme heat or cold; seasonal flooding; drought; and other changes in weather, water, and climate systems.

Key Concept

NWS foundational datasets provide CDC with critical weather and climate information it needs to produce health-based forecasts that protect public health concerns. IDSS will bridge the gap between scientific environmental knowledge and its application to health agencies' decisions.

In addition to the direct impact of weather on human health, weather also impacts the ability of the health sector to provide medical services. Conditions that disrupt surface transportation also disrupt the ability of emergency medical services to reach patients, the ability of hospital employees to arrive at work, and in severe cases the ability to deliver medical supplies. In addition, the same conditions that disrupt medical services often increase the demand for those services through injuries in traffic accidents and other forms of trauma and through increased stress on vulnerable populations. Providing IDSS to emergency medical services is an important part of the overall IDSS support to core partners.

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2. Workforce Evolution Plan

The NWS WRN Roadmap's vision for the future includes an enhancement of IDSS that will extend NWS' capability to provide services that are superior to those provided today. The emerging needs in NWS services for a better understanding of social science and physical science, and the increase in technological abilities, demand a modification in the operations and services provided by the NWS workforce. In addition, NWS will establish a workforce planning initiative through which core competencies are continually identified and assessed against current skill sets. The agency's training and recruitment strategies will be adjusted to ensure that any gaps in skill sets are reduced or eliminated over time. NWS will leverage the expertise of NOAA's Workforce Management Office (WFMO) to assist in process development and skill assessment.

This section of the NWS WRN Roadmap lays out a framework for the evolution of the NWS workforce as NWS implements IDSS and helps America to become a Weather-Ready Nation.

Key Term	Definition
Pathways Program	A cooperative program that offers undergraduate and graduate students majoring in a variety of disciplines (e.g., computer science, mathematics, meteorology, oceanography, hydrology, and social science) an opportunity to alternate full-time paid employment with periods of full-time study.
Onboarding	The mechanism through which new employees are familiarized with the operational culture of the agency.
Succession Planning	A manner in which NWS ensures that institutional knowledge and leadership skills are passed on to the younger generation as the aging workforce retires.

2.1. Underlying Workforce Concepts

NWS' Workforce Evolution Plan aligns with the underlying service concepts outlined in the Services Plan from a personnel perspective. NWS recognizes the ever-increasing need for interpretation and enhancement of critical weather information as NWS begins to deploy Emergency Response Specialists (ERSs) to support core partners. Personnel must be adequately trained to incorporate social science principles into day-to-day operations, and this training includes the ability to communicate effectively and build sustainable relationships with core partners.

Underlying Workforce Concepts

- *Adapt current suite of staffing profiles and skill sets to fully address emerging IDSS requirements*
- *Provide the requisite training to ensure that personnel are fully versed in IDSS and the COP*
- *Shift from product-focused service to interpretation and consultation*
- *Incorporate social science principles into day-to-day operations, including effective communication*

The IDSS concepts outlined in the Services Plan will require a workforce transformation to accommodate the shift from product-focused service to interpretation and consultation. As America's demographics evolve, so too will the need to hire and embrace a more diverse workforce – one that can leverage a more robust and flexible dissemination strategy to better reach and serve a changing American society.

Given the rapid advances in technology, NWS personnel must also be trained to transition to digital services, using the Common Operating Picture (COP) and the Data Cube. The skills required for this transition – critical in providing IDSS – will be tested through simulation exercises in the proving grounds, test beds, and Pilot Projects.

The following sections expand upon the underlying service concepts and the workforce-specific elements on which NWS must focus to accomplish its vision.

2.2. Staffing Profiles

The last significant change in NWS staffing occurred with the NWS Modernization effort in the 1990s. This was due to the shifting of personnel from a two-tier structure with Weather Service Forecast Offices and Weather Service Offices to a single-tier, nationwide system of equivalent offices – today's WFOs. There are exceptions to this standardized structure outside the continental United States, such as in the Alaska and Pacific Regions.

Key Concept

Meeting the demand for NWS services of the future will require both sound meteorological, hydrological, and climate sciences, and an increase and expansion in decision support services, including social science and communication expertise.

The change in staffing included a shift from a majority of meteorological technicians to a majority of meteorologists. Changes also included staffing and operational adjustments in RFCs, including creating a Hydrometeorological Advisory and Support unit, colocation of every RFC with a WFO, and creation of the Development and Operations Hydrologist position.

Significant changes in staffing occurred at NWS regional headquarters, with staffing reductions from 60 to 45 on average. (These numbers were and continue to be smaller in the Alaska and Pacific Regional Headquarters).

There were small deviations from a standardized staffing model (e.g., recognition that not all WFOs have marine responsibility), and a few variations based primarily on the technology needs at particular offices. This staffing model was adequate for the offices (WFOs, RFCs, and regional headquarters) of the 1990s and for the first few years of the new millennium. However, rapid changes in technology and dissemination capabilities have created a need to adjust NWS operations to expand and enhance IDSS.

Today, it is vital that NWS remain agile to keep up with the changing science and technology and remain relevant to its evolving core partner and user requirements. NWS must address its current suite of staffing profiles and skill sets – in addition to structure, systems, processes, technology, and resources – to fully address these emerging requirements.

Enhancing NWS IDSS will require a workforce analysis to determine the optimal staffing profile for each NWS office. Results from the Pilot Projects will also help to determine the requirements for each office.

2.2.1. Expertise Required to Provide IDSS

IDSS will require NWS specialists to possess a wider range of skills. NWS must provide the following tools and skill sets:

- **Geospatial Information Systems (GIS).** Analyzing, forecasting, and communicating impacts in high-resolution, three-dimensional space is complex. Relating environmental impacts to customers who lack GIS skill is even more complex. Therefore, most employees will require significantly greater knowledge of GIS.
- **Data Visualization.** This skill will become increasingly important as NWS moves from animation of two-dimensional meteorological fields to 3-D animation of meteorological, hydrologic, and other environmental data fields integrated with other variables to derive customer impacts.
- **Modeling.** A much greater understanding of numerical modeling will be required, including details of microphysics and parameterizations. The NWS workforce will need this knowledge to comprehend and communicate uncertainty information to decision-makers.

- **Forecast Confidence.** The key to critical decisions during high-impact weather is some measure of confidence in the information NWS provides. NWS must develop skills to allow the agency to communicate probabilistic information in ways understandable to decision-makers.
- **Communication.** NWS must be able to communicate IDSS information effectively. This will require enhanced verbal, text, data, graphics, in-person, and remote communication methods.
- **Program and Project Management.** The workforce will need to acquire a much deeper background on how to effectively manage programs and projects as NWS becomes focused less on manual product production and more on assisting core partners to address their broad environmental requirements. That background will include better communication skills (both written and oral), promotion of NWS services to core partners, and budget and personnel management. In addition, improved consultative skills will enable employees to cultivate and enhance core partners' use of NWS information and identify emerging areas for partnership.
- **Biological and Ecological Impacts.** Federal agencies integrate environmental information and impacts into their planning and decision-making. NWS will need broader environmental science skills and knowledge to support core partners.

2.3. Training

Training current and future employees is critical to ensure the workforce is prepared for IDSS to create a Weather-Ready Nation. Components of the training plan must be cross-cutting and focus on all aspects of a high-performing agency. These components include:

- Improved physical science
- User training for emerging science and technology
- Impact-based services and social science
- Communication and collaboration
- Leadership and management training
- External education and outreach

Key Concept

The NWS workforce must remain agile and flexible to meet core partner needs, and personnel will be trained in IDSS. NWS will use a blended learning approach, including online courses, webinars, and residence training.

Implementation of these training initiatives requires new and enhanced methods and technologies for training delivery, such as simulations and on-demand training integrated into applications and other systems. These new and enhanced methods and technologies should be considered critical for the Commerce Learning Center, NWS Training Division, and Cooperative Program for Operational Meteorology, Education, and Training (COMET).

Concepts defined in this Roadmap include greater interdisciplinary training, deeper understanding of the scientific method and research design, and additional education on communicating science effectively. These concepts should be developed through prototype exercises via funding mechanisms such as the Collaborative Science, Technology, and Applied Research (CSTAR) Program, which sponsors collaborative research projects with NWS and academic personnel working together to design research projects.

In addition to CSTAR, NWS should enhance existing partnerships with other NOAA groups engaged in similar educational and scientific pursuits. These include the Regional Integrated Science Assessments, which develop prototype services in close collaboration with stakeholders and many NWS offices and the Regional Climate Centers, which often provide NWS offices with unique climate expertise to support stakeholders.

2.3.1. Training Components of IDSS

A top priority for IDSS training will be to use event simulations for evaluation, certification, and training.

National-level training and simulations used for ERS certification will be conducted at the NWS Operations and Services Proving Ground in Kansas City.

Operations and Services Proving Ground

Simulation training at the Proving Ground will ensure that ERSs are trained and experienced to provide world-class IDSS as an integral part of the National Response Framework.

To ensure that the NWS workforce remains agile and flexible, the agency's personnel will be trained in IDSS. In addition, other personnel who *may* be called upon to support core partners (e.g., during emergencies) will also receive IDSS training. NWS will use a blended learning approach that incorporates the advantages of online courses, webinars, and residence training to meet the objectives outlined in the NOAA and NWS Strategic Plans and this Roadmap.

As training requirements are established, NWS course designers will determine the most appropriate method of training delivery. The blended approach will enable NWS to maximize the benefits of human interaction and distance learning efficiencies.

2.3.1.1. Physical Science

NWS will continue to need world-class experts in key fields (e.g., numerical modeling and cloud physics). Training in the physical sciences for the NWS workforce of the next several years will also include topics to enhance and expand employees' hydrological and meteorological knowledge. However, it is important to recognize the need for training in a more diverse set of the physical sciences and training that shows how they are interrelated. The NWS employee of the next 10 years could be called upon to provide prediction, interpretation, and information services for a wide variety of physical processes including geomagnetic storms emanating from the sun, effects of storms on coastal areas, ecosystems, air and water quality, marine and deep ocean processes, the behavior of ice and snow, and climate change. No single degree can prepare a meteorologist or hydrologist to face the high demand for environmental expertise expected from customers in the near future. Therefore, training in a wide variety of physical science disciplines should be made a high priority. In addition, universities should encourage their meteorology, hydrology, oceanography, and other physical science students to broaden their academic program of study to include courses that cover a wide range of physical processes.

2.3.1.2. Production Training

The cultural transformation to IDSS and integrated environmental services will also drive change in routine forecast production. Transforming the current digital forecast grids to the Data Cube and the COP will require another level of training effort for operational forecasters.

Training is critical to ensure that forecasters are proficient in the use of numerical weather prediction, ensembles, and probabilistic forecasting.

NWS will leverage the blended learning approach (described above) and a Professional Development Series to meet production training needs and ensure that personnel receive comprehensive training in each subject area.

2.3.1.3. Social Science and Its Impact on IDSS

Developing the NWS workforce's understanding of the importance and application of social science in the weather enterprise is an ambitious goal that depends in large part on recruitment of qualified social scientists, leveraging NOAA's existing social science capabilities and capacity and targeted training in this area. Social science concepts and approaches, especially in risk communication, are highly relevant to decision support. Building workforce competency in the social sciences is important for moving NWS toward IDSS.

To improve IDSS and mission delivery through the integration of social science principles, the NWS workforce must:

- Improve understanding of the impacts of weather, water, and climate on society.
- Provide more effective products and services by better understanding and incorporating information on societal effects.
- Develop more effective products and services through an increased understanding of the ways that society interprets and responds to information.
- Provide more efficient delivery of products and services by understanding changes in society and more effectively using social media.
- Understand the diversity of topics the social sciences address and their applications to weather operations.
- Recognize how social science methods and findings can inform the effectiveness of forecaster and researcher duties related to meteorology and hydrology operations.
- Have access to best practices and examples of how social science concepts can improve weather services for customers.
- Articulate forecast risk and uncertainty.

Key Concept

In improving IDSS and mission delivery through the integration of social science principles, the NWS workforce will improve understanding of the societal impacts of weather, water, and climate.

NWS should develop an introductory social science training module written for people who have been highly trained in a physical discipline, but may have limited previous experience in social science. Completion of such training should be required of all those in the NWS operational workforce. Additional course units should be developed to build upon knowledge and concepts introduced in the introductory module and support the grooming of the workforce toward IDSS capability. Training should address means of integrating social sciences into the weather enterprise.

The intent of these training modules is not to transform the NWS workforce into social scientists; rather, it is to provide the NWS workforce with adequate tools and understanding for the integration of relevant social science with decision support.

2.3.1.4. Communications

External and internal communications skills are core competencies that improve NWS interactions with stakeholders. At the core of the IDSS mission is ensuring that customers understand impending weather, climate, and water issues. To successfully communicate NOAA science and forecasts, NWS personnel require both strong foundational science expertise and the ability to communicate effectively in every forum, independent of the technologies.

Evolution of services from a product-based focus to real-time, two-way information sharing will require a cultural shift to improve communications – both within NWS and with core partners and other users. New technologies will put more demands on communication skills by allowing ERSs to provide on-demand support to core partners and collaborate interactively within NOAA/NWS.

Improving internal communication and collaboration will require a combination of training, simulation exercises, and technology. To help make America a Weather-Ready Nation, the NWS training community will expand its ongoing efforts in communication, conflict management, and leadership training. As NWS looks forward, it will deploy new technologies with more real-time and interactive collaboration and communication.

The NWS training community will expand training in these core requirements. In addition, certification training will be added for Senior ERSs. Much of the training will be provided using the blended approach, with a capstone in-residence simulation/exercise at the NWS Operations and Services Proving Ground in Kansas City.

2.3.1.5. Impact vs. Cause

Demand-driven IDSS will require a significant change in how NWS personnel communicate environmental information to core partners and users. Weather forecasts, watches, advisories, and warnings will need to evolve into impact-based forecasts tailored to user-defined thresholds. This change represents a significant cultural shift and requires in-depth training to ensure that critical weather information is communicated in terms of societal impacts to those most at risk.

The transformational change will be a movement away from communicating what weather will occur and why, to enabling core partners to communicate how and when the weather will affect communities, as summarized in **Figure 2-1**.

Figure 2-1: Examples of Transformation

Traditional NWS Forecast	IDSS Forecast
"60 percent chance of thunderstorms this afternoon"	"Thunderstorms between 2:00 and 4:00 pm will likely cause 30-60 minute flight delays"
"Thunderstorms will be in the response area this afternoon"	"People in the immediate area should take shelter due to the possibility of lightning from 2:00 to 4:00 pm"
"Heavy snow with accumulations of 8 to 12 inches tonight"	"I-80 will likely be impassable after midnight due to heavy snowfall"

NWS personnel will leverage the Impacts Catalog, as well as decision aids, to help users better understand the impact of daily environmental events. Whenever possible, NWS will endeavor to provide this information in graphical format to its users.

2.3.2. External Education and Outreach

External partners are an important component of developing – and changing – the NWS workforce for the future. Significant partners include academia and professional organizations. As NWS develops concepts for how the workforce in the future will be different from the current workforce, NWS needs to collaborate with these external partners to appropriately modify curricula, develop new courses where needed, recruit top students to work for the agency, and implement research projects of interest to NWS.

Besides academia, professional organizations such as the American Meteorological Society (AMS) and the National Weather Association (NWA) are important in defining baseline requirements for undergraduate education in meteorology. Professional organizations exist for scientific disciplines outside of meteorology. Examples include the American Geophysical Union, the American Water Resources Association, and the Consortium of Universities for the Advancement of Hydrologic Science. Organizations such as these should be leveraged to broaden the foundational requirements for undergraduate programs and to increasingly encourage future NWS employees to pursue graduate degrees.

NWS' Outreach Program and Education Plan supports NOAA's goals and vision for an informed society that understands the role of oceans, coasts, and atmosphere in the global ecosystem, and that can make the best social and economic decisions. The Plan sets forth two main goals:

- An environmentally aware public supported by a framework of education and outreach opportunities
- A future workforce, reflecting the diversity of the Nation, skilled in all disciplines critical to NOAA's vision

NWS is also collaborating with NOAA on promoting partnerships with both formal and informal science education groups to integrate environmental science into the educational process. Expanding grant opportunities and partnering with science education groups will support the development of a future workforce in science, technology, engineering, mathematics (STEM), and other disciplines.

2.3.3. Communications Strategies

As NWS transitions to IDSS while continuing to build a Weather-Ready Nation, external communications embody the critical relationship between NWS and its core partners and customers. NWS' local community, state, regional, Federal, national, and international core partners require close coordination and collaboration with the agency to accomplish their mission objectives. The quality of NWS' communication is paramount to the success of the agency's partners.

2.3.3.1. Assessing Communication Tools

NWS already uses multiple communications tools and will increasingly rely on a spectrum of strategic and tactical communication tools to meet its needs, as well as the needs of core partners and other users. As NWS periodically assesses the performance and the resources applied to these tools for effectiveness, greater emphasis should be placed on the communication tools deemed most effective to meet the agency's needs. Decisions regarding tool usage should be based on experience working with those tools as well as quantitative social science studies.

Strategic communications tools include:

- **National, Regional, or Local Town Hall Meetings** – NWS currently uses town hall meetings to communicate internally about challenges, successes, and new organizational initiatives. Town halls, whether in person or virtual, provide an opportunity to concurrently share a message and facilitate dialogue between management and staff around the country.
- **Social Media** – Social media such as Facebook, blogs, and Twitter are rapidly outpacing traditional media for distributing and sharing information. These social media as well as others that have not been invented yet will be important communication tools in the future.
- **Traveling Road Show** – A common element of current NWS stakeholder interactions is presentations to stakeholders in their offices, at their trade meetings, or at other venues where stakeholders are likely to be. These presentations allow face-to-face interaction and networking of NWS staff with key stakeholders.
- **Web sites** – Web sites are probably the most common way for stakeholders to access NWS forecasts and datasets.
- **NWSNews** – Continuous electronic newsletter communication is used for internal communication.
- **Visiting Forecaster Programs** – Facilitates visits by forecasters and other NWS staff to other NWS offices or stakeholder offices to gain a better understanding of their operations. This is a best practice that has yielded strong results and should be continued.

As NWS progresses toward IDSS, multiple means of tactical communication are necessary to convey the threat that an upcoming event may present to communities. For example, a major winter storm (or other significant environmental event) is currently conveyed via many methods, including:

- Traditional outlook/watch/warning products via text on NOAA Weather Radio All Hazards and NOAA Weather Wire, and via Family of Services
- Emails sent to core partners/stakeholders (such as emergency managers) as a "heads up" message

- Chat rooms to communicate threats, hazards, and expertise with primary stakeholders
- Graphical depictions of hazards on NWS Web sites, conveying the threat in a format that is easily interpreted and understood
- Multimedia weather briefings for key partners, using web pages and remote methods to provide two-way IDSS to key stakeholders
- Quick messages and graphics disseminated by mobile devices to provide information directly to first responders and other key field personnel
- Social media interaction with stakeholders and the general public to convey the threat and receive impact information in real time, using methods already used every day by a majority of people
- ERSs deployed to Emergency Operations Centers as necessary

2.3.3.2. Measuring and Communicating Success

Communicating the success stories – as well as areas that need improvement – will be vital. If communicated effectively, success stories will provide an even stronger foundation for building ties with core partners and other users, and for reinforcing new successes. This effort requires techniques, capabilities, avenues, and metrics that clearly measure progress toward meeting goals that are important to NWS.

NWS has a long history of forecast verification and associated metrics that track various attributes of forecast skill using Government Performance and Results Act metrics (e.g., Tornado and Flash Flood Warning lead times) augmented by periodic measures of customer satisfaction in key groups (e.g., emergency and water managers). Many of these tell powerful stories on their own about the increasing power of science and technology over the past several decades.

NWS is moving toward developing success criteria that ultimately relate to societal outcomes. These outcomes depend on both NWS outputs and effective societal use of, and response to, these outputs. While performance evaluation based on outcomes is more challenging, it is also more meaningful as it seeks to assess how and to what extent NWS products and services create value for society in terms of economic efficiency, economic output, and improved public safety.

Progress in measuring such outcomes will depend largely on using economic and social science evaluations. NWS will use the measures of success as a starting point to define a detailed plan for how to define, baseline, and track more specific societal measures and targets.

2.3.3.3. Ensuring High-Quality Communication

Timely and relevant communications are major strengths of NWS. The agency’s ability to respond quickly to natural disasters with public statements relevant for the protection of life and livelihoods and the advancement of the Nation’s economy is excellent. NWS needs to set similarly high bars for accuracy – especially scientific accuracy – in its communications. As NWS evolves its decision support capabilities by encouraging personnel to participate more directly with core partners and users, NWS should set a high bar for the scientific literacy of its staff and for ensuring accurate messages are communicated, particularly to external stakeholders. NWS personnel engaging with core partners and other users may find themselves being asked for expert opinions on subjects in which they have little or no expertise. These personnel need training to identify these situations and redirect those stakeholder engagements to the appropriate subject matter experts in the agency. For example, an NWS meteorologist working with a water management group on a specific flood issue may be asked about the capabilities of the NWS hydrologic prediction system. That meteorologist should know when to bring in appropriate experts.

2.4. Recruitment and Diversity of the Workforce

Diversity is beneficial to both NWS and its employees. Diversity brings substantial potential benefits, such as better decision-making, improved problem solving, and greater creativity and innovation, which lead to enhanced service development and more successful communication with a range of customers. The benefits of diversity will make NWS much more effective, especially in an era of IDSS.

Recognizing diversity is a first step in helping to link the variety of talents within the organization and allows employees with these talents to feel needed and have a sense of belonging. Diversity is not only about preventing unfair discrimination and improving equality but also valuing differences and inclusion, spanning such areas as ethnicity, age, race, culture, sexual orientation, physical disability, and religious belief.

Overall, the U.S. population has become more racially and ethnically diverse over time. According to the Census Bureau, during the past 10 years, the Hispanic and Asian populations have grown considerably, in part due to relatively higher levels of immigration.

To better understand and communicate with the changing U.S. population, the long-term success of NWS must include a diverse body of talent that brings fresh ideas and perspectives to the agency, along with a corporate mindset that values them.

The agency's workplace currently includes individuals from five generations. Embracing these different cultures will contribute to more creativity and productivity. As NWS moves toward IDSS, taking advantage of the agency's mix of work and life experiences will make the organization more effective in meeting the needs of its customers and fulfilling its mission. NWS must capitalize on this cultural diversity as the organization moves forward.

2.4.1. Diversity of Disciplines

NWS is focused on two basic sciences to support operations, meteorology and hydrology. These positions support the primary mission by providing the meteorological and hydrologic skill sets necessary to interpret information and to provide the best possible forecast and warning services to customers. Supporting the current operations is a group of electronic technicians, IT officers, engineers, and administrators. The entire organization is focused around science, engineering, electronics, and government administrative functions. These are diverse disciplines that work together to support NWS' mission.

As NWS develops IDSS, the diversity of disciplines in NWS will expand. While weather and water will still be the cornerstone of NWS operations, the organization will need to expand its workforce to include environmental scientists, industrial hygienists, social scientists, GIS experts, and public communicators. These expanding roles will afford NWS the opportunity to expand its diversity to more effectively match the diversity of the society of the future. NWS should capitalize on this opportunity to effectively match the society's demographics and provide more effective and relevant services to the Nation.

2.4.2. Recruitment and Retention

Given NWS' mission, it is no surprise that meteorologists make up the majority of the organization's workforce. In 2010, the top five recruited occupations in NWS included:

- Meteorologists
- Hydrometeorological technicians
- IT specialists
- Electronic technicians
- Hydrologists

One of NWS' strategic goals is to extend weather, water, and climate service to better serve those making ecological and health-based outlooks. To that end, the knowledge of meteorologists, hydrologists and other personnel will expand to include ecology and health, social sciences and economics, communication, information technology, leadership, and management.

NWS employs a skilled and talented workforce, and enjoys a high retention rate. In FY 10, the average attrition rate for NWS was 3.6 percent, which translates to low turnover. For any organization, higher retention of competent employees has positive impacts on costs, productivity, and morale. While NWS' attrition rate is low, the agency needs to continue to examine and develop retention strategies that will enhance its reputation as a desirable place to work. Retention strategies include:

- Establishing career paths and growth opportunities
- Providing opportunities for training and development
- Showing recognition through monetary and nonmonetary compensation
- Strengthening communication through the organization to build credibility
- Enhancing work/life balance initiatives
- Creating a work environment that builds on trust and makes employees feel valued

2.4.2.1. Student Recruiting

NWS currently recruits students through programs such as the NOAA Education Partnership Program and the Pathways Program (Pathways). In the future, NWS should establish or reestablish other strategies to recruit students, such as:

- **Strengthening partnerships between WFOs and their local colleges and universities.** As part of their duties, Science and Operations Officers, Warning Coordination Meteorologists (WCMs), Development and Operations Hydrologists, and Service Coordination Hydrologists should seek partnerships with colleges and universities located in their community. These partnerships could create another avenue by which students can be informed about internship or employment opportunities.
- **Connecting with student organizations and college fair conferences.** NWS can continue to foster its relationship with AMS student organizations and the NWA to provide them with information regarding employment and internship opportunities. NWS management should develop a national recruitment team composed of meteorologists, hydrologists, or other critical personnel to attend college fairs throughout the country.
- **Leveraging alumni and other social networks.** NWS personnel who are alumni of colleges and universities could serve as NWS ambassadors to their alma maters in speaking to students about NWS and what it has to offer. Furthermore, NWS can maximize the use of social media such as Facebook or Twitter to advertise and broadcast opportunities to students.

2.4.3. Onboarding and Training Personnel

Onboarding is the mechanism through which new employees are familiarized with the operational culture of the agency. The onboarding period provides the hiring agency an opportunity to ensure that new employees are mission-focused, high-performing professionals.

Newly onboarded personnel require training to ensure that they are fully integrated into the operational environment. To maximize efficient use of training dollars, NWS can use both national and regional blended learning via computer-based modules, virtual classrooms, and on-site courses. In addition, coaching and mentoring are effective ways to reinforce NWS' core culture and values.

The focus of the NWS onboarding program includes:

- Introduction to NOAA/NWS
  - Where do I fit in the organization
  - What are the organization's and my supervisor's expectations
  - Organizational culture and values
  - Early career support (mentoring/guidance)
  - Roles and responsibilities as employee
  - Entitlements/benefits
  - Career paths
  - Communication and teamwork
  - Additional leadership development opportunities
- Job-specific training
  - Professional development tracks (e.g., meteorologist/hydrologist/ET/IT/administrative)
  - 3–4 year training tracks with measurable milestones to determine employee development
  - Specialized training to work certain functions in the future NWS (e.g., IMET/emergency response/aviation/marine)

2.4.4. Succession Planning

The aging workforce across the Federal Government has created the need to focus more attention on succession planning. In the next 5 years, approximately one-third of the NWS workforce will be eligible for retirement. Many of these incumbents are in leadership or management positions and possess a great deal of institutional knowledge of the organization's operations. If no plan or mechanism is put in place to address this rising trend, NWS runs the risk of losing that institutional knowledge and having a shortage of people with the skill sets required to effectively run programs and meet the agency's mission.

NWS will define a succession planning strategy to ensure that the agency continually provides training programs and cultivates the leadership skills necessary to fulfill its mission. To that end, NWS will conduct analyses to determine the ratio of upcoming retirements to gaps in skill levels, and how to best fill those gaps.

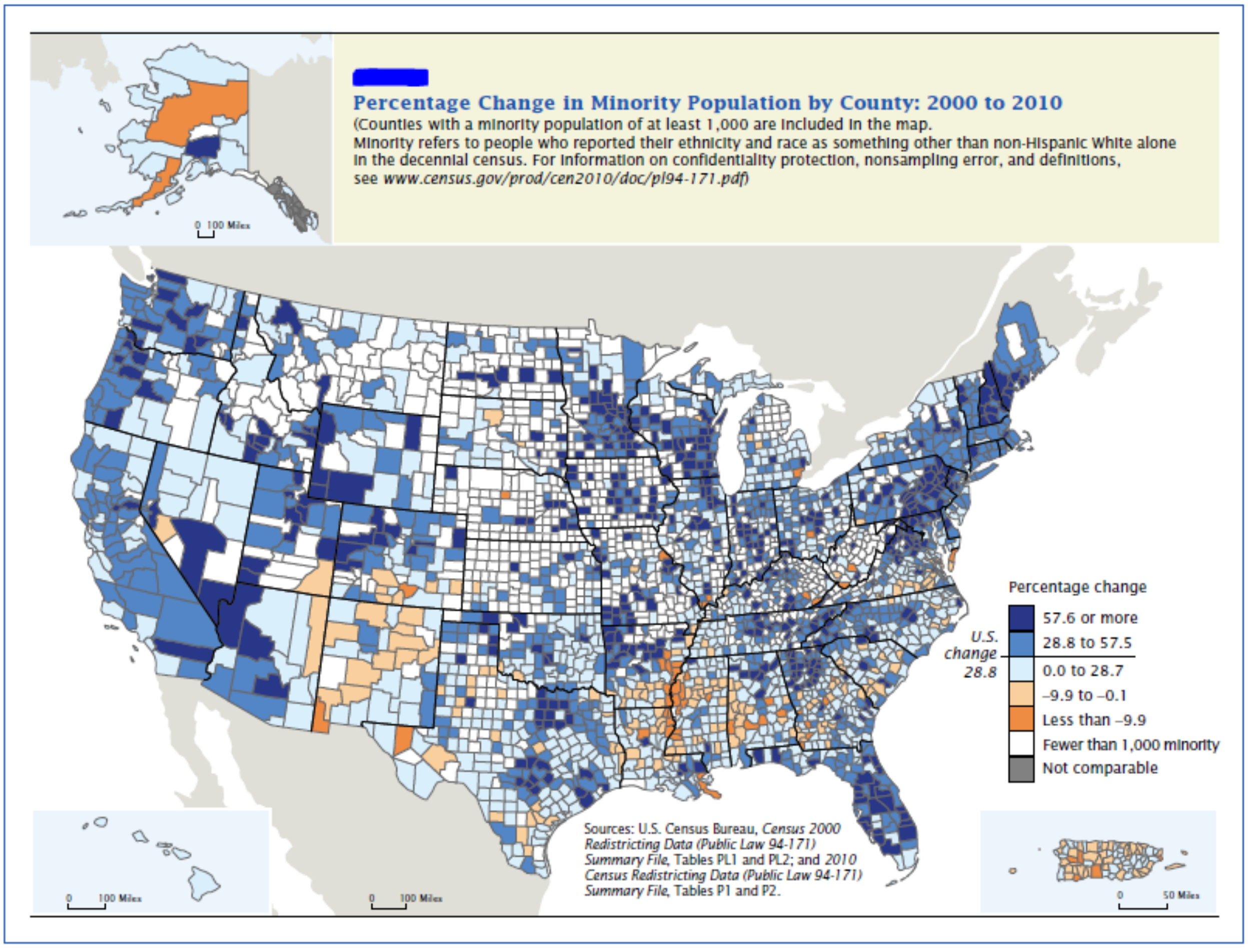
2.4.5. Demographics

NWS recognizes America's changing demographics, and can keep pace with these changes by remaining flexible to evolving community needs. Based on findings by the NWS WCM Initiatives Team, not all communities are adequately equipped to prepare for, protect from, or cope with environmental hazards and their impacts. Inadequacies may be caused by:

- Social or geographic isolation
- Limited access to educational resources
- Different ethnic and cultural backgrounds
- Economic vulnerability

The demographic changes over the past 10 years, as depicted in **Figure 2-2**, have presented challenges in providing decision support information about environmental hazards. For example, an increasing number of U.S. households speak a language other than English. While it is commonly assumed that a local community knows the weather – especially hazardous weather – this perception needs to be reconsidered, given the extent of domestic migration. Greater minority population migrations indicate a need for NWS to conduct more extensive outreach campaigns to reach evolving communities. NWS should interact with civic organizations within different linguistic and ethnic groups to better communicate IDSS benefits to diverse communities.

Figure 2-2: Demographic Changes by County



Many NWS offices have employed successful diversity awareness programs and partnerships, and NWS must capitalize on these efforts.

2.5. Evaluation of Personnel

Job performance evaluation of NWS IDSS personnel of the future will require a new approach and an in-depth understanding by employees and managers. Personnel performance must be measured against specifically defined IDSS skill sets. Employees and their managers must set clear performance objectives, goals, and expectations measured by objective and subjective performance metrics. These metrics ultimately enable managers to help guide personnel through their career paths.

Managers must be aware of NWS' evolving mission requirements, and must be able to blend subjective and objective performance metrics in evaluating IDSS personnel.

2.5.1. Goal-Setting and Follow-up

As NWS moves toward IDSS, it must work closely with NOAA, the Department of Commerce, and the Office of Personnel Management to re-align performance and career development to reflect the changing workload. IDSS will require a significant shift in performance expectations. Education and training to clearly identify expectations is critical to achieve individual and corporate goals. In making the transition to IDSS, NWS must be mindful of the following:

- Emphasizing the importance of open dialogue between managers and employees.
- Encouraging personal development through an Individual Development Plan for realistic career development that is tied to agency goals.
- Motivating employees to complete objectives by giving employees a voice in goal setting.
- Holding poor performers accountable for improving their performance.
- Integrating individual personal goals with organizational goals.
- Developing specific, measurable, time-targeted objectives to provide a foundation for the individual and supervisor to use as guidance.
- Providing managers and supervisors with training in communicating with and evaluating personnel.
- Holding rating managers and supervisors accountable for objective and subjective performance conclusions.
- Developing performance plans that reflect the work being performed, and accurately reflecting the complexity or level of work performed.
- Ensuring that performance plans are site-specific to each NWS office due to the wide range of specialties required.

As described above (in Section 3.3.1), NWS' Workforce Evolution Plan emphasizes the need to ensure that all NWS personnel are adequately trained to provide IDSS. As NWS begins to deploy ERSs to support core partners, the agency must take into account the variety of skill sets that may be needed to support evolving requirements.

2.6. Colocation of Facilities

NWS' IDSS is moving toward more team efforts with core partners and other critical customers. The closest relationships are at field offices with emergency management officials. As NWS supports more local decision-makers, these relationships will become even more critical for the Nation's security.

In addition to considering consolidating and relocating into joint facilities with NOAA line offices, NWS will need to look at other Federal, state, regional, and local entities where common operating bonds would lead to colocation. For example, WFOs/RFCs could be colocated with NWS regional headquarters, FEMA, local emergency management offices, USGS, USACE, or the FAA.

Colocation can be at different levels (e.g., local, regional, national) for different locations, and may be temporary (i.e., for specific events) or long term. This colocation would involve a long-term agreement (Memorandum of Agreement/Understanding or lease) with an organization. The most cost-effective way to accomplish these moves would be during targets of opportunity, such as when a current lease expires.

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3. Science and Technology (S&T) Plan

The S&T concepts outlined in this chapter are the major technical areas needed for supporting the IDSS, the COP, and the envisioned integrated environmental services and emerging service sectors. In future operations, innovation will drive improvements in operational efficiency and productivity; better numerical guidance will reduce forecast uncertainty through more precise and accurate forecasts; and advanced technology solutions will provide readily usable and highly relevant information to enable key decision-makers to make rapid, lifesaving decisions for the Weather-Ready Nation.

These S&T concepts must be implemented in a prioritized manner due to the complexity of the weather information system, the sheer volume of required work, and the inherent scientific challenges of delivering high-quality and reliable products.

Underlying S&T Concepts

- *Comprehensive situational knowledge*
- *Forecaster Decision Support Environment (FDSE)*
- *Coupled, computer-generated Earth system predictive guidance*
- *On-demand, reliable, quantified, and comprehensible forecast confidence*
- *Agile, scalable, cost-effective data processing, management and dissemination*
- *Symbiotic Research to Operations (R2O) and Operations to Research (O2R)*

Key Term	Definition
Data Assimilation	Provides initial conditions for numerical weather prediction by optimizing the value of all observations and the prior model solution for enhanced situational knowledge.
Data Fusion	Process of synthesizing raw data from multiple sources to generate more meaningful information that is of greater value than any single data source.
Data Mining	Process of discovering new patterns and trends from large datasets.
Earth System Model	Extension of an atmospheric (weather) prediction model to include coupling with the ocean, land surface, and cryosphere (ice- and snow-covered land).

Society requires more precise and accurate environmental knowledge and forecasts further in advance of high-impact weather. These need to be delivered on demand, and must be tailored to core partners' preparation, response, and recovery actions. The forecast value chain is enduring, but the capabilities forecasters use within the chain are constantly evolving with science and technology. The chain begins with the collection of observations, followed by the assimilation and processing of observations by both high-performance computers and AWIPS to develop situational knowledge. It ends with the production of forecasts and warnings through the generation of unified predictive guidance from coupled Earth system models and forecaster expertise. Technology solutions include data fusion and mining capabilities, hybrid Ensemble-Kalman Filter/4-D data assimilation, high-resolution convection-scale Earth system prediction models that bridge the hydrometeorological-climate spectrum, probabilistic data, and forecaster intervention tools and applications. Increased observations from polar and geostationary satellites; Doppler, dual polarization, and phased-array radar; profilers; and in-situ sources require integrated and optimized observing "systems of systems" to control costs and to fully exploit the data's value.

3.1. Underlying S&T Concepts

The S&T Plan outlines six underlying concepts, when implemented through a "build a little, test a little, field a little" paradigm, will enable NWS to provide enhanced IDSS, helping America become a more Weather-Ready Nation. The S&T Plan also identifies NWS' critical S&T needs and how the agency can work with NOAA research labs, field innovators, academia, and the private sector to implement agile, cost-efficient solutions.

3.1.1. Comprehensive Situational Knowledge

Comprehensive situational knowledge facilitates the weather enterprise in better identifying high-impact events. NWS must work with core partners to establish their relevant decision thresholds for events, thereby setting the stage for the enterprise to communicate with the public and work with decision-makers to prepare communities. Maintaining situational knowledge will be a major challenge given an increasing volume of observations and computer-generated guidance. The increase in information is compounded by the need to provide decision-makers increasingly precise and tailored impact information to inform their decisions.

The outcome is a more complete understanding of the state of the atmosphere in near real-time and its impacts on the population and critical infrastructure. The following capability focus areas will address the challenge of realizing the vision of comprehensive situational knowledge:

- A fully integrated observing network designed to optimize the strengths and weaknesses of various sensor types in the most efficient and cost-effective fashion
- Rapidly updating, three-dimensional environmental knowledge available to the weather enterprise
- A comprehensive understanding of societal vulnerabilities and environmental phenomena that informs and empowers forecasters and core partners to mitigate impacts on lives and livelihoods

Fully Integrated and Optimized Observing Network: Observations are critical to achieving situational knowledge and enabling improved computer-generated analysis and predictive guidance. Observing techniques and capabilities can no longer be developed in isolation, but must operate as system within a system as part of the greater weather enterprise. Every sensor has strengths and weaknesses. For example, a satellite sensor's effectiveness is diminished by cloud cover, resulting in degraded measurements in the lower atmosphere. However, the same sensor provides the best resolution and coverage of any observing capability available. Radar "sees" through weather and provides the most comprehensive understanding of weather over a large area, but is limited by the Earth's curvature. In the future, the NWS will judge investments in sensors by their incremental value added to the entire system and their contribution to the observation enterprise across the public, private and academic sectors.

Decisions will address, at a minimum, the following:

- Observation gaps, such as the lowest 5,000 feet of the atmosphere; the Earth's surface and sub-surface; and above 100,000 feet into deep space
- Agile observational systems, such as mobile and targeted observing capabilities, to fill gaps that do not require persistent surveillance and provide critical high-resolution information to forecasters and across the weather enterprise when most needed

Improving the precision and accuracy of neighborhood-scale forecasts requires observation and analysis of the lower atmosphere. The collection of water vapor, temperature, and wind information, in three dimensions, is fundamental to forecasting, including thunderstorm development that can trigger aviation delays, challenges for wind power generation, or localized flash floods. The National Academy of Sciences report, *From the Ground Up*, discusses the importance of improved sensing of the atmosphere below 5,000 feet and the Earth's surface and subsurface through a variety of strategies integrated via a network of networks. Today's observing system falls short of providing sufficient information to adequately define the structure of the lowest 5,000 feet of the atmosphere. This information is important for solving these forecast challenges using computer-generated predictive guidance (e.g., High-Resolution Rapid Refresh (HRRR) guidance, Localized Aviation MOS Program (LAMP) and bias-corrected, fully calibrated ensembles). Such a network would also improve forecasts and warnings for decisions across numerous industries including water management, energy, aviation, ground transportation, marine, and recreation.

Radar is critical to improving situational knowledge, and there is a requirement to modernize the Nation's radar capabilities. The highest priority is ensuring continuity of the radar data NWS receives today through the implementation of a NEXRAD Service Life Extension Program. Future priorities include closing current radar coverage gaps by leveraging existing, non-NOAA-owned radars, and working with the private sector to fill those gaps through deployment of a network of small, gap-filling radars such as those being prototyped in the Collaborative Adaptive Sensing of the Atmosphere (CASA) program. Finally, the Nation must look toward advancements in radar technology through investment in phased-array radar research. Phased-array technology, combined with total lightning flash rates, provides the greatest promise of reducing false alarm rates for severe thunderstorm and tornado warnings without degradation in detection and lead time. Additional research is required in this area, and any phased-array radar program may require public-private collaboration and/or inter-agency cooperation to provide an optimal solution for the Nation.

Satellite capabilities remain a vital component of a fully optimized observation and remote sensing strategy. These systems are critical to filling gaps in data-sparse areas. Polar and geostationary satellites provide spatial and temporal data needed to maximize forecaster situational knowledge, and deliver precise and accurate computer-generated predictions. Today, programs such as COSMIC II, JPSS, and GOES-R form the basis of the operational satellite sensing constellation. Reliable, remote sensing technologies that can detect ocean surface winds, geomagnetic storm threats, and temperature and moisture vertical profiles are vital to an adequate observing strategy.

Mobile observing strategies, along with adaptive sensing strategies, can also enable situational knowledge and forecast operations. Manned and unmanned aircraft or surface/submerged vessels, mobile radar, mobile profilers, and other instruments (including NOAA and non-NOAA), applied adaptively in a given situation, could significantly improve on-demand situational knowledge.

Rapidly Updating, Three-Dimensional Environmental Knowledge: To fully exploit the value of observations in near real-time, research and enhancements are needed in state-of the-art data assimilation, data fusion, and data mining capabilities to aid the forecaster and computer-generated prediction. As such, NWS will support the development of the national mesonet, a nationwide network of networks, which is designed to collect and disseminate comprehensive, standardized data. These data are needed to support real-time data assimilation for analysis, improved local weather forecasts, plume-dispersion modeling, climate monitoring, and air-quality analyses down to increasingly precise scales.

Developing these capabilities will require collection of metadata and a mechanism for making locally acquired observations accessible and discoverable across the enterprise. It will also require software development and investment in infrastructure such as next-generation, high-performance computing (HPC) capabilities; centralized processing to execute data fusion; discoverable data services; and intuitive graphical user interfaces.

Data assimilation provides environmental information that is near real-time, fine-scale, and dynamically consistent. Emerging capabilities such as the hybrid Ensemble-Kalman Filter/4-D data assimilation system hold much promise. Even with a robust data assimilation capability, forecasters will face scenarios where changing conditions require real-time access to a host of sensing data. Complicating this is the fact that some types of raw data, though valuable for complete situational awareness, may not be useful to assimilate or are beyond the scope of current capabilities. For these reasons, forecasters require real-time access to both raw and fused data for local, time-critical decisions. With the introduction of the GOES-R satellite and its wealth of data later this decade, forecasters will need algorithms and smart tools to mine and fuse data without reaching "data overload." One example of fused data is a product that combines radar, lightning, in-situ, and satellite data producing a thunderstorm initiation product. Providing data mining techniques places the right data at the fingertips of forecasters, enabling them to pinpoint areas for intervention or action based on critical thresholds.

Comprehensive understanding of the societal vulnerabilities to environmental phenomena: To fully obtain situational knowledge, forecasters need automated tools, algorithms, and intelligent software to quickly ascertain what environmental conditions pose the greatest risk to life and property. Fused data outputs should synchronize societal impact and environmental data, alert forecasters of the threat to life and property, and aid in prioritizing actions based on anticipated impacts. For example, real-time access to data could pinpoint the placement of first responders for a dirty bomb release in a major city where any unanticipated change in wind direction could cause injury or loss of life. Fusion tools can be designed to alert the forecaster to a particular threat or sensitivity and automatically trigger contact with the emergency operations center to communicate the emerging threat, allowing responders to redeploy to safer locations.

Objectives
• Optimize observing capabilities by exploring new observing techniques, eliminating redundancies, reducing observing gaps, and leveraging new data assimilation capabilities.
• Develop locally accessible data fusion and data mining capabilities.
• Integrate Impacts Catalog data with analysis and forecast data to allow data fusion and mining capabilities to alert forecasters.
Outcomes
• Integrated observing network with improved lower atmosphere, surface and subsurface, and deep space observations; and data assimilation, mining, and fusion capabilities.
• Comprehensive situational knowledge that links environmental and external situational awareness through concepts such as the Impacts Catalog.

3.1.2. Forecaster Decision Support Environment (FDSE)

The success of the NWS WRN Roadmap depends in large part on the agency's ability to integrate transformational science and technology directly into the forecaster environment. This integration will not only support a powerful forecast process but also enable NWS centers, field offices, and ERSs deployed to the field to provide IDSS to meet service demands at command centers and remote sites. The flexibility and agility of NWS staff, including forecasters, hydrologists, and climatologists, will be facilitated by:

- Their oversight of the forecast production including the capture, generation, and distribution of forecasts
- Forecaster intervention tools to improve computer-generated guidance (including on-demand capabilities) to improve situational knowledge, short-term forecasts, response to non-weather-related hazards, and warning accuracy and lead time
- Reduced complexity of forecast operations and improved forecaster knowledge of the environment and users' needs
- Synchronization of societal impact information with environmental knowledge to quickly determine what matters to the decision-makers
- Effective collaboration tools for on-demand connectivity with neighboring WFOs and operations centers to create and easily communicate seamless forecasts

IDSS will require processing capabilities that relieve forecasters of labor-intensive tasks and allow them to focus on decision support operations. FDSE will generate outputs in discoverable geo-referenced, industry-standard data formats for integration with users' decision-making platforms.

Weather-Ready Nation Forecast Operations: Increasing demand for IDSS means forecaster assistance tools must become more automated to help forecasters quickly focus attention on what matters to NWS' core partners and the general public. Automatic monitoring processes will identify any significant divergence between forecasts and both current conditions and new computer-generated guidance to help forecasters determine where to intervene to add measurable improvements. This will require advanced visualization techniques, new forecast intervention and collaboration tools, on-demand neighborhood-scale computer-generated predictions, and calibrated probabilistic knowledge.

As envisioned in the Services Plan, the forecaster will serve as the expert managing operations, exploiting new tools, techniques, and better guidance to create and interpret forecast knowledge. Less time spent on routine forecast production means forecasters can focus on areas and tasks that leverage their expertise.

A key challenge for NWS is its ability to manage an increasing volume of environmental data. These data will produce an increasingly accurate forecast and COP. The majority of knowledge generated will exploit computer-generated, post-processed predictive guidance with statistical applications and techniques that fuse data in different ways, to aid forecasters in determining when and where they can best add value to the forecast. For example, the forecaster may intervene when alerted that observed conditions or updated computer-generated guidance are deviating from previously forecast conditions and will adversely impact users. Forecasters will continuously monitor current conditions and impact thresholds so that timely mitigation actions occur (see Section 4.1.1., Comprehensive Situational Knowledge). Achieving this will require significant advances in forecast tools, analysis techniques, and communication capabilities.

Current forecast operations rely primarily on the generation and delivery of categorical warnings and forecasts. These products and services provide little or no quantifiable forecast confidence information to customers. The most notable exceptions are hurricane track forecasts and some hydrologic forecasts. A robust end-to-end forecast confidence capability (see the Quantification and Communication of Forecast Confidence section) will enable NWS' core partners to better manage risk and optimize decisions. Observations, analysis techniques, forecasts, and the forecasters' knowledge of local, regional, and national events and activities all contribute to situational awareness. Data mining and fusion tools will allow forecasters to better identify high-impact events and communicate threats.

Imagine This…

By mid-morning, computer-generated guidance alerts forecasters to a high probability for tornadic thunderstorm development in a 50-mile corridor over a major metropolitan area. Forecasters believe the highest risk of damaging weather will occur between 2:00 PM and 4:00 PM – potentially impacting school transportation and the rush-hour commute. The local forecast office initiates collaboration with the media and responders to develop shared understanding of the threat and communicates the threat and potential impacts through the COP. ERSs support school superintendents, local government officials, and other community decision-makers in early preparations, while the weather industry provides similar support to their clients.

At 2:10 PM, the developing thunderstorms approach from the west. Every few minutes, forecasters interpret neighborhood-scale, computer-generated guidance that provides precise locations and probabilities of the developing tornado threat for the next 2 hours. Forecasters incorporate GIS information and use "nowcasting" applications to generate tornado warnings, pinpointing threatened neighborhoods. The weather industry incorporates this information into their services, helping their clients near the threat area avoid unnecessary disruptions and costs while alerting their threatened clients inside the threat area to initiate emergency plans.

Incorporating social media intelligence, ERSs are in constant contact with incident commanders and first responders, who use NWS-produced information to identify likely response and recovery locations.

Objectives
• Incorporate objective forecast confidence information into IDSS
• Exploit new S&T data fusion, mining, and modeling capabilities
• Facilitate real-time collaboration among local, regional, and national NWS offices
• Prototype and develop forecaster intervention tools and applications
• Develop realistic simulation capability for training of field office staff
• Implement real-time comprehensive verification tools
Outcomes
• More precise and accurate forecasts and warnings
• Greater focus on decision support resulting from improved productivity
• Better ability to meet unique local needs
• More consistent, discoverable, and interoperable data and information
• An end-to-end forecast interface that synchronizes production capabilities at all levels (national centers, WFOs, RFCs).

3.1.3. Improved Earth System Predictive Guidance

Computer-generated predictive guidance includes numerical weather prediction models, ensembles, and post-processing techniques necessary to calibrate and refine raw model outputs through bias correction or statistical methods. It is the foundation of precise and accurate warnings and forecasts, and is dependent on an optimized observing network, powerful data assimilation systems, and HPC. Society has greatly benefited from dramatic improvements in computer guidance over the last decade. For example, improved forecasts of the track and intensity of a winter storm can result in warnings that a heavy snow band will cripple rush-hour traffic and commerce along an interstate corridor and close airports. These recent improvements have also enabled the weather enterprise to warn of the societal impacts of drought, solar storms, storm surge and river flooding inundation, and many other hazards. The foundational datasets formed from this information will continue to present opportunities across the weather enterprise. Within NWS, the datasets will be combined with production tools to form the COP.

Imagine This…

Residents and businesses along the James River, located along the Piedmont hills in central Virginia, are susceptible to flooding. In recent years, sophisticated inundation mapping, completed jointly by the NWS and partner agencies, has been used by local officials to help inform and prepare residents.

NWS computer-generated river valley-scale predictions alert hydrologists of an impending heavy rain event. Using the latest hydrologic models, fed by calibrated ensemble guidance, the hydrologists determine from the 7-day forecast that there is a 60 percent probability of exceeding flood stage at city center. Interactive inundation maps show decision-makers the range of possible flood stages.

The ERS works with the county sheriff and emergency managers to determine which neighborhoods should begin mitigation strategies. Other neighborhoods are alerted to the threat. The ERS works with officials daily to further refine the threat as the event unfolds. Detailed support from the weather industry helps businesses along the river minimize downtime and leads railroads to order special inspections to avoid derailments.

IDSS and forecast production operations, integrated environmental and emerging services, the production and use of foundational datasets, and the delivery of forecast confidence information will require an expansion of NWS computer-generated predictive capabilities. By focusing on the following items, NWS will realize improved warning and forecast precision and accuracy with computer-generated:

- Convective-scale guidance to increase lead times and reduce false alarm rates for warnings and forecasts
- Earth system predictions, combining the atmospheric, land, ocean, space, and ice components, with a focus on emerging service areas such as ecological, tsunami, health, and space forecasting
- Probabilistic guidance for the quantification of forecast certainty

Convective-scale guidance: Convective-scale guidance is critical to improving neighborhood-scale forecast accuracy and prediction. Today, forecasters can accurately convey the development of thunderstorms with a precision spanning a few hours and several counties or states. Precise identification of where and when thunderstorms will develop is beyond today's capabilities.

Currently, forecasters issue severe weather warnings based primarily on the detection of the phenomenon. In the future, forecasters will also integrate computer-generated guidance into the warning process. This warn-on-forecast capability will extend lead times and reduce false alarm rates. The same capability will improve forecasts of clouds, fog, visibility, and precipitation. Combined with IDSS, this would transform how communities prepare, mitigate, and respond to high-impact events that threaten lives and livelihoods.

Improved combining of atmospheric, land, ocean, space, and ice components: There is growing demand for the integration of diverse information into a suite of environmental products and services to provide, for example, health-based and ecological forecasts. NWS, in collaboration with other NOAA line offices, other Federal agencies, and the research community, will increase the range of information supporting emergency management, energy, human health, and ecosystems. NWS and its partners can achieve this capability by increasing their focus on Earth as a system with interconnected land, ocean, atmosphere, space, and ice components. Advanced Earth system numerical prediction models will be capable of assimilating a vast array of environmental observations to predict future states of the Earth system and create information that the weather enterprise and core partners can use to optimize risk-based decisions. Enabled by these improvements, decision-makers will prepare for and mitigate environmental and non-weather-related hazards more proactively.

Computer-generated probabilistic guidance: Historically, computer-generated forecast output has been almost exclusively provided as a single solution. Yet, for decision-makers to make the best possible risk-based decisions for unique situations, they require a range of possible outcomes that represent a forecast's uncertainty, or ensemble forecasts. This need cuts across multiple time and space scales, ranging from thunderstorms to climate. To meet this need requires significant post-processing to ensure that biases are corrected and that the ensemble is calibrated to provide the most reliable spread of predictive solutions and associated probabilities.

Ensemble forecasts are required to produce probabilistic data, and NWS must continue to address this need to meet the needs of its core partners and the weather enterprise.

Probabilistic data are derived from statistical post-processing techniques using climatological data to estimate skillful probabilities of sensible weather parameters finely tuned for specific point locations. This method, known as Model Output Statistics (MOS), adds precision and accuracy to the raw numerical weather prediction output for any weather parameter observed from the surface of the Earth. Additional emerging techniques, including Ensemble-Kalman Filter systems, promise additional improvements in estimating forecast confidence. Probabilistic information will be a critical part of the 4-Dimensional Data Cube and enable the NWS and entire weather enterprise to improve forecast services to the Nation.

For NWS to remain a trusted provider of probabilistic predictions, it must maintain a high priority on using critical increases in high-performance computing to enhance the ensemble forecasting system. Another major ingredient for success is a robust and agile R2O framework that ensures collaboration, links funding and resources with expertise across the research community, and provides an infrastructure to efficiently transfer new capabilities into operations.

Objectives
• Improve accuracy of ensemble-based numerical guidance systems across multiple space and time scales
• Develop and implement an on-demand, warn-on-forecast, predictive guidance capability for convective initiation, severe weather, and fire weather
• Collaborate with others to deliver a predictive guidance suite executed within a coupled Earth system modeling framework to support integrated environmental services
• Develop high-quality real time and historical analyses-of-record and datasets of retrospective forecasts (hindcasts) to support situational awareness, forecast initialization, calibration, and forecast confidence information/applications
Outcomes
• Communities that are better able to manage risk decision-making
• Increased modeling precision and accuracy through a fully coupled Earth system numerical prediction capability
• A foundation for the 4-Dimensional Data Cube and COP
• Increased forecast accuracy and warning lead time through thunderstorm-scale predictive guidance and other scientific advances, allowing more time to prepare for and mitigate against severe weather
• Reduced tornado false alarm rates while maintaining or improving probability of detection and lead-time performance

3.1.4. On-Demand, Reliable, Quantified, and Comprehensible Forecast Confidence

To empower IDSS, future forecast operations will generate reliable information on forecast confidence (used synonymously in this plan with "forecast uncertainty") in fully accessible and customizable formats. Achieving optimal use of forecast confidence to improve decision support will require a comprehensive approach that includes advances in ensemble prediction, post-processing, interpretation, delivery, and communication. Additionally, in order to deliver and communicate intuitive and usable products and services, the application of social science research is needed early in and throughout the development process.

Every day, NWS disseminates forecast information that is used to make decisions. These decisions, which often have significant impacts, are often based on a forecast that provides little insight into forecaster confidence and the range of possible outcomes. NWS forecasts historically have been binary in nature; either it was going to rain, or it was not going to rain. While a great deal of social science study is still required on the subject, evidence indicates some decision-makers want more information about the probability or likelihood of an event to make more informed risk-based decisions. As weather-sensitive industries place greater reliance on increasingly skillful weather prediction, they are seeking a better understanding of probabilities to make optimal, objective decisions, factoring in risk, impacts, costs, and benefits. Quantifying and communicating forecast uncertainty is thus fundamental to the success of IDSS.

The potential for NWS to take a leading role in providing foundational uncertainty information has been broadly recognized. The 2006 National Research Council report, "Completing the Forecast," observed: "By partnering with other segments of the Enterprise to understand user needs, generate relevant and rich informational products, and utilize effective communication vehicles, NWS can take a leading role in the transition to widespread, effective incorporation of uncertainty information into hydrometeorological predictions." NWS recognizes this leading role and will focus on delivering a comprehensive forecast capability that meets service needs by focusing on three key capabilities:

- Use of ensemble modeling and statistical post-processing techniques to produce, calibrate, and verify quantifiable forecast confidence
- Full integration of probabilistic information into the forecast process, including mature, tested methods for forecaster refinement and use of probabilities
- Understanding user needs and communicating relevant forecast confidence and risk information to those who can benefit from such information

A key initiative underway is frequently updated, high-resolution (4 km resolution or finer) ensemble predictions to accurately portray forecast confidence for severe weather and other high-impact events. Another critical innovation will be the development of "reforecasts" (datasets of retrospective forecasts) to detect and calibrate or correct common forecast errors, thereby improving forecasts of rare events such as hurricanes or heavy precipitation.

While the role of the forecaster will evolve to one of intervening when required and providing professional value-added interpretation of objectively produced information, the exact course and pace of this transition remains unknown. As experts in understanding local weather, forecasters excel at conceptualizing processes and recognizing patterns. Such strengths will further enable forecasters to add value to objectively produced information. NWS will use test beds and proving grounds to develop forecaster applications and tools to allow them to exploit probabilistic guidance in improving IDSS.

NWS will work with social scientists early and throughout the development process to synthesize, condense, and adjust the forecast confidence information to best match decision-maker needs. NWS will educate its partners to use this information and seek feedback from them on ways the products can be refined. Achieving this high-level decision support for NWS core partners and other users requires neighborhood-scale probabilistic guidance, increases in HPC capacity, forecast calibration, education of both forecasters and users, effective communication of forecast confidence, and development of tailored decision aids.

Objectives
• Expand and refine the spatial and temporal resolution of the ensemble post-processing suite
• Provide post-processed data in intuitive and standardized formats
• Integrate probabilistic information into the forecast operations, including well-developed and tested methods for forecaster refinement of probabilities
• Discover and apply ways to effectively communicate forecast confidence information
• Evaluate and quantify societal and economic benefits of probabilistic forecasts
• Collaborate with the weather enterprise on the meaning and use of probabilistic forecast information
Outcomes
• Forecast confidence information that enables decision-makers to make better risk management decisions, save lives, and reduce environmental impacts on infrastructure
• Forecasters will have an increased awareness of the spectrum of potential outcomes, which will provide them a heightened level of situational knowledge
• The weather enterprise improves products and services through expression of forecast certainty

3.1.5. Agile, Scalable, Cost-Effective Data Processing, Management and Dissemination

Achieving the vision of a Weather-Ready Nation requires an agile, scalable organization capable of quickly responding to high-impact environmental events. NWS must have an IT infrastructure capable of the same. Therefore, it is critical to find cost-effective methods to transform the way NWS collects, uses, and disseminates information so its users have the data they need – when and where they need it. It also means having the HPC capacity needed to increase forecast accuracy and lead time *and* the right infrastructure to transmit those data to anyone who needs them.

NWS will focus on three key IT service capabilities to meet emerging requirements of the weather enterprise, and public and private sector decision-makers:

- Develop a scalable, agile, and cost-effective infrastructure capable of delivering data and information anytime and anywhere
- Implement an "Open NWS" that provides easy access to NWS information across the weather enterprise
- Partner with industry to acquire next-generation, HPC capabilities and increase capacity

The above service capabilities are consistent with Office of Management and Budget guidance, security directives, and industry trends.

Forecasters need the ability to communicate with their partners through easy collaboration methods, enterprise GIS, and mobile applications. Achieving agility and scalability requires that NWS not only invest in IT, but also change how it *manages* IT. A challenge for the agency is how to keep up with evolving technology in a cost-effective and agile manner.

Developing and implementing an "Open NWS" means eliminating the current paradigm that places users either "inside" or "outside" of the NOAA/NWS domain. Under "Open NWS," the entire weather enterprise will have access to all NOAA/NWS information. The weather enterprise will participate in NOAA/NWS development as a full partner and help to develop the technology and its information.

The NWS' IT infrastructure will evolve over the next 3–5 years. Today's IT infrastructure, including HPC, is insufficient to meet these future needs. It provides little flexibility or capacity for adding new capabilities, services, or users. Data are often in disparate and inconsistent formats, and IT systems are often stovepiped. In the future, technologies must easily scale to meet fluctuations in user demand when major weather events occur or new capabilities become operational. NWS must develop cost-effective infrastructure solutions to existing shortcomings in bandwidth capabilities to exchange increasing amounts of data through smart subscription-based push-pull technologies. An agile infrastructure will enable the NWS to work collaboratively from any location with any device, including laptops, smartphones, and tablets, while retaining full access to necessary applications and data. Agility will also make data accessible and interoperable, and facilitate the creation of a geospatial COP to support a wide variety of users. This approach gives NWS the flexibility to meet future dissemination requirements by leveraging new and emerging technologies.

Obtaining sufficient HPC resources is essential to the success of this plan. Additional observational data, increased forecast skill, and expanded computer-generated guidance suites will have little effectiveness without the necessary computing resources. NWS must work with industry to find more cost-effective HPC and data fusion and mining solutions to meet these demands.

NWS must also change how it manages IT infrastructure to meet these goals, from an essentially system-centric approach to one that is services-centric and directly linked to mission goals and priorities. This includes capitalizing on new and evolving IT solutions, such as service-oriented architecture and cloud technologies. This will allow NWS to focus more on service delivery and less on IT infrastructure management and sustainment.

NWS WRN Roadmap

Objectives
• Improve dissemination capabilities through accessible, interoperable data
• Identify and implement more efficient HPC capabilities by working with private industry and the research community
Outcomes
• An environment focused on service delivery
• A single point of access to NWS data and information
• Scalable and cost-effective secure IT infrastructure

3.1.6. Symbiotic Research to Operations and Operations to Research

Scientific and technological achievements come from both internal and external bodies. Infusing these advances into operations (R2O) is crucial to improving NWS' forecast and warning performance. However, new concepts must be validated in an operational environment prior to implementation. NWS will evaluate these advances using Pilot Projects, test beds, and proving grounds. Fully addressing the questions associated these evaluations will require the full commitment of collaborative R2O efforts. Overall, R2O will be based on four concepts. NWS will:

- Develop requirements, opportunities, and innovations through an open dialogue across the physical and social science community. This development process will include NWS operations and development organizations, NOAA research, and NWS' public and private sector partners.
- Leverage the core competencies of NOAA laboratories, cooperative institutes, the private sector, universities, and other governmental and nongovernmental research organizations throughout this development process.
- Exploit operational systems and cloud architectures to facilitate collaboration and sharing of ideas. The use of operational data, automated tools and applications, and IT standards and protocols in research activities will yield more responsive and less costly transitions into the operational environment.
- Develop virtual test beds to facilitate collaboration with partners and to reduce the cost and impact associated with physically bringing NWS operational personnel to test locations.

Transitions must align with NWS priorities and follow a systematic approach that includes evaluation at key points. **Figure 3-1** summarizes major transition phases and key metrics for evaluating each transition stage. This systematic approach helps balance requirements and opportunities to make the process more efficient and effective.

Figure 3-1: Phases to Adapt and Implement S&T Capabilities

Phase	Key Question	Key Metric	Facility
Research and Development	Does the concept have a solid scientific foundation?	Peer-reviewed publication	Universities, government laboratories, private industry
Developmental Testing	Does it work with and improve operational S&T?	Successful feasibility/ engineering analysis	Test bed with operations-like environment
Experimental Testing	Does it meet operational performance criteria?	Go/no-go based on: Objective performance (e.g., accuracy) Subjective feedback Production readiness	Operational proving ground for clinical tests and full "dress rehearsal"
Integration into Operations	Does it maintain required performance?	Objective criteria: accuracy and reliability	NWS field offices

With tight budgets and rapidly advancing technologies, NWS must leverage the core competencies of all of its partners through an integrated, collaborative approach. Doing so will save time and resources and allow NWS to develop required operational improvements while accelerating the development, testing, and implementation of operational advances.

NWS will achieve more efficient and responsive developments if Research and Development (R&D) efforts leverage existing operational systems and data. New capabilities may have broad impacts and applications, but for the transition to NWS operations to be timely, R&D must take place in environments compatible with NWS operational IT infrastructure. In addition, it must leverage Commercial-Off-the-Shelf (COTS) products and their core competencies through collaboration with Pilot Projects, test beds, and proving grounds.

NWS field innovators must have the opportunity and means to share their requirements and ideas with NWS leadership. Working in concert with NWS regional and national offices, field innovators will be provided with the ability to team up with laboratories to collaborate on development of new applications and capabilities in line with NWS priority needs.

As NWS strives to better define its understanding of the environment, it will explore observing capabilities in the context of an overall strategy critical to ensure best value. In some cases, this may require the use of data denial and Observing System Simulation Experiments to determine the impacts of different observational data on analyses and forecasts.

Objectives
• Foster open dialogue across the physical and social scientific community to support the S&T development process
• Collaborate with NOAA line offices and laboratories, cooperative institutes, the private sector, universities, the research community, and other governmental and nongovernmental agencies
• Exploit cloud architectures to yield faster and less costly transitions of new S&T into the operational environment
• Ensure a clear connection between service requirements and research investments
• Improve the effectiveness and efficiency of transition projects

NWS WRN Roadmap

Objectives
• Increase the use of operational data, models, applications, IT protocols, and systems in research activities
• Ensure consistent understanding of NOAA's R2O/O2R processes and requirements
Outcomes
• Transitions are cost-effective, well-staged, and properly resourced
• Field innovators are equipped to team with laboratories to develop new applications and capabilities in line with NWS priority needs
• Research partners are prepared to respond to opportunities for enhancing NWS operations
• Current operational capabilities, data, systems, and protocols are accessible to external R&D communities to advance S&T
• Transition projects and processes will be clearly articulated and executed according to NOAA's goals for emerging S&T
• Weather and climate industry coordinates development of new services for its clients with new NWS capabilities, leading to "simultaneous rollout" across the entire weather enterprise

3.2. Priorities for S&T Development

This section lists some of the top priority S&T development thrusts for implementing the WRN Roadmap. Implementation plans describing available technical approaches will need to be generated and presented via the NOAA Strategy Execution and Evaluation (SEE) process.

3.2.1. Comprehensive Situational Knowledge, Earth System Predictive Guidance and Forecast Confidence

Comprehensive situational knowledge, Earth system predictive guidance, and forecast confidence are all critical development areas for the WRN and they all rely on improved operational software for NWS' numerical forecast systems (comprised of data assimilation, forecast models, and post-processing) together with steady increases in HPC over the next decade.

The top software development priorities in these areas are:

- Techniques for generating high-resolution, fused data analyses to support a rapidly updating, three-dimensional product stream for forecaster situational awareness. The rapid updating must generate (with greater accuracy, frequency and use of available and new observations) real-time analyses of precipitation, radar reflectivity, clouds, temperature, wind, convective potential, hazardous chemicals and other fields required by forecasters to generate warnings and forecasts with greater lead time and accuracy than today.
- Application of high-resolution data assimilation for ~1–3 km model initialization to provide continuity of 1-6 hour model forecasts with the rapidly updating fields, especially for convectively forced events. This is a major challenge due to the scientific difficulties of representing evolution of extreme and rapidly evolving mesoscale weather patterns at high resolution with input from scattered and often unrepresentative observations.
- Continued exploitation of a suite of multi-scale forecast models that can represent high-impact weather events and their environment on continental, regional, and local scales. Critical development for severe weather involves forecasting the complete hydrological cycle from surface fluxes to cloud generation and growth (often in complex terrain), which requires coupling with land surface and hydrological models. Longer-term forecasts (to predict the environment spawning high-impact

events) derive increased accuracy from coupling with the ocean (particularly in coastal areas) and cryosphere (for the Arctic).

- Continued exploitation of ensemble techniques to represent forecast uncertainty. A multi-model strategy will be continued for both regional and global guidance while addressing fundamental issues in representation of stochastic physical processes that capture realistic uncertainty estimates.
- Continued exploitation of post-processing techniques that provide bias-corrected and calibrated probabilistic products for the forecaster. Often, the best guidance is generated from combination of available fields from multiple sources. The combination methodology may differ depending on the output, however, so optimal methods, possibly involving artificial intelligence tools, will be developed and compared with more standard techniques.

These development thrusts must also address the most important observing gaps, taking into account the ability of models to represent high-impact weather and the cost-effectiveness of radar, surface, aircraft, and satellite-based platforms to provide critical information. A plan will be developed as a supplement to this WRN Roadmap.

3.2.2. Forecaster Decision Support Environment

The following development areas are the highest priority for enhancing the FDSE capability in the NWS operational AWIPS.

- Development of the Impacts Catalog from available climatological information and analysis of historical user impacts at the local level.
  - The Impacts Catalog is a fundamental item for enhancing FDSE capability. Together, the Impacts Catalog and calibrated probabilistic guidance can provide the basis for beginning the IDSS process at the NWS WFO.
  - Placing a forecast event in a climatological context enables the forecaster to estimate impact and to connect efficiently with the most impacted users. Real-time assessment of climate factors, such as El Niño, provides a weather context for some areas of the country.
  - Automated tools for the above will be incorporated into AWIPS and be applied to available deterministic and ensemble guidance for user-relevant applications and forecaster use.
- Automated performance tracking tools, measuring the consistency between forecast guidance and evolving phenomena, and the time consistency of current and previous guidance. Time consistency in the guidance is a key factor in determining forecaster confidence and intervention for putting out warnings, planning ahead for significant events and providing updates in critical situations.
- Support for local impact areas outside the traditional weather area will be enhanced. In collaboration with NOS, AWIPS applications will be developed in the context of the WRN Pilot Projects.

3.2.3. Data Processing, Management, and Dissemination

Efficiency is critical for reducing costs and enabling the right information to be accessed by those who need it, when they need it. This thrust is essential due to the major increases in raw information available in the future. The following high-priority items will be developed.

- Design and implement a Virtual Laboratory (VL) for software development within AWIPS. Being based in the cloud, the VL will be a fundamental change in software development strategy for forecaster applications and will enhance both O2R and R2O,.
- Continue VL systems for operational numerical guidance development, including NCEP's Hybrid Gridpoint Statistical Interpolation system (supported by the NCAR Developmental Testbed Center, the NOAA Environmental Modeling System).

- Exploit the prototype capabilities of NOAA's Operational Model Archive Distribution System (NOMADS) with improved software engineering and data selection capabilities and integrate with the AWIPS and NCEP model guidance datasets.

3.2.4. R2O and O2R

The R2O process dictates the vibrancy and capacity for ongoing improvements to NWS systems. Leveraging a broad and motivated community of contributors is a major strategic thrust. In order for R2O to succeed through focused test bed and proving ground activities, access to and encouragement for using operational systems (i.e., O2R) is critical. The following activities are high priority for R2O.

- Enhanced ability to develop, test, and implement new applications in operational software through a cloud strategy as discussed in Section 4.2.3. Access to managed operational software through the cloud requires regulated access to a group of skilled software developers who build parts of a complex software system according to their expertise and commit to standards for code structure, regression testing, long-haul multi-investigator contributions, and a disciplined development environment.
- Establish a NWS Visitors Program for scientific development within AWIPS and for numerical guidance
  - The Visitors Program will enable top-level developers, external to NWS, to engage at a deep immersive level with NWS strategic planners and major development projects.
  - A Visitors Program is a fundamental pillar of NWS' strategy for enhancing science-based services.

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4. Business Plan

4.1. Introduction

The Business Plan defines NWS' strategic business and operating objectives. Strategic business objectives can be thought of as high-level, enduring principles that shape operation of the agency. The Business Plan is built on three underlying concepts for the agency's strategic objectives:

- Be sustainable
- Be flexible and agile
- Increase value to the Nation

Underlying Business Concepts

- *Be sustainable*
- *Be flexible and agile*
- *Increase value to the Nation*

These objectives are not mutually exclusive; rather, they support each other. Increasing the value of NWS services to the Nation increases the support for NWS and enhances its sustainability. Becoming more flexible and agile, and adapting to the evolving needs of existing users and the needs of new users, increases value to the Nation and in turn, enhances sustainability. Being sustainable in and of itself increases value to the Nation. Activities and investments within the agency will be evaluated against these strategic business objectives.

Key Term	Definition
Weather-Ready Nation	A nation prepared to protect against, mitigate for, respond to, and recover from weather-related disasters, hazards, and disruptions to safeguard lives and livelihoods.
Core Partners	Government and nongovernment entities that are directly involved in preparation, dissemination, and discussions involving weather, water, and climate or other emergency information put out by NWS.
Weather Enterprise	All government agencies, private sector entities, nonprofit groups, and academic and research institutions contributing to the business and/or science of weather observing, forecasting, and warning.
Impact-Based Decision Support Services (IDSS)	NWS' provision of tailored, relevant information and interpretative services to enable core partners' decisions when weather, water, or climate has a direct impact on the protection of lives and livelihoods.
Common Operating Picture	A shared database, capable of on-demand, customized, user-configured output, from which all NWS weather, water, and climate information is derived.

The Business Plan reviews the current financial operating state of the agency in terms of the current business model, and proposes plans and activities that address the strategic business objectives.

4.2. Current Business Strategy and Model

The current NWS business strategy builds upon lessons learned from the Modernization and Associated Restructuring (MAR), completed in 1999. The MAR implemented the:

- Current NWS office and headquarters structure, including the 6 regional headquarters, 122 WFOs, 13 RFCs, 21 CWSUs, and 9 NCEP
- Observing strategy
- Forecasting system, including digital services transition
- Next-generation HPC and models

The current business model for the NWS was developed under the NWS Modernization. Under the Modernization, the NWS was re-structured, both organizationally and physically, to optimize performance for short fuse warnings and forecasts. The business and operational model was further refined during the late 1990's with the introduction of digital forecast services.

NWS WFOs were reorganized under the coverage umbrella of the Weather Surveillance Radar 88 Doppler (WSR-88D) Next-Generation Radar (NEXRAD) to support warning operations and local communities. Digital services eliminated the manual production of text forecast products, allowing forecasters to concentrate on the generation of forecast elements from which a suite of text forecast products could be derived.

Overall, the NWS Modernization was built around six major improvements: the new Geostationary Operational Environmental Satellite (GOES), the Automated Surface Observation System (ASOS), NEXRAD, the Advanced Weather Information Processing System (AWIPS), HPC and weather forecast models, and the facilities for the WFOs and RFCs. Funding for the system improvements (AWIPS, ASOS, and NEXRAD) included both Operations and Maintenance (O&M) and product improvement funding.

4.2.1. Facilities

NWS operates and maintains its core services of 24/7 weather forecasts and warnings from 122 field-based WFOs supported by 9 national centers, 6 regional headquarters, 21 CWSUs, and 13 River Forecast Centers (RFCs) with nationwide networks of state-of-the-art observational systems via nationwide IT infrastructure backbone facilities. NWS data, products, and expertise form an international information database and infrastructure that can be used by decision-makers in the public and private sectors, both domestically and abroad.

A key component of the MAR was the building of state-of-the-art facilities to house the 122 WFOs and the 13 RFCs. WFO and RFC facilities were constructed during the NWS Modernization effort in the early 1990s. Both the WFOs' and RFCs' critical facility infrastructure will need to be refreshed over the next several years.

As of summer 2011, NWS owned 87 of the 122 WFOs, and leased the remainder. The average age of NWS-owned facilities was 29.2 years old and the average age of NWS-owned structures (e.g., towers, instrumentation) was 43.1 years old. Many of these NWS-owned facilities need significant facility repairs, including roofs; Heating, Ventilation, and Air Conditioning (HVAC); control systems; Uninterruptible Power Supply (UPS); and office backup generators at the end of their useful life. NWS must invest in its facilities to ensure their continued occupancy. Of the 35 NWS-leased WFOs, many are nearing the end of their initial 20-year lease and will need new leases or relocations. Critical elements of these facilities are reaching end-of-life.

4.2.2. Observational Infrastructure and Programs

A core foundation of the current NWS infrastructure is its observations and observational systems Operations and Management (O&M) programs. NWS relies on an integrated suite of observations and nationwide observational systems to accurately detect and forecast weather events. These systems include NEXRAD (Doppler Weather Radars), ASOS, Upper-Air (GPS radiosondes), and ocean-observing systems (data buoy networks). Data from these observational systems are used 24/7 in support of NWS' core weather, water, and climate forecast and warning mission. Observations and observational systems represent NWS' historic legacy. Because input from these systems is the starting point for all forecasts, these programs represent a mission-critical part of the essential foundation of NWS.

Similar to NWS facilities, many of the above core NWS observational systems are aging and will need significant technical refresh. Moreover, inflation has eroded the adequacy of system O&M funds, extending preventive maintenance schedules and adding risk for extended system outages. NWS should also consider using COTS solutions in the future to reduce overhead in O&M programs.

In the future, NWS will experience a paradigm shift in terms of observational equipment. In the past, observing equipment was mainly the province of Government agencies, as during the MAR. Since the completion of the MAR and with the decreasing costs of sophisticated observing equipment, the weather enterprise has been able to make similar investments in observing equipment. Therefore, NWS must consider public-private partnerships as a means of reducing infrastructure costs, data sharing, and further engaging the weather enterprise.

4.2.3. Science and Technology Infrastructure

Under the MAR, the centerpieces of NWS' IT infrastructure were AWIPS and HPC. Today, both AWIPS and HPC are critical to NWS operations. They form the cornerstone of NWS' ability to accurately predict weather. NWS also relies on a variety of dissemination systems, including the NWS Telecommunication Gateway (NWSTG), its Operations Network (OpsNet), the 1,000-transmitter-based NOAA Weather Radio All Hazards (NWR) Network, and the Internet.

As with NWS facilities and observational systems, NWS' IT infrastructure faces resource challenges. Inflation has eroded the O&M funding for AWIPS, NWR, and the NWSTG. Both the NWR and NWSTG require significant technology refresh and/or complete re-architecture. The need for improved model guidance to support WRN requirements for severe weather and expanding applications to integrated environmental services and emerging service sectors will require increasingly complex models with increasing resolution and run frequencies. All of these factors mandate a larger HPC capacity, which is a challenge to achieve in a time of budget constraints.

IT remains an area in which NWS can identify opportunities to save costs by leveraging new and emerging technology. NWS leadership must keep pace with technology and identify which technology investments have the potential to drive down current and future costs.

4.2.4. Analysis of the Near-Term Fiscal Environment

The current fiscal landscape for all Federal agencies is not encouraging. Both the President and Congress have recognized that the growing Federal budget deficit needs to be significantly reduced. Therefore, it is critical to the future of NWS that it be proactive in planning and developing a new sustainable Business Plan that recognizes the current and future fiscal landscape and NWS' emerging service and S&T infusion opportunities.

Though maintaining current operations is itself a constant budget pressure, NWS cannot ignore its responsibility to invest in innovations that save future costs (especially nonlabor costs). NWS must aggressively monitor technological developments to identify cost-saving opportunities, and invest in technology that improves the agency's future fiscal position. NWS must also look at how it uses people, its most valued resource, to meet mission needs.

4.3. Current Business Model Gaps

Overall, the success of the NWS MAR is clear. Today, NWS is recognized as one of the most respected and service-oriented Federal agencies and internationally viewed as the "Gold Standard." The dedicated work of a professional workforce, coupled with planned S&T advances and supported by state-of-the-art tools and infrastructure support systems, has been beneficial for the country. NWS has advanced the core goals of the MAR by achieving more uniform and consistent weather services across the Nation, improving weather forecasting, providing more reliable detection and prediction of severe weather and hydrologic events, and achieving higher productivity.

While NWS still strives to improve its products and services, the costs to operate and maintain the NWS MAR operations model exceed available funding. The unfortunate casualty of these events is the continuous improvement goal under MAR. Efforts toward continuous improvement have become secondary to prioritizing funding to maintain critical infrastructure, labor, and services funding.

The Weather-Ready Nation initiative provides a unique opportunity to set the course for the upcoming decades, building upon the NWS MAR. As part of the Weather-Ready Nation, a new business model will be launched to mitigate critical gaps in the NWS MAR. The foundation for the new business model is three strategic objectives: to be sustainable, to be flexible and agile, and to increase value to the Nation.

4.4. New Business Model

The NWS Business Plan defines a new business strategy and business model to sustain current NWS operations and enable implementation of the proposed Services, Workforce Evolution, and S&T concepts. In this era of Federal Government fiscal austerity, NWS has developed strategies designed to enable the agency to focus on its core mission of protecting lives and livelihoods. This Business Plan ties into NOAA's Strategy Execution and Evaluation (SEE) process, defines a framework to prioritize the agency's objectives, and incorporates the following key principles:

- NWS' core mission is protection of the life, safety, and property of the Nation.
- Community presence (engagement and partnerships) is essential to NWS' core mission.

Any proposed changes to NWS operations must be fully tested and proven, given the critical nature of the NWS mission and the goal of making America a Weather-Ready Nation.

4.5. Sustainability

Sustainability should be among NWS' highest priorities as the agency executes its mission and accomplishes its goal of making America a Weather-Ready Nation. Sustainability also means building support from users. Organizational sustainability has multiple facets, such as:

- Maintaining fiscal responsibility and discipline
- Adopting diverse income streams without sacrificing core mission and core services
- Developing and articulating the ROI for weather services
- Implementing best practices and business methodologies

The first challenge in achieving NWS' strategic business objective of being sustainable is to address the structural deficit. Structural deficit is defined as the imbalance between our fixed and variable operating costs (labor, facilities, O&M) and the funds appropriated for them. This requires near-term actions to reduce operating costs and identify additional sources of revenue.

Plan	Activities	Outcomes
Drive down operating costs	• Leverage technology to reduce costs	**Reduced/eliminated structural deficit**
	• Assess organizational operations (e.g., contractor support, corporate services)	
	• Enter into public-private partnerships to offload S&T costs	
	• Reduce hardware and software application costs through Enterprise IT solutions	
	• Increase use of geospatial information systems (GIS) to slow the growth of demands on communications	
	• Use cloud services to reduce computational costs	

There are a number of ways to reduce the cost of day-to-day operations. Technological advances, particularly in IT, can reduce long-term operating costs. Changes in organizational operations can also reduce operating costs. Building partnerships that enhance the NWS mission while delivering services in a more efficient manner will also reduce operating costs.

Plan	Activities	Outcomes
Expand opportunities to leverage assets and grow resources	• Investigate reimbursables/cost recovery • Explore fee-for-service model for high-end commercial users • Investigate business models from other national meteorological/hydrological/climate services	**Enhanced revenue and/or lower operating costs**

Despite significant legal constraints and political challenges, NWS should explore opportunities to enhance revenue. For example, NWS should investigate reimbursable agreements for services provided in support of the National Response Framework (addressed in the Services Plan) beyond its core mission capacity. NWS should also pursue opportunities for cost recovery for certain defined levels of service for data access above and beyond what is currently offered for the agency's private sector partners.

NWS should also compare its business efficiency with other national meteorological and hydrological services. Improving organizational and operational efficiencies will maximize available budgetary resources.

Plan	Activities	Outcomes
Streamline operations to reduce costs	• Eliminate redundant contractor support • Eliminate low-value services • Investigate streamlining headquarters functions and organization	**No redundant systems or outdated services**

NWS should review all contracts for overlapping requirements and support. The agency should eliminate redundancies and reinvest the savings toward sustainability. Similarly, services, products, or activities that have low value with respect to NWS' core mission should be targeted for reduction or elimination.

Plan	Activities	Outcomes
Implement business process improvements	• Improve cost accounting • Create economic model for services • Calculate ROI • Implement NWS-wide Quality Management System (QMS)	**Defined best practices-based business methodologies**

Enabling NWS' sustainability requires the implementation of best-practice business process improvements. More detailed information on expenditures is an essential first step to any business process improvement. NWS must continue to improve its cost accounting and implement methodologies that capture costs associated with decision support services for high-impact events.

Improved cost accounting will be necessary to capture costs associated with services rendered under reimbursable agreements. For example, when the government seeks reimbursement from an oil company for its expenses related to responding to an oil spill, NWS cost accounting systems must document NWS expenses accurately to support reimbursement.

NWS must develop cost models for each service. The agency is currently funding research to develop a cost model, with two objectives: (1) determine the value of a particular NWS service to a specific economic sector, and (2) assess the increased value of economic service due to increased accuracy. This methodology would enable NWS to calculate the ROI and cost of improved services.

NWS must also implement an agency-wide QMS, which is defined as the organizational structure, procedures, processes, and resources needed to implement quality management. A key component of QMS is a continuous improvement cycle. QMS is being developed according to World Meteorological Organization (WMO) and International Civil Aviation Organization (ICAO) requirements for aviation services. A QMS provides technical measures of performance, in addition to business measures of performance.

Plan	Activities	Outcomes
Implement NOAA/NWS Enterprise IT Infrastructure	• Identify dissemination requirements for enterprise solutions • Investigate cloud-based AWIPS II solutions • Implement AWIPS II thin client • Adopt NOAA-wide data service standards • Implement open standard GIS protocols	**Flexible, scalable, agile, and cost-efficient IT**

There is ample evidence from industry and other government agencies that Enterprise IT solutions can save money as well as enable faster implementation of new capabilities. NWS should continue to work with NOAA on delivering a NOAA-wide solution that meets NWS needs and requirements. This should include rendering all NWS information GIS friendly so that NWS, NOAA, and external users can more efficiently exploit the Government's environmental data.

4.6. Flexibility and Agility

NWS must become a more flexible and agile agency, and this means that NWS must quickly adapt to:

- Technological advances
- New scientific breakthroughs
- Evolving needs of NWS' core users and partners
- Emerging needs of new users and economic sectors
- Changing workforce requirements
- Evolving organizational needs

Given the broad forces that drive flexibility and agility as a business objective, NWS must meet this challenge by responding in two broad areas: operations and management. Operational flexibility means adapting the agency's core forecasting and warning capabilities to new scientific advances, new technologies, and new procedures. It also means adapting service and decision support delivery to the changing needs of NWS' users and to new technological advances. This operational flexibility must also be backed up by organizational flexibility. NWS must adapt its organization, personnel, and management practices to promote and instill flexibility as an organizational value.

The first steps in meeting this business objective are to adopt new strategies that are documented in the Services, Workforce Evolution, and S&T Plans.

New service and operations concepts cannot be implemented without first having a mechanism to ensure no degradation in current capabilities, measure effectiveness and impact on the workforce, and provide data to calculate return on investment. This requires both a physical infrastructure and a governance infrastructure. First, NWS should establish an independent oversight board that would evaluate the effectiveness of any proposed changes to NWS services or operations. Much like the Modernization, the board would be responsible for assessing the effectiveness of tests of new concepts. Second, NWS must establish a physical infrastructure for testing and evaluating new operations and service concepts.

All of this requires resources dedicated to innovation. Once the structural deficit has been addressed, NWS should reserve a percentage of its budget for activities that promote flexibility and agility. Activities include validating concepts in the NWS Operations and Services Proving Ground, transitioning field innovation to national implementation, and sustaining it until the maintenance can be integrated into the O&M budget. This pool of funding should be defended against cuts because it is essential to a strategic business objective.

A key component of being flexible and agile is having the means to test out new concepts. This is a cultural issue as much as a management and infrastructure one. NWS must adopt a culture where there is a willingness to test new concepts, new science, new technology – and be willing to "fail well." That means understanding that learning from failed ideas will improve the mission.

Given the critical nature of NWS' mission, it is essential that the agency validate new concepts in nonoperational settings before testing them as Pilot Projects in an operational setting. NWS must enable innovation without jeopardizing its core mission. NWS must have an operational proving ground to test new operational, science, and technology concepts. Such a proving ground must be able to simulate WFO operations, RFC operations, NCEP operations, and interactions with key partners such as emergency managers.

The last significant change in NWS staffing occurred during the MAR. During this time, personnel shifted from a two-tier NWS Weather Forecast Office and Weather Service Office structure to a single-tier nationwide system. Under the MAR, a standardized staffing model was used nationwide with only a few exceptions.

The staffing model that evolved from the MAR is no longer effective in our current economic and technological era. It does not recognize the variable workload imposed on WFOs when trying to implement IDSS for different sized communities. It is critical for NWS to adjust staffing profiles to meet the changing needs of core partners and users, recognizing budgetary constraints.

As such, an evolution of the existing workforce will be necessary to better meet the needs of core partners and users. NWS will evolve the best practices of the IMET program to align with the National Incident Management System (NIMS). NIMS allows for emergency response to expand and grow with the needs of the incident. Fundamental to the Weather-Ready Roadmap is the scalable deployment of ERSs. NWS' ERSs will be trained in providing decision support services and will be able to communicate the risks and impacts associated with varying environmental phenomena.

As the services model is implemented, the diversity of disciplines in NWS may expand to include environmental scientists, social scientists, GIS experts, and public communicators. These new roles will afford NWS the opportunity to more effectively reflect the diversity of the society of the future.

Plan	Activities	Outcomes
Better train and equip the NWS workforce	• Cross-train NWS personnel as ERSs • Engage mobile ERSs as needed to support core partners • Create additional opportunities for career advancement	**Enhanced services and workforce skills**

NWS will work to streamline and expedite research to operations (R2O) activities to bring new techniques and technologies to operations. NWS will gain efficiencies by reducing redundancies and by leveraging gains by research partners, academia, and industry.

More efficient and agile S&T development can be achieved if R&D efforts leverage existing system capabilities – commonly referred to as O2R. Exploratory work on new capabilities may have broad impact and applications, but for transition to NWS operations, R&D by partners in environments closely compatible with the operational IT infrastructure will be the most efficient. In addition, partners are expected to leverage COTS products, and work to integrate their core competencies through collaboration, test beds, prototypes, and proving grounds.

Plan	Activities	Outcomes
Proactively adopt new S&T	• Establish operational proving ground and conduct S&T Pilot Projects • Leverage field innovation for national deployment • Partner with the weather enterprise throughout the R2O/O2R cycle • Leverage opportunities to collaborate on innovation with the public and private sectors	**Science and technology that enhance services**

S&T development efforts will be streamlined by ensuring that NWS' partners use NOAA operational data streams, enterprise interfaces, protocols, and dissemination endpoints. The process of setting priorities and identifying solutions, including testing and validation, will be critical to improving services.

NWS Headquarters (NWSH) program management functions currently located at NWSH, and determined not critical to central NWSH program management, should be considered candidates for in-depth review to be decentralized and strategically colocated with the regional headquarters throughout the United States. This adjustment would allow for greater exchange and interaction between NWS management and the field staff, and create an environment for career enhancement and advancement. It would potentially reduce costs due to lower cost-of-living allowances at most of the regional headquarters.

As part of the Pilot Projects, NWS will conduct Independent Verification and Validation (IV&V) activities to ensure the soundness of each Pilot Project. NWS management, in consultation with the National Weather Service Employees Organization, will review the relevant staffing configurations during each Pilot Project and provide input for any adjustments.

Plan	Activities	Outcomes
Introduce new services to meet customer needs	• Conduct and evaluate effectiveness of Pilot Projects • Leverage core partner and weather enterprise capabilities	**Increased value to the Nation**
Reduce barriers to innovation	• Streamline internal processes to minimize bureaucracy • Improve communications to maximize field and weather enterprise feedback	**Reduced time to national implementation of science and service**

4.6.1. Continuous Improvement Process

As NWS examines the results of its Pilot Projects, the agency can begin to infuse process improvements into its day-to-day services. This approach allows NWS to infuse best practices and lessons learned from the Pilot Projects as applicable into its service model. In addition, following this flexible and agile approach enables NWS to continuously incorporate feedback from core partners and thereby improve its services.

In following a continuous improvement process, NWS will need to continue to implement its practice of incorporating lessons learned from severe environmental events as a means of developing a best-practice toolkit for reuse. These lessons learned should include service, forecast, and warning best practices. NWS should consider a variety of inputs and measures with regard to service improvements, such as:

- Customer satisfaction scores, determined through core partner surveys
- Regulatory requirements that impact NWS services
- Societal impacts of extreme environmental events
- Infusion of social science and communications principles into services

Plan	Activities	Outcomes
Implement continuous process improvement	• Identify repeatable best practices and capture lessons learned • Incorporate core partner feedback into lessons learned cycles • Continually assess and expand training available to NWS personnel • Infuse proven S&T concepts or developments into operational practices	**Higher quality and more efficient services**

4.6.2. Develop a Quality Management System

NWS is entering a new phase as it develops its business model to provide IDSS to core partners and the weather enterprise, as discussed in the Services Plan. A QMS is required to sustain the agency's plan to improve services. The QMS will serve as a focal point for NWS' strategy to ensure high-quality, standardized, responsive, and consistent NWS products and services. The main goal of the QMS is to use performance measures to augment the implementation and sustainment of IDSS as a business strategy.

NWS will adopt a quality assurance methodology to ensure that the agency aligns relevant performance measures to NOAA, NWS, and IDSS strategic objectives. NWS will select measures based on their relevance to the mission. Selected measures must be actionable, and must directly relate to and support achievement of the NWS Strategic Plan.

Plan	Activities	Outcomes
Develop an agency-wide QMS	• Identify best practices • Develop customer satisfaction surveys • Use metrics to exploit and transform data into actionable information • Track linkage of strategies to end results • Enable integrity of programs by using IV&V processes	**Alignment of performance measures to NOAA and IDSS strategic objectives**

4.7. Increased Value to the Nation

The last business objective is to increase NWS' value to the Nation. Ensuring that the agency continues to focus on and improve on its core mission of protecting life and property is the most obvious method of increasing value to the Nation. However, enhancing the economy and strengthening the weather enterprise as a whole will also serve to increase NWS' value. Successfully executing NWS' mission enables America to become a Weather-Ready Nation.

Plan	Activities	Outcomes
Better protect lives and livelihoods	• Improve foundational warning and forecast capability • Enhance dissemination • Better communicate NWS services	**Minimize loss of life and damage to property**

A key component of the NWS mission is to protect lives and livelihoods; improving NWS' execution of its core mission will increase value to the Nation. This can be done by improving the foundational warning and forecast capabilities of the agency to provide greater lead time, fidelity, precision, and quantification of uncertainty in NWS information and data. In addition, NWS information and warnings must be disseminated as broadly as possible using the greatest possible number of communication mechanisms and technologies in language and formats that are most easily understood and exploited and provide the basis for action.

This broad dissemination explicitly requires a robust weather and climate industry to partner with NWS in delivering its core mission of warning support to the American public.

Plan	Activities	Outcomes
Enhance the weather enterprise	• Collaborate on new and emerging services • Partner with academia • Partner with other government agencies • Partner with America's weather and climate industry	**Enhanced economy; strengthened partnerships with the weather enterprise**

Increasing value to the Nation means enabling the entire weather enterprise, which includes NWS. America's weather and climate industry is a critical partner in warning the public, and provides environmental support to sectors of the economy based on foundational observational and forecast datasets from NWS. When the agency's information is exploited and tailored to the unique needs of industry, the private sector generates jobs and enhances the economic competitiveness of American industry. The entire weather enterprise enhances the economy.

The weather enterprise also includes the meteorological services in other government agencies and academia. Partnering with academia will increase the transfer of state-of-the-art S&T into NWS operations, increasing foundational forecast and warning capacity. Partnering with other government agencies will improve decision support to government decision-makers, improve government services, and reduce the overall operating burden on American taxpayers.

4.8. Summary and Next Steps

The NWS Business Plan charts a business strategy and model to sustain current NWS operations and enable implementation of the proposed Services, Workforce Evolution, and S&T concepts. In undertaking the WRN Roadmap, NWS will gradually yet systematically implement the types of changes required to meet NWS' strategic objectives.

The Business Plan focuses on three strategic business objectives that should frame all NWS operations:

- Be sustainable
- Be flexible and agile
- Increase value to the Nation

The Business Plan will help address current business deficiencies by:

- Achieving cost efficiencies by leveraging IT investments and public-private partnerships across the weather enterprise to solve the long-term structural deficit.
- Optimizing current resources by ensuring sufficient training and new skills.
- Pursuing cost recovery and reimbursement where appropriate.
- Prioritizing NWS services and new investments as appropriate.

In addition, NWS will launch a series of Pilot Projects to prove scientific concepts and enhanced services in an IDSS environment. Through these Pilot Projects, NWS can begin to calculate the ROI associated with new services and optimized resources. NWS will also develop a series of cost models and methodologies to ensure accurate budget forecasts and guide project execution.