

NOAA

WWW.COMMERCE.GOV
WWW.NOAA.GOV

RESEARCH AND DEVELOPMENT AT NOAA

Five-Year Research
and Development Plan
2013-2017

Environmental
Understanding to Ensure
America's Vital and
Sustainable Future





LETTER FROM THE NOAA ADMINISTRATOR

NOAA is an agency that enriches life through science. From the surface of the sun to the depths of the ocean floor, we work to understand and keep citizens informed of the changing environment around them. Working with partners, NOAA studies, monitors, and predicts changes in Earth's environment to provide critical environmental information to the Nation and support NOAA's responsibilities as stewards of our Nation's fisheries, coasts and oceans.

NOAA's research and development push the boundaries of scientific understanding and integrate information across scientific disciplines to explore, observe, and understand the Earth's dynamic systems and enable the Nation to make informed decisions about resource management and our changing environment. NOAA's science and technology enterprise supports targeted needs in NOAA's goal areas of climate, weather, oceans, and coasts, and deepens our understanding of our complex and dynamic planet.

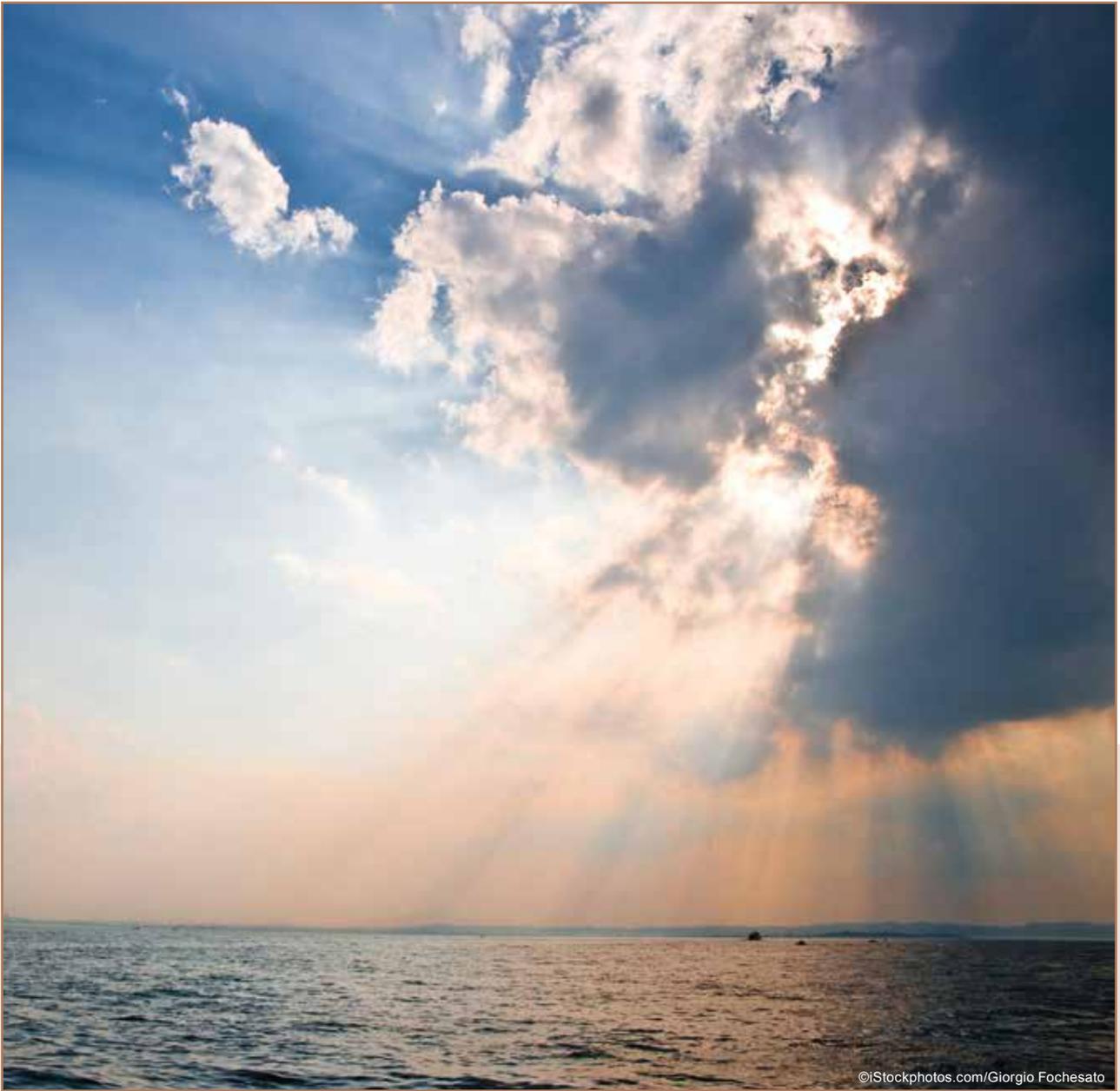
NOAA's mission touches the lives of every American, every day. From providing daily weather forecasts and severe storm warnings, to increasing our understanding of our climate, providing management for sustainable fisheries, and creating more resilient coastal communities, NOAA science underpins products and services that support the lives and livelihoods of our citizens.

Developed in collaboration with NOAA partners, this Research and Development Plan, the third of its kind at NOAA, will help guide NOAA's scientific enterprise over the next five years. NOAA will continue to work closely with its scientific partners to support and advance the research and development needed to serve NOAA's mission and the needs of the Nation.

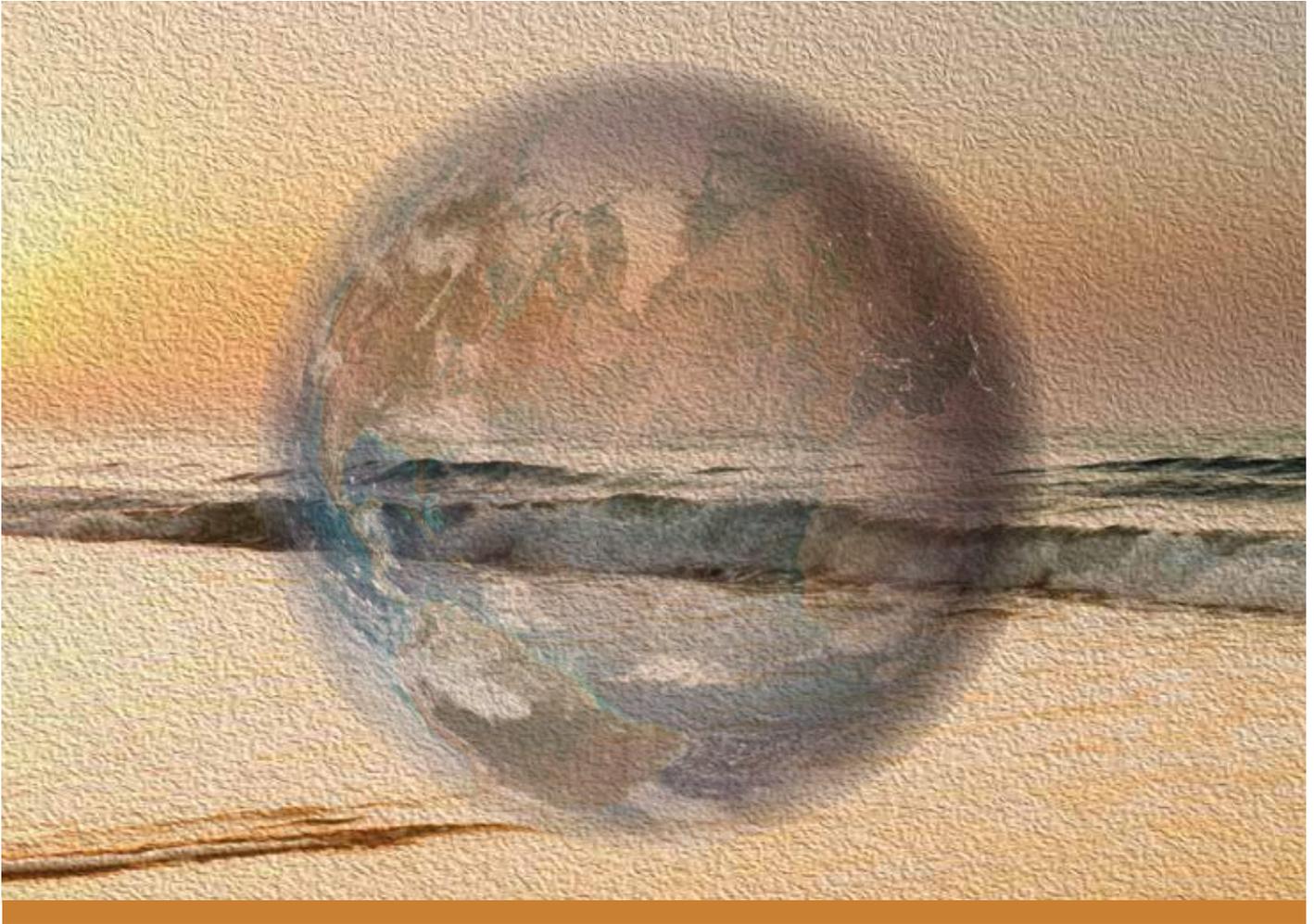


Kathy Sullivan
Acting Under Secretary of Commerce for Oceans and Atmosphere
and Acting NOAA Administrator





©Stockphotos.com/Giorgio Fochesato



N OAA's Research and Development (R&D) is inspired by both immediate and long-term needs and applications.

It is focused on the Agency's strategic goals and reflects many contemporary scientific and technological challenges. R&D at NOAA is supported by a network of individuals, institutions, and infrastructure consisting of the Agency itself, as well as its broad suite of partners. The execution of NOAA R&D rests on a core set of values and rigorous system of strategic management.

PLAN PURPOSE AND SCOPE

The Five Year R&D Plan will guide NOAA's R&D activities over the next five years. The Plan provides a common understanding among NOAA's leadership, its workforce, its partners, constituents, and Congress on the value of NOAA's R&D activities. As such, the Plan is a framework with which NOAA and the public can monitor and evaluate the Agency's progress and learn from past experience. This Plan will guide R&D activities that NOAA funds or conducts itself. NOAA abides by the Federal definitions of research and development set by the National Science Foundation. NOAA's extended R&D enterprise includes, but is not limited to internal laboratories, science centers, Cooperative Institutes, grant recipients, Sea Grant Programs, and contractors.



The main sail raised on the Derek M. Baylis, a "green" research vessel primarily powered by sail. An important element of the mission will be to track the carbon footprint of the Baylis and compare it to conventional vessels. *Credit: NOAA*



NOAA ship *Okeanos Explorer* Program is the only federal program dedicated to systematic exploration of the planet's largely unknown ocean. *Credit: NOAA*



Researchers at NOAA developed Science On a Sphere as an educational tool to help illustrate Earth System science to people of all ages. Animated images of atmospheric storms, climate change, and ocean temperature can be shown on the sphere, which is used to explain what are sometimes complex environmental processes, in a way that is simultaneously intuitive and captivating. *Credit: NOAA*



Crepuscular rays illuminate half the sky - Antarctic sunset *Credit: Dave Mobley, Jet Propulsion Laboratory*



Nancy Kachel and Carol Ladd deploy a bongo net to sample for zooplankton at the ice edge in the Bering Sea aboard the Research Vessel Thomas G. Thompson. Kachel is with the NOAA Joint Institute for the Study of the Atmosphere and Ocean at the University of Washington. Ladd is with the NOAA Pacific Marine Environmental Laboratory in Seattle. *Credit: NOAA*

Why R&D? NOAA is a mission agency, and R&D is an integral part of the Agency's mission of science, service, and stewardship.¹ R&D at the Agency seeks an understanding of global ecosystems² to support informed decision-making. R&D leads to improved understanding of the Earth system from global to local scales, improved ability to forecast weather, climate, and water resources, increased understanding of ecosystem health, and how all of these factors affect – and are affected by – people and communities. At NOAA, R&D is “use-inspired” – they not only increase our understanding of the world, but also produce applications that are useful and used.³ Maximizing “use-inspired” R&D depends upon the effective transfer of knowledge and tools into applications useful to society. NOAA continually seeks to increase the transition of information and technologies from R&D to applications.

¹ NOAA's Mission: To understand and predict changes in climate, weather, oceans, and coasts; to share that knowledge and information with others; and to conserve and manage coastal and marine ecosystems and resources.

² At NOAA, an ecosystem is a geographically specified system of organisms (including humans), the environment, and the processes that control its dynamics.

³ Stokes, D. (1997). *Pasteur's quadrant : Basic science and technological innovation*. Washington D.C.: Brookings Institution Press.

Developing the NOAA 5 Year R&D Plan. The foundations of the plan are NOAA planning documents (e.g., Next Generation Strategic Plan, SEE Implementation Plans), specific strategic documents, such as the Arctic Action Plan, Science Challenge Workshop reports, and NOAA Science Advisory Board reports, such as the Portfolio Review Task Force Report.⁴ Based on these inputs, a writing team composed of representatives from cross-NOAA strategy teams (organized by the Agency's strategic goals and enterprise objectives) defined a number key questions facing society that can only be answered through research or development. Underneath each question were developed specific objectives and discrete, five-year targets for R&D that lay the path forward for NOAA and its R&D partners. NOAA actively solicited feedback from NOAA scientists and NOAA partners, such as Cooperative Institutes, Sea Grant programs, Cooperative Science Centers, and others, as well as the external community of stakeholders and collaborators. NOAA recognizes that only through the combined effort of the Agency and its partners can we conduct the breadth of R&D required to meet NOAA's mission.

The Evolving Context for NOAA's R&D. NOAA's R&D enterprise will change as the needs of the agency and the Nation evolve. The result of this evolution has largely been the convergence and integration of multiple disciplines. However, critical events and emergent phenomena have further refined NOAA's R&D investments.

- **Climate Change and Impacts from Greenhouse Gas Emissions.** Since the last 5 Year R&D plan, the world has seen the on-going effects of increased greenhouse gases and global climate change, including significant changes to the Arctic ecosystem; sea level changes affecting our coastal communities; increased ocean temperatures threatening our coral reefs; and increasing ocean acidity challenging our coastal, marine, and Great Lakes ecosystems.
- **More Extreme Weather and Water Events.** The Nation has experienced a wave of severe weather events that demand improvements in NOAA's forecast, communication and response abilities. 2011 was an unusually active and deadly year for tornadoes across the U.S. Additionally, Hurricane Irene and Superstorm

⁴ NOAA's Science Advisory Board has recently completed a review of the NOAA R&D portfolio. While this R&D plan has been greatly informed by the SAB's findings and recommendations, particularly those focused on NOAA's R&D, this plan does not constitute the formal response from NOAA to the SAB, nor does this plan attempt to address the recommendations on NOAA's organization and management.

Sandy have highlighted NOAA's unique ability to generate forecasts critical for decision makers, but also demonstrated areas where improvements can be made in the observations, models, forecasts and information delivery.

- ***Integrating Disciplines for a Systems Perspective.*** Integrating different disciplines, including natural and social sciences, is essential to develop a more holistic understanding of the Earth system. Nowhere is the need for integrated expertise more clear than in the implementation of the National Ocean Policy, which requires advancing our understanding of marine ecosystems.
- ***Preparing for and Responding to Unpredictable Events.*** While the results of R&D often take years to come to fruition, several recent events have demonstrated the need for, and the ability of, NOAA science to be responsive on more immediate time frames. Events such as the Deepwater Horizon oil spill and the 2011 tsunami and subsequent radioactive materials release have demonstrated that maintaining – and expanding – the diversity of NOAA's expertise and experience makes the Nation and the world more resilient to high-impact events that have yet to occur.
- ***Managing and Leveraging Big Data.*** NOAA must meet the challenge of managing large and complex data sets. Increasingly, NOAA will need to meld its observation and model output data sets into validated, coherent, and easily usable “supersets” to better address complex environmental problems. Big data also offers the opportunity to create innovative searching, sharing, analysis, and visualization capabilities.
- ***Modeling and Managing Complex Systems.*** In many cases, what limits our ability to sustainably manage natural resources or respond to natural hazards is the complex and dynamic interconnectedness of large-scale physical and ecological systems. We can improve predictive capabilities by connecting and nesting models of physical systems, and by integrating biogeochemical with physical models, and biological with economic models. Ecosystems are also difficult to understand and even more difficult to simulate, but the potential value of making ecosystem predictions is enormous.

NOAA'S R&D STRATEGY

R&D at NOAA is directed toward the Agency's outcome-oriented goals for Climate, Weather, Oceans, and Coasts, as well as its capability-oriented “enterprise” objectives. Focusing attention on outcomes rather than activities is the basis for making rational investment choices, aligning requirements, and clarifying roles and responsibilities. Goals and enterprise objectives are NOAA's highest-level outcomes; the former are outcomes for society and environment, and the latter are outcomes for NOAA's own capabilities, in conducting its mission. The requirements for new knowledge and technology are defined by a series of key questions that respond to each goal or objective, as illustrated in the outline of NOAA's R&D strategy presented below. The reader will notice the breadth of environmental and societal outcomes NOAA strives to achieve, as well as the broad scientific expertise needed to address the questions that follow. In the body of the plan, particular R&D objectives and targets show the steps toward addressing each question.

CLIMATE ADAPTATION AND MITIGATION



Ice and open water in the Beaufort Sea north of Alaska.
Credit: NOAA

NOAA's goal for **Climate Adaptation and Mitigation** is *an informed society anticipating and responding to climate and its impacts*. To achieve this goal, R&D will be directed to answer the following questions:

- What is the state of the climate system and how is it evolving?
- What causes climate variability and change on global to regional scales?
- What improvements in global and regional climate predictions are possible?
- How can NOAA best inform and support the Nation's efforts to adapt to the impacts of climate variability and change?

A WEATHER READY NATION



NOAA center for weather and climate prediction, College Park, Maryland. Credit: *University of Maryland*

NOAA's goal for **A Weather Ready Nation** is that *society is prepared for and responds to weather related events*. To achieve this goal, R&D will be directed to answer the following questions:

- How can we improve forecasts, warnings, and decision support for high-impact weather events?
- How does climate affect seasonal weather and extreme weather events?
- How can we improve space weather warnings?
- How can we improve forecasts for freshwater resource management?

HEALTHY OCEANS



Coral Reef, Florida Keys. Credit: NOAA

NOAA's goal for **Healthy Oceans** is that *marine fisheries, habitat, and biodiversity are sustained within healthy and productive ecosystems*. To achieve this goal, R&D will be directed to answer the following questions:

- How do environmental changes affect marine ecosystems?
- What exists in the unexplored areas of our oceans?
- How can emerging technologies improve ecosystem-based management?
- How can we ensure aquaculture is sustainable?
- How is the chemistry of our ocean changing and what are the effects?

RESILIENT COASTAL COMMUNITIES AND ECONOMIES



Bleached brain coral. To determine the effects of bleaching events, NOAA assesses the extent of bleaching, recovery, and mortality of corals. Credit: NOAA

NOAA's goal for **Resilient Coastal Communities and Economies** is that *coastal and Great Lakes communities are environmentally and economically sustainable*. To achieve this goal, R&D will be directed to answer the following questions:

- What is the value of coastal ecosystems?
- How do coastal species respond to and relate to habitat loss, degradation and change?
- How do we ensure that growing maritime commerce stays safe and sustainable?
- How do we reduce the economic, ecological, and health impacts of degraded water quality?
- How is the Arctic affected by expanding industry and commerce?

STAKEHOLDER ENGAGEMENT



NOAA ship *Okeanos Explorer* conducts operations in the northern Gulf of Mexico. Credit: NOAA

NOAA's enterprise objective for **Stakeholder Engagement** is *an engaged and educated public with an improved capacity to make scientifically informed environmental decisions*. To achieve this objective, R&D will be directed to answer the following questions:

- How can we support informed public response to changing environmental conditions?
- How can we improve the way scientific information and its uncertainty are communicated?

ENVIRONMENTAL DATA



Data collected by NOAA's polar-orbiting operational environmental satellites are fed into sophisticated models that help National Weather Service forecasters "see" the early beginnings of heat waves. Credit: NOAA

NOAA's enterprise objective for **Environmental Data** is *accurate and reliable data from sustained and integrated Earth observing systems*. To achieve this objective, R&D will be directed to answer the following questions:

- What is the best observing system to meet NOAA's mission?
- How can we best use current and emerging environmental data?
- How can we improve the way we manage data?

ENVIRONMENTAL MODELING



IBM supercomputers used for climate and weather forecasts.
Credit: NOAA

NOAA's enterprise objective for **Environmental Modeling** is *an integrated environmental modeling system*. To achieve this objective, R&D will be directed to answer the following questions:

- How can modeling be best integrated and improved with respect to skill, efficiency, and adaptability?
- What information technology developments can help NOAA improve quantitative predictions?

NOAA's strategic goals, and the key questions guiding R&D toward these goals, are the foci for integrating the work from NOAA programs, laboratories, and science centers, Cooperative Institutes, grantees, contractors and other partners. Within this framework of strategic goals and questions, the R&D objectives and targets are actively managed through a corporate system for Strategy Execution and Evaluation (SEE) including regular planning, budgeting, monitoring, and evaluation activities.

People, Places and Things. NOAA R&D rests upon a foundation of indispensable assets. NOAA's laboratories, science centers, grant programs, and cooperative agreements support leading-edge research. NOAA's progress depends on the coordinated functioning of this vibrant scientific enterprise, drawing on a broad range of skills and capabilities. NOAA R&D requires the experience and expertise of a top-notch workforce that extends beyond the Agency itself. The talent of the NOAA's own bench scientists and engineers is complemented by extramural research partners who provide additional expertise (for example, the social science and science extension expertise at Sea Grant institutions) and additional technologies (for example, the satellite launch vehicles provided by NASA).

In addition to these "soft" assets (e.g., people, institutions, and partnerships) successful implementation of this plan involves "hard" assets (e.g., data, models, computers, ships, planes, satellites, buoys, laboratories). The increasing number of societal issues for which NOAA provides decision support requires improving and extending the range of our environmental analysis and modeling capabilities, both regionally

and globally. Models and data assimilation systems provide essential forecasting and analysis tools for decision-making. These, in turn, rely on a base of integrated observations across many levels of space and time. Increased understanding through improved analysis and modeling can lead to better weather, ecosystem, and climate forecasts, and ultimately to better decisions.



What's that? Interns serve as assistant naturalists during public collecting trips at the Woods Hole Science Aquarium (WHSA) summer programs for high school students in 2013. The programs are designed for students who are interested in marine science. Credit: WHSA/NOAA

A Healthy R&D Enterprise. A healthy R&D enterprise means that the Agency directs innovation that has direct impact on the NOAA mission and funds and executes those efforts through an organization with the appropriate capabilities and expertise, of external partners. Enterprise health also requires building upon existing best practices to promote scientific and technological excellence and to enable scientists and science leaders to pursue varied and valued R&D. NOAA is committed to ensuring its research is of demonstrable excellence, is responsive to societal needs, and provides the basis for new and more effective operational services and management actions. To achieve this, NOAA's R&D enterprise rests on the following fundamental principles.

Integrity. For science to be useful, it must be credible. NOAA's research must be conducted with the utmost integrity and transparency. The recently established NOAA Administrative Order on Scientific Integrity establishes a code of conduct for scientists and science managers that allows us to operate as trusted source for environmental science.

Collaboration. NOAA requires the unique capabilities and expertise of its partners. The R&D required by NOAA's mission cannot be conducted by the Agency alone. Extramural and cooperative research provides both increased flexibility and a diversity of expertise and capabilities that the Agency does not maintain. NOAA's partners contribute to meeting

the Agency's goals and objectives, as well as promote the wider use of our joint research results.

Integration. A holistic understanding of the Earth system comes from both understanding its individual components, as well as understanding and interpreting the way all of the components fit together, interrelate, and interact. NOAA is committed to providing both the discipline-specific foundation and the multi-disciplinary integration required to achieve and use a holistic understanding of the Earth system.

Innovation. Innovation is the implementation of a new or significantly improved product, process, business practice, workplace organization, or relationship.⁵ Ideas and inventions are necessary for innovation; however, alone, they are not sufficient.⁶ Innovation is the process of using ideas and inventions to create value.⁷ NOAA is committed to supporting innovation throughout its R&D enterprise to improve the understanding, products and services that support the Nation.

⁵ Organisation for Economic Co-operation and Development. (2005) *Oslo manual: Guidelines for collecting and interpreting innovation data*. Paris: Organisation for Economic Co-operation and Development.

⁶ Freeman, C., and Soete, L. (1997). *The economics of industrial innovation*. Cambridge, MA: MIT Press.

⁷ US Council on Competitiveness. (2005) *Innovate America: National innovation initiative summit and report*. Washington DC: US Council on Competitiveness.



EMILY, a 65-inch water-tight craft, is one of NOAA's hurricane research platforms. Outfitted with a satellite link, camera, battery and gasoline motor, and a variety of sensors, EMILY will collect sea-level data from within a hurricane. *Credit: Hydronalix Inc.*

Balance. NOAA is committed to addressing the immediate needs of the Nation and the emerging challenges for the future. Therefore, NOAA must balance its portfolio of activities to achieve both long-term and short-term outcomes across its strategic goals and enterprise objectives. NOAA also strives for balance between innovations that are required (“pulled”) by stakeholders versus those that are discovered or developed (“pushed”) by researchers, those that are low-risk versus high risk, and those that will yield incremental versus radical change.



A healthy R&D enterprise requires effective R&D management. This includes actively planning, monitoring, evaluating, and reporting on the Agency’s R&D to ensure the Nation receives a sustained return on its investment. For R&D, as with all other aspects of NOAA’s mission, performance management is conducted by all NOAA line offices through an iterative, corporate process of Strategy Execution and Evaluation (SEE). Strategy-based performance management is an iterative process of implementation planning, budgeting, execution, evaluation, and the application of evaluation to subsequent planning, budgeting, and execution. Greater detail on this can be found in NOAA’s Administrative Order on Strengthening the R&D Enterprise.

A well-functioning innovation system also requires coordination across its components, a vibrant exchange of scientific and management viewpoints, and a clear understanding of the mission, goals and objectives -- not only by NOAA but partner organizations as well. A strong scientific enterprise, like any

One of the world’s premier science centers, the Exploratorium has been reaching the public through creative programs and exhibits that let visitors experience scientific discovery for over 40 years. Now that experience includes NOAA science, thanks to a partnership started in 2009 to bring oceanic and atmospheric science to the public. “The NOAA partnership and our work with scientists across the agency the last few years have given us a leg up on developing exhibits and programs that reflect current research on weather, fisheries, climate, and environmental monitoring of the San Francisco Bay and California coastline,” said Mary Miller, director of the NOAA-Exploratorium partnership. *Credit: Exploratorium*

resilient system, is determined not only by the quality of its components, but also in how well connected they are. As social and economic systems evolve and become more complex, the tools and information needed to promote growth, to preserve and improve human and environmental health, to develop and maintain a viable national infrastructure, and to provide security for present and future generations must advance as well.⁸

⁸ National Oceanic and Atmospheric Administration (2008). *Research in NOAA: Toward Understanding and Predicting Earth’s Environment*. Silver Spring, MD.

RESEARCH AND DEVELOPMENT AT NOAA.....



ENVIRONMENTAL UNDERSTANDING TO ENSURE AMERICA'S VITAL AND SUSTAINABLE FUTURE

