National Oceanic and Atmospheric Administration
Strategic Research Guidance Memorandum

The National Oceanic and Atmospheric Administration (NOAA) maintains a robust research and development (R&D) portfolio that enables the Agency to

- Understand and predict changes in climate, weather, oceans, and coasts;
- Share that knowledge and information with others; and
- Conserve and manage coastal and marine ecosystems and resources.

To accomplish these goals, NOAA brings together the best R&D from within NOAA and from external organizations and transforms that R&D into operations, applications, policies, and commercial products that create value for partners and end users. NOAA's R&D efforts therefore span the full range of readiness levels, from fundamental research for advanced understanding to the development of stakeholder-ready tools.

In addition to investing across readiness levels, NOAA strategically engages in research across the risk spectrum from low-risk incremental advances in well-established fields to high risk, potentially transformative research that pushes the boundaries of current knowledge. NOAA's R&D investment portfolio should be appropriately balanced across this risk spectrum to grant the nimbleness necessary to address the changing needs of NOAA, NOAA's partners and stakeholders, and the greater Earth science community as a whole.

NOAA's R&D activities also form the basis for the agency's commitment to build a scientifically literate public ready to adapt to a changing environment. NOAA's educational efforts are enabled through strategic engagement and partnerships with educational organizations that contribute to and use NOAA R&D for the advancement of NOAA-relevant science, technology, engineering and mathematics (STEM) fields and the training and development of the future NOAA workforce.

All NOAA R&D is directed, formulated, and evaluated through the application of the following principles: mission alignment, transition readiness, research balance, effective partnerships, mission-optimized facilities and infrastructure, workforce excellence, scientific integrity, and accountability (as described in NAO 216-115A[1]). Taking these principles into consideration, along with stakeholder needs and emerging scientific priorities, this SRGM seeks to provide guidance to facilitate the evolution of NOAA's future research.

Research Priorities

When determining R&D priorities, researchers, technology developers, and managers at all levels of the Agency should review their current portfolios in light of the principles articulated in

[1] NAO 216 115A
http://www.corporateservices.noaa.gov/ames/administrative_orders/chapter_216/216-115.pdf

NAO 216-115A[2]. When choosing among R&D projects and/or programs or developing R&D ideas for new investment, priority will be given to those investments that show a clear plan for transition[3] to higher levels of mission readiness (*see* NAO 216-105B[4]). The following areas merit further consideration and are not listed in priority order:

Integrated Earth System Processes and Predictions

NOAA has a broad set of predictive responsibilities, as reflected in its large and highly diverse modeling enterprise. Models are essential tools for enhancing scientific understanding, making predictions and projections, and ensuring informed decision-making to meet NOAA's mission needs. NOAA uses models for operational weather, air quality, and ocean forecasting; for providing predictions and projections of atmospheric, hydrologic, cryospheric and oceanic dynamics and composition over a range of temporal and spatial scales; for hazard mitigation such as tsunami models and oil spill trajectory models, and ecological forecasting models for harmful algal blooms, pathogens, hypoxia, ocean acidification and other biological events and processes; and for supporting ecosystem-based management of marine resources including understanding and predicting associated socio-economic impacts. Model development and improvement at NOAA depend on process understanding developed through targeted field and laboratory studies as well as the exploitation of new types and sources of data. Model development is also contingent upon access to and the ability to fully exploit high-performance computing; this is especially important for the recapitalization of the NOAA R&D High Performance Computing (HPC) system. NOAA is moving to develop a ***unified modeling approach*** through the development of an agency-wide taskforce, where best practices in process understanding, model development, data assimilation, post-processing, and product dissemination will be leveraged across disciplinary boundaries. Advancement and integration of NOAA's modeling capabilities will be pursued in three domains: targeted process studies; model resolution and scaling (in time and space); and model complexity.

Process Studies

The inherently complex nature of the Earth system dictates that NOAA continue to strive for an enhanced understanding of the underlying mechanisms that drive the variability and trends of relevant natural parameters. NOAA's suite of Earth system models depends on process understanding from field and laboratory studies. Specific emphasis will be placed on those process studies that are targeted towards clearly articulated mission needs including understanding predictability on weather-to-climate timescales and the Earth system response to environmental stressors, as well as the model development needed to meet regulatory and management requirements. These include process studies needed to develop indicators of ecosystem resilience, implement ecosystem-based approaches to marine resource management, and advance the capabilities of operational models in light of changing environmental

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[2] Ibid.

[3] Example Transition Plans http://nrc.noaa.gov/NOAARDPolicies/ExampleTransitionPlans.aspx

[4] NAO 216-105A http://www.corporateservices.noaa.gov/ames/administrative_orders/chapter_216/NAO%20216-105A%20UNSEC%20Signed.pdf

conditions.

Additional emphasis will be placed on process studies to support aquaculture. Studies examining how environmental variability affects the growth and health of cultured species, as well as aquaculture technology development and transition are important for sustainably managing marine resources. This focus is also consistent with the agency focus on research transition to applications.

Model Resolution and Scaling

Current models do not regularly produce reliable forecasts of high-impact weather events with more than two weeks of lead time. Increasing lead time and accuracy requires focused effort to mitigate the gap in predictive skill at weeks three to four, and is a necessary step, along with collecting and integrating advanced data and modeling capabilities, toward meeting the goals of Pub. L. 115-25, Weather Research and Forecasting Act of 2017[5] for reliable and timely foundational forecasts of temperature and precipitation at the time range spanning from two weeks out to two years. Increased spatial resolution is also necessary for improved hazard warning in the one- to three-hour range, such as for development and extension of accurate, effective, and timely tornado forecasts, predictions, and warnings, including the prediction of tornadoes beyond one hour in advance.[6] Further focus is needed on improving prediction of rapid intensification and track of hurricanes, improving the forecast and communication of storm surges from hurricanes.[7] Building resilience in the face of climate variability and change requires credible and reliable information products and services at spatial scales much finer than those produced by most global climate models. Research and development challenges for improving environmental prediction include atmosphere-ocean-cryosphere coupling, methods for calibration and downscaling, forecast improvement, and establishment of impact-based decision support systems.

Model Complexity

Anthropogenic stressors and climate variability and change are shifting the way in which ecosystem processes and biodiversity provide and sustain ecosystem services. Assessing and understanding these shifts, which impact stakeholder lives and livelihoods, requires NOAA to build additional complexity into models. NOAA will target significant advances in true integration of biological, chemical, geological, and physical Earth system models and where appropriate, incorporate social, behavioral and economic dimensions. This particularly applies to enhancing ecosystem change detection through improved ecological forecasting and understanding and predicting impacts on habitat, living marine resources, and stewardship. Within coastal and nearshore waters, NOAA will pursue strategic approaches concerning scaling in order to incorporate regionally relevant coastal dynamics such as riverine flooding, sediment transport, and estuarine and continental shelf trophodynamics into models used to inform living marine resource management decisions.

Ecological Forecasting

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[5] Pub. L. 115-25. Weather Research and Forecasting Innovation Act of 2017.

[6] Ibid.

[7] Ibid.

NOAA's suite of ecological forecasts provides valuable decision support tools that protect human health and promote vibrant coastal economies. Currently, NOAA's Ecological Forecasting Roadmap identifies four priority areas: harmful algal blooms (HABs), hypoxia, pathogens, and habitat. These areas demonstrate the value of transitioning advanced science into operational forecasts that meet the needs of managers and stakeholders at local, state, and regional scales. In addition, NOAA's forecasts operate at time scales ranging from near-real time to seasonal outlooks and long-term projections. Near-real time HAB and pathogen forecasts are prime examples of the value NOAA provides to managers and communities along the coast and the Great Lakes. These forecasts guide local and state water monitoring efforts, prevent human exposure to contaminated water, and manage fishery resources to protect against human and animal consumption of HAB toxins and pathogenic bacteria. It is vital that NOAA continue to coordinate and conduct agency-wide research and development to promote successful transition of current ecological models into operational forecasts, products, and services. Continued emphasis on applied research to support all four priority areas, outreach to stakeholders to define their specific forecast needs, and investment in the observation and forecast dissemination infrastructure will ensure NOAA's success in this endeavor.

Environmental Observations

As the only federal agency with the operational responsibility to provide weather, water, ocean, climate, and ecosystem forecasts, NOAA is responsible for collecting accurate, timely, and comprehensive observations of the Earth and its surrounding space. These activities are performed by a vast and heterogeneous fleet of observing systems that collect greater than 20 terabytes of data each day, which, in turn, NOAA manages and exploits in order to produce useful environmental intelligence for society. These data, and the intelligence derived from these data, are critical tools that support government decisions and policies, scientific research, and the economic, environmental, and public health of the United States. Hence, optimization and advancement of NOAA's environmental observation portfolio is a critical endeavor that should be pursued in the following two domains: observing systems optimization, and; data science advancements.

Observing Systems Optimization
NOAA uses a wide range of sensing elements and platforms to conduct sustained and experimental observations of phenomena ranging from solar flares to undersea earthquakes. These observations are essential to NOAA's environmental intelligence mission. Optimizing NOAA's observing systems requires R&D to improve the performance of extant observing systems, and lead to the development of novel sensing elements and platforms, with the end goal being to increase efficiency and reliability, improve data return, and reduce costs. Appropriate resources should be dedicated to the demonstration and evaluation of emerging atmospheric, oceanic, and coastal sensing elements and platforms that address areas of interest—ocean exploration, atmospheric and ocean biogeochemical sensing, marine resource assessment and management, and long term environmental change monitoring— and show mission relevance in accordance with NOAA's policy on the transition of research to operations, applications, commercialization, and other uses (*see* NAO 216-105A[8]). Quantitative and qualitative

[8] NAO 216-105A

assessment techniques will need to be expanded (or new ones developed), as called for in Pub.L. 115-25, [9] to objectively assess the impact and utility of improvements to existing observing systems as well as deployment of novel observing systems, such as constellations of small satellites, unmanned vehicles, moored platforms, and the use of unconventional sources of environmental data (e.g., citizen science)

Data Science Advancements

Data science efforts within NOAA span the entire data exploitation spectrum—an end-to-end process including movement of data and information from the observing system sensing elements to the data user—including acquisition, quality control, metadata cataloging, validation, reprocessing, storage, retrieval, dissemination, and production of useful intelligence and products for society. To support NOAA's data management efforts, advances in signal processing (e.g., compression, sampling, thinning) are needed in order to keep pace with the scale at which NOAA is generating and collecting environmental data. Furthermore, NOAA should also investigate and leverage emerging developments in high-performance data access, storage and computing, data mining, natural language processing, and machine learning. Innovative processing techniques and R&D are needed to extend sensor capabilities to extract new products from measurements and find ways to increase the signal-to-noise ratio of measurements, specifically with regards to enhanced extraction of data from measurements (e.g., micro-physical properties). To support improved data applications, NOAA must continue to make advances in the current capabilities to couple 'traditional' datasets (e.g., physical, chemical, and biological) and fuse those data with 'non-traditional' data (e.g., social, behavioral, and economic) and 'un-conventional' sources (e.g., citizen science). All of NOAA's data products need to have built-in synthesis capabilities with objective standardized reporting indicators.

Decision Science, Risk Assessment and Risk Communication

NOAA invests billions of dollars monitoring and observing risk from environmental hazards, and predicting the consequences of environmental changes. This investment in societally relevant science is critical to meeting the Agency's mission. However, that investment's value is diminished unless we communicate the consequences and risks effectively, empowering individuals and groups to pursue the outcomes that are best for them. Meeting NOAA's strategic goals requires that the agency expand its capacity in societally relevant science, including decision science, specifically focusing on how NOAA and its partners assesses and communicates risk and in turn understanding how that information is rationalized and used by the decision maker. This is best accomplished by transitioning research to application and policy including within and across a variety of social science disciplines—such as psychology, economics, political science, sociology, and anthropology—into the broader R&D enterprise. Several NOAA programs specifically focus on conducting and applying such science directly to critical issues. This is also an opportunity to exploit newly established relationships with other

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http://www.corporateservices.noaa.gov/ames/administrative_orders/chapter_216/NAO%20216-105A%20UNSEC%20Signed.pdf

[9] Ibid.

federal agencies, most notably the National Science Foundation (*see* NOAA-NSF MOA[10]), who invest considerable resources in social, behavioral, and economic sciences research. NOAA must work to identify other agencies that are involved in communicating risk pertinent to NOAA, understand their activities, and establish coordination with these agencies. Key questions are how can NOAA best assess and communicate national environmental risks and how NOAA-supported resilience strategies mitigate those risks. Also of particular importance is research into innovative ways to develop, improve, and deliver actionable information, including construction of management strategy evaluations, to aid in improving real-time situational awareness and accurate comprehension of risk factors. Specific focus on incorporating risk communication research to create more effective watch and warning products related to hurricanes is called for in Pub. L. 115-25[11].

Integrated Water Prediction

Leveraging capabilities and expertise from across NOAA to better understand and predict all aspects of the water cycle remains a critical national priority and key to evolving the National Weather Service and providing information and services to help communities and businesses manage risk, build resilience, and plan for the future. Water security is intimately linked to food security and energy security. NOAA is uniquely positioned to provide the tools, data, and information people need to strengthen the nation's water security, reduce vulnerability to climate variability and change, and catalyze more effective management and use of our valuable water resources. Building on planned investments in FY17 and FY18, NOAA should strengthen the agency's ability to incorporate water quality (including temperature, salinity, and dissolved and suspended constituents) into an integrated water prediction capability, along with associated decision support services.

Arctic

In order to understand, mitigate, and adapt to the impacts that anthropogenic and climatic stressors are having on the Arctic, NOAA must engage in innovative research to fill critical gaps in the understanding of the Arctic environmental system. The priorities of NOAA's Arctic Program align with the research drivers of the Interagency Arctic Research Policy Committee. Developing more accurate and timely predictions of changing sea-ice cover requires sustained observational efforts, as well as the development of improved sea-ice models. In Arctic coastal zones, NOAA must undertake further research and monitoring of water levels, erosion, and changes in coastal bathymetry to strengthen resiliency efforts in coastal communities and improve coastal navigation services. NOAA must conduct research to advance scientific understanding of key Arctic species and how climate-related changes and biophysical interactions impact those species, other marine resources, and the communities that rely on them. This research will assist in the development of responsible High Arctic fisheries management plans. Finally, NOAA must invest in the development of new or improved polar observation technologies that will advance the agency's research and operations in the Arctic region.

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[10] NOAA-NSF Memorandum of Agreement
http://nrc.noaa.gov/LinkClick.aspx?fileticket=WUMNFX0AYF8%3d&portalid=6
[11] Ibid.