Next Generation Global Prediction System (NGGPS)

Executive Summary

The National Weather Service will design, develop, and implement a global prediction system to address growing service demands, and increase the accuracy of weather forecasts out to 30 days. The goal is to expand and accelerate critical weather forecasting research to operation (R2O) through accelerated development and implementation of current global weather prediction models, improved data assimilation techniques, and improved software architecture and system engineering. Over the next five years, contributions from a wide sector of the numerical weather prediction community including NCEP, NOAA and other agency laboratories and universities, will be incorporated into an operational system to deliver a Next Generation Global Prediction System (NGGPS) that meets the evolving national prediction requirements.

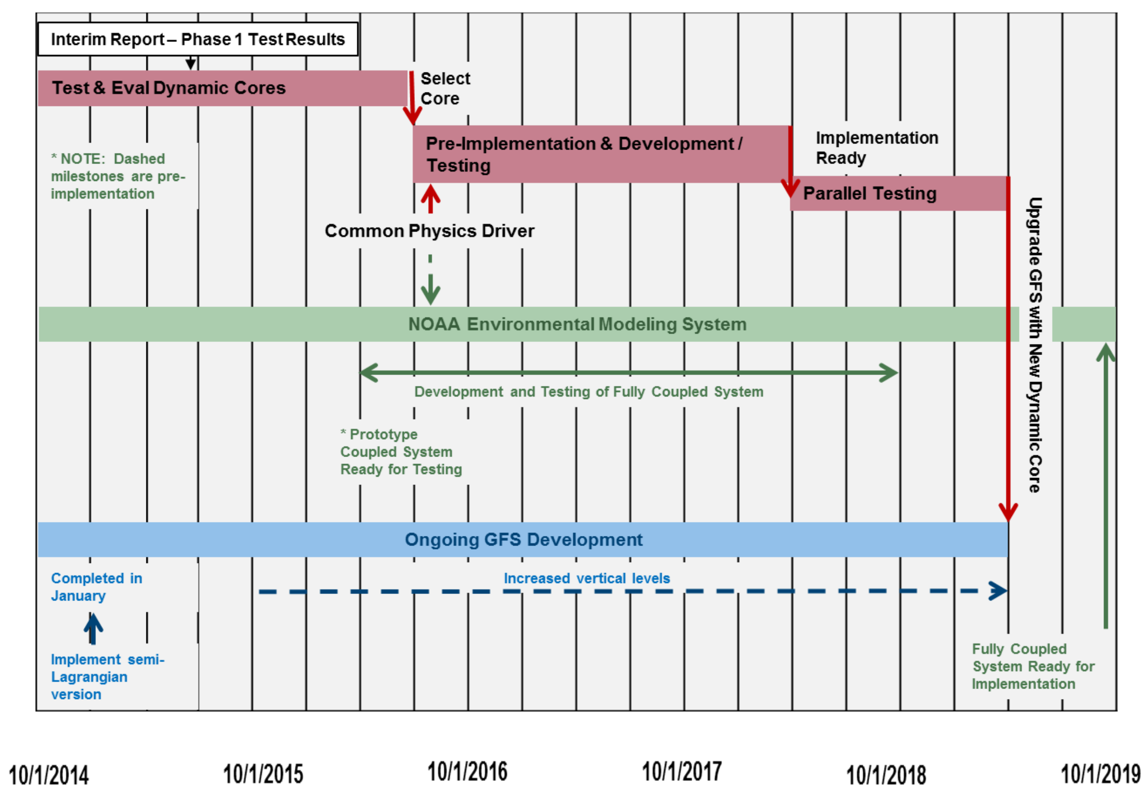
Major work areas include:

- selecting an atmospheric dynamic core from existing research and operational models;
- improving model physics packages to better describe weather phenomenon at global to regional scales;
- developing multiple, interacting, high resolution nested grids within the global model to accurately account for the evolution of such weather systems as hurricanes and severe thunderstorm complexes in middle latitudes;
- accelerating development and implementation of weather prediction model components, such as ocean, wave, sea ice, land surface and aerosol models; and improve coupling between these various components of the model system;
- developing advanced data assimilation methods at global and regional scales and for specific storms such as hurricanes;
- incorporating all system components into the NEMS framework;
- improving software architecture and systems engineering though
    - building a high-performance, flexible software infrastructure to increase ease of use, performance, and interoperability
    - investigating effective use of emerging HPC technologies, simplifying software structure, and implementing a community-based model infrastructure which will streamline the incorporation of proven research advances into operations;
- increasing the resolution of key environmental models to improve the specificity of forecasts (target 3-9 km for the global models, 0.5-2 km for the interior nests);
- enhancing probabilistic forecast systems using advanced ensemble systems;

- conducting data impact studies of future observing systems such as the next-generation satellites to lend guidance to observing system strategies and requirements and to enable rapid incorporation of data from those systems.

The plan is to have an operational-ready fully coupled system by the end of fiscal year 2018 (FY18). A single dynamic core will be determined in FY16, a physics package will be developed and coupled to the atmospheric model, and all components including atmospheric, aerosol, ocean, wave, ice, and land models; data assimilation systems; and guidance products will be within the NEMS framework by the end of FY17.

The following figure shows the general NGGPS development schedule.



1. R2O Initiative: Next Generation Global Prediction System

1.1 Background

The National Oceanic and Atmospheric (NOAA) National Weather Service (NWS) has the responsibility to provide weather, water, and climate information to protect life and property, and enhance the national economy. The NWS mission is to provide the best possible guidance to a wide variety of customers, including emergency managers, forecasters, and the aviation community. Fundamental to this mission, the global numerical weather prediction system provides initial condition data and initial states for regional atmospheric and ocean models, space weather applications, air quality forecasters, and the National Centers for Environmental Prediction (NCEP) service centers. To properly service the customers, the forecasts must be available reliably and at the appropriate time within available resources.

NWS supplies information to support and protect the Nation's social and economic development by ensuring society is prepared to respond to environmental events, resulting in a weather-ready nation. In order to build a weather-ready nation, NWS must have access to cutting edge weather prediction techniques and develop them for operations.

In 2012, after Hurricane Sandy hit the east coast of the United States, causing extensive damage, flooding, and deaths, an accelerated research to operations project to produce a more accurate and timely prediction of storms was presented to Congress. Congress then appropriated an increase in $14.8 million in base funding for a Research to Operations (R2O) Initiative to produce a state-of-the art prediction model system, along with a $15 million increase in the operational computing budget to increase high performance computing (HPC) architecture to enhance the new modeling capability. This initiative was coordinated with both NWS and the Office of Oceanic and Atmospheric Research (OAR), and language in the FY14 President's Budget and Appropriation was agreed to by NOAA/NWS, the Department of Commerce (DOC), and the Office of Management and Budget (OMB). The overarching initiative objective is to build a Next Generation Global Prediction System (NGGPS).

> Over the next five years, design, develop, and implement the Next Generation Global Prediction System and maintain world-class forecast capability for the protection of life and property and economic growth and prosperity.

1.2 Goals

The R2O Initiative will expand and accelerate critical weather forecasting research to operation to address growing service demands and increase the accuracy of weather forecasts. For the next five years, NOAA NWS will design, develop, and implement a global prediction system that extends weather forecasting skill to 30 days. The design of this weather forecasting system will be accomplished through the development and implementation of global weather prediction model, improved data assimilation techniques, and improved software architecture and system engineering. This R2O Initiative will deliver:

- A next generation global prediction system that meets the evolving national prediction requirements
- Effective assimilation for environmental observations at global and regional scales
- A software architecture and engineered system that maximizes the benefit from HPC enabling quicker transition of internal and external research to operations
- Hurricane forecast models that meet societal requirements to improve public safety and effectively mitigate economic disruption

To achieve these goals the major work areas will include:

- Selecting an atmospheric dynamic core from existing research and operational models
- Improving model physics packages to better describe weather phenomenon at global and regional scales
- Developing multiple, interacting, high resolution nested grids within the global model to accurately account for the evolution of severe weather systems including hurricanes
- Accelerating development and implementation of weather prediction model components, such as ocean, wave, sea ice, land surface and aerosol models; and improve coupling between the component model systems
- Developing advanced data assimilation methods at global and regional scales and for specific storms such as hurricanes
- Incorporating all system components into the NOAA Environmental Modeling System (NEMS) framework
- Improving software architecture and systems engineering through:
    - Building a high-performance, flexible software infrastructure to increase ease of use, performance, and interoperability
    - Investigating effective use of emerging HPC technologies; simplifying of software structure; and implementing a community-based model infrastructure which will streamline the incorporation of proven research advances into operations.

- Increasing the resolution of key environmental models to improve the specificity of forecasts (target 3-10 km for the global models, 0.5-2 km for the interior nests)

- Enhancing probabilistic forecast systems by including more ensemble members at higher resolution

- Conducting data impact studies of future observing systems such as the next-generation satellites to enable both rapid incorporation of future observing systems data and guide observing systems strategies and requirements

This initiative will serve as a "transition to operations" project for current and future research and development efforts both inside and outside the NWS, and will include NWS participation with university research community and partnership efforts, such as the National Earth System Prediction Capability (ESPC) and the Earth System Modeling Framework (ESMF) support within NEMS. Proposal driven support will be considered for other on-going initiatives and projects such as: Hurricane Sandy Supplemental, including the High Impact Weather Prediction Project (HIWPP); Gap Mitigation; Hurricane Forecast Improvement Project (HFIP); U.S. Weather Research Program (USWRP); and Testbeds, including the Development Testbed Center (DTC).

1.3 Five Year Schedule

This five-year effort will incorporate all aspects of weather prediction models.

- FY 2014
  - Define Prototype Next Generation Global Prediction System
- FY 2015
  - Extend NEMS infrastructure to include ice, ocean, near shore water level (storm surge), and land surface prediction models
  - Define model re-architecture requirements for next-generation heterogeneous fine-grain computing platforms
- FY 2016
  - Demonstrate increased skill (7-day skill extended to 14 days) for coupled global ocean-atmosphere-ice-wave system
- FY 2017
  - Redesign architecture and re-engineer component models for efficient transfer to fine grain computing platforms
- FY 2018
  - Implement Next Generation Global Prediction System

1.4 Overall Deliverables

In general, the NGGPS overall deliverables are:

- Annual upgrades to operational Data Assimilation System
- Upgrades to NEMS infrastructure
- Upgrades to component models (ocean, atmosphere, ice, land surface, wave, aerosols) for a coupled system
- Coupled global system using re-engineered system component models
- Improved utilization of HPC resources and cost effective implementation of science
- Agile HPC environment with quicker operational transition of research and development efforts

2 The NGGPS Model

NOAA's Next Generation Global Prediction System will be the foundation for the operating forecast guidance system for the next several decades. The system will include a single atmospheric dynamic core; a suite of atmospheric physics; numerical ocean, wave, ice, aerosol, and land surface models; supporting functions including data assimilation systems, ensemble design and initialization, post-processing; and guidance products. Developing a global prediction system based on the best operational and research models available entails identifying candidate components that have the potential to contribute to the complete system, identifying any scientific gaps therein, and modifying/customizing the components to incorporate them into the new system.

The new prediction system will be weather focused with forecast skill from 0-30 days, with the fully coupled ocean, wave, aerosol, land surface, and ice models at 3-10 km resolution. It will incorporate telescoping moving convection-resolving nests for severe weather and hurricanes, (one or two for a nested region and an ability to include several of these nests simultaneously over individual hurricanes), state-of-the science data assimilation, and probabilistic forecasts using ensembles.

The increase in computational capacity needed for greater accuracy and detail achieved by the new prediction system will be addressed with next generation computing technology. NWS will take advantage of the most cutting edge information technology by continuing to adapt and optimize codes for increased performance in multi-cores, participating in co-design to improve suitability hardware, and exploring new algorithms.

All aspects of observation processing, data assimilation, numerical modeling, ensemble forecasting, post-processing and verification, along with increased HPC, together will produce the best possible prediction.

The next generation global system will be:

- Non-hydrostatic

- Applicable and stable for all NWS applications currently using Global Spectral Model (GSM)
    - Global high resolution weather prediction
    - Whole Atmosphere Model
    - Multiple high resolution nests with moving capability for hurricane and severe weather forecasting
    - Aerosol forecasting
    - Seasonal climate modeling
    - Ensemble forecasting
    - Atmospheric composition forecasting (currently only ozone)
- Usable in NEMS infrastructure
- Usable within NWS data assimilation system

2.1 Fully Coupled Model Components

NEMS is a shared, portable, high performance software superstructure used by NCEP to streamline operational modeling suites into a common modeling framework. The foundation for NEMS is the Earth System Modeling Framework (ESMF), a community software infrastructure system that enables different model components to operate together. The model components for the new global prediction model will be included in this NEMS framework. Individual models will be run both as stand-alone and coupled. Multiple storm-scale phenomena will be modeled on movable grids nested within the global domain.

The global atmospheric model contains two components: a dynamic core and a physics package. The atmospheric model dynamic core is the basic numerical model of the governing equations (equations of motion, thermodynamic energy equation, equation of state, mass conservation and usually an equation for advection of various atmospheric species like water vapor). The physics packages are subsystems used by the model to simulate various other atmospheric processes such as cloud microphysics, radiation, surface fluxes, etc. Given a reasonable dynamic core and initialization system for that core, the quality of the physics package will largely determine the quality of the forecasts.

Development and upgrades to individual model components: land surface, ocean, wave, sea ice and aerosol, will be accelerated for coupling within NEMS. All components have a certain amount of interaction with other components and the work must be closely coordinated. Coupling space weather models that forecast solar and geophysical events (which impact satellites, power grids, communications, navigation, and many other technological systems) is considered a long term goal of this initiative.

One of the early NGGPS milestones is to develop a prototype coupled prediction system within the NEMS framework by the end of FY15. As of the beginning of FY15, NEMS included Global Forecast System (GFS), its dynamic core, the GSM and two global ocean models: the

Modular Ocean Model, release 5 (MOM5), and the Hybrid Coordinate Ocean Model (HYCOM). The goal is to include the GFS physics driver, the Wave Watch III wave model; and the Los Alamos sea ice model (CICE) in FY15. By the end of FY15, the components will be coupled in a test-ready system. The eventual coupled structure including initial component models is shown in Figure 1.

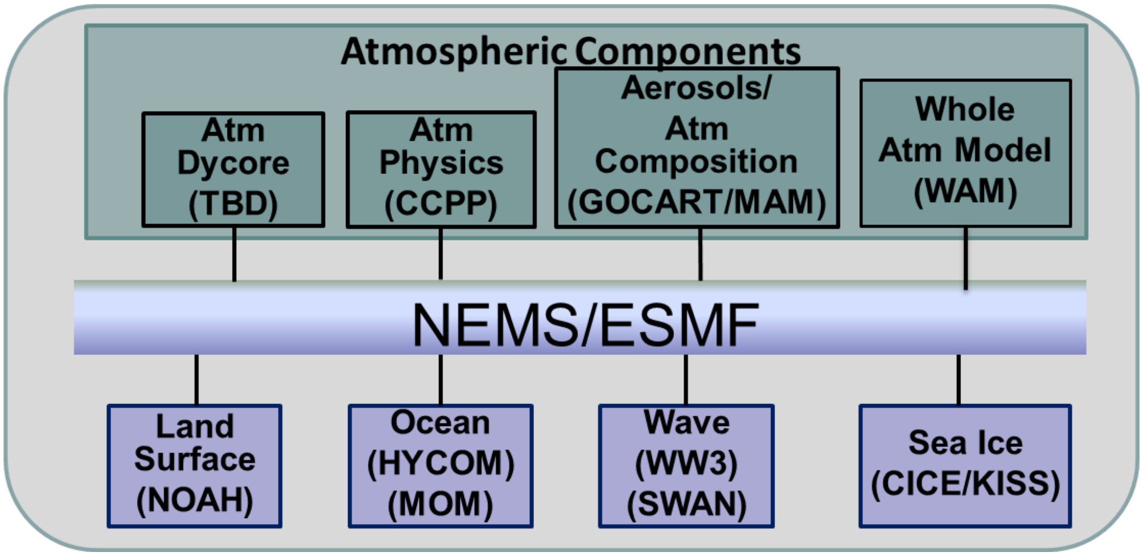


Figure 1. NGGPS Model Components

Component models will be continually upgraded, tested, improved further, and coupled through the NEMS framework. Each newly-coupled system then goes through further testing and validation resulting in tweaking, or tuning, before the new or enhanced model is operational.

2.2 Support Functions

Supporting the model components, data assimilation will be addressed to provide the best possible initial conditions for the forecast model by integrating data observations into the system. Due to the diverse nature of the initial data types, a variety of data formats will be evaluated, used and integrated into the system, as well as modified as needed. The data assimilation, ensemble predictions, and post-processing components of the system will take this initial data, the model uncertainty and supporting data sets, to reduce the forecast error as much as possible; with specific goals to make the forecast guidance more skillful, reliable and detailed. To fully evaluate the individual components and coupled systems of NGGPS, NOAA Testbeds and Proving Grounds (TBPG) will test, evaluate/develop, and demonstrate operational readiness to deploy the operational NGGPS.

Infrastructure items, such as documentation of scientific and algorithmic aspects of the model, including documentation within the code, as well as an online science reference guide, and training will be addressed and can expand as the system comes into operation. Training will be focused on the model bias, strengths and weaknesses with respect to various skill metrics and typical forecasting situations.

NWS will depend on HPC for the comprehensive numerical modeling. The prediction systems are computationally very expensive due to the complex interactions of the different model components as they are integrated into a single system to provide the forecast data. Increased numerical resolution, increasingly complex models and the use of ensembles to better quantify uncertainty require significantly enhanced HPC capabilities, as well as new evaluation of data management, transmission, and storage.

2.3 Production Suite Compatibility

The specific effort for NGGPS must integrate with and add to the NCEP's Environmental Modeling Center (EMC) work plan. To run properly within the NWS production suite, all models in the system along with any changes/upgrades must satisfy certain requirements. These requirements are applicable to groups both internal and external to NWS:

- The components and modifications must be compatible with input/output and architecture through inclusion in NEMS.
- Models and changes must satisfy all current downstream requirements and uses of the system, (i.e., no reduction in downstream capability for users).
- The computational resources required for any changes or component modification should not exceed the available computational resources. Available resources are defined by NCEP to be the resources (time, number of processors, disk space) that can be used by that particular component of the operational suite. Generally, a change that uses the same or reduces the amount of resources satisfies this requirement. Additional resources may be available, but must be approved by NWS/NCEP management with consideration given to cost versus benefit, balance between systems and future planning.
- Modifications must be maintainable and sustainable, allowing quick diagnosis and repair of problems and upgrades by other groups. This can be achieved with any combination of sufficient documentation, and long term external support.
- Modifications must be introduced into NCEP's EMC code management system following the established code management procedures.
- Testing must convince NWS developers and downstream users that the changes are valid and will not result in degradation or failure of the system. Final validation will be done as part of the implementation process at NCEP.
- All modifications will become property of the government and restrictions on the distribution or use of the modifications will not be allowed.

2.4 Strategy for the Implementation of NGGPS

Performing a cycle of research-upgrade-testing-operational implementation to continuously improve the guidance offered by the system will result in a state-of-the art weather prediction system, accelerated due to a research-to-operations pathway.

The plan is to have an operational-ready fully coupled system by the end of fiscal year 2018 (FY18). In FY16, a single dynamic core will be selected and the existing models and system components inventoried, with components integrated within the NEMS framework by the end of FY17. Inventory includes existing and next generation components, and ongoing upgrades including enhancements pursued through parallel initiatives.

Figure 2 shows the NGGPS development schedule. At the onset, the prototype NGGPS is defined, including performance, design and architecture requirements, the latter making the system easily adaptable to advanced computer technologies (e.g., next generation heterogeneous fine-grain computing platforms). While candidate dynamic cores are evaluated and existing components are incorporated into NEMS, the development infrastructure will be established with code restructuring and memory management optimization; developing a verification system; establishing and standardizing performance measures; establishing a testbed capability and testing program; and preparing documentation and training programs. The testing program will likely require new testbed capabilities.

The dynamic core should be established in the second quarter FY16. Over the following two years, the selected core will undergo pre-implementation development and testing and, when deemed ready at NCEP, enter a year of testing parallel to the current (FY18) operational system. As shown on Figure 2, improvements to the operational GFS will continue throughout the selection, development and testing of the NGGPS dynamic core. Those improvements include the Semi-Lagrangian version to be implemented in the present upgrade cycle (November 2014) and the non-hydrostatic version with an increase in vertical levels, not yet scheduled.

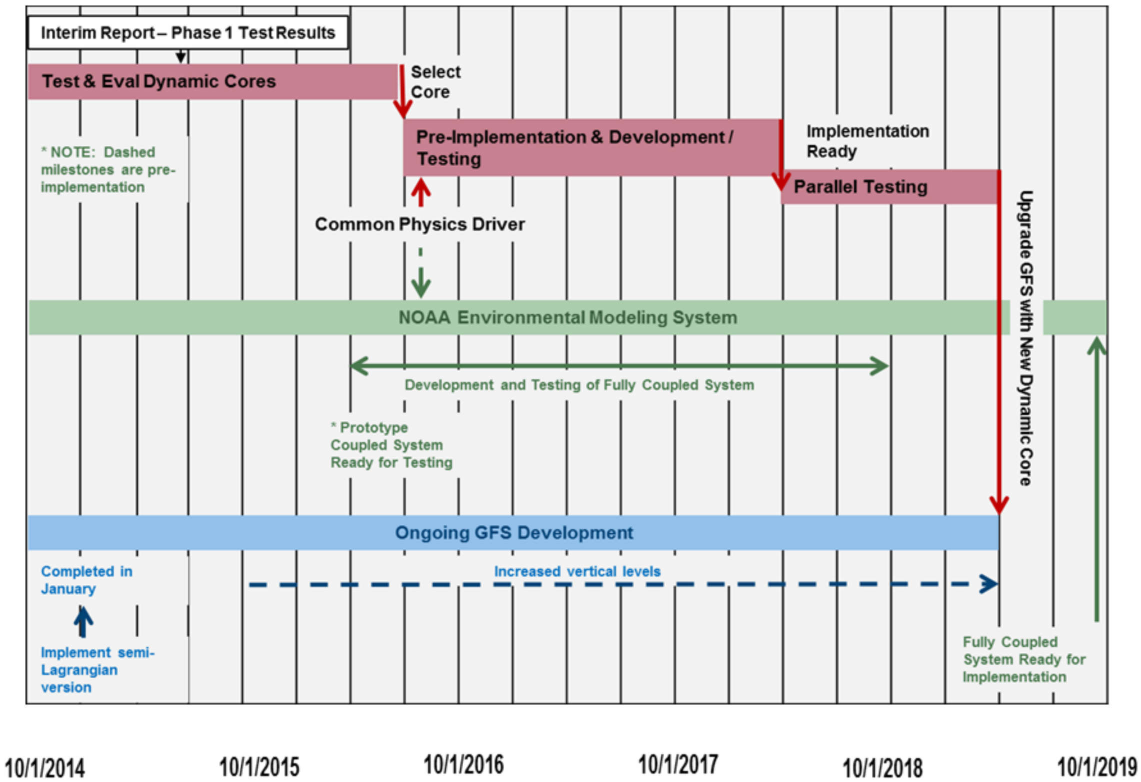


Figure 2. NGGPS Implementation

NGGPS will not become operational until it has been demonstrated to provide forecasts equal to or better than the operational system during parallel testing. Forecasts are evaluated through the implementation process at NCEP. The new model prediction system must demonstrate forecast accuracy, and do so reliably and within the computational time and resource constraints of the operational system. Once NGGPS becomes operational, further upgrades must meet the same standards. The fully coupled NGGPS should be implementation ready by FY2019.

3 Performance Goals and Metrics

Specific metrics have not yet been established for NGGPS performance. To focus on creating a weather prediction model out to 30 days, the system must not only meet the accuracy of the current operational system, but have the capability to go beyond. The new system will have capability, scalability, and upgrade potential beyond that of the current system. As component models are integrated and nested, these goals will be developed over time for this initiative. A small team will be identified to define a limited number of performance goals which will be reviewed by the management team, and presented to the EOB. Each performance goal established for this project will address goals of NOAA's Government Performance and Result Act (GPRA) and each of the NGGPS objectives. Quantifying (i.e. x percent improvement within y years) the list below is the initial set of proposed goals to track the project's progress.

- Increase rate of improvement of skill for global numerical weather prediction
- Extend forecast skill of numerical weather prediction out to 30 days
- Improve overall accuracy and reliability of probabilistic forecasts

More detailed tracking of performance at the project level will entail a larger set of criteria. Some ongoing projects have goals in place that will continue to be tracked as part of the R2O Initiative. For example, HFIP's ten-year goals associated with mean hurricane track and intensity errors will apply as five year goals to this effort. In addition, the teams will determine a common set of standard metrics from a list of already established at NCEP for evaluating improvements in model performance. Additional measures not yet defined may be evaluated as the capabilities of the prediction system increases. This common set of metrics will be measured and reported on a recurring basis.

4 Management

The NGGPS Project is a collaborative effort between OAR and NWS, with NWS having the overall responsibility to implement an operational prediction system. The goals and deliverables will be implemented through a management structure comprised of expertise from both operations and research communities. The cross-community partnership requires open communication and a clear definition of responsibilities and authority for each organization. The management structure and lines of communication are shown on Figure 3.

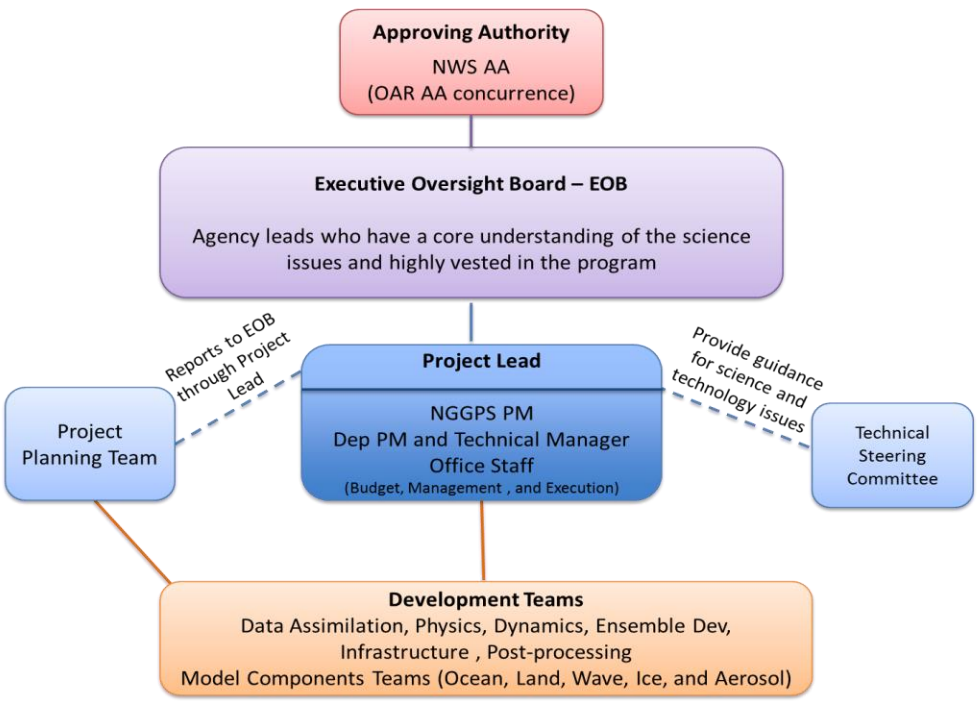


Figure 3. Management Structure

The roles and responsibilities within that management structure are described below and summarized in Table 1.

Table 1. Roles and Responsibilities

Position	Role
Approving Authority	
NWS Assistant Administrator	Final approval of plans, priorities, and goals
OAR Assistant Administrator	Concurrence of plans, priorities, and goals
Executive Oversight Board Members	
NCEP Director	Decision authority on selection of identified next generation dynamical core
NWS Office of Science and Technology Director	Responsibility of implementation of NGGPS
NWS Science and Technology Integrations Director	Recommends approval of plans, priorities, goals and execution of spend plans to AA; strive for consensus on every issue; ensure formation of partnerships and broad multi-agency participation; ensure congressionally mandated milestones and deliverables are met
NESDIS/STAR Director	
NWS Central Processing Portfolio Director	
OAR Office of Policy Planning and Evaluation Director	
OAR ESRL Global Systems Division Director	
OAR ESRL Physical Sciences Division Director	
Project Lead (NWS/OST)	Ex-Officio member
NGGPS Management Team	
NWS/OST Project Lead (appointed by EOB)	Single focal point for the effort in NWS. Oversees and coordinates entire project
Technical Manager (appointed by Project Lead)	Single focal point for the research and development activities. Oversees that coordination is across NOAA collaboration
Project Management Office Staff (NWS/OST)	Staff directly supports the Project Lead. Manages and track all programmatic activities; provide administrative support
Technical Steering Committee (Science Steering Group)	Monitor technical progress and provide guidance on science and technical issues
Project Planning Team (Subject Matter Experts)	Deliver a multi-year project plan; define detailed technical scope of activities. Chairs and manages development team
Development Teams	Submit proposals for activities and deliver milestones; reports status and progress of deliverables

4.1 Approving Authority

National Weather Service Assistant Administrator (NWS AA) and Office of Oceanic and Atmospheric Research Assistant Administrator (OAR AA)

The NWS AA with concurrence from the OAR AA approves plans, priorities and goals recommended by the Executive Oversight Board (EOB). The EOB will report and recommend approvals based on general consensus. In cases where consensus cannot be achieved, the NWS AA has the final decision authority.

4.2 Executive Oversight Board

The Executive Oversight Board provides oversight of the project including reviewing and recommending annual operating plans and budgets for approval. The EOB is comprised of Division Directors from NWS, OAR, and National Environmental Satellite, Data, and Information Service (NESDIS), and the Project Lead as an Ex-Officio member. The primary role is to recommend approval of plans, priorities and goals. The board ensures a solid transition to operations; and that both short-term and long-term objectives, particularly congressionally mandated milestones and deliverables, are met through proper prioritization and allocation of resources. The EOB ensures the formation and development of internal and external partnerships resulting in broad multi-agency participation.

Director, National Centers for Environmental Prediction
As a member of the EOB, the Director of NCEP has input in approving priorities, plans and goals and recommendation to the NWS AA. The NWS/NCEP Director oversees the development of and improvements to numerical prediction and, therefore, has the final decision authority on the selection of the model that will transition from research into the NOAA Operational Production Suite. Within NGGPS project, the NCEP Director will approve the testing plan for selecting the next dynamic core.

Director, NWS Office of Science and Technology (OST)
The NWS/OST Director manages the implementation of NGGPS and oversees the NGGPS Project Office, including implementation of the program within the approved scope, cost, and schedule, and management of top level planning, acquisition, development, and transition to operations of the fully coupled global modeling system. The NWS/OST Director jointly coordinates transition to operations with the NWS/NCEP Director.

Director, NWS Science and Technology Integration Portfolio
In addition to the role and responsibility of an EOB member, when the pending NWS reorganization commences, the role and responsibility of the NWS/OST Director regarding the EOB transfers to NWS/STI Portfolio Director. That responsibility includes coordinating transitions to operations with the NWS/NCEP Director.

NESDIS and OAR Members
The remaining EOB members are Division Directors and key members in coordinating jointly funded activities. They ensure broad multi-Agency participation. The NESDIS and OAR members will serves as the focal point for their respective organizations. They form and develop internal and external partnerships.

NWS/OST Program Manager or Project Lead
The Project Lead serves as the single focus for the effort within the NWS and has execution oversight authority for project plan elements endorsed by the EOB and approved by the AA.

4.3 Project Lead and Project Office

The Project Office, managed by the Project Lead oversees and coordinates the entire project. The Project Lead, along with supporting contractor staff, develops annual operating plans, annual budgets, annual reports, and facilitate all aspects of the program including regular communication with and between all parts of the project, maintaining a webpage, facilitating workshops and other meetings. The Project Lead leads the Project Planning Team in organizing applicable research and development activities, coordinating project efforts internal and external to the NWS and NOAA, and presenting plans and reports to the EOB for approval. The Technical Manager position is within the project office. The Technical Manager designs and manages the developmental and scientific strategies. The Technical Manager aligns collaborative activities submitted by the developmental teams. The Technical Manager is a member of the Technical Steering Committee and co-leads the Planning Team along with the Project Lead.

4.4 Technical Steering Committee/Science Steering Group

The Technical Steering Committee (TSC) will oversee the design and development activities of the project, monitor technical progress, and ensure cross-collaboration. This committee is charged with chartering task-oriented working groups/tiger teams and chooses internal or external experts to address specific elements of the NGGPS development and deployment. Working groups include independent review panels and evaluation teams that provide guidance on science and technical issues.

4.5 Project Planning Team

The Planning Team defines and develops the approach and process for building the next generation system. The team determined the Development Teams, their memberships and leads (many of whom are Planning Team members). The Planning Team is comprised of subject matter experts for each of the major development areas. The team will propose partition of activities between directed development and competitively awarded grants and define the detailed technical scope of activities.

4.5.1 Development Teams

The Development Teams were established to work on various aspects of the NGGPS development. Each team drafted a plan identifying gaps in the state-of-the-science, opportunities to leverage other ongoing programs and projects, and near- and long-term objectives associated with their particular focus. They meet periodically and, when needed, conduct technical workshops to gather information from the community on aspects of the global model system development. The Development Teams report progress and results to the Project Office, and recommend funding priorities and changes in emphasis within the project. In addition to developing and enhancing the predictive capabilities and efficiencies, the teams are responsible for considering developments from and establishing requirements for the general research and development community (NOAA and other US Government agencies and laboratories, cooperative institutions, universities, the international operational numerical weather prediction community, etc.). The teams and their charges are listed in Table 2.

Table 2. Development Teams

Team	Charge
Atmospheric Prediction, Dynamics	Assess dynamic cores for use as NGGPS core; upgrade and enhance dynamic core
Atmospheric Prediction, Physics	Define NGGPS physical parameterization suite; assess impacts of additional environmental parameterizations (e.g., aerosols); upgrade physics packages to accommodate increases in resolution
Data Assimilation	Formulate strategy and identify gaps for data assimilation components for atmosphere, ocean, sea ice, and land, at various scales; plan future requirements
Ocean Prediction	Plan the updating, incorporation, and coupling of ocean model components, including ocean, waves, and sea ice; identify gaps; form strategies to increase resolutions
Land Prediction	Formulate strategy and identify gaps for the land surface system, including links to hydrologic forecasts
Nested Subsystem for Storm-scale, Fire Weather and Severe Convective Weather Prediction	Ensure NGGPS architecture and software can address storm-scale data assimilation and forecasts in operations
Ensemble Development	Plan future development of NGGPS ensemble prediction system including data assimilation and forecast applications
Post-processing	Develop strategy and next-steps for evolution of post-processed products from NGGPS, including atmospheric, marine, and land-hydrologic products
Verification and Validation	Provide tools and metrics for evaluating model performance and provide the source for evidence-based approach to decision making, modeling system development, and model improvement
Testing/Testbeds	Develop and test coupled system; conduct feasibility studies with current software
Infrastructure	Define supporting infrastructure requirements; plan upgrades enabling testing, verification, documentation, and training of and for NGGPS
Software Architecture and Engineering	Define software architecture and engineered systems; assess and plan scalability
Overarching System	Focuses on the overall software architecture of NGGPS modeling applications and coordination of software development