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Foreword

The National Oceanic and Atmospheric Administration's (NOAA) accountability for accurate and reliable forecasts and warnings serves our nation by protecting life and property and enhancing the economy. To accelerate improvements in operational model guidance that underpin forecasts and warnings while remaining open to all, the Earth Prediction Innovation Center (EPIC) will integrate the latest user requirements, scientific research, and modeling developments from the whole community.

In the near term, defined as the next two years, EPIC will be an extramural center with funding from NOAA to support a cloud development environment, code repository, observations, tools, community support, and user engagement. EPIC will facilitate innovation and accelerated research to operations to research (R2O2R) in a cloud development environment with some physically co-located personnel and continuous community engagement.

The first phase of improving numerical weather prediction (NWP) is improving the Unified Forecast System (UFS) consistent with the UFS Strategic Implementation Plan (SIP).[1] To do so, EPIC will address the full UFS community that shares science components and software infrastructure for weather forecasting. EPIC will also foster partnerships with other agencies, academia, industry, and the international community through community engagement activities, community modeling governance structures and process, and by supporting a user friendly, well-supported modeling code base from which NOAA can draw the best for its mission needs and that also serves broad community needs.

In the mid to longer term, defined as three years and longer, EPIC's scope includes additional models that are critical to the full earth-system model coupling that can improve forecasting skill beyond three weeks and address the full range of NOAA mission applications. Those models may join EPIC as new components to the UFS or may join EPIC independently. This second phase of improving numerical weather prediction extends EPIC's mission to full earth-system model coupling across all environmental phenomena and time scales.

The EPIC authorization in the National Integrated Drought Information System Reauthorization Act of 2018 (NIDISRA, Public Law 115-423) in February 2019[2] and subsequent appropriation in December 2019,[3] have already spurred initial successes such as advances to the modeling systems, the release of the Finite-Volume Cubed-Sphere Dynamical Core (FV3), and structural changes within NOAA, including new research initiatives at NOAA's laboratories and Cooperative Institutes. These legislative mandates and initial successes are now the foundation for this five-year strategic plan with the associated investment strategy and quantitative goals.

Kandis Boyd, PhD, PMP
Acting Director, NOAA's Weather Program Office

[1] The Unified Forecast System. 2018. "Strategic Implementation Plan for Evolution of NGGPS to a National Unified Modeling System." FY19-FY21 SIP.
[2] National Integrated Drought Information System Reauthorization Act. 2019. Public Law 115-423 as amended.
[3] Departments of Commerce and Justice, Science, and Related Agencies Appropriations Bill, 2020: Report. 2019. Calendar No. 231.

Executive Summary

The Earth Prediction Innovation Center (EPIC) will enable the most accurate and reliable operational numerical forecast model in the world (**The Vision**). To be the catalyst for community research and modeling advances that continually inform and accelerate advances in our nation's operational forecast modeling systems (**The Mission**), EPIC is partnering with the community for the benefit of the nation (**The Mantra**).

Goal: Accelerate scientific research and modeling contributions through continuous and sustained community engagement to produce the most accurate and reliable operational modeling systems in the world.

1.0 Why is EPIC needed?

As our Nation pursues comprehensive and accurate Earth system models, advances in research and modeling must be rapidly incorporated into operational modeling systems. Where it was once reasonable to provide forecasts that were accurate to 2 or 3 days out, it is now necessary to provide forecasts that are usable and reliable at subseasonal (i.e. 2 weeks to 3 months) and seasonal (i.e. 3 months to 2 years) timescales.[4] This opportunity to provide the types of accurate forecasts that underpin decisions across societal and economic sectors depends upon making significant advances in science and modeling that can be continually incorporated into operational model systems.

Historically, this has been accomplished through a mix of research and modeling at NOAA laboratories, cooperative institutes, academia, and in the private sector that filters through the organization to operational use. Constraints to that transition into operations have included the complexity of introducing the required innovations into the existing operational model suite; consistently applying resources from research/modeling and operations to get the job done; balancing research/modeling interests with operational priorities; and the daily operational pressures to produce forecasts crowding out resources for innovation. Over many decades, each of these pressures has been eased by introducing testbeds, increasing co-development between research/modeling and operations, moving to a unified model system approach, and clarifying research priorities. However, NOAA has sizable opportunities to improve in each of these areas by transitioning to the EPIC strategic approach.

The EPIC strategic approach leverages advances NOAA has introduced, combined with commercial computing, software, and development process advances through an extramural, distributed center having strong connections to both the research and operational (i.e. National Weather Service (NWS)) elements of the community. It will be accountable for continuous connections between research and operations to communicate, and align operational needs, innovation possibilities, the programs that fund research and development; ongoing engagement between modeling and operations; and access to an integrated development environment that is platform-agnostic and co-locates the high-performance computing environment, storage and delivery of data with the latest codes, utilities, documentation, and user support. EPIC will accomplish this transformation by offering a cloud development environment; code repository; observations and tools; and community support and engagement that will, in turn:

- **Phase One (near term, 1-2 years):** Improve the global weather element of the Unified Forecast System (UFS),[5] here defined as the dynamical core, physics, assimilation system, and post processing; the UFS community shares science components and software infrastructure for advancing global 7-10 day weather forecasts by incorporating contributions from the external research and modeling community.

[4] Weather Research and Forecasting Innovation Act. 2017. Public Law 115-25.

[5] Unified Forecast System. 2019. https://ufscommunity.org.

- **Phase Two (mid term, 3-5 years):** Extend infrastructure and user support for UFS to full earth-system prediction, transforming the operational suite of models such as convective-allowing models (e.g., High Resolution Rapid Refresh) and fully coupled forecast systems (e.g., the Seasonal Forecast System, National Water Model, and Ocean Forecast Systems). Also expand the breadth of earth-system modeling, consistent with NOAA's mission.

1.1 The Opportunity

The devastating impacts of hazardous weather and other environmental events on life, property, and the national economy can be mitigated with accurate and reliable forecasts. To meet this need while reclaiming global leadership in weather prediction, NOAA must serve the nation by implementing the EPIC as the catalyst for accurate and reliable weather forecasts in the near-term; full-earth system coupling in the mid-term; and integrated, multi-agency environmental modeling partnerships in the long-term. Constantly evolving and adaptable, EPIC is an extramural program that is leveraged by intramural investment.

The community, defined as every individual and organization from every sector, state, and nation, gains free access to cutting-edge research and modeling systems that are user-accessible and user-friendly in the integrated development environment. This opens simultaneous opportunities to inform NOAA's operational modeling systems; serve others in the community; fund research, modeling, and compute initiatives from related grant programs; and develop innovative observations and tools. In exchange, the UFS community will move to continuous improvement and continuous development with prioritized research and ongoing upgrades to operational modeling systems.

EPIC will therefore initially offer:

- **Cloud development environment** with access to cloud high-performance compute (including surge and parallel compute), modeling software, and adjacent data. Hosting for the data is paid by NOAA or the provider per the contract(s); processing of the data within the cloud environment is paid by users, although users may apply for compute dollars where permitted by grant programs.
- **Code repository** with access to the latest release, dynamic documentation, private branches, and with active and well-defined code management rules, standards and practices.
- **Observations and tools** that include data assimilation approaches, retrospective data, and satellite and in situ observations.
- **Community support and engagement** that includes access to extraordinary software engineers and developers to support researchers and modelers with technical assistance, code development support, training, and materials; and community software infrastructure.
- **Culture, responsibilities, and roles** that are clear and tailored to the various constituencies within the community.
- **Continuous improvement, continuous development, and co-developed approaches** to deliver code standards, test cases and protocols, configuration management standards, integration timelines, and maintain community governance, R2O2R standards and co-developed, agile modeling systems.
- **Value propositions:**
    - For the model research and development community: a) access to a well documented and supported code base that is current with operational models and governed by the community, providing an efficient, effective framework for researchers and developers to accomplish their objectives, b) a chance for earth system modeling scientists to make a substantial impact on society through the enhanced ability to directly impact operational outcomes in NOAA, c) enhanced career pathway enabled by the community engagement and recognition fostered by EPIC that will lead to opportunities for collaboration and high visibility in the community.
    - For NOAA's operational models: a) access to model researchers and developers across other agencies, academia and industry who will be attracted to the UFS code base by the services and benefits provided by EPIC, b) an efficient, rigorous, agile research to operations pipeline to frequently and routinely incorporate the latest innovations into NOAA's operational modeling suite, c) the pathway to communicate and gain alignment between the research and development (R&D) and operations communities, so that R&D will be aligned with addressing the highest impact operational needs.
    - EPIC becomes a model for other public-private collaborations.

1.2 The Community Requests

Requests from the community have been collected in conversations, workshops,[6] responses to a request for information, and the Industry Day that together inform EPIC.

EPIC will demonstrate early successes, by aligning funding programs across the agency that already support earth system modeling and by building on successful business models. Relative to the latter, successful business models for community development and scientific innovation include, but are not limited to, the Joint Center for Satellite Data Assimilation (JCSDA), Developmental Testbed Center (DTC), Community Earth System Model (CESM), Weather Research and Forecasting Model (WRF), Model for Prediction Across Scales (MPAS), HYbrid Coordinate Ocean Model (HYCOM), and the UFS.

In alignment with the community requests for robust user support services, EPIC's value to the community follows a model similar to innovative companies. EPIC will build and support the most advanced earth system modeling framework in the world. EPIC will provide the community with an easy to use, reliable, fast, cost effective, accessible, and well-documented system that will aid them in their research and operational priorities and support the expansion of the private weather enterprise focused on earth system modeling.

1.3 The Legislative Mandates

The Weather Research and Forecasting Innovation Act of 2017 (WRFIA, Public Law 115-25) directs NOAA to prioritize improving weather data, modeling, computing, forecasting, and warnings for the protection of life and property and for the enhancement of the national economy. The authorizing language for EPIC, in the National Integrated Drought Information System Reauthorization Act of 2018 (NIDISRA, Public Law 115-423), specifically calls for NOAA to accelerate community-developed scientific and technological enhancements into the operational applications for NWP, which requires "advancing weather modeling skill, reclaiming and maintaining international leadership in the area of numerical weather prediction, and improving the transition of research into operations. This includes creating a community global weather research modeling system that is accessible by the public; meets basic end-user requirements for running on public computers and networks located outside of secure National Oceanic and Atmospheric Administration information and technology systems; and utilizes, whenever appropriate and cost-effective, innovative strategies and methods, including cloud-based computing capabilities, for hosting and management of part or all of the system described in this subsection."[7]

In the Senate report accompanying the FY2020 appropriation, the Committee directs NOAA to provide, "...a five-year strategic plan for EPIC that outlines: (1) NOAA's investment strategy for the Center, which is expected to consist of an extramural center approach that is leveraged by intramural investment; and (2) quantitative goals for improving NOAA's operational weather forecasting capabilities."[8]

1.4 The Executive Mandates

In the Memorandum on Fiscal Year 2021 Administration Research and Development Budget Priorities, the Executive Office of the President called for improved earth system predictability: "Departments and agencies should prioritize R&D that helps quantify Earth system predictability across multiple phenomena, time, and space scales. Strategic coordination and leveraging of resources across agencies on research and modeling efforts is needed to accelerate progress in this area. Additionally, agencies should emphasize how measures of and limits to predictability, both theoretical and actual, can inform a wide array of stakeholders. They also should explore the application of artificial intelligence (AI) and adaptive observing systems to enhance

[6] NOAA's Weather Program Office. 2019. "EPIC Workshop Reports." https://go.usa.gov/xpSa3.

[7] National Integrated Drought Information System Reauthorization Act of 2018 (Public Law 115-423). For the FY2020 Departments of Commerce and Justice, Science, and Related Agencies Appropriations Bill language, see https://go.usa.gov/xpJRG.

[8] Departments of Commerce and Justice, Science, and Related Agencies Appropriations Bill, 2020: Report. 2019. Calendar No. 231.

predictive skill, along with strategies for obtaining substantial improvements in computational model performance and spatial resolution across all scales."[9]

Consistent with that priority, in NOAA's FY2020 Blue Book, agency leaders note that "[a]ccelerating the advancements in the U.S. global modeling program is a top priority of the administration and at NOAA. In 2018, NOAA exceeded its target of transitioning research and development products, moving 24 products to application or operations. However, despite these advancements, significant problems exist with the current structure of weather research to operations. The internal and external strategy is fractured, the procurement process for high-performance computing capacity is cumbersome and uncoordinated, and the funding process disincentivizes collaboration."[10] Addressing EPIC's mandate to innovate and integrate will address this while also supporting a "weather-ready nation," lead by NOAA's NWS, with an environmental observation and modeling system that is consistent with the Department of Commerce's Strategic Plan,[11] the OAR Strategic Plan,[12] and the NWS Strategic Plan.[13]

In particular, the OAR Strategic Plan, Objective 3.1, calls for OAR to "[d]evelop models that reflect the physical, chemical, biological, and ecological properties of the Earth system and the intersecting human, ecosystem, and environmental factors. Develop and operate next-generation Earth system models using a community-based approach in concert with advances in high-performance computing."[10] Similarly, the NWS Strategic Plan, Objective 2.2, calls for the NWS to "[h]arness the power of ensemble modeling as the starting point for NWS forecast operations and to quantify certainty and promote consistency across all NWS service areas."[11]

2.0 How will EPIC work?

From the requests and mandates listed above, the following concepts and approaches emerge to realize the full potential of EPIC.

2.1 Concept: Vision, Mission, and Mantra

Vision. Enable the most accurate and reliable operational numerical forecast model in the world.

Mission. To be the catalyst for community research and modeling system advances that continually inform and accelerate advances in our nation's operational forecast modeling systems.

Mantra. Partnering with the community for the benefit of the nation.

2.2 Approaches, Practices, and Scenarios

EPIC demands an approach that prioritizes:

- Collaborating with integrity and trust across our community.
- Posing the problems rather than defining solutions.
- Leveraging existing objective evaluation processes and agreed-upon metrics.
- Pursuing realistic near-term wins with attribution for everyone.
- Co-developing research and modeling.

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[9] Executive Office of the President, "Memorandum for the Heads of Executive Departments and Agencies: Fiscal Year 2021 Administration Research and Development Budget Priorities." https://go.usa.gov/xpJRf.

[10] National Oceanic and Atmospheric Administration. 2019. "NOAA's FY2020: Budget Summary [Blue Book]." https://go.usa.gov/xpJRA.

[11] Department of Commerce. 2018. "U.S. Department of Commerce Strategic Plan: 2018-2022: Helping the American Economy Grow." https://go.usa.gov/xpJRp.

[12] NOAA's Oceanic and Atmospheric Research. 2019. "DRAFT OAR Strategic Plan 2020-2026: Delivering NOAA's Future."

[13] NOAA's National Weather Service. 2019. "2019-2022 Strategic Plan: Building a Weather-Ready Nation." https://go.usa.gov/xpJRd.

Informed by the EPIC Vision Paper,[14] the following is a study of practices and scenarios across each of the seven components of EPIC:

2.2.1 External Engagement and Community

Engagement is the opportunity to share and learn from each other. Projects in this category will include, but are not limited to, grants; annual meetings; visiting scientists/modelers; seminar series; hack-a-thons; code sprints; summer institutes; road shows; partnerships; and overall communication.

2.2.2 Software and Performance Engineering

Aligning software engineers with researchers and modelers is necessary to create well-documented, cloud-friendly, performance-optimized code and to free scientists to perform research and development. Projects in this category will include, but are not limited to, management and documentation of code; coordination with researchers; integration with other NOAA and community modeling efforts; and identification of criteria for improving computational abilities.

2.2.3 Software Infrastructure

The community development environment depends upon accessibility, reliability, and security, among other factors. Projects in this category will include, but are not limited to, the user management system; user interface; parallel computation; improvements in computation; storage; secure ingest; repository; workflow; and coupling of components. EPIC will continue to leverage the Memorandum of Agreement between the National Center for Atmospheric Research (NCAR) and NOAA to build shared infrastructure between research and operations.

2.2.4 User-support Services

As the community transitions to development in this new environment, teams will staff a central communication forum with individual accountabilities for answering questions and updating the frequently-asked questions. The primary focus of this service will be to ensure access and usability by all community members, regardless of the level of expertise and nationality. Projects in this category will include, but are not limited to, customer service; documentation; evaluation; technical assistance and experiences, including training, workshops, code sprints, and hack-a-thons.

2.2.5 Cloud-based High-performance Computing

NOAA's current capacity to provide operational and research-related High-Performance Computing is a limitation to the advancement of numerical weather prediction. The transition of research and development to a cloud environment has the potential to dramatically improve NOAA's capacity. Projects in this category will include, but are not limited to, setting requirements; learning lessons from research and practice; making cloud-ready model components and the necessary computational environment available; adding data needed for model execution, evaluation, validation to the cloud; and establishing incentives and business models.

2.2.6 Scientific Innovation

Fostering scientific innovation is embedded in the design of EPIC and the five approaches: collaborating with integrity and trust across our community; posing the problems rather than defining solutions; leveraging existing objective evaluation processes and agreed-upon metrics; pursuing realistic near-term wins with attribution for everyone; and co-developing research and modeling. This category highlights two of the major EPIC contributions: (1) making the UFS the most attractive modeling system in the world to use for model system research and development; and (2) aligning programs and providing a transparent R2O2R process that the community and programs can follow to mature innovations into operations. Projects in this category will include, but are not limited to, encouraging researchers;

[14] National Oceanic and Atmospheric Administration. 2019. "A Vision Paper for the Earth Prediction Innovation Center (EPIC): Version 5.0." https://go.usa.gov/xpJRy.

fostering grand challenges; inventing tools and software; and incentivizing use and contributions to the UFS.

2.2.7 Management and Planning

EPIC will be established as an extramural, distributed center with strong connections to both the research and operational (i.e. NWS) communities. Projects in this category will include, but are not limited to, identifying an accountable and authoritative individual at both NOAA and the extramural center and setting the respective accountabilities, acknowledging that the authority for the production suite will remain with NWS.

3.0 How will EPIC succeed?

Initially, the success of EPIC will be measured by the amount of interest and traffic associated with the Github repository. Later, the success of EPIC will be measured by the improvements in model skill scores (measures of relative improvement of a forecast over some benchmark forecast). To produce those successes, EPIC will deliver the investment strategies delineated below in the form of goals, objectives, and quantitative and qualitative outcomes. **Phase One (1-2 years)** and **Phase Two (3-5 years)** milestones are also denoted.

Goal: Accelerate scientific research and modeling contributions through continuous and sustained community engagement to produce the most accurate and reliable operational modeling systems in the world.

3.1 Accurate and reliable operational models: continually update and provide accurate, efficient, and advanced operational models that are a seamless, best-in-class system of software and hardware.

3.1.1 Objectives

- **Objective 1.1 // Co-develop research and models.** Smoothly and continually co-develop research modeling systems and implement them into operations.
- **Objective 1.2 // Prioritize code.** Prioritize implementation into operations using evidence-based decisions on science, societal benefit, and software optimization.
- **Objective 1.3 // Leverage assets.** Leverage assets across the Federal Government by using current research portfolios and establishing clear priorities.
- **Objective 1.4 // Increase understanding.** Increase the understanding and use of physical, geological-chemical-biological processes while simultaneously increasing the understanding and use of the interactions between the land, ocean, frozen water (cryosphere), and atmosphere.
- **Objective 1.5 // Leverage observations.** Leverage new environmental observations that could contribute to existing and future weather models.
- **Objective 1.6 // Partner.** Partner with the community early and often, especially to align integrated environmental modeling resources and efforts.

3.1.2 Outcomes

- **Outcome 1.1 // Incorporate JEDI tools. Phase One Milestone.** In the near term, incorporate the Joint Effort for Data assimilation Integration (JEDI).
- **Outcome 1.2 // Increase accuracy & clarify uncertainties.** In the near term, increase the accuracy of the initial state estimations and identify and quantify the uncertainties.
- **Outcome 1.3 // Extend useful forecast lead time & clarify uncertainties. Phase Two Milestone.** In the near term, extend usable and reliable subseasonal and seasonal forecasts and identify and quantify the uncertainties.
- **Outcome 1.4 // Co-develop priorities.** In the near term, implement at least 15 research innovations into operational modeling systems.[15]

[15] National Oceanic and Atmospheric Administration. 2019. “NOAA’s FY2020: Budget Summary [Blue Book].” https://go.usa.gov/xpJRA.

- **Outcome 1.5 // Evaluate.** In the near term, continue to evaluate the skill and timeliness of the operational outputs and share those findings.
- **Outcome 1.6 // Increase the use of UFS components. Phase One Milestone.** In the near term, increase the use of UFS components by other Federal agencies.
- **Outcome 1.7 // Increase the contributions of UFS components. Phase One Milestone.** In the near term, increase the contributions of UFS components from other Federal agencies.
- **Outcome 1.8 // Develop additional operational applications.** In the mid term, improve operational applications in support of the coastal marine environment, hydrological forecasting overland and at the coasts, and the sustainable use of living resources.
- **Outcome 1.9 // Share accurate and reliable modeling systems. Phase Two Milestone.** In the mid term, United States modeling systems are timely and produce the highest skill scores in the world.
- **Outcome 1.10 // Support fully-coupled modeling systems. Phase Two Milestone.** In the long term, support fully-coupled modeling systems for seasonal, ocean, and other forecasts.

3.2 Community contributions to operational modeling systems: make EPIC the most community-accessible and user-friendly system in the world so that everyone benefits from collective advancements.

3.2.2 Objectives

- **Objective 2.1 // Ensure that operational priorities are addressed.** Ensure that operational priorities are addressed by the research and modeling communities.
- **Objective 2.2 // Catalyze engagement.** Serve as the catalyst for researchers and modelers to engage and benefit.
- **Objective 2.3 // Inspire outcomes.** Inspire other operational outcomes within NOAA and other parts of the community.

3.2.3 Outcomes

- **Outcome 2.1 // Host distributed center.** In the near term, host an extramural, distributed center with strong connections to both the research and operational (i.e. NWS) communities. It will be accountable to funders through a governance board: (1) for the accuracy of the research and models incorporated into operational systems; (2) for the speed of the process; and (3) for the use of funds.
- **Outcome 2.2 // Host community development environment. Phase One Milestone.** In the near term, host a community-accessible and user-friendly development environment that provides access to the UFS, data, user support services, and return of code to the GitHub repository. Code will be free and easy to download, use, and upload; that ease is partially a function of the development environment and in part because of the dynamic documentation. This version of the UFS must be cloud-usable, co-located with a data tank/lake containing archived (and later real-time) observations for initialization, well-documented, and must pass the graduate student test,[16] thus bringing computing closer to the researchers and speeding development by reducing barriers to entry; increasing portability; minimizing costs; minimizing environmental impacts; and enabling better applications of artificial intelligence and machine learning.
- **Outcome 2.3 // Align and share research requirements and priorities. Phase One Milestone.** In the near term, share the research requirements and priorities for directors of NOAA centers, laboratories, and programs to show the connections to current and proposed funding for research and modeling.
- **Outcome 2.4 // Move data to the cloud. Phase One Milestone.** In the near term, move NOAA data to at least three cloud providers and support the centralized observation repository in the cloud per the World Meteorological Organization Information System (WIS 2.0).[17] Note that compute costs are

[16] United Forecast System. 2019. "Graduate Student Test." http://ufs-dev.rap.ucar.edu/index.html#/science/gst.

[17] World Meteorological Organization. 2019. "WIS 2.0." https://library.wmo.int/doc_num.php?explnum_id=4620.

borne by the individual user, but that some compute credits may be feasible, and it may be appropriate to include compute costs in grant proposals.

- **Outcome 2.5 // Foster the fast path to operations. Phase One Milestone.** In the near term, foster the fast and easy path from research and modeling to operations.
- **Outcome 2.6 // Reduce UFS complexity.** In the near term, invite the community to reduce the complexity of the UFS code by: (1) producing code that is scalable and optimized; and (2) recommending a sunsetting strategy for older code and products, when appropriate.
- **Outcome 2.7 // Build the user base.** In the near term, build the user base to increase year over year, in general and among graduate students (measured by the percent increase in monthly active users).
- **Outcome 2.8 // Assess continually.** In the near term, assess continually the research and modeling systems in process using peer reviews, expert groups, and leaderboards.
- **Outcome 2.9 // Leverage laboratories and Cooperative Institutes.** In the near term, leverage laboratories and Cooperative Institutes.
- **Outcome 2.10 // Provide startup grants. Phase One Milestone.** In the near term, provide startup grants through EPIC or related programs, in part with proof-of-concept projects.
- **Outcome 2.11 // Engage with other programs.** In the near term, continue to engage with other earth system forecasting modeling systems and agencies that have similar responsibilities to produce a full earth-system coupled model to include but not limited to ocean, atmospheric, cryosphere, land surface processes, hydrology, space weather, and biogeochemistry to improve forecasting skill beyond three weeks. In the mid term, expand those engagements.
- **Outcome 2.12 // Eliminate institutional delays.** In the near term, eliminate institutional delays to innovations and transitions. In particular, share publicly the priorities and requirements for transitions to operations and name the accountable individual.
- **Outcome 2.13 // Offer incentives.** In the near and mid terms, offer incentives that serve NOAA operations and the community (e.g., allow the community, including private sector providers, to prove data by demonstrating it in the GFS).
- **Outcome 2.14 // Leverage investments. Phase Two Milestone.** In the mid term, facilitate new investments in research and development that increase NOAA's total research and development funding to the community.

3.3 Community engagement: engagement is the opportunity to share and learn from each other.

3.3.1 Objectives:

- **Objective 3.1 // Accelerate contributions.** Accelerate contributions to a globally accurate operational prediction system.
- **Objective 3.2 // Document community engagement plan.** Dynamically document the community engagement plan that includes clear, consistent communication, listening sessions, and online fora for engaging.
- **Objective 3.3 // Document governance structure.** Dynamically document the governance structure (with updated procedures in the documentation) and the attendant incentives for the community. Consider successful business models for community development and scientific innovation that may include the JCSDA, DTC, CESM, WRF, MPAS, HYCOM, and the UFS.
- **Objective 3.4 // Align programs and funding opportunities. Phase One Milestone.** Align programs and funding opportunities to meet these goals and objectives while incentivizing engagement, collaboration, and innovation.
- **Objective 3.5 // Communicate the importance.** Consistent with the engagement plan, communicate the importance of EPIC globally in an easy-to-understand way by targeting each audience's interests, needs, and incentives.
- **Objective 3.6 // Learn continually.** Learn continually from research and practice (e.g., Cooperative Institutes, the Next Generation Global Prediction System, the Community Earth System Model, and the Weather Research and Forecasting Model).

- **Objective 3.7 // Build and maintain trust.** Build and maintain trust by continually aligning to core values:

  Fairness and integrity depend upon setting clear rules and following them using transparent and objective evidence-based decisions. Organizationally, this means posting all guidelines and agreements to the website and following them with rigor. Operationally, this means clear notices of funding availability and consistent rules for engaging in the community development environment.

  Transparency means sharing everything, which means open meetings; detailed minutes posted within ten business days of meetings; open elections; and dynamic documentation.

  Accountability means responsibility to funders and beneficiaries.

  Viability means creating long-term value.

  Collaboration means balancing the tensions between competing and cooperating.

  Attribution means giving credit for organizational and individual efforts.

  Effectiveness is measured by the best, prioritized use of human, technological, financial, and environmental resources, which will be evaluated annually.

3.3.2 Outcomes

- **Outcome 3.1 // Engage everyone.** In the near term, simultaneously engage researchers, modelers, and operations at every stage of development.
- **Outcome 3.2 // Amplify information about funding.** In the near term, amplify information about funding opportunities.
- **Outcome 3.3 // Host experiences. Phase One Milestone.** In the near term, host experiences, including at least two workshops and at least one code sprint per year.
- **Outcome 3.4 // Build a deep bench.** In the mid term, build a deep bench of modelers and engineers who can improve operational modeling systems.

4.0 What are the parallel timelines for EPIC and UFS?

Consistent with these goals, objectives, and outcomes, and aligned to the UFS timeline (Figure 1), the summaries and scenarios for the two phases follow. The UFS is a community-based, coupled, comprehensive Earth modeling system. The UFS numerical applications span local to global domains and predictive time scales from sub-hourly analyses to seasonal predictions. UFS is designed to support an active research program and to be the source system for NOAA's operational numerical weather prediction forecasts. Parallel timelines for EPIC and UFS:

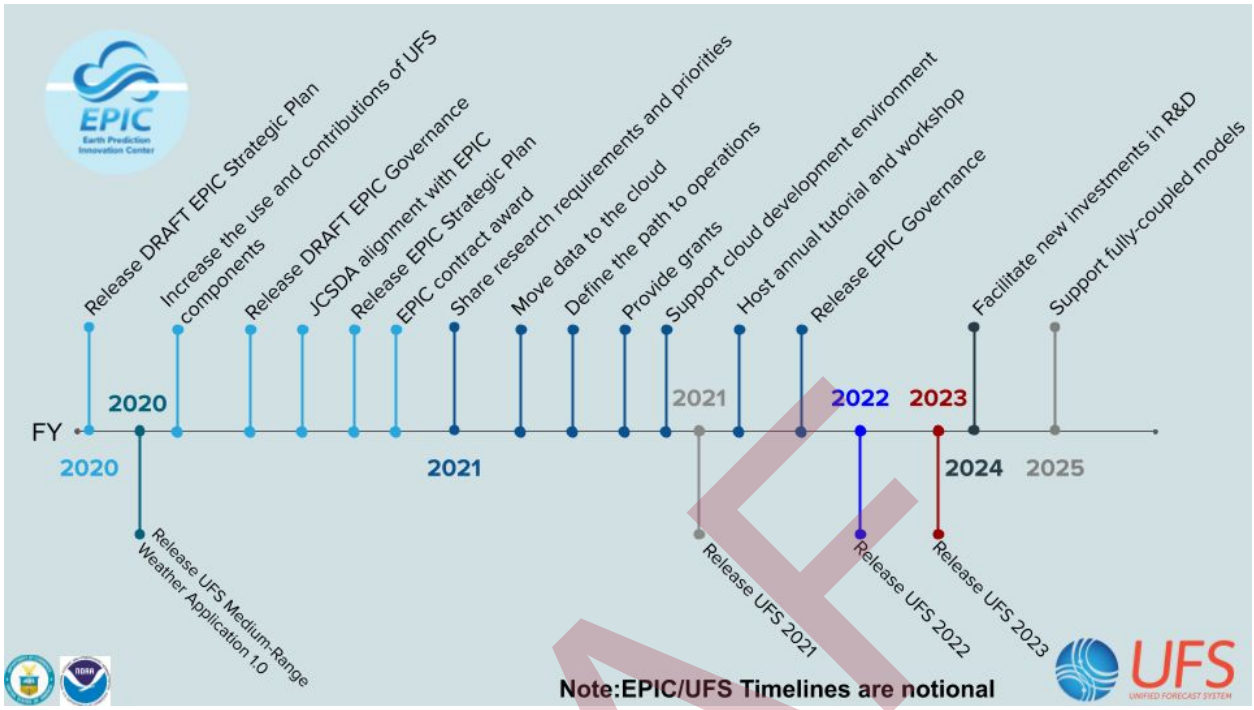

Figure 1: A parallel timeline of the UFS and EPIC from FY2020 to FY2025.

4.1 Phase One (near term, 1-2 years)

In Phase One (near term, 1-2 years), EPIC will focus on being the catalyst for accurate and reliable weather forecasts and will measure success based on code utilization and GitHub forks. EPIC will focus on integrated, multi-agency and external stakeholder environmental modeling partnerships and will measure success by the increase in those partnerships.

Phase One Scenario: A user easily works on a cloud development environment to make an update to the UFS that improves the skill score. To test this update, the user is given access to additional retrospective or real-time data. Following the test, and based on the science, safety, skill, and reviews, the code is considered for the operational modeling system and is updated into the main (or parallel) version for use by other community users. Community peer reviewers update the leaderboard of scientific merit, skill, and incorporation into the operational modeling system as a celebration of the user's accomplishment.

4.2 Phase Two (mid term, 3-5 years)

In Phase Two (mid term, 3-5 years), EPIC will focus on full-earth system coupling in the mid-term and will measure success by the increase in skill scores.

Phase Two Scenario: A user navigates to an integrated community development environment in the cloud, with access to high-performance parallel compute resources (paid by the user), and finds fully-coupled modeling systems and data. Updates to the modeling system are proposed through the environment and, following a series of tests by peer reviewers and the accountable code manager, are included in the next modeling system release.

5.0 The EPIC way forward

EPIC's success across time is a function of the sense of urgency, results, and an approach that prioritizes:

- Collaborating with integrity and trust across our community.
- Posing the problems rather than defining solutions.
- Leveraging existing objective evaluation processes and agreed-upon metrics.
- Pursuing realistic near-term wins with attribution for everyone.
- Co-developing research and modeling.
- Increasing usage of the UFS (i.e. downloads, community code contributions, and tutorials).
- Improving synoptic scale forecasts (i.e. 500 hPa anomaly correlation scores for global weather and ensemble forecasts).
- Improving usability and reliability of subseasonal and seasonal forecasts.
- Increasing accuracy of high-impact weather events (i.e. hurricane track and intensity and tornado warning lead-time).
- Fostering long-range Earth system planning out to ten years.
- Providing the world's best forecasts at all time scales and phenomena.
- Accelerating the rate of innovation from the external community by 50 percent.

Just as EPIC facilitates and supports the agile and continuous development of research and modeling, this strategic plan will be continually developed and updated to leverage progress and prioritize new investments. Watch for early successes as measured in code utilization and GitHub forks, and later successes measured in increased skill scores from code improvements to operational modeling systems.