

Released November 2019

# The Earth Prediction Innovation Center (EPIC) Community Workshop Report

August 6-8, 2019

University of Colorado, Boulder

University Memorial Center



OFFICE OF WEATHER  
AND AIR QUALITY

National Oceanic and Atmospheric Administration

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# The EPIC Community Workshop Report

## Executive Summary

This report is a summary of the presentations, discussions and community feedback gathered during the Earth Prediction Innovation Center (EPIC) Community Workshop that was held August 6-8, 2019 at the University of Colorado, Boulder University Memorial Center. This workshop was convened by the National Oceanic and Atmospheric Administration (NOAA) and was designed to engage the weather enterprise (i.e. academic, public, and private sectors) in the planning, development, and strategy for EPIC.

The objectives of the EPIC Community Workshop are outlined below:

1. Co-create a vision for EPIC to accelerate the transition of research to operations (R2O).
2. Share the current status and future of community-based Earth System Modeling.
3. Understand NOAA's developmental process for EPIC and create shared next steps in the development of EPIC.
4. Identify emerging technologies for Earth System Modeling.

To fully engage workshop participants, the EPIC Team used a Twitter hashtag (#EPICworkshop2019) and Google Form to ask reflection questions, gather participant input on EPIC's planning and execution, and track sentiment about the workshop. In response to participant feedback, the Workshop Execution Team amended the original agenda to include a NOAA panel discussion on Day Three (August 8). During this panel discussion representatives from NOAA were able to answer participant questions and address concerns gathered from Google Form submissions and on Twitter.

Participants identified aspects of community modeling important to integrate into EPIC, including:

- Robust User Support Services;
- User- and developer- oriented software development and software engineering best practices;
- Strong leadership that is accountable to funding organizations and the community;
- A positive, collaborative culture that facilitates community innovation;
- Early successes, including Congressional funding support;
- Development of a governance structure and business model;
- Flexible and sufficient compute environments that decrease barriers to entry and increase portability;
- Provision of community research tools derived from resources such as High Performance Computing (HPC), Cloud HPC, and centralized data centers; and
- A strong communications management plan focused on engaging the next generation of scientists and engineers.

Community members suggested the following next steps to meet short-term goals, gain community support, and begin standing up EPIC:



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- Release of the UFS 1.0 through GitHub;
- Provide user support services for the UFS community;
- Accelerate the integration of the Joint Effort for Data Assimilation and Integration (JEDI) as the next-generation data assimilation system into the UFS and NWS Operations;
- Identify a leader of EPIC and develop a governance plan;
- Provide short and long-term funding to groups that are now working with the Finite Volume on a Cubed Sphere (FV3) model and other UFS components and are making improvements;
- Release a draft request for proposals (RFPs) for EPIC;
- Seek partnerships across the weather enterprise; and
- Develop an EPIC Strategic Plan and Cloud Computing Strategic Plan.



**Image One:** EPIC Community Workshop Participants, Day Two (August 7)



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## 1. Introduction

### 1.1 Background

Congress has instructed the National Oceanic and Atmospheric Administration (NOAA) to establish the Earth Prediction Innovation Center (EPIC) to accelerate scientific and technological enhancements into the operational applications for earth system forecasting and prediction by supporting a community-developed model.<sup>1</sup> EPIC will initially focus on the development of the Unified Forecast System (UFS) to advance weather modeling skills in the United States.

### 1.2 The Unified Forecast System

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. The UFS is designed to support the Weather Enterprise (public, private, and academic sectors) and to be the core system for NOAA's operational Numerical Weather Prediction (NWP) applications.<sup>2</sup>

### 1.3 EPIC's Goals

EPIC will reclaim and maintain international leadership in NWP and improve Research to Operations (R2O) by:

- Leveraging the weather enterprise to provide expertise on removing barriers to improving NWP;
- Enabling scientists and engineers to effectively collaborate in areas important for improving operational global NWP skill, including model development, data assimilation techniques, system architecture integration, and computational efficiencies;
- Strengthening NOAA's ability to undertake research projects in pursuit of substantial advancements in weather forecast skill;
- Utilizing and leveraging existing resources across NOAA's enterprise;
- Creating a community global weather research modeling system.

## 2. Meeting Structure

The EPIC Community Workshop was a three-day community event structured to engage

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<sup>1</sup> The EPIC Legislative Language can be viewed in [Public Law 115-423](#), Section 4: "Earth Prediction Innovation Center."

<sup>2</sup> For more information about the UFS, please see the [UFS Website](#).



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members of the weather enterprise to create a vision for the future of Earth Systems modeling and high performance computing. The workshop was held from August 6-8, 2019 at the University of Colorado, Boulder University Memorial Center, located in the center of the country to ensure the event was convenient for all participants. The workshop was not hosted at a NOAA facility - a strategic decision made by the Workshop Planning Committee to ensure the venue was a “neutral” location.<sup>3</sup> This decision symbolized NOAA’s commitment to foster the development and operational application of a community model that is *from* the community *by* the community *for* the community.

Speakers and panelists for each session represented members of the weather enterprise, from private industry cloud vendors to federal employees and academics. Presenters shared their suggestions and perspectives about various aspects of EPIC, including how EPIC can facilitate improvements in NWP, potential models of organization, computing needs, and EPIC’s organization, management, and governance ([See Appendix One](#)).

The workshop was designed to be interactive for participants by including reflection questions to be submitted via Google Forms, a Twitter hashtag, networking breaks, and breakout group sessions ([See Appendix Two](#)).

## 2.1 Feedback Collection

Participants at the workshop were encouraged to provide their feedback about EPIC, the workshop, and reflection questions by using a Twitter hashtag and a Google Form called the “Triple S.” Data collected from the “Triple S,” Twitter, and recorder notes was analyzed to inform Session VI: “Strategy, Summary and Recommendations” on Day Three presented by several of the Workshop Planning Committee Members.<sup>4</sup> A detailed analysis of all collected feedback is provided in [Section 3: Meeting Summary and Participant Comments](#). The analysis provided during “Session VI: Strategy, Summary and Recommendations” and information included in this report will be used to inform EPIC’s Program Formulation, Strategic Plan, and program implementation.

### 2.1.1 Twitter



**Image Two:** Callout Box of the Twitter Hashtag #EPICWorkshop2019

<sup>3</sup> Planning Committee Members: DaNa Carlis (NOAA Office of Weather and Air Quality(OWAQ)), Sarah Perfater (NOAA OWAQ), Bill Lapenta (NOAA OWAQ), Fred Carr (University of Oklahoma), Peter Neilley (International Business Machines (IBM)), Cliff Mass (University of Washington), Tiffany Vance (NOAA National Ocean Service (NOS)), Brian Gross (NOAA Environmental Modeling Center (EMC)), and Lisa Taylor (NOAA Environmental Satellite and Information Service (NESDIS)).

<sup>4</sup> Fred Carr, Jim Kinter, Cliff Mass, Peter Neilley, DaNa Carlis, and Brian Gross.



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Participants were encouraged to use the hashtag #EPICworkshop2019 in their social media posts, especially on Twitter ([Appendix Three](#)). In total, 29 Twitter users posted over 200 tweets according to keyhole.co,<sup>5</sup> a hashtag analytics software used to track the workshop hashtag. Posts were liked or retweeted 705 times, seen by 26,621 individual Twitter users, and exposed an additional 183,121 Twitter users to the hashtag ([Appendix Four](#)).

## 2.1.2 “Triple S” Reflection Questions

To collect feedback about speaker presentations, the workshop design, and community recommendations for EPIC, reflection questions were provided at the conclusion of each workshop session ([Appendix Five](#)). Responses to reflection questions were provided in the “Triple S” Google form, provided to participants as an email link, quick-access (QR) code, and in the Participant’s Guide.<sup>6</sup>

Responses to the “Triple S” form were anonymous, so audience members could openly share their thoughts and opinions ([Appendix Six](#)).

Reflection questions were provided to participants in a PowerPoint presentation and were emailed to participants at the conclusion of the workshop. Participants were provided access to the “Triple S Form” for ten days, from August 6, 2019 - August 16, 2019.

In total the EPIC Team received 434 “Triple S” submissions over the three days of the workshop and the following week. Responses to “Triple S” questions will be analyzed in [Section 3: Meeting Summary and Participant Comments](#).

## 2.1.3 Volunteer Recorders

Approximately twenty individuals from across NOAA Line Offices assisted in the execution of the EPIC Community Workshop. To ensure speaker presentations, panel discussions, and questions in the room were accurately captured, eight members of the Workshop Execution Team notated in-room conversations.<sup>7</sup>

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<sup>5</sup>Keyhole’s real-time hashtag tracking product collects every single post and mention of your hashtag as they happen, automatically updating engagement and reach metrics and in-depth analytics so your data is always accurate and ready to go via keyhole.co.

<sup>6</sup> “Triple S” stands for the “Session Summary Survey,” we named this form the “Triple S” to make the form mysterious and fun, which participants enjoyed.

<sup>7</sup> Recorders: Sarah Perfater (NOAA OWAQ), Jordan Dale (NOAA OWAQ), Tamara Battle (NOAA OWAQ), Johnna Infanti (NOAA OWAQ), Sheema Lett (NOAA Office of Science and Technology Integration (OSTI)), Bhvana Rakesh (NOAA OSTI), Bill Pryor (NOAA OSTI), and Susan Cobb (NOAA Global Systems Division (GSD)).



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## 2.2 Attendee Statistics

Of the 188 people pre-registered for the EPIC Community Workshop, 141 participants attended the meeting in person which included 27 members of the private sector, 47 academics, and 67 federal employees ([Appendix Seven](#)).<sup>8</sup>

### 2.2.1 Online Attendee Statistics

The EPIC Community Workshop was streamed via GoToWebinar, an online meeting platform, so community members that could not attend in person could listen-in to speaker presentations, panels, and plenary sessions ([Appendix Eight](#)). Over the course of the event, 133 individuals tuned in to the Webinar ([Appendix Nine](#)).

### 2.2.2 Total Engagement

In total, the EPIC Community Workshop engaged 274 community members both in-person and online ([Appendix Ten](#)).

## 3. Meeting Summary and Participant Comments

### 3.1 Summary of Session I: Introduction to the Earth Prediction Information Center

**Bill Lapenta**, the NOAA Acting Director of Oceanic and Atmospheric Research's (OAR) Office of Weather and Air Quality (OWAQ), provided an introductory overview of EPIC. Dr. Lapenta's presentation included a brief history on U.S. NWP, industry collaboration, and research-to-operations efforts that brought us to the need for EPIC, as well as a brief overview of the Weather Research and Forecasting Innovation Act (WRFIA) of 2017 which authorizes EPIC. Dr. Lapenta shared EPIC's objectives to leverage the weather enterprise, enable scientists and engineers to effectively collaborate, strengthen NOAA's ability to undertake research projects, leverage existing resources in NOAA, and create a community global weather prediction modeling system. This modeling system should be innovative, accessible by the public, computationally flexible, and cost-effective to host and manage all or part of the UFS. Dr. Lapenta concluded his presentation by discussing EPIC's core investment areas, which include program management, the implementation of software engineering and software infrastructure, engaging the weather modeling community, and investing in Cloud High Performance Computing (HPC).

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<sup>8</sup> This count does not include speakers or Execution Team members.



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## 3.1.1 Participant Comments

Concerns emerged about balancing the one-year and five-year visions for EPIC as each pertains to initial investments, leveraging existing efforts, addressing cultural change, and caution to not neglect innovation early in the EPIC process. Dr. Lapenta emphasized that strong leadership is critical to breaking away from NOAA's current paradigm and moving toward change. With limited resources, EPIC will make substantial initial investments in software engineering. To break the current paradigm, the community must begin to think about community modeling differently and integrate software engineers throughout the entirety of the development process. Although EPIC is initially focused on the NWP part of the modeling problem, cloud computing will continue to be explored. Social and behavioral science will be integrated into post-processing to create usable products and services.

Survey respondents felt that Dr. Lapenta's presentation helped to clarify the goals and projected evolution of EPIC and established its strong connection to the UFS. Some respondents expressed concerns about NOAA not sharing the contents of the EPIC Request for Information (RFI), in spite of legal proprietary requirements.

Common areas of concern where clarity is needed emerged in the "Triple S" responses:

**Execution:** Participants and presenters discussed the importance of establishing a clear vision for EPIC, especially in terms of execution. EPIC's early execution and implementation needs to be done in a sustainable manner, especially focusing on short-term wins. Decision makers need to be aware that early decisions may not immediately improve U.S. NWP, but need to be included for success in the long run.

**Engagement:** Attendees discussed the need for a clear definition of community, especially in defining what collaboration looks like between sectors. Concerns were raised about the strategy to engage academic community members when there is a culture of "publish or perish" and in securing buy-in from the private sector.

**Cost :** Concerns were raised about whether or not EPIC would provide new funding opportunities, such as grants, and how EPIC's funding will interact with the Joint Technology Transfer Initiative (JTTI) portfolio. Participants voiced concerns about the costs associated with cloud technology and how cloud will be funded in the future. Participants also discussed the need for NOAA to prioritize funding software engineers, who may not be interested in the relevant federal positions as they are currently funded.

## 3.2 Summary of Session II: Perspectives on Numerical Weather Prediction and EPIC

This session was comprised by a panel that included Anthony Busalacchi of the University Corporation for Atmospheric Research (UCAR), Simon Vosper of the United Kingdom Meteorological Office (U.K. Met Office), Peter Neilley of International Business Machines (IBM),



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Steven Pawson of the National Aeronautics and Space Administration (NASA), Cliff Mass of the University of Washington (UW), Jim Kinter of George Mason University (GMU) and Fred Carr of the University of Oklahoma (OU). Each shared their perspectives on the frustrations experienced with advancing NWP and their vision for how EPIC would be most successful. Common themes were the need to have NOAA at the helm as a fully invested partner committed to being innovative, competitive, and open for collaboration with the external community. Community incentives to participate in EPIC would have to come from funding and assurance of cutting-edge innovation such as cloud computing, physics coupling, improved data assimilation (DA), talented software engineers, robust technical infrastructure, artificial intelligence (AI) and machine learning. For EPIC to truly engage the external community, it must be able to reduce NOAA operational compute and bureaucratic constraints that often lead to development silos, and enable innovative methodologies.

**Tony Busalacchi** of UCAR discussed the structure of the National Center for Atmospheric Research (NCAR), the National Science Foundations (NSF) funded atmospheric research center. Dr. Busalacchi discussed NCAR's potential role in EPIC, stating that NCAR would have a secondary role since it is primarily focused on base research and is driven by the needs of the academic research community. NCAR can assist in a push approach but EPIC can only be successful if there is operational demand and incentive. The operations must have a need and a clear vision for academic research contributions. However, the demand to pull from EPIC by the National Weather Service (NWS) is key to EPIC's success, lots of agreements can exist, but this is still a roadblock. Dr. Busalacchi suggested that academics will follow funding opportunities, which is a way EPIC can incentivize participation. EPIC must establish basic research platforms for participation, clarify roles and responsibilities, and provide access to compute resources.

**Simon Vosper** of the U.K. Met Office discussed the importance of sharing lessons learned and pursuing a seamless collaboration to forge a powerful ensemble system. Dr. Vosper discussed the U.K. Met Office's seamless prediction framework for weather and climate that spans timescales from hours to decades, similar to the goals outlined in the UFS. Each different time and spatial scale uses different DA, horizontal resolution, aerosol representations, and other dependencies. Performance metrics are tracked against other global systems and are provided through an NWP index system that includes other global models/communities. The U.K. Met Office participates in strategic partnerships with academic communities and weather/climate research programs and centers; coordinated partnerships are a key to success. For continued success The U.K. Met Office is continuously iterating with its partners and ensuring there are open lines of communication. This includes hosting an annual conference to identify top problems.

**Peter Neilley** of IBM's The Weather Company highlighted the success of IBM's modeling innovation which has been a result of the ease of access to community models for research and development. This includes access to user support and the scientific collaboration framework within which the model improvements and testing knowledge are given back to the community to enhance innovation. Dr. Neilley stated that EPIC must put forth a clear mission statement to achieve a world class community based modeling approach that is measurable and unites the



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community in marching toward this goal. If successful, the UFS should stand to be the world's best modeling framework within the next ten years. Dr. Neilley emphasized that the NWS should take credit for getting this new innovation into practice and for spring boarding efforts to foster innovation from the community. Concurrent with the NWS mission to protect life, property, and the economy, they have released new model updates, technologies, operational products and forecasts into the field, furthering the atmospheric science mission. In developing EPIC's mission statement, accountability is important. EPIC must strive to have the broadest possible participation of modeling communities to combine and share resources toward a common goal. Collaboration must be a two-way street with not only research being transitioned into operations, but researchers in return receiving new tools, data, and evolving NWS requirements. Development within EPIC must support a common goal as opposed to fractured with multiple efforts. Dr. Neilley expressed the risk of EPIC being owned/operated by NOAA as opposed to an outside entity fearing hesitation by the community to engage in collaboration.

**Steven Pawson** of NASA discussed strides NASA has made in terms of observations and assimilations in NWP by examining problems across time scales and focusing on observing systems in space. Dr. Pawson's biggest frustration in working with NOAA is the chain of people that needs to be "in the know" to make something happen, which poses a challenge to collaboration. However, there has been a long and successful collaboration with the Meteorological Development Laboratory (MDL), the Environmental Modeling Center (EMC) and the Earth System Research Laboratory (ESRL) on global DA and observation systems. Pawson feels the culture within EMC has inhibited R2O in the past, therefore EMC needs to be open to NASA's suggestions and ideas to improve collaboration. EPIC's vision is to invest in tools for environmental prediction across a range of timescales to provide the best possible tools to the community and reduce redundancy in observational networks, models, and research efforts. To fulfill this vision, EPIC must not converge on a single model, but rather explore the impacts of what different observations can do and compare them to make an informed decision on the strongest model. Dr. Pawson envisions NASA's role in EPIC as providing a footprint for a seamless suite of prediction and a deep observational network for DA. Specifically, the Global Modeling and Assimilation Office (GMAO) could lead this effort because they have the tools and skills in place to be successful. Establishing objectives are critical to successful collaboration. EPIC needs to address the R2O needs and constraints of both hardware and software and invest in these computing environments.

**Cliff Mass** of UW provided a detailed introduction to NWP, including the status of U.S. NWP modeling skills on the international stage and how EPIC can facilitate improvements in U.S. NWP. Dr. Mass stated that U.S. NWP now ranks second or third in the world, even though the U.S. has the world's largest atmospheric research community and global NWP budget. Mass suggested that we will not advance to the first tier if we do not take drastic steps to change NOAA's culture, organization, leadership, and structure. Dr. Mass shared his view on problems facing U.S. NWP, which include fragmented resources, divided responsibility, and a failure of the Global Forecast System (GFS) Finite-Volume on a cubed sphere (FV3) dynamical core to lead the state of the science in cloud precipitation, microphysics, convective parameterization, data assimilation, boundary layer parameterizations, and post-processing. He shared his view on the



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impacts associated with U.S. NWP shortcomings which may contribute to NOAA's struggle to hire the most talented recent graduates and academic researcher's decision not to develop on the GFS-FV3, but instead contribute to other community models. Dr. Mass stated that while there has been attempts to improve U.S. NWP in the past, it still lags behind the best because the U.S. is an "uncoordinated giant" with divided responsibility. Dr. Mass stated that there is no individual failure in previous attempts at improvement, rather, it has been a failure of the system as a whole. He ended on an optimistic note, stating that we are in a critical moment with the "stars aligned" for EPIC to succeed in advancing U.S. NWP.

**Jim Kinter** of GMU and **Fred Carr** from OU represented the Model Advisory Committee (UMAC). Dr.'s Kinter and Carr shared findings from a 2015 UMAC review of NOAA's operational model suite. The report found that NOAA separates basic research and development from operations in a way no other organization does, to its detriment. NOAA produces a widely diverse suite of prediction systems, most without the critical mass of resources or top-level oversight needed to make them the best. Research and development is not tightly integrated into operations, making it difficult for the research community to see where they can contribute and connect with operations. The UFS-Strategic Implementation Plan (SIP) and working groups are proving to be successful in facilitating a paradigm shift within NOAA. For continued success, EPIC must resource the UFS and working groups properly rather than relying upon in-kind funding and volunteers. The community must stay vibrant and engaged, which is derived from a healthy collaborative environment and unified effort. For EPIC to be successful, Dr. Kinter and Dr. Carr conveyed the need to support documentation, workflow, community support, and compute resources as the research environment needs. NOAA needs a coordinated effort among line offices and among NOAA labs. NOAA also needs to consider funding research for lower readiness levels. Dr.'s Kinter and Carr emphasized that amongst the changes NOAA needs to make, EPIC should implement a sunset strategy and coordinate a concerted water initiative to ensure Office of Water Prediction (OWP) models are compatible with the atmospheric suite. With EPIC, there can be no independent model development. Dr.'s Kinter and Carr pointed out that the NWS, OAR, and the academic community have made great strides to work together towards a common goal and must continue to build bridges. All of EPIC cannot be virtual, therefore a physical location should exist as a focal point for collaboration. To summarize, Dr.'s Kinter and Carr shared their EPIC vision to establish a community of users, establish priorities from the NWS, and simplify the modeling suite. EPIC needs aspirational goals, accountability, and a single focal point.

## *3.2.1 Participant Comments*

In-room discussion and responses to the "Triple S" Form identified several of the biggest problems facing NWP and how they may be addressed. Three broad themes can be identified: access to the UFS code, integration of software engineering best practices, and the need for clear leadership and management.

**Access to Code** :Many respondents agreed that to improve NWP, the UFS needs to improve access to code and improve code documentation. Code documentation needs to be robust in



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order to support a community model, and the most updated version of the code need to be available to the community.

**Software Engineering:** Respondents agreed that EPIC leadership needs to provide clear expectations about their software engineering priorities, and especially need to ensure software engineering best practices are integrated into the development of the UFS. User and developer support services are a critical aspect of EPIC’s software engineering priorities.

**Management:** Participants have many suggestions for how EPIC can be successful, especially in the short term (i.e. providing user support services, tutorials and training, code documentation, advancements in DA, and passing the Graduate Student Test).<sup>9</sup> Respondents agreed that EPIC needs a clear vision and definition of the program’s priorities. The leader of EPIC will need to facilitate a cultural change within NOAA organizations to foster a more collaborative environment, and manage the seams between modeling initiatives within other organizations, or remove the seams altogether.

## 3.3 Summary of Plenary: The Role of EPIC

**Fred Carr** (OU) chaired the Plenary Session entitled “The Role of EPIC.” During this Session, speakers from Session II: Perspectives on NWP and EPIC returned to the stage to answer questions about their presentations and engage with the audience. This provided an opportunity for participants to share their opinions and concerns and gain further clarity on the contents of the session presentations.

### 3.3.1 Participant Comments

Audience members and panelists discussed several components of EPIC specifically related to the allocation of resources, EPIC’s mission as it relates to managing collaboration, and model requirements.

**Leveraging Resources:** Attendees discussed the importance of efficiently leveraging EPIC’s financial resources for the greatest chance of success. Early program execution will have to be strategically focused on long-term goals to advance innovation. Leadership will have to ensure that EPIC allocates its funding towards the most efficient projects.

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<sup>9</sup> The Graduate Student Test (GST) defines the requirements for enabling capable graduate students studying meteorology, physical oceanography, land surface hydrology or climate dynamics to conduct research with operational codes held in common publicly accessible repositories. Separate GSTs may be needed for different applications, including the FV3-GFS, S2S, regional stand-alone and others. The GST includes steps for obtaining, being trained on, running, changing, testing, evaluating, and transitioning code. A scenario for how researchers outside NOAA might take up community codes to do original research such that it could undergo a transition to operations was also developed. This task is to create and assess metrics of the Graduate Student Test relevant to the UFS system architecture. Ongoing evaluation of the strategies for engaging graduate students will be used to evolve and refine the tasks.

([https://www.weather.gov/media/sti/nggpps/UFS%20SIP%20FY19-21\\_20181129.pdf#page=29](https://www.weather.gov/media/sti/nggpps/UFS%20SIP%20FY19-21_20181129.pdf#page=29)).



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**Managing Collaboration:** Managing community collaboration is critical to ensure community efforts are working towards common goals. There were two dichotomous options discussed: broad community engagement or small focused teams. Attendees identified the need to balance broad community engagement with more focused teams to ensure efforts are collaborative across community boundaries and manage the seams.

**Model Requirements:** Panelists and audience members discussed the importance of supporting the development of all aspects of the community modeling system and ensuring developers have access to the model. For this reason, one of EPIC's early priorities should be in establishing the UFS infrastructure and ample user support services. An easy to understand, easy to use, and well-supported model will influence a researchers decision about whether or not to use the model. Panelists from this session concluded that once model requirements are set, milestones, metrics, and other aspects of the model will fall into place. Participants discussed the need for the EMC to be involved in at least part of the model design to ensure that transitions are seamless as EPIC progresses. Participants agreed that NOAA should own and be accountable for EPIC, but EPIC should reside outside of NOAA to facilitate innovative outcomes.

## 3.4 Summary of Session III: Business Models for Community Modeling

This session included presentations from Richard "Ricky" Rood of the University of Michigan, Thomas "Tom" Auligné of the Joint Center for Satellite Data Assimilation (JCSDA), Chris Davis of UCAR, Louisa Nance of the Developmental Testbed Center (DTC), and Eric Chassignet of Florida State University (FSU). Speakers shared how their organizations and centers are organized to support various community models including the Weather Research Forecast Model (WRF), the UCAR Community Earth System Model (CESM), the HYbrid Coordinate Ocean Model (HYCOM), and the NOAA/Geophysical Fluid Dynamics Laboratory (GFDL) Modular Ocean Model (MOM6). Speakers discussed successful business models, lessons learned, and provided suggestions for EPIC.

**Ricky Rood** from the University of Michigan provided an overview of the UFS including its purpose, governance, scope, design, and impact. The UFS is a "comprehensive, community-developed Earth modeling system, designed as both a research tool and as the basis for NOAA's operational forecasts" that supports a paradigm-shift to a model built *with* the community, not *for* the community. The UFS simplifies the modeling suite and supports eight applications including medium-range weather, sub seasonal-to-seasonal (S2S), hurricane, convective allowing short-range weather, space weather, marine, cryosphere, coastal, and air quality systems. Dr. Rood stated that the governance model for the UFS is based on the analysis of ten community model structures and is designed to evolve as community needs change. Communication and continuity in the UFS is key; each new problem does not require us to start over, but rather build on what has already been created. The UFS is attempting to move away from the classic research funnel towards a model of a narrowing gate and stage. Dr. Rood shared that the UFS release team has been charged with improving the usability of code,



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defining and targeting early adopters, and identifying functional and resource gaps while working closely with their EMC counterparts.

**Tom Auligné** of the JCSDA (“Joint Center”) began by citing a paper by Magnusson et al. (2019)<sup>10</sup> that compares the impact of initial conditions between the European Centre for Medium-Range Weather Forecasts (ECMWF or EC), FV3-ec, FV3-GFS, and GFSv14. This study demonstrates the importance of initial conditions by demonstrating ten-day model forecast improvements in American models when ECMWF initial conditions are utilized. The primary focus of European models are initial conditions and DA, which are both areas where U.S. weather models can be improved. Dr. Auligné provided a brief overview of the Joint Center, which is a partnership between the U.S. Air Force, U.S. Navy, NOAA OAR, NOAA National Environmental Satellite, Data, and Information Service (NESDIS), NOAA NWS, and NASA with the vision to “become a world leader in applying satellite data and research to operational goals in environmental analysis and prediction.” The Joint Center demonstrates the “strength of a common goal” by overcoming stovepipes between agencies to support collaboration within the Joint Effort for Data Assimilation and Integration (JEDI). JEDI supports more than just Earth systems models and is designed for scientific exploration and operational applications by integrating software engineering best practices to improve DA. Dr. Auligné emphasized the importance of supporting the community by testing new code, ensuring the most up to date version of the application is available on GitHub and available for download on laptops. JEDI also hosts workshops, trainings, tutorials, “JEDI Academies,” code sprints, and visiting scientist programs.

**Chris Davis** of UCAR provided an overview of models supported by NCAR, including the CESM, WRF, and the Model for Prediction Across Scales (MPAS). Dr. Davis discussed the key elements of standing up a community model which includes excellent documentation and modeling code that is easy to access. Dr. Davis emphasized the need to provide tutorials, participate in inclusive outreach that includes the international community, and host workshops to discuss both shortcomings and development. Dr. Davis shared ways to incentivize community participation in EPIC which include supporting successes in the CESM, WRF, and MPAS, as well as ensuring the funding of a physical co-location of researchers to fuel collaborations and generate ideas.

**Louisa Nance** of the DTC provided an overview of the DTC’s purpose and structure and subsequently an overview of their community software philosophy. The DTC community software philosophy supports on-going development maintained under a mutually agreed upon software management plan, provides periodic releases of new capabilities and techniques to the community, and centralized support including software downloads, code documentation, and tutorials. Dr. Nance shared an overview of DTC-supported software and tools including legacy systems, core capacities, and future capabilities. Dr. Nance shared the key elements of success for community modeling, including centralized user support services and well-documented, portable code with enough flexibility to conduct exploratory research. Dr.

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<sup>10</sup> Magnusson, L., Chen, J.H., Lin, S.J., Zhou, L., and Chen, X. (2019). Dependence on Initial Conditions Versus Model Formulations for Medium-Range Forecast Error Validations. *Quarterly Journal of the Royal Meteorological Society*, 145(722), 2085-2100. DOI:<https://doi.org/10.1002/qj.3545>.



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Nance emphasized the importance of providing the community with clearly defined and documented protocols for engagement and welcoming community contributions that advance the capabilities of the system.

**Eric Chassignet** of FSU pointed out that currently, the National Centers for Environmental Prediction (NCEP) use two ocean models: MOM4 in the Coupled Forecast System (CFSv2) for S2S prediction, and HYCOM uncoupled for short term prediction. Both have an active community of users. Dr. Chassignet discussed the need to move to one ocean model in a seamless suite for the UFS. The HYCOM consortium was established as a collaboration between the Navy, Earth System Prediction Capability (ESPC), and GFDL to explore the development of HYCOM 3.0. This has included not just ocean modeling but also pre- and post-processing, standalone programs, and testing and evaluation. This has been a beneficial collaboration and allowed development to move forward. EPIC should include an open source ocean model (i.e. HYMOM), based on MOM6, to allow for applications development, open source DA as well as implementation and testing of eddy-resolving configurations. Dr. Chassignet shared his opinion that EPIC should explore whether or not MOM6 can be adapted to the coastal environment, which requires open-source DA codes, access to model configurations that can be modified in a test environment, and compute resources.

## 3.4.1 Participant Comments

Session III speakers were asked to follow-up on software engineering best practices and how EPIC can put forth a user-friendly model. Speakers discussed the need for decisions within EPIC to be evidence-based and state-of-the-art and to include considerations for the end-user throughout the process. Speakers suggested that to work within EPIC it should not be necessary for individuals to sign a non-disclosure agreement (NDA), but there does need to be attribution and licensing regulations.

Respondents to the "Triple S" Form supported business models organized to support agile, focused teams. Participants determined that of the presented business models, the JCSDA's or the DTC's business models would be the best examples for EPIC to follow. Participants liked that both JCSDA and the DTC support agile groups working on focused issues and suggested that EPIC take the successful aspects of DTC and JCSDA functions to inform EPIC's organizational model.

## 3.5 Summary of Keynote: Dr. Neil Jacobs

**Dr. Neil Jacobs**, the Assistant Secretary of Commerce for Environmental Observation and Prediction, performing the duties of Under Secretary of Commerce for Oceans and Atmosphere ("Acting NOAA Administrator"), gave the workshops keynote address. Dr. Jacobs addressed many of the concerns he was hearing from the audience in his presentation, specifically related to EPIC's key objectives, funding, short-term wins, and the positives and negatives of a physical versus virtual location.



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Dr. Jacobs addressed the need for NOAA to focus on providing portable, well-documented code available for community use that allows for the expertise of community members to be leveraged. To ensure the code is accessible, requirements supporting user community involvement, especially the Graduate Student Test, need to be integrated throughout all aspects of the model. EPIC's direction will be informed by the community, but ultimately EPIC will need strong governance that determines EPIC's direction. Dr. Jacobs addressed the need for a sunset strategy for legacy products, simplification of the NOAA modeling suite, and cultural changes within NOAA, specifically the reorganization and culture shift within EMC.

Dr. Jacobs addressed concerns from audience members about funding EPIC in the case of a continuing resolution (CR), stating that NOAA would leverage JTTI funding and NESDIS Center for Satellite Applications and Research (STAR) funding to ensure the EPIC Program continues its progress. There was a recognition amongst leadership that metrics between labs that determine funding are too competitive and need reformed to support a collaborative environment. EPIC will need to execute short-term wins, such as supporting a successful UFS 1.0 release and meeting year one and year five goals to show to Congress that they need to continue funding EPIC. EPIC will be located outside of NOAA, supporting an "external-NOAA sandbox, internal-NOAA sandbox, and secure-NOAA sandbox."

## 3.5.1 Participant Comments

Participants who responded to the "Triple S" Google Form expressed a positive sentiment regarding the presentation and especially appreciated that Dr. Jacobs tailored his speech to address community concerns. Common themes amongst respondents included technical issues for EPIC, managing collaboration, and computing strategies.

**Technology:** Dr. Jacobs discussed many of the highly-technical aspects of EPIC with attendees, specifically the need for improvements in DA and initial conditions to "catch-up" to the European models. There was discussion between the two dynamical core options for the UFS: the MPAS or the FV3. Dr. Jacobs stated that the chosen dynamical core for the UFS would be the FV3 and provided insights into why the FV3 was chosen.

**Collaboration:** Cultural changes within NOAA will have to take place to facilitate a more collaborative environment between internal- and external- NOAA entities. Respondents recognized that cultural changes do not happen quickly, but that EPIC can start facilitating these long-term changes. NOAA will need to be patient as they coordinate cultural changes within and between NOAA organizations. Dr. Jacobs emphasized the need for EPIC to exist outside of NOAA, so that researchers can work on an external model without waiting months for security access. Developments made in the external-NOAA sandbox will need to meet well-defined requirements and tests in order to be incorporated into the internal-NOAA model.

**Computing Resources:** Respondents expressed concerns about the cost of computing resources and EPIC's apparent reliance on cloud technologies. Dr. Jacobs addressed these



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concerns by discussing the need for NOAA to continue working on its corporate Cloud strategy to support research development projects throughout NOAA.

## 3.6 Summary of Session IV: Computing Needs for World Class Earth System Modeling

During this session, Frank Indiviglio of NOAA, Kevin Jorissen from Amazon Web Services (AWS), and Tim Carroll from Microsoft discussed computing needs for improved Earth system modeling in NOAA. Speakers during this session discussed the need for NOAA's computing strategy to be agile and informed by software engineering best practices. This session can be summarized with the following: *from the community, by the community, for the community.*

**Frank Indiviglio** of NOAA discussed the issues surrounding HPC, specifically that there is more demand for compute than supply. This gap must be addressed or the problem will continue to grow. Additional funding is a temporary solution so bigger thinking is required. Barriers to entry by external researchers must also be addressed. The important part of EPIC is the collaboration piece in the center - providing open access and enabling development across platforms. The NOAA Office of the Chief Information Officer and High Performance Computing and Communications (OCIO/HPCC) is currently evaluating seven different vendors for usability, portability, performance, cost, and scalability of new compute resources. Indiviglio states that data transfer and related infrastructure will be updated as a result of this evaluation and expanded with new tools and updated networking. Outcomes of this evaluation will also include a containerized version of the GFS-FV2 and Unified Post Processor (UPP), an improved strategy for fusing the existing environments with future environments, modernization of the hardware and software infrastructure, and improved data management for large workloads. This is essential for reducing costs and overhead. Indiviglio shared his view that EPIC should allow flexible compute environments, which brings computing closer to the researchers. This will speed up development by reducing barriers of entry and increasing portability, which allows for better applications of AI and machine learning.

**Kevin Jorissen** of AWS discussed the current state of HPC in the Cloud and emphasized that companies and organizations can experience great computing successes without massive financial investments. Dr. Jorissen discussed weather and climate workflows supported on the cloud for development across several sectors including big-agriculture, Wall Street, the insurance industry, meteorological agencies, and universities and national labs. Global models and AI are able to be run on the cloud as well as tutorials and user support services. Dr. Jorissen observed that people do not understand HPC and do not want to learn it; however, Cloud-HPC is more flexible than traditional HPC. Dr. Jorissen observed that "compute follows the data" and cloud is the perfect platform for collaboration around data. Dr. Jorissen suggested that EPIC needs to support young faculty by providing good jobs with perspectives towards permanent positions, ensuring they have mechanisms to collaborate so they have a strong publication record, and include them as an integral part of EPIC's plan. Jorissen encouraged the EPIC Team to pay attention to machine learning, utilize community-oriented interfaces, and "think outside the box" as EPIC is about more than just solving an NWP problem.



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**Tim Carroll** from Microsoft suggested that before we start thinking about forecasts and prediction, we need to step back and observe the human factor. User problems with data, tools, and products drive the roadmap to innovation. EPIC needs to support the research community with the right tools which rely upon HPC resources, Cloud, and centralized data centers. In history, technical breakthroughs have typically been driven by science - the need to achieve something big that required increasing accessibility and worrying about cost and sustainability afterwards. Market growth comes from increasing the number of people that have access to certain systems and resources that have never had it before. This is the opportunity that EPIC and HPC in the Cloud present. Carroll points out that we need to be thoughtful about how to move forward and ensure that we do not waste computing resources going down blind paths. Carroll ensures that Cloud technology gives individual users control over their cluster while simultaneously allowing the centralization to manage those efforts in parallel. Carroll also conveys that it is as difficult for a vendor to figure out what Cloud is going to cost the EPIC community. The workflows themselves is the only thing that is a fixed cost. Therefore, as a community, we need to better understand the workflows and requirements both technically, and by ranking of priority. The catalog of use cases and requirements are critical to map costs.

## 3.6.1 Participant Comments

Attendees discussed the details of computing needs for EPIC, which included mentions of Cloud and AI. Several attendees addressed the lack of early-career diversity for panelists and speakers and the need to make opportunities for young professionals entering the field a priority to attract talent.

**Cloud:** Attendees discussed the potential for NWP and model component improvements by utilizing Cloud computing technologies. Some “Triple S” respondents cautioned EPIC Leadership away from so quickly adopting and relying on Cloud. They encouraged the EPIC team to continue exploring other options and avoid creating a “Cloud Hammer.”

**AI:** Respondents suggested that by incorporating AI into EPIC’s computing processes it could allow for more rapid and consistent DA.

**Early-Career Diversity:** Participants and speakers discussed the need to include early-career professionals in programmatic decisions. EPIC needs to provide young career professionals with professional development opportunities, training, and opportunities to learn. Young career professionals need the opportunity to contribute to future software engineering and development efforts within NOAA.

## 3.7 Summary of Session V: Organization, Management, and Governance

This plenary session was chaired by Russell Schneider of NOAA’s Office of Science and Technology Integration (OSTI), who facilitated panelists William Mahoney of NCAR, Kevin Petty of IBM, and Michael Farrar of the United States Air Force. Each panelist had five minutes to



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share their thoughts on EPIC's organization, management, and governance before answering audience questions. Panelists discussed the need for EPIC to have a clear strategy with strong, agile leadership that has the ability to navigate cultural changes over the long-term.

**Bill Mahoney** from NCAR defined a joint venture as separate entities agreeing to participate in a project by contributing assets. The parties in a joint venture share in the management and the risk according to the agreement. The business model for EPIC gets tricky because it needs to have a core for coordination purposes and focused objectives because it is impossible to be everything to everyone. Not everyone that is able to take advantage of the open-access and portability of the data will have success in getting their research back into UFS operations so it is important to establish expectations, goals for improvement, and metrics for success. Dr. Mahoney shared his view that the governance of EPIC should be outside of NOAA but accountable to NOAA, structured as a trusted matrix organization with experience in community engagement and a deep connection with operational partners. Dr. Mahoney stated that EPIC must be coordinated with the academic community and be a center of excellence with permanent staff that can strive to strategically meet its goals. Dr. Mahoney then pointed out that the hand-off in the R20 process is still nebulous to most. The validation metrics of success within the UFS framework must be established with EMC from the start. The community needs to be involved in establishing the metrics with the understanding that they will evolve over time. Dr. Mahoney also cautioned that too much governance creates paralysis. Leadership must be in place to balance out the EPIC overarching management tied to the financial and organizational investment.

**Kevin Petty** of IBM discussed EPIC's governance challenges including the need to define EPIC's vision, mission, strategy, and execution. Dr. Petty shared his view that while the community has gotten closer to defining EPIC's vision at this workshop, we have a long way to go in terms of defining strategy, which needs to include both what EPIC will and will *not* do. Petty emphasized the importance of ensuring the right culture is in place to execute strategy, or "culture eats strategy for lunch." Strong leadership, especially within EPIC, is essential to facilitating cultural change within an organization and throughout the community. EPIC's leadership needs to leverage available community talent and integrate software engineers into EPIC to support new perspectives and diversity of thought. Petty suggested that EPIC leadership adopt lean management principles, support agile development, and utilize DevOps<sup>11</sup> as a way to integrate existing practices outside of the meteorological community into EPIC.

**Michael Farrar** from the U.S. Air Force conveyed that EPIC should be organized around what needs to be achieved. EPIC doesn't have to be one center that does everything. Instead, setting up smaller organizations to tackle different pieces of the R20 problem should be considered. Dr. Farrar suggested that EPIC adopt a structure similar to the Joint Center. That way each model component would be properly resourced and maintained making it easier to achieve quick wins. Dr. Farrar discussed the need to decide whether or not the FV3 will be EPIC's focus

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<sup>11</sup> Development and operations (DevOps) is a set of practices that automates the processes between software development and IT teams, in order that they can build, test, and release software faster and more reliably.



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for a community resource, or instead focused on what's next (beyond FV3). With respect to EPIC's governance, Dr. Farrar stated that when three people are in charge, no one is in charge. NOAA should consider what it would look like to pull all of the modeling components from end to end under one boss. In response to leadership, Dr. Farrar said that EPIC should be led by a board of directors with members inside and outside of NOAA. This model has been successful in the past. Dr. Farrar feels that EPIC staffing should be a priority to be innovative and fast, bringing on the best and brightest without being hindered by the federal hiring process, security clearances, and noncompetitive salaries (specifically for software engineers). When discussing metrics, Dr. Farrar stated that EPIC needs to examine what metrics are important to the American people, not just developers and scientists, to maintain Congressional support. To move forward efficiently, Dr. Farrar conveyed that NOAA needs to decide which legacy systems can be considered for removal and discontinuance. Dr. Farrar's closing statements were that EPIC should be engaging the next generation of scientists and engineers which will pay huge benefits for this community and its future, and is much more important than actually deriving successful improvements to the UFS. EPIC must find common ground and mutual core interagency interests, get the data and computing power in the cloud, and work to improve code portability and usability.

## 3.7.1 Participant Comments

During this session, attendees discussed the importance for EPIC to have a strong and accountable leader and implement an innovative organizational structure that facilitates community collaboration.

**Leadership:** EPIC's leadership will need to be lean and agile, with the ability to adapt to new opportunities and problems as they arise. The EPIC leader will need to be a strong leader that is able to facilitate the coordination of efforts across community boundaries. To foster an innovative environment the EPIC leader will need to support an environment where employees can take risks and support them even if the project is not successful.

**Accountability:** The EPIC leader must ultimately be held accountable for the success of EPIC while ensuring community collaborators are accountable for their contributions. To maintain accountability, EPIC will need to provide data that is evidence-based and ensure there is robust testing and verification before it is integrated into the internal-NOAA model. EPIC management still needs to determine how the UFS components and metrics can be improved by EPIC and how EPIC will standardize and manage code documentation.

**Organizational Structure:** Attendees discussed the need for EPIC to be external to NOAA to be successful. This innovative structure will need to promote community collaboration and innovation. Additional discussions are needed to determine exactly how this structure would function.



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## 3.8 Summary of Session VI: Strategy, Summary and Recommendations

Fred Carr (OU), Jim Kinter (GMU), Peter Neilley (IBM), DaNa Carlis (OWAQ), and Brian Gross (EMC) shared the “Strategy, Summary, and Recommendations” during Session VI. This presentation was informed by the discussions during plenary and breakout sessions during the previous two days of the workshop. They defined EPIC’s community-developed vision to create “the world’s best community modeling system of which a subset of components will create the world’s best operational forecast model” and EPIC’s community-developed mission to “advance Earth system modeling skills, reclaim and maintain international leadership in Earth system prediction and its science, and improve the transition of research into operations.” The group summarized areas where there was community consensus and where open issues remained, and provided recommendations for the future.

Please see [Section 5: Conclusions and Next Steps](#) for an in-depth overview of the “Strategy, Summary, and Recommendations” presentation.

### 3.8.1 Participant Comments

Questions and comments from the audience following Session VI suggested how EPIC might foster community innovation and be successful. Several concerns remained in the community, however, especially related to reanalysis and reforecasts.

**Innovation:** EPIC needs to identify potential areas for early successes and promote community buy-in. The UFS needs to have robust user support services and be accessible to the community. Graduate Student Test requirements are extremely important for the success of the UFS, and the UFS needs to be downloadable to a laptop to encourage student use.

**Defining the “C” in EPIC:** Attendees suggested that the “C” in EPIC should stand for a multitude of words, including; community, culture, and collaboration. EPIC will need to adequately address each of these areas to be successful, and they need to be included in EPIC’s vision.

## 3.9 Summary of Session VII: Vision and Priorities for EPIC

During this session, Jennifer Mahoney from NOAA’s ESRL Global Systems Division (GSD) and Bill Kuo from UCAR shared their visions and priority areas of focus for EPIC. Even though EPIC will be external to NOAA, there needs to be collaboration internal and external to NOAA.

**Jennifer Mahoney** provided an overview of ESRL’s GSD, shared her vision for EPIC and ideas about how EPIC may be organized. GSD partners with NCAR, the DTC, Global Monitoring Division (GMD), and collaborates with the JCSDA on executive and managerial oversight committees. GSD supports regional and global model development with extensive work on verification and evaluation. Mahoney suggested that EPIC needs to explore HPC, cloud capabilities, and machine learning, as well as work closely with partners at EMC to improve R2O.



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Mahoney discussed the need to support an organizational structure that bridges the gap between operational requirements and the external community. Mahoney recommended that EPIC produce well-defined targets, define EPIC's role in achieving goals, forge linkages between research and operations, and provide funding to support UFS infrastructure development and implementation.

**Bill Kuo** of UCAR discussed gaps he observed during workshop discussions and how they may be addressed. Dr. Kuo suggested that we proceed with caution when including "to become the world's best community modeling system and maintain international leadership in global NWP" in the vision and mission statements for EPIC. Dr. Kuo cautioned participants and leaders from assuming that just because we create the world's best community model does not mean we will automatically reclaim international leadership in NWP. Kuo expressed concerns that the proposed \$15 million FY20 President's Budget may not be enough to "coordinate the giant." NOAA needs to efficiently and effectively manage EPIC's money. The goal of improving NWP needs to extend beyond EPIC to programs throughout NOAA and partnering organizations to support NWP research. We need to think about how, in Line Offices, funding programs and grants can focus on the goal of improving global NWP by creating a network to align missions. Dr. Kuo suggested that EPIC needs to define their organizational structure and determine how they will collaborate with external community partners.

## 3.9.1 Participant Comments

Audience members discussed what lessons could be learned from previous model developments, what organizational changes need to take place to support EPIC, and the need to improve the research to operations to research (R2O2R) communication funnel.

**Lessons from the Past:** The U.S. has many successful weather models and lessons learned from the implementation of these models. For the UFS to be the best in the world, we need to apply these lessons.

**Organizational Changes:** There are changes that need to be made within NOAA's culture and organization to support a successful community model and improve U.S. NWP. In essence: there needs to be disruption to allow for success.

**R2O2R:** Communication between the research and operations communities needs to be improved; research must address the needs of the operational community and vice versa.

## 4. Summary of EPIC Breakout Sessions

### 4.1 Organization

Each breakout group had differing suggestions about how to best organize EPIC. Most groups were in consensus that the software engineering component, infrastructure, and user support



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services as top priorities for EPIC. EPIC software engineers will need to utilize industry best practices for robust evaluation and metrics and integrate end user requirements throughout the development process. The EMC will need to be integrated into EPIC's organization and decision-making structure to provide insights on development and user support. To foster innovation, EPIC will need to support a culture change within NOAA by cultivating an environment that "empowers individuals to be responsible for driving results" and allows people to take risks and fail.

EPIC will need to provide a robust coding infrastructure and user support to attract the academic community to use the UFS. Other ways to attract the academic community are teaching the UFS code in university classes, ensuring the UFS passes the Graduate Student Test, providing graduate fellowships, and supporting visiting scientist programs.

Breakout groups suggested a combination of funding sources to support projects with different objectives (grants, contracts, and CI's), yet all groups were in agreement that EPIC needs to provide both short- and long-term funding. For example, several groups suggested that EPIC could use a funding mechanism that provides long-term support with the opportunity for funding short-term focused goals that leverage the strength of the community. No group came to a clear consensus on the specific funding mechanisms (i.e. grants, contracts, and cooperative agreements) that EPIC should utilize; however, some groups suggested that the funding be based on deliverables.

## 4.2 Management

Breakout groups supported EPIC having a clearly-defined management structure with a strong leader. Groups established that the EPIC leader needs to empower and support their team to work collaboratively in a high risk/reward environment that allows failure. EPIC's management should support focused, short-term projects and adopt Lean Management principles. It was suggested in many discussions that we are too early in the process of standing up EPIC to develop a management strategy. Some feel the management structure will be better realized during the process of executing the initial functions of EPIC, including portability of the code and implementing a software engineering strategy.

## 4.3 Governance

The only clear consensus between breakout groups was that governance needs to be outside of NOAA or in partnership with NOAA, with strong community input and co-development. Some groups suggested non-NOAA governance with a Science Advisory Board (SAB) that provides guidance. Other groups suggested that resource owners should contribute money towards EPIC with their degree of governance determined by how much money they contribute. Overall, breakout groups were in agreement that the governance needs to allow for maximum flexibility by supporting short-term and focused teams.



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Breakout groups agreed that the governing body needs to set clear priorities as they relate to EPIC; which include the vision, mission, and general direction of EPIC. The governing body needs to define the problems EPIC faces and provide recommendations while engaging the community to fostering collaboration.

## 5. Conclusions and Next Steps

### 5.1 Conclusions

Members of the EPIC Community Workshop Planning Committee drafted a potential community-developed EPIC vision and mission statement based on presentations, question and answer sessions, and breakout group discussions at the workshop.<sup>12</sup> Their draft EPIC vision statement is to “create the world’s best community modeling system of which a subset of components will create the world’s best operational forecast model.” EPIC’s proposed mission statement “is to advance earth system modeling skills, reclaim and maintain international leadership in earth system prediction and its science, and improve the transition of research into operations.” Planning Committee Members outlined the top priority areas of funding, which are community support and user services, defining the business model and governance, initiating EPIC, and computing resources.

As defined by synthesizing the community comments, a community modeling system requires robust user support which includes the following: easy access to the latest version of code, input and output data, a code repository maintained under version control software, thorough and understandable documentation; user-friendly workflows, adequate software infrastructure, tutorials, workshops, and developer involvement. Robust user support also requires hierarchical testing capability, clear pathway for incorporating new science, easy access to adequate amounts of computing resources, special attention to students as next-generation users, and code portability. Issues that need to be addressed in terms of user services are how community support will evolve in a sustainable fashion from the short to the long term; whether or not computing resources will be allocated (and if so, how they will be allocated), whether or not there is sufficient expertise to provide ample user support for all UFS components, and how developers will be involved in user support.

Participants agreed that EPIC is from the community, by the community, for the community. While it was determined that EPIC will sit outside of NOAA, NOAA is still a key member of this community. There was consensus that EPIC needs to have a strong leader with decision making ability supported by a lean management structure. EPIC leadership will need to be accountable to the funding organizations and to the community. EPIC needs to create a positive collaborative culture across the weather enterprise. Community members agreed that EPIC can not only exist as a virtual center and that there will need to be some physical presence for governance and community support. There was not a clear consensus on how NOAA plans to

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<sup>12</sup> View the summary presentation slides on the OWAQ Website: <https://owaq.noaa.gov/Programs/EPIC>



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spend the \$15 Million proposed in the President's FY20 Budget, what the composition and scope of the EPIC staff will be, and what the specific qualifications are for EPIC leadership.

The early stages of EPIC will need to demonstrate early successes for community buy-in and continued Congressional support. The best way to demonstrate EPIC's success is to improve U.S. forecasting skill, for example by closing the accuracy gap between the ECMWF and GFS. To make this success possible, EPIC needs to provide initial funding to groups such as the JCSDA, EMC, university groups, and other NOAA Labs that have already adopted the FV3 and other UFS components and are making improvements to them. Early successes also include identifying the managing institution, hiring the EPIC leader, and establishing user support services such as tutorials, a help desk, and successful implementation of new DA approaches. There was no consensus on how exactly the structure of the EPIC organization will be selected and funded.

Participants agreed that NOAA currently does not have enough computing resources to support environmental prediction requirements, such as development, operations, and reanalysis/reforecasting. Cloud computing may be able to provide support for some aspects of EPIC, such as distribution and archival or model output, but may not be the best option for operational forecasting. Strategies for computing resources need to be agile to allow for flexibility in a rapidly evolving computer landscape. There was no consensus on the specific sources of computing, and the degree to which EPIC should support diverse computing architectures.

## *5.2 Next Steps*

The EPIC Team has been analyzing information received from the RFI to identify priority areas of funding and inform an acquisition strategy. In the future, the EPIC Team will also draft and release a Request for Proposal (RFP). The acquisition process will be led by a cross-NOAA team and monitored by NOAA senior leadership.

OWAQ and OSTI are prioritizing the first public release of UFS and working across UFS working groups to stand up a Release Team. Internally, NOAA is focused on funding projects that will allow success in transitioning the agency to the UFS framework of development. In order for EPIC to be successful, NOAA will focus on the development of the UFS and continue to engage the community throughout the process. Parallel to the newly-developed NOAA Cloud Computing strategy, an EPIC Strategic Plan will be developed. The Strategic Plan will be informed by the collection of recommendations and considerations brought forth by the community and subject matter experts during the EPIC Community Workshop.



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## Acknowledgements

Thank you to Leah Dubots, Sarah Perfater, and DaNa Carlis for executing the analysis of workshop materials and drafting the Workshop Report. Thank you to Chantel Bivins and members of the Workshop Planning Committee (Bill Lapenta (OWAQ), Fred Carr (OU), Peter Neilley (IBM), Cliff Mass (UW), Tiffany Vance (NOS), Brian Gross (EMC), and Lisa Taylor (NESDIS)), for reviewing and editing the Workshop Report. In addition, we would like to thank all the speakers that took time out of their schedules to prepare thoughtful talks that engaged the community and informed the future of EPIC.

Thank you to EPIC Community Workshop Execution Team members: Bill Lapenta (OWAQ), EPIC Community Workshop Executive Sponsor; DaNa Carlis (OWAQ), Lead Facilitator; Leah Dubots (OWAQ), Lead Organizer and Author of the Facilitation Guide and Participants Guide; Gina Eosco (OWAQ), Facilitator; Sarah Perfater (OWAQ), Facilitator/Recorder; Chandra Kondragunta (OWAQ), Facilitator; Pam Heinselman (NSSL), Facilitator; Mark Vincent (OWAQ), Facilitator ; Melissa Petty (GSD), Facilitator; Rich Fulton (OWAQ), Facilitator; Jessie Carman (OWAQ), Facilitator; Kathryn Mozer (PPE), Facilitator; Arun Chawla (NWS/EMC), Facilitator; Jordan Dale (OWAQ), Recorder; Tamara Battle (OWAQ), Recorder; Johnna Infanti (OWAQ), Recorder; Sheema Lett (NWS/OSTI), Recorder; Bhavana Rakesh (NWS/OSTI), Recorder; Bill Pryor (NWS/OSTI), Recorder; Susan Cobb (GSD), Recorder; Barbara Eubanks (OAR/CPO), Registration and Logistics; Chantel Bivins (OWAQ), Communications and Staff Support; and Sarah Venema (ESRL), Workshop Logistics.



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## Remembering Dr. William “Bill” Lapenta



**Image Three:** Dr. Bill Lapenta

The EPIC Team is deeply saddened by the unexpected passing of Dr. William “Bill” Lapenta, an admirable leader, mentor, and friend. Bill was the Acting Director of OWAQ, a dynamic office within NOAA that supports world-class weather and air quality research. Bill joined OWAQ from the NWS where he was the Director of the National Centers for Environmental Prediction (NCEP). While at NCEP he oversaw the planning, science and technology, and operational responsibilities of NCEP’s nine national centers. Lapenta received his Ph.D. in meteorology from Pennsylvania State University in 1990 and a Bachelor of Science Degree in meteorology with a minor in mathematics from the State University of New York at Oneonta in 1983. A native of Nyack, New York, Bill was residing in Northern Virginia. He and his wife, Cathy (also a meteorologist) have two adult children.

Bill championed for EPIC like no other and we are dedicated to making EPIC the success that he imagined it being. The OWAQ Team moves forward in his legacy. Several events, memorials, and scholarships are being planned to honor Bill. Please visit his [Memorial Page](#) for updates.



**Image Four:** Dr. Bill Lapenta Presenting “An Introduction to the Earth Prediction Innovation Center (EPIC)” on Day One of the EPIC Community Workshop (August 6)



# The EPIC Community Workshop Report

## Appendix

### Appendix One: EPIC Community Workshop Agenda

#### Day One - August 6, 2019

- 8:00 am Registration**
- 8:30 am Welcome**  
*DaNa L. Carlis, NOAA*
- 8:45 am Session I: Introduction to the Earth Prediction Innovation Center (EPIC)**  
*Bill Lapenta, NOAA*
- 9:45 am Break**
- 10:15 am Session II: Perspectives on US NWP and EPIC**  
Chair: *DaNa L. Carlis, NOAA*
- 10:15 am - *Antonio "Tony" Busalacchi, UCAR*
- 10:30 am - *Simon Vosper, UK Met Office*
- 10:45 am - *Peter Neilley, IBM*
- 11:00 am - *Steven Pawson, NASA*
- 11:15 am - *Cliff Mass, University of Washington*
- 11:30 am - *James Kinter, George Mason & Fred Carr, University of Oklahoma*
- 11:45 am - *Table Talk*
- 12:00 pm Lunch**
- 1:15 pm Plenary Session: The Role of EPIC**  
Chairs: *James Kinter, George Mason & Fred Carr, University of Oklahoma*
- 1:15 pm - *Panel Q&A with Session II speakers*
- 1:45 pm - *Plenary session*
- 2:30 pm Break**
- 3:00 pm Session III: Business Models for Community Modeling**  
Chair: *Cliff Mass, University of Washington*
- 3:00 pm - *Ricky Rood, University of Michigan*



# The EPIC Community Workshop Report

## Day One Continued:

- 3:15 pm - *Thomas Auligné, JCSDA*
- 3:30 pm - *Chris Davis, NCAR*
- 3:45 pm - *Louisa Nance, DTC*
- 4:00 pm - *Eric Chassignet, Florida State University*
- 4:15 pm - *Panel Q&A with Session III speakers*

**5:00 pm      Adjourn**

## Day Two - August 7, 2019

**8:00 am      Registration**

**8:15 am      Keynote Speaker**

*Dr. Neil Jacobs, Acting NOAA Administrator*

**9:00 am      Summary of Day One (highlights and recommendations)**

**9:15 am      Session IV: Computing Needs for World-Class Earth System Modeling**

*Chair: Peter Neilley, IBM*

*9:15 am - Frank Indiviglio, NOAA*

*9:30 am - Kevin Jorissen, Amazon Web Services*

*9:45 am - Tim Carroll, Microsoft*

*10:00 am - Panel Q&A with Session IV speakers*

**10:30 am      Break**

**11:00 am      Session V: EPIC Organization, Management, and Governance (Plenary)**

*Chair: Russell Schneider, NOAA*

*Panelist: William Mahoney, NCAR*

*Panelist: Kevin Petty, IBM*

*Panelist: Shuyi Chen, University of Washington<sup>13</sup>*

*Panelist: Michael Farrar, USAF*

**12:00 pm      Lunch**

**1:15 pm      Breakout Session: EPIC Organization, Management, and Governance**

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<sup>13</sup> Dr. Chen could not present due to technological difficulties.



# The EPIC Community Workshop Report

*Day Two Continued:*

- 3:00 pm**      **Break**
- 3:30 pm**      **Breakout Session Findings and Discussion**
- 5:00 pm**      **Adjourn**

Day Three - August 8, 2019

- 8:30 am**      **Registration**
- 9:00 am**      **Session VI: Strategy, Summary, and Recommendations**  
*Chairs: James Kinter, George Mason & Fred Carr, University of Oklahoma*
- 10:15 am**      **Break**
- 9:30 am**      **NOAA Panel<sup>14</sup>**  
*Bill Lapenta, NOAA*  
*Brian Gross, NOAA*  
*DaNa Carlis, NOAA*  
*Jennifer Mahoney, NOAA*
- 10:45 am**      **Session VII: Vision and Priorities for EPIC**  
*Chair: Bill Lapenta, NOAA*  
*Panelist: Jennifer Mahoney, NOAA*  
*Panelist: Ying-Hwa “Bill” Kuo, UCAR*
- 11:30 am**      **Adjourn**

## **Appendix Two: Breakout Group Discussion Questions**

Organizational Questions:

- How would you wish to contribute to the national success of EPIC (and the UFS)?
- In your experience, which funding opportunities have been the most productive? Why? Which criteria are you using?
- EPIC has \$15M in the President’s Budget for FY20, what are the top three priority areas for financial investment?

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<sup>14</sup> The NOAA Panel was added to the agenda on Day Three in response to participant’s requests received in the “Triple S” Form and on Twitter.



# The EPIC Community Workshop Report

## Management Questions:

- In your experience, which organizational structures have best supported innovation? Communication? Engagement? What criteria are you using?

## Governance Questions:

- What is the balance of governance between institutions and government? How do they share this role?
- What are the responsibilities of the governing body?

## Appendix Three: Tweet Example

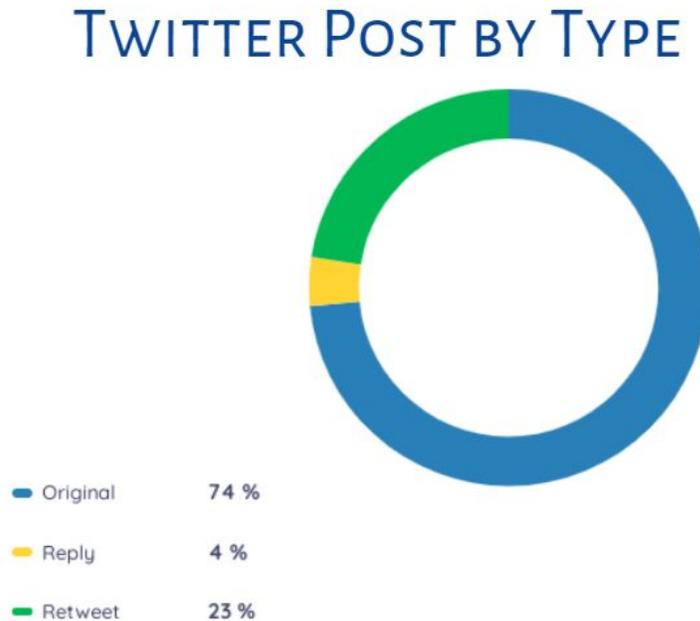


**Image Five:** An Example of a Tweet on Day One (August 6) From Participant Luke Madaus.



# The EPIC Community Workshop Report

## Appendix Four: Breakdown of Tweet by Type<sup>15</sup>



**Figure One:** Twitter Post by Type

## Appendix Five: “Triple S” Reflection Questions

Session One Reflection Question:

- What questions or concerns remain after hearing Dr. Lapenta’s presentation? What is clear now that wasn’t clearly communicated before?

Session Two Reflection Questions:

- What’s the biggest problem facing US NWP that needs to be solved? What are the common themes that we’ve heard regarding US NWP?
- What is EPIC and why is it needed to advance US NWP?

Session Three Reflection Question:

- Which business model best fits your vision for EPIC? How can EPIC work within the current infrastructure to advance U.S. NWP?

<sup>15</sup> An analysis of 215 total Tweets.



# The EPIC Community Workshop Report

Session Four Reflection Question:

- What are other emerging technologies should EPIC consider to develop a world leading global community earth system model?

Session Six Reflection Question:

- What recommendation is most important to the implementation strategy of EPIC?

Session Seven:

- After 2.5 days at the workshop, what is your vision for EPIC for year 1 and year 5?

## Appendix Six: EPIC Community Workshop Feedback Form

**Image Six:** EPIC Community Workshop Feedback Form



# The EPIC Community Workshop Report

## Appendix Seven: In-Person Attendees

<b>Last name:</b>	<b>First name:</b>	<b>Organization/Affiliation:</b>
Alejo	Pablo	Accenture
Alexander	Charles	NOAA
Anderson	Whit	NOAA
Auligné	Tom	UCAR
Baldwin	Michael	Purdue University
Beck	Jeff	NOAA NOS
Bendale	Rajiv	SAIC
Benjamin	Stan	NOAA ESRL
Blau	Bianca	NOAA AGO
Brogan	Kate	NOAA
Brown	John	NOAA ESRL
Burger	Eugene	NOAA PMEL
Burke	Patrick	NOAA WPC
Bush	Anthony	Raytheon
Carley	Jacob	NOAA NWS
Carlis	DaNa	NOAA OAR
Carpenter	Ilene	Cray
Carr	Fred	University of Oklahoma
Carson	Laurie	UCAR
Cash	Benjamin	George Mason University
Chu	Philip	NOAA GLERL
Clark	Adam	NOAA OAR
Clark	Elizabeth	NOAA
Colle	Brian	Stony Brook University
Compo	Gilbert	University of Colorado, Boulder
Cooley	Kevin	NOAA NWS
Cossuth	Josh	U.S. Navy
Creager	Gerry	NOAA NSSL
Croll	Brittany	NOAA
Dalal	Manan	NOAA NESDIS



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Dale	Jordan	NOAA OAR
Deheza	Veva	NOAA
Dias	Juliana	NOAA ESRL
Dobbins	Brian	UCAR
Doll	Mike	AccuWeather
Doyle	James	U.S. Navy
Drobot	Sheldon	L3Harris Technologies
Eosco	Gina	NOAA OAR
Etherton	Brian	Maxar Technologies
Eubanks	Barbara	NOAA OAR
Farrar	Mike	U.S. Air Force
Firl	Grant	UCAR
Frost	Gregory	NOAA ESRL
Gagne	David	UCAR
Gallo	Kevin	NOAA NESDIS
Garrett	Kevin	NOAA NESDIS
Gehne	Maria	NOAA ESRL
Gerstman	Ari	UCAR
Gibbs	Philip	UCAR
Gilbert	Kathryn	NOAA NWS
Gopalakrishnan	Sundararaman	NOAA AOML
Govett	Mark	NOAA ESRL
Grell	Georg	NOAA ESRL
Gross	Brian	NOAA NWS
Hartman	Travis	Maxar Technologies
Heinselmann	Pamela	NOAA NSSL
Heinzeller	Dom	NOAA ESRL
Herdies	Dirceu	INPE: National Institute for Space Research
Holub	Kirk	NOAA ESRL
Hu	Ming	NOAA ESRL
Ide	Kayo	University of Maryland, College Park
Infanti	Johnna	NOAA OAR
Intrieri	Janet	NOAA ESRL



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Jacobs	Neil	NOAA
James	Sim	NOAA
Jankov	Isidora	NOAA ESRL
Jensen	Tara	UCAR
Jirak	Israel	NOAA
Johnson	Benjamin	UCAR
Jorissen	Kevin	Amazon Web Services
Jung	Youngsun	University of Oklahoma
Kain	Jack	NOAA
Kalina	Evan	NOAA CIRES
Ketefian	Gerard	NOAA CIRES
Khanbilvardi	Reza	The City College of New York
Kinter	Jim	George Mason University
Kleist	Daryl	NOAA NWS
Klemmer	Carissa	NOAA NWS
Koch	Dorothy	NOAA NWS
Kondragunta	Chandra	NOAA OAR
Kummerow	Christian	Colorado State University
Kuo	Ying-Hwa (Bill)	UCAR
Lapenta	Bill	NOAA OAR
Lett	Sheema	NOAA NWS
Levit	Jason	NOAA NWS
Leyva	Salim	NOAA NESDIS
Liang	Xin-Zhong	University of Maryland, College Park
Lindsey	Dan	NOAA NESDIS
Lovern	Marie	Accenture
Lumpkin	Rick	NOAA AOML
Madaus	Luke	Jupiter Intelligence
Mahoney	Bill	UCAR
Mahoney	Kelly	NOAA ESRL
Mahoney	Jennifer	NOAA ESRL
Manobianco	John	BASF
Marquis	Melinda	NOAA ESRL



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Mass	Cliff	University of Washington
McCarren	Dave	NOAA
McFarquhar	Greg	University of Oklahoma
McKenna	Brian	RPS Group
Mehra	Avichal	NOAA NWS
Merchant	Shakila	The City College of New York
Methot	Richard	NOAA Fisheries
Miller	Steven	Colorado State University
Miller	Shawn	Raytheon
Miralles-Wilhelm	Fernando	University of Maryland, College Park
Moore	Berrien	University of Oklahoma
Mozer	Kathryn	NOAA OAR
Nance	Louisa	UCAR
Neilley	Peter	IBM
Newman	Kathryn	UCAR
Parks	Derek	NOAA
Pasti	Carolyn	RedLine Performance Solutions
Perfater	Sarah	NOAA OAR
Petty	Missy	NOAA ESRL
Petty	Kevin	IBM
Pryor	William (Bill)	NOAA NWS
Putnam	Jacquelyn	NOAA OMAO
Rajan	Bhavani	NOAA NWS
Rakesh	Bhavana	NOAA NWS
Ramamurthy	Mohan	UCAR
Romine	Glen	UCAR
Rosencrans	Matthew	NOAA NWS
Rosenlof	Karen	NOAA
Sakaeda	Naoko	University of Oklahoma
Saylor	Rick	NOAA
Schlatter	Paul	NOAA
Schneider	Tim	UCAR
Schneider	Russell	NOAA NWS



# The EPIC Community Workshop Report

Schwartz	Craig	UCAR
Seroka	Greg	NOAA NOS
Settelmaier	Jack	NOAA NWS
Sheffield	Amanda	NOAA
Shontz	Kathryn	NOAA NESDIS
Sienkiewicz	Joseph	NOAA NWS
Skupniewicz	Chuck	U.S. Navy
Stajner	Ivanka	NOAA NWS
Staudt	Amanda	National Academy of Sciences
Stewart	Jebb	NOAA
Stritzel	Will	University of Colorado, Boulder
Strong	Bonny	NOAA ESRL
Sun	Shan	NOAA ESRL
Tallapragada	Vijay	NOAA NWS
Taylor	Matt	Raytheon
Tolman	Hendrik	NOAA NWS
Tremolet	Yannick	UCAR
Tucker	Sara	Ball Corporation
Vertenstein	Mariana	UCAR
Vincent	Mark	NOAA OAR
Warner	John	USGS
Weatherhead	Elizabeth	Jupiter Intelligence
Weygandt	Steve	NOAA ESRL
Whitaker	Jeffrey	NOAA ESRL
Wiedinmyer	Christine	University of Colorado, Boulder
Wolff	Jamie	UCAR
Woodward	Kathryn	Accenture
Wright	Jeff	UCAR
Xue	Yan	NOAA NWS
Yang	Fanglin	NOAA NWS
Yoe	Jim	NOAA NESDIS
Zinn	Sonny	Earth Resources Technology, Inc.
Zupanski	Dusanka	Spire, Inc.



# The EPIC Community Workshop Report

## Appendix Eight: Online Attendees

Last name:	First name:	Organization/Affiliation:
Adimi	Farida	NOAA
Anderson	Whit	NOAA
Auligné	Tom	NOAA JCSDA
Aviles	John	IBM
Bao	Jian-Wen	NOAA
Baringer	Molly	NOAA
Barker	Dale	UK Met Office
Beck	Jeff	NOAA
Belanger	James	IBM
Bell	Charles	NOAA
Biondolillo	Frank	Microsoft
Biswas	Mrinal	UCAR
Blaylock	Brian	University of Utah
Bliss	Kathryn	NOAA
Boyd	Kandis	NOAA OAR
Brammer	Alan	Colorado State University
Brooks	Maureen	University of Maryland
Brown	Bonnie	NOAA OAR
Brown	Timothy	Spire, Inc.
Buonanno	Chris	NOAA
Bush	Anthony	Raytheon
Chen	Shuyi	University of Washington
Cortinas	John	NOAA AOML
Dale	Robert	Ingham County Homeland Security & Emergency Management
Deheza	Veva	NOAA
Dobbs	Laura	Microsoft
Drobot	Sheldon	L3Harris Technologies
Dubots	Leah	NOAA OAR



# The EPIC Community Workshop Report

Etherton	Brian	Maxar Technologies
Flamig	Zac	Zorm
Fox	Andrew	UCAR
Gagne	David	UCAR
Gehne	Maria	NOAA
George	Andrew	NOAA
Hall	Edward	Centuria Corporation
Hardesty	Michael	University of Colorado, Boulder
Heinzeller	Dom	NOAA
Hosansky	David	UCAR
Howlett	Eoin	Applied Sciences, Inc.
Jacob	Robert	Argonne National Laboratory
Jensen	Tara	UCAR
Jones	Dave	StormCenter Communications
Jung	Youngsun	University of Oklahoma
Keith	Karen	NOAA
Kell	Dalton	RPS Group
Ketefian	Gerard	NOAA
Kiladis	George	NOAA
Knee	Kelly	RPS Group
Kumar	Krishna	NOAA
Kuo	Bill	UCAR
Lakhankar	Tarendra	The City College of New York
Lindsey	Dan	NOAA
Mahalik	Matthew	NOAA OAR
McKenna	Brian	RPS Group
Meyers	Mike	NOAA
Miller	Shawn	Raytheon
Navarra	Antonio	Euro-Mediterranean Center on Climate Change
Neale	Richard	UCAR
Nesbitt	Stephen	University of Illinois



# The EPIC Community Workshop Report

Nusbaumer	Jesse	UCAR
Olson	Michele	NOAA OAR
Otkin	Jason	University of Wisconsin - Madison
Pagowski	Mariusz	NOAA
Pierce	Brad	University of Wisconsin - Madison
Pirring	Andrew	Innovim
Powers	Dan	Co-Labs
Putman	William	NASA
Putterman	Joshua	Extreme Event Risk
Rajan	Bhavani	NOAA
Rayder	Scott	UCAR
Rosenlof	Karen	NOAA
Rostaminia	Mojgan	NOAA
Rothenberg	Daniel	ClimaCell
Santanello	Joseph	NASA
Scharfenberg	Kevin	NOAA
Schwarber	Adria	AIP: American Institute of Physics
Sienkiewicz	Joe	NOAA
Slivinski	Laura	NOAA
Stegemiller	Victor	NOAA
Stein	Ariel	NOAA
Stewart	Jebb	NOAA
Subramanian	Aneesh	University of Colorado, Boulder
Summars	Emily	NOAA
Tallapragada	Vijay	NOAA
Thomas	Bruce	Midland Radio Corporation
Tulich	Stefan	NOAA
Valentine	Katie	NOAA
Wang	Xuguang	University of Oklahoma
Wanser	Kelly	SilverLining
Weiss	Michael	NOAA

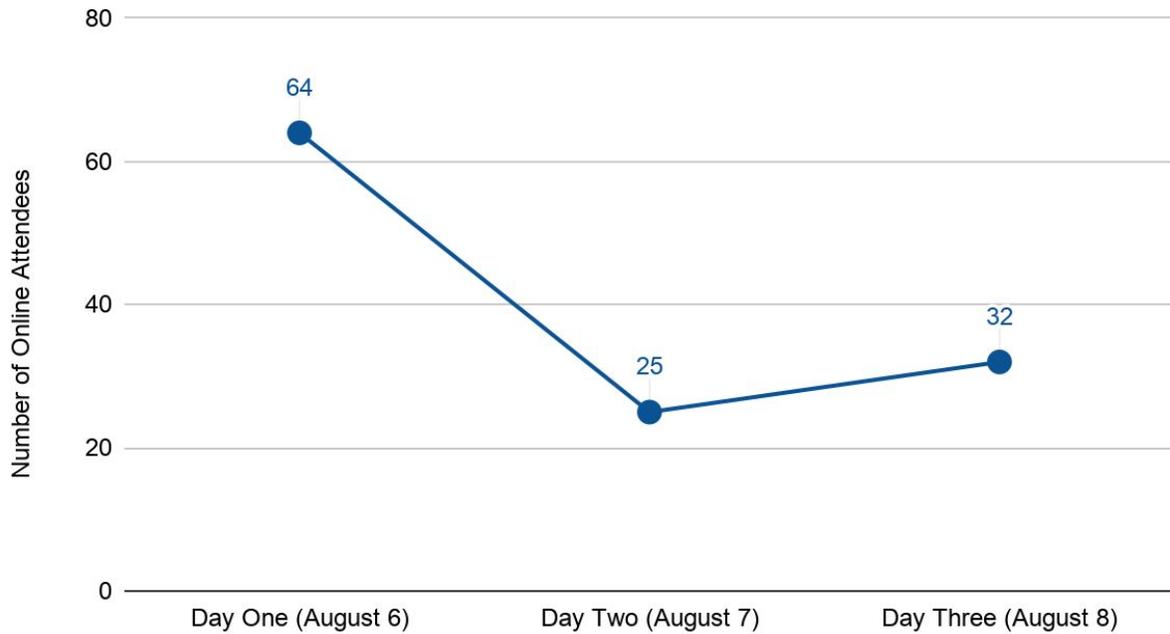


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Wells	Sawyer	University of Washington
Wilkinson	Ayesha	NOAA OAR
Wong	May	UCAR
Yu	Wei	NOAA
Yuan	May	University of Texas, Dallas
Yussouf	Nusrat	NOAA
Zarzycki	Colin	Pennsylvania State University
Zhang	Xin	UCAR
Zhuang	Jiawei	Harvard University

## Appendix Nine: Daily Breakdown of GoToWebinar Statistics

### Online Attendance



**Figure Two: Daily Online Attendance**



# The EPIC Community Workshop Report

## Appendix Ten: Total Attendance by Sector

Total Attendance by Sector

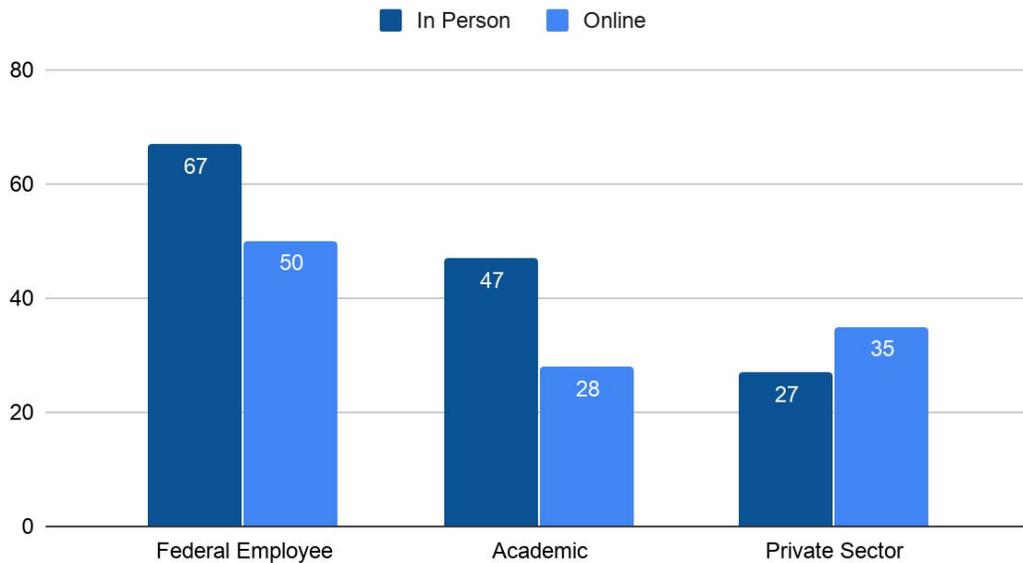


Figure Three: Total Attendance by Sector

## Appendix Eleven: List of Acronyms

AI	Artificial Intelligence
AWS	Amazon Web Services
CESM	Community Earth System Model
CFSv2	Coupled Forecast System Model Version Two
CI	Cooperative Institute
CIRES	Cooperative Institute for Research in Environmental Sciences
CPO	Climate Program Office
CR	Continuing Resolution
DA	Data Assimilation
DTC	Developmental Testbed Center
ECMWF/EC	European Centre for Medium-range Weather Forecasting
EMC	Environmental Modeling Center
EPIC	Earth Prediction Innovation Center
ESPC	Earth System Prediction Capability
ESRL	Earth Systems Research Laboratory



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FSU	Florida State University
FV3	Finite-volume on a cubed sphere
GFS	Global Forecast System
GFDL	Geophysical Fluid Dynamics Laboratory
GMAO	Global Modeling and Assimilation Office
GMD	Global Monitoring Division
GMU	George Mason University
GSD	Global Systems Division
GST	Graduate Student Test
HPC	High Performance Computing
HPCC	High Performance Computing and Communications
HYCOM	Hybrid Coordinate Ocean Model
IBM	International Business Machines
JEDI	Joint Effort for Data Assimilation Integration
JCSDA	Joint Center for Satellite Data Assimilation/"Joint Center"
JTTI	Joint Technology Transfer Initiative
MDL	Meteorological Development Laboratory
MOM6	Modular Ocean Model Version Six
MOM4	Modular Ocean Model Version Four
MPAS	Model for Prediction Across Scales
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NDA	Non-Disclosure Agreement
NESDIS	National Environmental Satellite, Data, and Information Service
NIDIS	National Integrated Drought Information System
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NSF	National Science Foundation
NSSL	National Severe Storms Laboratory
NWP	Numerical Weather Prediction
NWS	National Weather Service
OAR	Oceanic and Atmospheric Research/"NOAA Research"
OCIO	Office of the Chief Information Officer
OSTI	Office of Scientific and Technical Information
OU	University of Oklahoma
OWAQ	Office of Weather and Air Quality
OWP	Office of Water Prediction
PPE	Policy and Program Evaluation



# The EPIC Community Workshop Report

QR	Quick-Response
R&D	Research and Development
R2O	Research to Operations
R2O2R	Research to Operations to Research
RFI	Request for Information
RFP	Request for Proposal
S2S	Subseasonal to seasonal
SAB	Science Advisory Board
STAR	Center for Satellite Applications and Research
UCAR	University Corporation for Atmospheric Research
UFS	Unified Forecast System
UFS-SIP	Unified Forecast System Strategic Implementation Plan
UMAC	UCAR Community Advisory Committee for NCEP(UCACN)/ Model Advisory Committee
UPP	Unified Post Processing
USAF	United States Air Force
USGS	United States Geological Survey
UW	University of Washington
WRF	Weather Research and Forecasting Model
WRFIA	Weather Research and Forecasting Innovation Act

## Appendix Twelve: List of Images

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