DRAFT

Unified Forecast System Organization and Governance

The Unified Forecast System mission is to create more accurate National Weather Service forecasts by harnessing the diverse and substantial expertise of governmental, academic, and private enterprise partners.

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1 Introduction

This document describes the governance bodies and processes of the Unified Forecast System (UFS). UFS is a community-based, coupled, comprehensive numerical Earth modeling system. UFS applications span local to global domains and predictive time scales from sub-hourly analyses to seasonal predictions. UFS is designed to support the Weather Enterprise[1] and to be the source system for NOAA's operational numerical weather prediction applications.

This document updates and replaces the September 2017 Governance Document. The document combines and replaces all original charters into a single document. The updates of the governance to meet the evolving needs of the UFS was anticipated in the original charters. This document describes current practice and is pending formal approval by the community-based oversight board envisioned for the UFS (see section 4).

UFS represents a fundamental change in the way that the forecast systems used in NOAA operations - collectively called the NOAA Production Suite - are developed. The change is motivated by the desire to rapidly increase predictive skill so that forecasts can be made that save lives and property. In order to accomplish this, resources are being focused on fewer components that are shared by multiple forecast applications. The many different forecast systems that were historically run in operations, which use different infrastructures and scientific components, are being simplified and unified, so that they share a common software architecture and a set of agreed-upon components such as a common atmospheric model. In this unified approach, improvements and updates need to be made in fewer places. Paired with this strategy is a move toward more open, community-based modeling that makes it easier for members of the research community to run, experiment with, and test advances in codes being run in operations. Software design, management and distribution strategies ensure that promising innovations can transition readily to operations. The UFS aims to improve operational modeling by developing the UFS into a world-class research tool.

The UFS organization and governance are aligned with these goals and strategies. They have been exercised and refined over the past three years. While they continue to evolve, the elements of a lasting, effective organizational transformation are becoming increasingly evident.

More information about UFS is available at: http://ufscommunity.org

[1] See: https://www.weather.gov/about/weather-enterprise

2 UFS Applications and Components

2.1 Applications

UFS configurations that support specific predictive targets (e.g. Medium-Range Weather, Subseasonal-to-Seasonal, Space Weather) are called applications. Each application combines a numerical model,[2] data assimilation, post-processing, workflow, and other elements. Application outputs are fields of model parameters with a given spatial and temporal resolution, cadence (how often the model is run), and accuracy. UFS applications assure a focus to research *and* operational outcomes, not just on creating models and software.

The list of applications is expected to change as the UFS advances toward greater unification and new and broader applications. Some applications may be retired as the UFS evolves, and others may be added. The current listing is as follows.

UFS Applications[3]

- Medium-Range Weather (MRW): Atmospheric behavior out to about two weeks
- Subseasonal-to-Seasonal (S2S): Atmospheric and ocean behavior from about two weeks to one year
- Hurricane: Hurricane track, intensity, and related effects out to about one week
- Short-Range Weather/Convection Allowing (SRW): Atmospheric behavior from less than an hour to several days
- Space Weather: Upper atmosphere and ionospheric behavior due to solar and geomagnetic activity and forcing from the lower atmosphere from real-time to about ten days
- Coastal: Storm surge and other coastal phenomena out to about one week
- Air Quality: Atmospheric aerosol and chemical atmospheric composition out to several days

Applications must go through an extensive transition to operations (T2O) process in order to become part of an operational *implementation*. The T2O process ensures that an operational upgrade represents an improvement in improvements in the numerical guidance used for forecasts. Once an application is implemented in operations, it is generally referred to as a forecast system (e.g. Global Forecast System, Rapid Refresh Forecast System, Seasonal Forecast System). Figure 1 shows UFS applications and the associated forecast systems. For example, the Medium-Range Weather Application shares a code base with the operational Global Forecast System (GFS).

The output fields of forecast systems constitute *guidance* that is used by forecasters to produce official *forecasts* and provide Impact-based Decision Support Services (IDSS).[4]

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[2] The numerical model usually consists of multiple coupled components, such as atmosphere, land, wave, etc.
[3] Also listed at: https://ufscommunity.org/science/aboutapps/
[4] More about IDSS: https://www.weather.gov/about/idss

The outputs of forecast systems are generally ensemble-based and post-processed. An example of post-processing is the correction of known biases.

In research and development, UFS applications are used to test hypotheses and increase scientific understanding. Applications released to the community are usually simplified relative to the forecast system in operations. This is done in order to increase usability and reduce the computational resources required. For example, a community release may not include a data assimilation system, all aspects of post-processing, or an ensemble configuration.

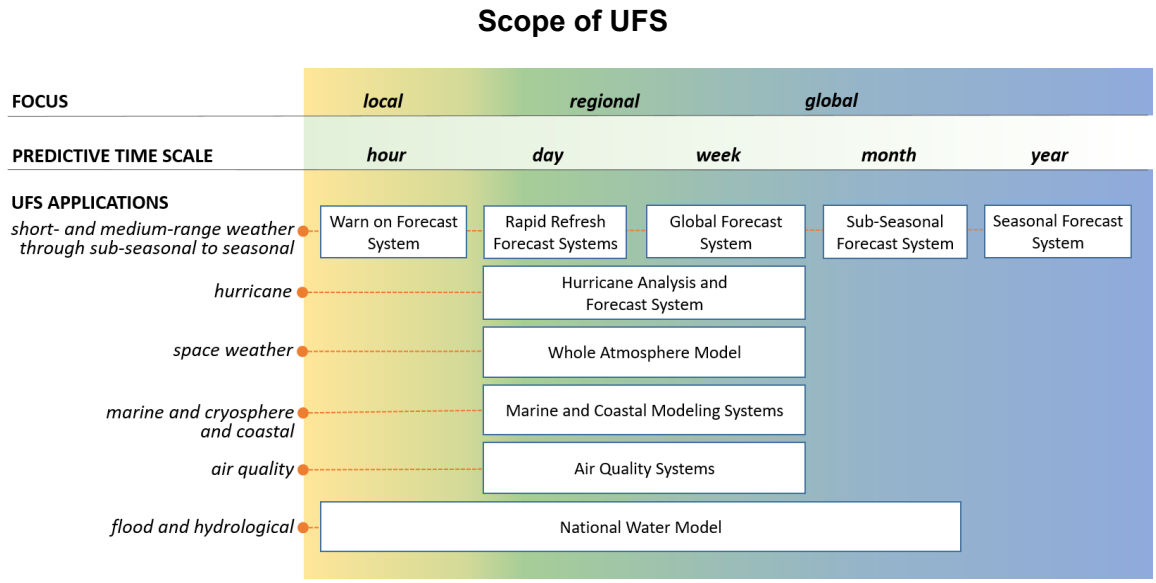

Figure 1. UFS applications span predictive timescales (less than an hour to more than a year) and focus on multiple spatial scales (local to global).

2.2 Components

Each distinct software element of an application is called a component.

Most of the numerical geophysical models in UFS consist of multiple, coupled model components. UFS model components include representations of the atmosphere, ocean, land, sea ice, wave, aerosol, and ionosphere. A modular design also treats separate parts of a workflow as components, e.g., data assimilation, ensemble forecasts, and product generation. An application may support multiple configurations of components as it evolves or is tested, and it may be justified as a distinct application if it uses significantly different versions of the same component(s) or a different workflow.

The UFS is a *unified* system because its applications share a set of agreed-upon scientific components (for example, a UFS atmosphere model based on the FV3 dynamical core) and a set of agreed-upon infrastructure components.[5] The scientific components and infrastructures are integrated into a consistent system architecture.

[5] See for example: https://ufscommunity.org/science/aboutinfra/

2.3 Open Source, Distributed Development

Each UFS *application* is being released to the community via an authoritative repository located in the ufs-community GitHub organization.[6]. The repository for each application does not contain all the source code of its constituent components; it is an "umbrella" that contains one or more configuration files that define a code base through externals (URLs) that link to the application's constituent components. The constituent components and infrastructure elements each maintain their own authoritative (GitHub) repository **(**see Section 5.5 for code management principles of the UFS.)

3 Key Documents and Events

There are key processes, events, and documents that define the UFS and forge connections across the UFS community. Although most of the documents and events described here relate to annual and longer planning time scales, they build on and inform daily and weekly communications and decisions.

3.1 Documents

A foundational set of documents define an organization and reflect its level of coordination and effectiveness. The key documents for UFS include this organization and governance document, legislation, planning, and strategic documents, advisory reports, and policies. These are briefly described in the sections that follow, and links to previous versions of the documents are in Appendix A.

3.1.1 UFS Organization and Governance (this document)

One of the most significant challenges of UFS is its potential for organizational complexity. Detailed plans and procedures are needed at the transactional level, so that participants understand how to fulfill roles and operate teams. At the same time, there needs to be a clear articulation of the overall organization and a system-wide approach to decisions and policies to ensure that the broadest and most ambitious UFS goals, including simplification of the code base of the NCEP Production Suite, community engagement, and significant improvements to forecast skill, are met. The UFS Organization and Governance document serves this purpose.

The UFS Steering Committee is responsible for developing this UFS Organization and Governance document. As the UFS and its full governance is still being established, this document may need to be updated as often as every 1-2 years. Once the UFS and its governance are mature, the target of updating this document is every 3-5 years.

[6] A GitHub "organization" is a collection of repositories that are grouped together. The ufs-community organization contains repositories for each of the UFS applications, the UFS Weather Model, which is used by several applications, and software for building library dependencies. See: https://github.com/ufs-community/ufs/wiki

3.1.2 UFS Conception

Early calls for a streamlined, community-friendly modeling system to serve as the basis for the NCEP Production Suite came from the UMAC (UCAR Community Advisory Committee for National Centers for Environmental Prediction (UCACN) Modeling Advisory Committee). UMAC was formed at the request of the Director of NCEP "to provide a comprehensive, technical review of the NCEP Prediction Suite (NPS) strategy for development." Starting in 2015 and continuing annually through 2017, UMAC meeting reports have called for "a unified, collaborative strategy for model development" and a need to "better leverage the capabilities of the external community" as the two lynchpins of such a strategy.

In May 2016, the NOAA Research Council addressed the concept of Unified Modeling by standing up a Unified Modeling Task Force (UMTF). The UMTF developed a technical report on Unified Modeling at NOAA,[7] and provided a brief description of the report in Nature.[8,9] NOAA demonstrated its commitment to Unified Modeling by transitioning the UMTF into a permanent standing committee (Unified Modeling Committee, UMC) under the NOAA Research Council in June 2017.

Also during the period 2016-2018, NWS and NOAA Oceanic and Atmospheric Research (OAR) leads initiated development of Vision and Roadmap documents for a unified modeling system extending out 5-10 years. These documents were finalized and signed by senior NOAA leadership in 2020 and are described in section 3.1.4.2.

3.1.3 Legislative Basis and Drivers

Several pieces of legislation inform the organization and objectives of UFS. The first of these is the *Weather Research and Forecasting Innovation Act of 2017* (Public Law 115-25, sometimes referred to as the "Weather Act" or WRFIA). The Weather Act was signed into law in April 2017, with goals to improve NOAA's weather research through investments in observational, computing, and modeling capabilities, to support improvement in weather forecasting and prediction of high impact weather events, and expand commercial opportunities for the provision of weather data. The structure and activities of the UFS are aligned with the Weather Act.

In January 2019, NOAA's National Integrated Drought Information System (NIDIS) program (Public Law 109-430) included reauthorization of the Weather Act, as well as amended language to the 2017 law. This amended language requires the creation of an Earth Prediction Innovation Center (EPIC) for "advancing weather modeling skill", "leveraging the weather enterprise to provide expertise on … improving numerical weather prediction", "enabling scientists and engineers to effectively collaborate in …

[7] Link et al. 2017, https://repository.library.noaa.gov/view/noaa/14156
[8] Link, J., Tolman, H. & Robinson, K. NOAA's strategy for unified modelling. Nature 549, 458 (2017). https://doi.org/10.1038/549458b
[9] Arguably, this manuscript represents the first systematic assessment of Unified Modeling in the United States.

model development, data assimilation techniques, systems architecture integration, and computational efficiencies", and "creating a community global weather research modeling system that is accessible to the public, meets basic end-user requirements for running on public computers and networks outside NOAA", and utilizes … innovative strategies and methods for hosting and management of part or all of the system".

NOAA has formal responsibilities for providing forecasts for all of its constituent components, as is described in Appendix A of the "2017-2018 Roadmap for the Production Suite at NCEP" document described in section 3.1.4.2.

3.1.4 Planning Documents

Documents targeting multiple planning periods are needed to organize UFS activities and teams. The nature and selection of these documents continues to evolve as the UFS project matures.

Strategic planning documents are especially critical to the "research to operations" (R2O) and "operations to research" (O2R) processes, since they outline areas in which the research community has the opportunity to make contributions to future operational implementations. The 2017 UMAC report offers some guidelines:

"The strategic plan needs to identify high-level, quantifiable 5- and 10-year goals. Two-year and three-year activities need to be aligned with these longer-term plans. The culture of short-term urgency undermining strategic, organizational goals must be changed. The strategic plan should emphasize evidence-based decision-making that balances scientific excellence, cost, and end user requirements. Strategic plans for forecast systems need to be aligned with high-performance computing. Strategic goals need to be announced publicly, creating a positive and visionary image, and citing the benefits for society."

3.1.4.1 UFS and NWS Strategic Plans (up to 5 year planning)

The UFS Strategic Plan (for 2021-2025) is a core document that outlines the direction of the UFS project over the next five years. It includes a set of forecast skill priorities for each of the UFS applications, along with other types of priorities (e.g. simplification of the production suite). To address these priorities, the Strategic Plan presents a set of integrated science goals. The planned activities of each of the UFS teams[10] are described in the context of these priorities and goals. In this sense, the Strategic Plan plays an important role in defining the balance between meeting near-term objectives and ensuring that the UFS remains unified.

The UFS Steering Committee is responsible for developing the UFS Strategic Plan, with oversight as outlined in Section 4. . Review and update cadences are defined in the UFS Strategic Plan.

[10] Application Teams, Cross-Cutting Teams, and component Working Groups.

An additional document that informs the near term goals of the UFS is the NWS Strategic Plan (latest version 2019-2022).[11]

3.1.4.2 Roadmaps (5-10 year and longer planning)

A project with the complexity, size, and national importance of UFS necessarily has longer term goals and initiatives. New scientific or technical strategies typically require years of planning and investment to traverse readiness levels. Achieving excellence in forecasts can mean ensuring that such strategies are appropriately balanced with the constant demand for maintenance and incremental improvements.

A pair of documents outlines a 5-10 year vision and a roadmap for UFS. The first of these, entitled "A Strategic Vision for the NOAA's Physical Environmental Modeling Enterprise"[12] has as its main goal "to provide a vision to streamline and unify the Physical Environmental Modeling Enterprise so that available resources can be focused on becoming the best Physical Environmental Modeling Enterprise in the world within 10 years." The second, the "2017-2018 Roadmap for the Production Suite at NCEP"[13] describes the basic concepts associated with a unified modeling system, examines the nature of the required design and architecture, and frames desired outcomes. Both documents were approved and signed by the Assistant Administrators for the NWS, OAR, Ocean Services and Coastal Zone Management, and Satellite and Information Services in 2020.

Other documents that inform longer term UFS development include NOAA's Next Generation Strategic Plan[14] and the Oceanic and Atmospheric Research Strategy for 2020-2026.[15]

Preparation of such documents are not currently on a set timeline, but updates could be expected at roughly 5 year intervals.

3.1.5 Annual Report

The UFS Annual Report is an overview of project accomplishments. It is designed to be a document for a general audience that highlights the successes of UFS.

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[11] See: https://www.weather.gov/media/wrn/NWS_Weather-Ready-Nation_Strategic_Plan_2019-2022.pdf
[12] See: https://drive.google.com/file/d/1d0wYa2S4gcYjuYbzvRlNtHBJaOwb4J11/view?usp=sharing
[13] See: https://drive.google.com/file/d/1sb6ZjGNmj4YuOvTHIEEt8JDXfd8yD_Ze/view?usp=sharing
[14] See: https://www.performance.noaa.gov/wp-content/uploads/NOAA_NGSP.pdf
[15] See: https://research.noaa.gov/Portals/0/Files/OAR%20Strategy%202020-2026.pdf

3.1.6 Advisory Reports

The Community Modeling review Committee (CMrC) issues periodic reports with their assessment of aspects of NOAA modeling ranging from overarching strategies to specific deficiencies in skill. This group is a successor to the UCAR Community Advisory Committee for National Centers for Environmental Prediction (UCACN) Modeling Advisory Committee (UMAC), which issued previous reports.

The CMrC and its previous incarnations have issued reports on a roughly annual cycle, or as requested by NOAA leadership. Its role is important for providing an external community perspective on UFS and NOAA modeling.

3.1.7 MOAs

An essential foundational part of the UFS is buy-in from the community outside of NOAA. A landmark event in this context is the development of an Memorandum of Agreement (MoA) on developing coupled modeling infrastructure between UCAR, NCAR, NWS and OAR.[16] This MoA identifies seven infrastructure elements to be developed jointly, including the identification of specifically targeted software packages and approaches, and was signed at the AA and Director level of the four organizations involved.

3.1.8 Policies

The UFS generates policy documents, especially policies related to definitions, code management, and code sharing. The UFS-SC leads development of these policies, which are approved by the TOB. The following policies have been published:

- Organizing Research to Operations Transition
- System Architecture for Operational Needs and Research Collaborations
- UFS Infrastructure: Code Repositories Policy
- Regression Test Policy for UFS Platforms and Compilers
- Code management policies are addressed here in Section 5.5

As the UFS is targeting improving operational forecasting, the UFS policies need to be cognisant of and consistent with NOAA policies. Theses policies include:

- The use of GitHub by the federal government has recently been FedRamp authorized. Details can be found, and questions can be asked here.
- NOAA Administrative Orders NAO 216-105B ("*Policy on Research and Development Transitions*") and NAO 216-115A ("*Research and Development in NOAA*") address research, development and transitions in NOAA. They define

[16] See https://www.weather.gov/media/sti/nggps/18-064553_SignedMOU.pdf

Readiness Levels (RLs) for use by NOAA, and they define transition plan requirements within NOAA, and for NOAA-funded projects.
- NOAA Administrative Orders NAO 201-103 ("*Cooperative Research and Development and Invention Licensing Agreements Under the Federal Technology Transfer Act of 1986 (Public Law 99-502)*", currently being rewritten) and a new NAO under development NAO 201-118 "*Software Governance and Public Release Policy*".

3.1.9 Glossary

The UFS encompasses a diversity of communities, each with their own understanding of terms. The UFS Glossary is a reference that encourages a common vocabulary and effective communication.

3.2 Events

UFS has two main meeting weeks: one a summer meeting week at the end of July/beginning of August and the other a winter meeting week at the end of February/beginning of March. The UFS Annual Users' Workshop is scheduled during the summer meeting week. Meetings of other bodies, such as CMrC, are typically scheduled during these weeks.

Below is an example of a summer meeting week schedule:

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
UFS Users' Workshop	UFS Users' Workshop	UFS Users' Workshop	Program Review	Oversight and UFS-SC Meeting

An example of a possible winter meeting week schedule:

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
Program Review	Program Review	Program Review	CMrC Meeting	Oversight and UFS-SC Meeting

3.2.1 UFS Annual Users' Workshop

The UFS Annual Users' Workshop is a science-focused meeting that encourages an exchange of ideas among new and existing scientists working with the UFS. The workshop is expected to improve communications, transparency, and mutual trust between operational centers and the broader community.

The first annual UFS Users' Workshop will be held at the end of July 2020 (virtually). It is being organized by the Developmental Tested Center, and is modeled on the annual

Weather Research and Forecast (WRF) and Community Earth System Model (CESM) community workshops.

3.2.2 Summer Training Institute

A summer training program is being established that will engage students and others interested in learning about UFS. The expectation is that it will be held outside of the summer and winter meeting weeks.

3.2.2 AMS Annual Meeting and Other Professional Meetings

The AMS annual meeting is the national meeting that is most directly relevant to UFS. In 2020, there were more than 50 presentations and events associated with UFS, in a meeting of about 5000 attendees. It is an opportunity to promote UFS and engage with activities that may benefit it.

There are many other professional meetings that are important to the UFS community, including the AGU Fall Meeting, the AGU Ocean Sciences Meeting, and the European Geophysical Union General Assembly.

4 Organizational Structure

4.1 Background

During 2016-2017 Strategic Implementation Plan (SIP) coordination activities, a Governance Working Group was established and was charged with making recommendations on the functions, roles, and responsibilities for governance of the community-based Unified Forecast System (UFS). The Governance Working Group recommended a UFS governance system that resulted in chartering a UFS Steering Committee (UFS-SC), a Technical Oversight Board (now named the Community Modeling Board) that receives reports from the UFS-SC, and a set of Working Groups.

During 2019, a governance strategy was proposed that recognized UFS applications as the main products of UFS, and a set of Application Teams were introduced. The matrix view of UFS governance shown in Figure 2 reflects that realignment.

4.2 Overview

The UFS organization is intended to include a **Community Modeling Board (CMB)** that will be organized with support of NOAA EPIC following contract award. The CMB is intended to provide guidance of oversight to a **UFS Steering Committee (UFS-SC)** that is governing day-to-day operations of the UFS.

Each application is a distinct UFS product associated with a forecast target.[17] **Application Teams** support defining, developing, and delivering releases of their product 1) to the transition to operations process and 2) to the research community.

Cross-Cutting Teams (CCTs) and component **Working Groups (WGs)** provide services and software components to application teams.

- Cross-Cutting Teams perform critical functions related to overall system design and integration, communication, verification and validation, and preparation of releases.
- Component Working Groups are focused on specific elements of UFS that typically span multiple applications. Their two main functions are component development and community engagement.

There is no dedicated funding associated with the ATs, WGs, CCTs, UFS-SC or Technical Oversight Board for federal employees. Compensation for other participants is considered on a case-by-case basis and provided, as applicable, in accordance with relevant contracts.

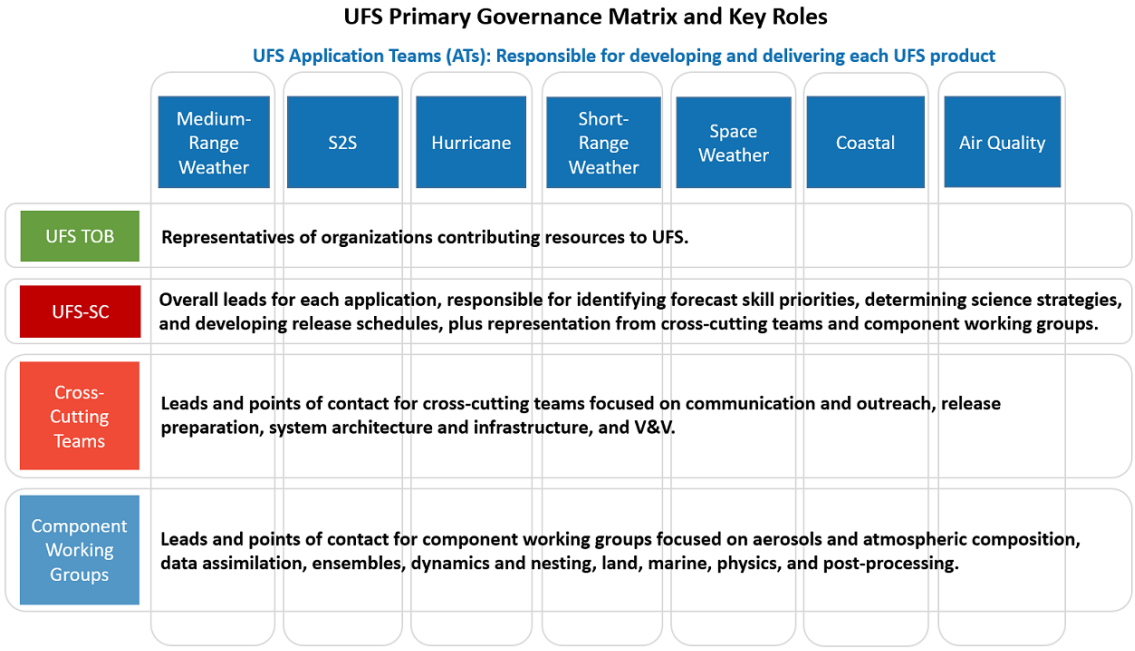

Figure 2. The primary governance matrix for the UFS includes a Technical Oversight Board (TOB), UFS Steering Committee (UFS-SC), a set of Cross-Cutting Teams, and a set of Component Working Groups that extend across a set of UFS Applications that each focus on a different type of forecast guidance.

[17] See https://ufscommunity.org/science/aboutapps/

4.3 Terms of Reference

The terms of reference that follow serve as the charters for UFS bodies and teams. They are in effect from the date of approval by the Technical Oversight Board co-chairs until terminated by the same. The terms of reference replace previous team charters.

Reviews of these terms of reference may be conducted as deemed necessary by the UFS-SC Co-Chairs or the Technical Oversight Board at any time. The latest date of amendment constitutes the new effective date unless some later date is specified.

4.3.1 Community Modeling Board

The Community Modeling Board (CMB) is intended to represent the UFS community in a broad and inclusive way. The CMB is intended to be self-organized, with executive support from NOAA. The development of the CMB is intended to start after the NOAA EPIC contract has been awarded. Once the CMB has been stood up, the present document will be adjusted accordingly.

Note that NOAA is presently exploring the possibility of standing up a **NOAA Modeling Board (NMB)** to coordinate all modeling efforts within NOAA, including those NOAA activities that use the UFS. It is expected that a NMB would work closely with the CMB.

Presently, informal oversight of the UFS-SC is provided by the UFS-SC executive committee (see below), as well as by the group that is developing the potential NMB.

4.3.2 UFS Steering Committee

The UFS Steering Committee (UFS-SC) is the primary coordination, review, and decision making body of UFS. It develops the UFS Strategic Plan and other defining documents. Once the CMB has been stood up, it is expected that the CMB will have oversight authority over the UFS-SC.

4.3.2.1 Charge

The UFS-SC focusses on community-based development of the UFS applications, identifying the maturity of application innovations, and prioritizing/optimizing the timing of their public release. The focus on applications assures operational and research outcomes, rather than on more fundamental code development only.

The UFS-SC shall:

- Represent the UFS to the broader community at the scientist and operator level, and work with the CMB for higher-level outreach and coordination. This is done in close collaboration with the Communications and Outreach WG.
- Engage the spectrum of UFS-related programs, projects, and groups in order to promote a unified view of the UFS with a proper balance

between unification (focus of resources) and diversity (providing a vibrant scientific environment).
- Monitor, update, and codify the organizational structure of the community governance of the UFS (with oversight and approval by the CMB). This includes:
    - Develop and vet UFS-wide policies, and maintain the UFS Organization and Governance document.
    - Monitor Application Teams, Cross Cutting Teams, and Working Groups to ensure that they are functioning, effective and needed as part of an integrated UFS.
- Develop strategic direction for UFS, and lead annual review and revision, if necessary, of the UFS Strategic Plan, coordinating with the CMB and ensuring consistency with NOAA's and other relevant strategic planning activities.
- Provide oversight on the development of proposed validation gates and metrics for the components, infrastructure and applications, as developed by the Working Groups, Application Teams and Cross-Cutting Teams.
- Ensure that forecast skill priorities, science goals, and delivery schedules (e.g., Application releases and operational implementations) are publicly available for all UFS applications.
- Solicit presentations, plans and reports from UFS-SC members and UFS teams and provide a forum to discuss questions and conflicts, in particular for integrative aspects such as the development of communication plans, test plans, and plans to evolve the overall system architecture.
- "As part of the regular reporting cycles of the UFS, provide recommendations to NOAA development organizations on how the UFS can be used to simplify and support the NCEP Production Suite."

The UFS-SC makes decisions by consensus. In the event that consensus is not met, a decision may be made by the co-chairs, or, for significant conflicts, may be referred to the CMB.

4.3.2.2 Composition and Leadership

The UFS-SC is led by three co-chairs

1. A community co-chair. This will become UFS Chief Scientist recruited from the community.
2. A federal (NOAA) co-chair. This is presently the NWS/Office of Science and Technology Integration (OSTI) Senior Advisor for Advanced Modeling Systems.
3. Once the NOAA EPIC Contract has been finalized, it is expected that EPIC will provide a third co-chair.

When organizations other than NOAA provide major resources to the UFS, additional co-chairs may be assigned. The UFS-SC co-chairs shall:

- Direct and schedule UFS-SC activities.

- Present UFS-SC recommendations and decisions to those who provide oversight to the UFS-SC. Presently this is an informal group mostly within NOAA. The oversight role will be taken up by the CMB.
- Lead selection of leadership of the WGs, ATs, and CCTs.
- Lead development of plans and deliverables of the UFS.

UFS-SC executive team consists of the UFS-SC co-chairs, and a representative of each of the contributing program offices and of the organizations responsible for operational implementation. Presently, the latter are a representative of the STI program office, the WPO program office and the EMC Director. The executive team assists the co-chairs in the above outlined responsibilities, particularly with respect to addressing leadership issues and identifying urgent topics for UFS-SC attention.

The full UFS-SC consists of the UFS-SC executive team and a representative each WG, AT and CCT. The latter members of the USF-SC are self-selected by the respective teams and approved by the executive team. In this process, the executive team will seek to retain a balance between federal and non-federal members.

4.3.2.3 Cadence

The UFS Steering Committee meets at least monthly. In practice, meetings have been weekly. The UFS-SC will hold a monthly open session for broader communication to the UFS community. The UFS-SC executive team will meet weekly.

4.3.3 Application Teams

Application teams ensure that the efforts of UFS-related projects and Component Working Groups are integrated and aligned with the most critical forecast priorities. Each application team is responsible for ensuring that their application is delivered to the transition to operation process, and is released to the community.

4.3.3.1 Charge

The Application Teams provide direction and coordinate across Component Working Groups for work needed to advance their respective UFS applications. The Application Team is the body which brings components together to address the requirements of a particular application. Application Teams report out to the UFS-SC at regular intervals as deemed necessary and requested by the UFS-SC.

The Application Teams shall:

- Establish forecast and operational performance priorities for the application
- Align scientific strategies and development to support the forecast and operational performance priorities
- Provide representation to the cross cutting teams to assure integration across the UFS system as a whole
- Support delivery of their application to the transition to operations process

- Provide representation on the Release Team for community code releases
- Contribute to intermediate milestones on the path to delivery to the transition to the operations process and to community releases
- Coordinate existing projects to enable integration of Working Groups and CCT activities to meet intermediate milestones.
- Participate in design and performance reviews.

4.3.3.2 Composition and Leadership

Members of the ATs possess expertise in their application area and ability to perform the tasks associated with the charge. In addition, ATs members should include people engaged with each of the CCTs who can serve as points of contact. The intent is to make sure that each AT has awareness of and input into UFS-wide plans for system architecture and infrastructure, testing, communication, and verification and validation. The ATs also include members of UFS WGs, depending on the application's specific needs.

Membership in the ATs, and to the extent that is feasible leadership of the ATs, should include representation from NOAA operational (NWS) and research (OAR) as well as from non-NOAA partners. Representatives from field offices should also be included as operational use of an application at the NWS implies providing Impact-based Decision Support Services (IDSS) by the NWS "field." Team leads approve new members. See the Selecting and Approving Team Leads for a description of these processes.

AT leads shall:

- Coordinate and communicate the efforts of the team and ensure its effective operation, including delivery of information, documents, and delivery and release milestones..
- Identify points of contact on the application team for CCTs and applicable WGs.
- Represent the team to the UFS-SC and other UFS teams.
- Review team membership, annually at a minimum, and make adjustments as needed.

4.3.3.3 Cadence

Application Teams meet as necessary. Larger teams are encouraged to have a regular meeting schedule.

4.3.4 Cross-Cutting Teams

Cross-Cutting Teams (CCTs) perform essential, integrative, and system-wide functions. They are listed below.

4.3.4.1 Cross-Cutting Teams

- System Architecture and Infrastructure
- Verification and Validation

- Communication and Outreach
- Release Preparation

More information about each of these teams is provided below.

System Architecture and Infrastructure CCT

System architecture has been defined as "the fundamental organization of a system, embodied in its components, their relationships to each other and the environment, and the principles that govern its design and evolution."[18] The UFS system architecture is essential to both the unification of UFS and the R2O2R process. It is essential to unification because a clear system architecture ensures that the UFS applications share common components and infrastructure, and that the applications are implemented as configurations of a common code base. The UFS system architecture is relevant to research community partners because using shared community infrastructure makes it easier and faster to move code from research to operations and operations to research. Using community infrastructure and components also promotes higher quality, portable, flexible, fully featured software. These qualities make it easier for UFS applications to pass "The Graduate Student Test."[19] Increased software ease of use and flexibility means that researchers can perform runs and experiments, and participate as full partners in model development. This team encompasses the UFS repository approach and the development and integration of software infrastructures that support workflows, interoperable model components and atmospheric physics, data assimilation, and pre- and post-processing.

Verification and Validation CCT

An evidence-based evaluation of all components of the UFS is needed to make effective decisions guiding the development of the UFS and to ensure that the new systems are better than those being replaced. The Verification and Validation Working Group is looking at ways to construct optimal verification methods and tools to evaluate the performance of the UFS at both global and meso scales and consider the spectrum of user needs including applications in aviation, severe storms, space weather, tropical cyclones, and precipitation forecasting. Ultimately, it is intended that this system will unify verification across the user community and create common metrics for multiple applications with the intent to provide consistent verification approaches.

Communication and Outreach CCT

The Communication and Outreach CCT Group aims to enable efficient and effective communications within the UFS project and to encourage communications between the UFS and the broader community. Implicit in this mission is the effort to grow and support the UFS community itself.

This team is responsible for establishing a UFS logo and visual identity, designing and maintaining the UFS Portal, and preparing newsletters and other communications. The

[18] See for example IEEE/ISO/IEC 42010-2011.
[19] See https://ufscommunity.org/science/gst/

Communication and Outreach team is also responsible for formulation and administration of Graduate Student Tests and for working closely with release teams on communications associated with releases. This team also organizes collaborative wiki spaces (e.g. GitHub, Confluence) and social media accounts in support of UFS communications.

Release CCT(s)

Release teams are assembled to prepare community releases of UFS applications. Though there may be overlap in personnel, each release team has elements specific to the application and may be largely constituted by personnel associated with the application.

Release teams are charged with developing plans for delivering releases, assembling sub-teams (focus teams), and executing those plans. Focus teams have included the following areas: code, workflow, build, data preprocessing, support, documentation, testing, and verification and validation. The focus teams are responsible for developing detailed plans, identifying and communicating gaps, and ensuring that the proposed release preparation work is successfully completed. The focus teams are not expected to undertake major development or redesign efforts, but to assess and execute the optimal strategies in the context of the four to eight months associated with the release preparation activity. It has proven useful for each focus team to have a point of contact that coordinates closely with the points of contact from other focus teams and with the release team leads. Since release involve many aspects of communication, the release team leads and focus teams work with the UFS Communication and Outreach Working Group to coordinate the communications and outreach associated with the release, including preparation of a release description, any press releases, development of GitHub wikis, schedule updates, presentation of the release on the UFS Portal, and Graduate Student Testing.

4.3.4.2 Charge

The CCTs shall:

- Provide the functions specific to the CCT that the ATs require for delivery to transition to operations and for community releases.
- Maintain planning and other documents as needed by ATs and requested by the UFS-SC (e.g. a test plan, system architecture overview, communication and outreach plan).
- Address the scientific and technical quality of the current implementation, identify causes of delays and difficulties, and recommend approaches to resolving difficulties and open questions. Recommendations may extend to the organizational relationship of key partner agencies and the broader community in supporting a unified modeling system, and the development of procedures and policies that may be needed to maintain and operate a community-based unified system.

- Follow an evidence-driven approach, and to that end organize planning exercises, performance tests, requirements collection, reports, case studies, etc. in which the methodology and results are documented and can be analyzed.
- Provide a regular forum for discussion about the CCT function that includes both funded projects and the broader community.
- Provide information to other UFS teams and the UFS-SC as requested.
- Respond to community requests to participate in activities, and encourage participation by clearly conveying the current status and development areas where community inputs are encouraged.

4.3.4.3 Composition and Leadership

CCT members are appointed by consensus of the CCT leads, and are drawn from operational modeling centers (e.g. NCEP/EMC), development organizations within NCAR and the government (e.g., NOAA, NASA, DoD, etc.), and outside members from across the broader scientific community. While there is usually a NOAA lead and a non-NOAA lead, there are no explicit requirements for the composition of the CCT leadership. See the Selecting and Approving Team Leads for a description of these processes.

4.3.4.4 Cadence

The primary mode of communication is through scheduled conference calls. Each CCT is expected to communicate on at least a monthly basis. The calls are led by the CCT leads. There may be additional invitees to the call depending on the topic.

4.3.5 Component Working Groups

At the core of the UFS are the component models for e.g., atmosphere, ocean, ice,, etc. A key principle on which the UFS is built, is that these are all community efforts. The UFS is intended to use these efforts, not replace them. Therefore, the UFS governance of the components models is based on the key principle that **component models used by the UFS have their own communities and governance. The UFS will work with these communities, rather than replace them**.

Presently, the following component Working Groups (WGs) are established:

- Aerosols and Atmospheric Composition
- Data Assimilation
- Dynamics and Nesting
- Ensembles
- Land
- Marine
- Physics
- Post-Processing

4.3.5.1 Charge

- It is a key principle that component WGs will work with existing communities rather than replace them. Toward that end the component Working Groups will:
    - Implement the components in the UFS, while assuring that the models meet software and scientific standards adopted by the UFS
    - Work with CCTs and ATs to assure that the component models are fully integrated and validated within coupled UFS applications.
    - Develop and communicate UFS needs to the component model community.
    - Provide a forum for the component model communities to provide direct input to the UFS, including both funded and unfunded participants.
    - Assure that work done by the UFS on the community models finds its way into the official releases of such models.
- Be responsive to forecast skill priorities and be aligned with science goals. WGs are expected to develop approaches that address both short-term needs and strategic directions.
- As subject matter experts for the components, provide information to other UFS teams and the UFS-SC as requested.
- Participate as subject matter experts in the development of UFS documents including strategic and implementation plans, annual reports, etc.
- Follow an evidence-driven approach, and to that end organize planning exercises, performance tests, requirements collection, reports, case studies, etc. in which the methodology and results are documented and can be analyzed.
- Respond to community requests to participate in development, and encourage participation by clearly conveying the current development status/timelines and development areas where community inputs are encouraged.

4.3.5.2 Composition and Leadership

WG members are appointed by consensus of the WG leads, and are drawn from operational modeling centers (e.g. NCEP/EMC), development organizations within NCAR and the government (e.g., NOAA, NASA, DoD, etc.), and outside members from across the broader scientific community. While there is usually a NOAA lead and a non-NOAA lead, there are no explicit requirements for the composition of the WG leadership. It is essential to have representation of the independent component community, if such a community exists outside of the UFS. See the Selecting and Approving Team Leads for a description of these processes.

4.3.5.3 Cadence

The primary mode of communication is through scheduled conference calls. Each WG is expected to communicate on at least a monthly basis. The calls are led by the WG leads. There may be additional invitees to the call depending on the topic.

4.3.6 Focus Teams

Focus teams may be formed at the request of any team or set of teams to address a particular issue; for example, organizing specific parts of a release. Focus teams typically have a limited number of members and are of limited duration. It is essential that when a focus team is created there is a written understanding of the scope of the team that includes the purpose of the team, the leads of the team, and the criteria for completion of the team's activities. Focus teams are not expected to undertake major development or redesign efforts, and if they determine the need for such efforts, they need to be escalated through the standing groups to the UFS-SC.

4.3.7 Community Modeling review Committee

The Community Modeling review Committee (CMrC) is an independent, ad hoc review committee, chartered by Modeling Programs in the NOAA National Weather Service (NWS) and Office of Atmospheric Research (OAR), convened to review the NOAA modeling program. Whereas this is technically a NOAA led activity, it is closely aligned with the UFS, and has communicated its support for the UFS, and is therefore included here. The objective of the CMrC is to represent the research community and periodically review the modeling strategy, priorities, resource requirements, developmental approaches, investment strategies, community engagement plans and activities, and scientific/technical challenges associated with NOAA's operational modeling research and development programs and activities, and to communicate this information throughout the community. The scope of the CMrC is Earth system prediction, which includes weather forecast and earth system predictions across time and space scales, out to and including sub-seasonal to seasonal prediction, as well as space weather, air quality, water modeling, and surge modeling. CMrC members collectively represent the technical expertise in relevant subject-areas necessary to gain a comprehensive understanding of NOAA's operational weather and climate modeling strategy.

4.4 Special Roles and Responsibilities

Project Engineer(s) An executive officer of the UFS to address activities such as proactively organizing meetings, preparing documents and presentations, organizing workspaces and resources, monitoring teams and projects, organizing and maintaining releases and release schedules, and adjudicating issues.

Communications Officer Responsible for coordinating communications, serves as a co-chair of the Communication & Outreach Working Group.

Code Managers A code manager is identified for each application and component authoritative repository associated with UFS. See a description of an "Ideal Code Manager" here.[20]

[20] <reference is missing …>

EMC Director The EMC Director, working within NWS Governance, decides what portion of UFS managed by the UFS-SC becomes the technical solution for producing operational guidance supporting NWS products and services.

NWS/Office of Science and Technology Integration (OSTI) Senior Advisor for Advanced Modeling Systems The federal employee in this role leads the effort to develop long-term strategic plans for modeling at NOAA. This position also provides guidance with respect to R2O, in general and for NWS.

NOAA NWS OSTI Director The NOAA OSTI Director serves as the Co-Chair of the Technical Oversight Board.

NOAA OSTI Modeling Division Director

NOAA OAR WPO Director The NOAA OAR WPO Director serves as the Co-Chair of the Technical Oversight Board.

5 Processes

5.1 Adding or Removing a Team

UFS-SC annually reviews WG activity and proposes continuation revision or removal of UFS Teams. Any UFS Team or community member can propose adding or removing a team, which is to be brought to the UFS-SC for consideration.

The creation or discontinuation of WGs is approved by consensus of the UFS-SC Executive Team. This group may request additional approvals or input from others.

5.2 Selecting and Approving Team Leads and Members

UFS teams (ATs, CCTs, WGs) are responsible for the nominations of new leads and submit nominations to the UFS-SC co-chairs. The UFS-SC co-chairs communicate the team lead nominations to the UFS-SC to solicit feedback including questions or concerns.

The team lead nominations are approved by consensus of the UFS-SC Executive Team This group may request additional approvals or input from others.

5.3 Team Lead Terms

Team leads (ATs, CCTs, WGs) have two year terms. The term starts at the next UFS summer or winter meeting week. Terms are renewable.

5.4 Making Team Decisions

Teams (ATs, CCTs, WGs) make decisions in a collective process that strives to develop consensus that represents the position, recommendation, or interests of the group as a whole. In the event that a decision cannot be reached, then the lead(s) take the issue to the UFS-SC for resolution.

5.5 Code Management and Code Governance

As a community model with components provided by a large number of groups and teams, code management and governance by origin is organic and distributed, with in particular many of the component models already having established this. To assure that the development of these models is not hampered by the UFS, the UFS does not aim to replace this governance at the “component” level. Nevertheless, rules are needed. A high level document on repositories was one of the first policy documents generated by the UFS community. Furthermore, the UFS expects the following high-level code management and governance principles to be followed by each self-contained component (including infrastructure) individually:

1. **Do no harm**. Considering the focus of the UFS on improving operational forecasting, any code update of the UFS that breaks operations is counterproductive. UFS code management therefore requires:
    a. Continuous regression testing, not only on science output, but also on computational expenses and robustness / reliability.
    b. Maintaining backward compatibility of an evolving code base (i.e., do not break what was already working).
    c. Explicit concurrence from operations for any code change that breaks or has a clear negative impact on operations.

2. **Coding Standards.** Modern maintainable code requires coding standards. Whereas we do not intend to enforce UFS-wide coding standards, we expect all components to define such as part of their governance. As part of this, and to be able to enforce “do no harm”, regression and unit testing are required for each UFS component.

3. **Ownership**: each contribution to the UFS or a part of its code base needs to have a designated entity responsible for its maintenance (at their cost). For code that is used in NOAA operations, this is often residing at, or funded by NOAA. However, for R&D contributions that are not yet accepted for use in operations, the developer has to commit to, or find resources for maintenance of the code contributed to the UFS.

6 Administration and Support

Members of the teams described in this document are maintained in a separate location.

Administrative support for the UFS TOB, UFS-SC, and other UFS teams may be provided by the OSTI and/or OAR WPO Program Office.

- Assist in scheduling of activities/meetings
- Assist in meeting coordination (including agendas, presentation material, minutes)
- Coordination of other administrative actions as needed

Membership of the UFS - Steering Committee

All people listed in this section have been invited to Steering Committee meetings and have had the opportunity to comment on this document. There have been different levels of active participation.

Richard B. Rood and Hendrik L. Tolman, Co-Chairs
Program Support: Karen Keith

Henrique Alves, Thomas Auligne, Jian-Wen Bao, Michael Barlage, Ligia Bernardet, Jacob Carley, Rocky Dunlap, Gregory Frost, Brian Gross, Tom Hamill, Lucas Harris, Tara Jensen, Henry Juang, James Kinter, Dorothy Koch, Geoffrey Manikin, Avichal Mehra, Louisa Nance, Shackak Peeri, Russell Schneider, Ivanka Stajner, Cristiana Stan, Vijay Tallapragada, Mariana Vertenstein, Jeffrey Whitaker, Xuejin Zhang

Appendix A: Documents

Strategic Implementation Plans

Strategic Implementation Plan (SIP) for Evolution of NGGPS to a National Unified Modeling System Version 4 (updated December 5, 2017)
https://vlab.ncep.noaa.gov/documents/12370130/12437941/SIP_FY18-20_v4.pdf/66eee0ca-6794-db32-2c75-438928a7c880?t=1604586523014

Strategic Implementation Plan for Evolution of NGGPS to a National Unified Modeling System, First Annual Update (November 29, 2018)
https://www.weather.gov/media/sti/nggps/UFS%20SIP%20FY19-21_20181129.pdf

UFS Strategic Plan for 2021-2025, Version 1 (April 6, 2021)
https://docs.google.com/document/d/1mprfdAg6EKoh5ZgpbvoIxn0r1mE1puc7dsiH4RUiYII/edit?usp=sharing