Unified Forecast System:
@ EPIC Community Workshop

August 6, 2019

for the UFS-Steering Committee

Richard B. (Ricky) Rood
Hendrik Tolman
Co-chairs

- About UFS
- UFS as a project
- Research to Operations
- Focus on code releases

[UFS Community Portal , May 2019: UFS Briefing at SIP Meeting]

About the UFS

Purpose The Unified Forecast System (UFS) is a comprehensive, community-developed Earth modeling system, designed as both a research tool and as the basis for NOAA's operational forecasts.

Governance Planning and evidence-based decision-making support improving research and operations transitions and community engagement.

Scope UFS is configurable into multiple applications that span local to global domains and predictive time scales from less than an hour to more than a year.

Design UFS is a *unified* system because the applications within it share science components and software infrastructure

Impact UFS is a **paradigm shift** that will enable NOAA to simplify the NCEP Production Suite, to accelerate use of leading research, and to produce more accurate forecasts for the U.S. and its partners. Use a community model in operations, not trying to make an operational model a community model.

UFS: Started from a set of important foundational decisions

- Dycore: Selection of the FV3 dynamical core for the GFS (Global Forecast System)
- Modular, community-based systems architecture for the coupled model
- Infrastructure:
  - Coupling (ESMF, NUOPC)
  - Data Assimilation (JEDI)
  - CCPP Framework (Atmospheric Physics)
  - METplus
- Strategic Implementation Plan (SIP)
- NCAR-NOAA Memorandum of Agreement
  - ~50 % shared code in models and infrastructure

- EPIC
  - Opportunity: Success of SIP and UFS is essential for EPIC.
  - SIP and UFS are part of the foundation for EPIC

UFS Applications

UFS applications include:

- Medium-Range Weather (Weather) - Atmospheric behavior out to about two weeks
- Subseasonal-to-Seasonal (S2S) - Atmospheric and ocean behavior from about two weeks to about one year
- Hurricane - Hurricane track, intensity, and related effects out to about one week
- Short-Range Weather/Convection Allowing - Atmospheric behavior from less than an hour to several days
- Space Weather - Upper atmosphere geophysical activity and solar behavior out to about one month
- Marine and Cryosphere - Ocean and ice behavior out to about ten days
- Coastal - Storm surge and other coastal phenomena out to about one week
- Air Quality - Aerosol and atmospheric composition out to several days

UFS Community Portal

Portal: https://ufscommunity.org/

Unified Forecast System

Building better forecasts through community partnerships

Quick links for this presentation:

- Applications
- Documents

Unified Forecast System – Steering Committee

- Governance model followed from comparative analysis of governance models of 10 communities (link)

- Governance Strategy
  - Facilitates community model research, development, and applications (Includes policy, practice, tools, …)
  - Focuses on near-term projects that have long-term consequences
  - Improves scientific integrity at organizational level
  - Leads towards unified forecast suite with coupled predictive models (Simplification)
  - A design feature: The governance evolves to meet community needs: There is currently an important evolution to include an application focus - and increase efficiency.
    - Develop and publicize: Forecast & science goals and priorities
    - Develop and publicize: End-to-end test plans for those goals
- UFS Governance is evolving as the UFS/SIP is reorganizing to be a funded project.

Programmatic direction

- The Program Offices of both the National Weather Service (NWS) and Office of Oceanic and Atmospheric Research (OAR) are committed to develop a managed, project-based approach to advance the Unified Forecast System (UFS) and will be supporting the UFS Applications Teams (AT) and Working Groups (WG) based on the Strategic Implementation Plan (SIP) and an updated AT and WG SIP-proposal.
- The AT and WG proposal and project will have a clear leadership and organizational structure, largely overlapping with the rest of the UFS structure.
- Federal Funding Opportunities (FFOs) will also be used to engage the University community in the UFS/SIP.
- Refer questions to
    - Russ Schneider and Dorothy Koch (NWS)
    - Bill Lapenta and DaNa Carlis (OAR)

Research and Operations (R2O & O2R)

- Organizing Research to Operations Transition

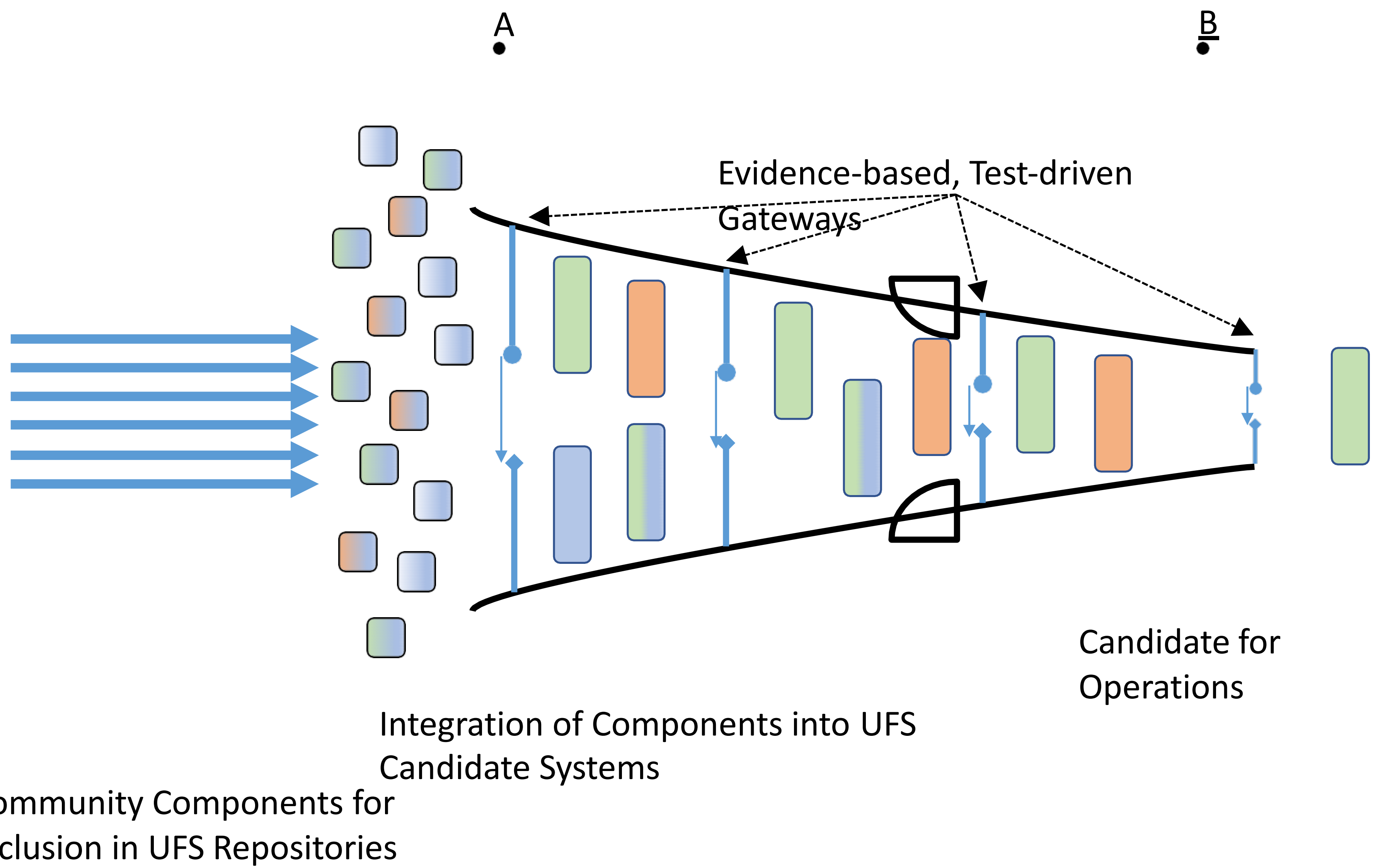
- Describe and analyze the R2O process in order to improve it
  - Transitions between research and operations are widely considered what we need to improve.
- We need to know what we are doing to be able to target resources for improvement.
    - Describe the end-to-end process
    - What are the key functions?
    - What are the barriers?
    - How does it all fit together?
- Improved O2R is interwoven with R2O

R2O: Process (Our behavior)

- Building usable complex information systems and software requires:
  - Systems engineering approach
  - Iterative design and testing
  - Iterations with developers, scientific experts, and application specialists (teaming and re-teaming)
    - Communications
    - Continuity
      - Definition (Developing common language)
      - Incremental Planning
      - Strategic goals
      - Integration into end-to-end systems to address application goals
      - Objective testing, verification, and validation at all steps

[Organizing Research to Operations Transition]

R2O: As a repeated, narrowing stage and gate process (see backup slides)



R202R: Functions and Analysis

Function	UFS-SC Analysis	Status Evaluation
Management and Decision Making	yes	some existing capacity
Workflow	yes	some existing capacity
Code Management	yes	some existing capacity
System Integration	no	major gap
Developer and User Support	no	major gap
Testing, Verification, and Validation	yes	some existing capacity

Computational Resources	no	some existing capacity

Developing capacity: Near-term projects that have long-term consequences

- Integrate UFS activities with operational cycles and a set of releases.
  - Define process
  - Improve process
  - Build capacity with existing resources
  - Identify gaps
  - Develop work and resource plans
- Foci (Applications Teams and Release Team)
  - GFSv15: operational June 2019
  - GFSv16: “Advanced physics”
  - GFSv17: Coupled system, JEDI-based DA, Integrated GEFS and GFS
  - GEFSv12: FV3-based GEFS
  - GEFSv13: First coupled sub-seasonal products
  - Regional model evolution

UFS-SC charge to the release team

- Improve usability of code release as compared to past releases
- Define target community and early adopters
- Use surveys and design reviews to collect information for evidence-based decisions (usability, scope, workflow, etc.)
  - Graduate Student Test
  - Focus teams (Reach out to current audience)
- Advance implementation of the UFS repository plan
- Define portability requirements
- Evaluate workflow and inform workflow development
  - Advance Hierarchical System Design
- Identify functional and resource gaps
- Develop a sustained focus on major releases and incremental updates as capability evolves
  - Joint NOAA-EMC, partners, and community
  - Operational and community needs are developed in concert

Release Team: ~ December 2019

- Anticipate UFS - Version #
  - Operational and experimental code base
    - GFSv15
    - Standalone Regional (SAR)
    - Considering feasibility to support coupled systems
      - GFSv15 with WaveWatch III and chemistry
      - Sub-seasonal to seasonal
  - **Initial support is provided for FV3GFS atmosphere (only)**
- Publicly available code repositories through github.com, with formal repository management
- Scope: forecast only, including initial conditions and verification datasets (subset of application, see defn)
- Documentation of code
- How-tos
- Monitored user forum
- Tutorials post-release
- Have used some SIP-proposal and FFO funds, existing UFS researchers to enhance start up
- Information on release, access provided through portal

UFS
UNIFIED FORECAST SYSTEM

Take away

- We are in a much different and improved place than two years ago
  - Implemented new medium range system, with improved forecast metrics and improved science foundation
  - Exercised and analyzed a systematic, evidence-driven transition from research to operations

- Changes in approach to programmatic and line management
  - Commitment of NWS and OAR leadership to fund UFS activities in a strategic, systematic and integrated (NOAA with community) approach
  - Use of SIP planning process to guide a managed, project-based approach to UFS activities.

- Importance of alliances with federal, academic, and private-sector partners, the community, is recognized through
  - NCAR-NOAA Memo of Agreement
  - Use of community infrastructure
  - Use of Federal Funding Opportunities to engage community through Working Groups (e.g. SIP)

UFS
UNIFIED FORECAST SYSTEM

Framing Questions for EPIC Meeting

1. What is the UFS and how can EPIC do something different to make that system accessible and useful to the weather enterprise?
    a. The UFS effort has identified a set of functions and gaps that are suitable for accessibility and usability. What would be different is to build of off existing efforts rather than, naively, starting over again.
2. Given your experience with the UFS, what are the most important risks EPIC must address in order to be successful?
    a. In the near term, developer and user support. The questions about how they address software engineering, portability, etc., not clear that EPIC is a way to reduce risk in the near term. A systems integration function is needed, but it requires substantially more definition.
3. How do we incentivize participation in EPIC?
    a. Aside from money, the incentive is that participants get something out of it. Hence, it needs to feel like a partnership on an intellectual and emotional level.

Framing Questions for EPIC Meeting

1. How does he envision EPIC and existing UFS/ SIP WGs to work together. Who's in charge? That is, who makes final code decisions? Who decides research and R2O priorities?
   a. The UFS has an evolving governance. One presumes EPIC will have a credible governance. Therefore, it is a governance to governance relationship. Who makes final code decisions is beyond the scope of discussion at this point, as in many instances, that is mandated to NOAA. Within the current UFS structure, the Steering Committee would have significant influence on the decisions and provide guidance to the program office.
2. Can and should the UFS be inclusive of modelling capabilities (e.g. dycores such as MPAS) that are not necessarily earmarked for operational deployment.
   a. Yes. However, one needs to consider both the need to meet scientific priorities and consider the viability and path to operations early in the process. An important consideration is the type of transition required (see r2o transition document).

Framing Questions for EPIC Meeting

1. What business models do you feel are successful for building community modeling?
   a. There are a number of successful communities. However, there is no community that is considering operational readiness. A fundamental question is how would the community would communicate the priorities to program offices in a way to influence funding decisions - legally.
2. How do you see US NWP becoming part of a larger “community-based Earth System Modeling”?
   a. First is a paradigm shift - models with community, not models for community. Nor, community is tasked with NOAA priorities. There are many cultural barriers to be addressed.
3. What new technologies do you see enhancing full Earth system modeling
   a. The problem is not fundamentally technical, but organizational.
4. What are the challenges/benefits you foresee in merging the UFS infrastructure with the EPIC community tools?
   a. We do not know what EPIC community tools are.
5. How are you preparing those who are currently integrated in the UFS infrastructure for the new capabilities EPIC will potentially provide?
   a. We are still figuring out what EPIC is, and trying to influence its evolution

Backup & Informational Slides

Unified Forecast System – Steering Committee

- Governance Strategy
  - Facilitates community model research, development, and applications (Includes policy, practice, tools, …)
  - Focuses on near-term projects that have long-term consequences
  - Improves scientific integrity at organizational level
  - Leads towards unified forecast suite with coupled predictive models (Simplification)
    - **Describe the end-to-end system**

- Meeting ~ weekly since March 2, 2018.
  - Presentations from invited working groups on priority items defined by SIP plan and Steering Committee members
  - Meet Friday at 11 Eastern
  - All presentation materials and minutes are posted at UFS - SC working site COG (link)

R2O: Maturity and Readiness Level

UFS: Notional Categories of Maturity

- Step 1: Ideation
- Step 2: Preliminary Experimentation
- Step 3: Pre-operational Experimentation
- Step 4: Integration and Testing in Prediction Packages

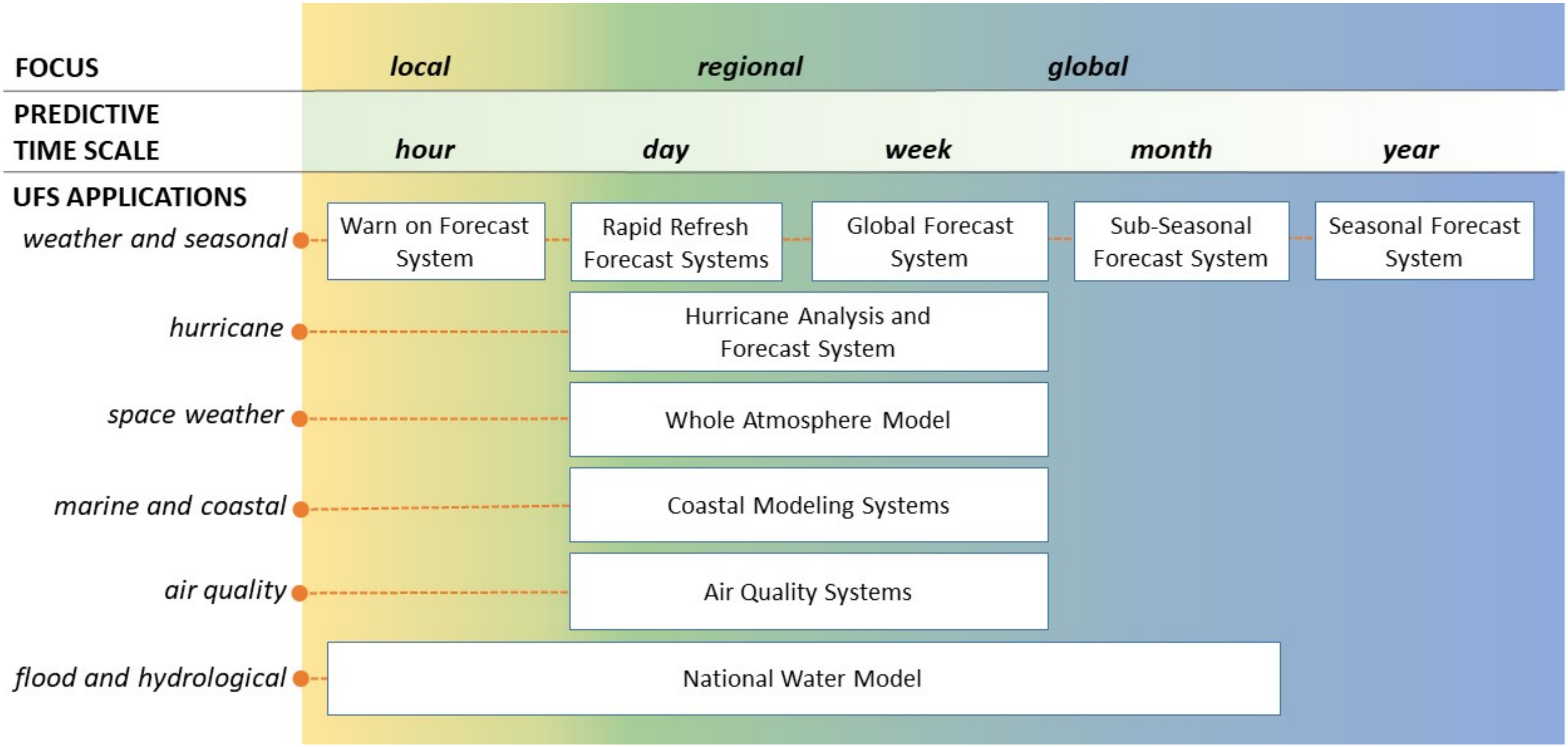
NOAA Readiness Level (RL)

- RL 1 and 2
- RL 3 and 4
- RL 5 – 9
- (Iterative processes)

Three types of R2O transitions:

- System Level Transition
  - Changing the dynamical core and physics of the GFS - GFSv15
- Application Level Transition
  - Physics upgrade for GFS – GFSv15 --> GFSv16
- Incremental Level Transition
  - Parameterization - level calibration (Improve cloud radiation interaction, super saturation in DA)

Scope of UFS



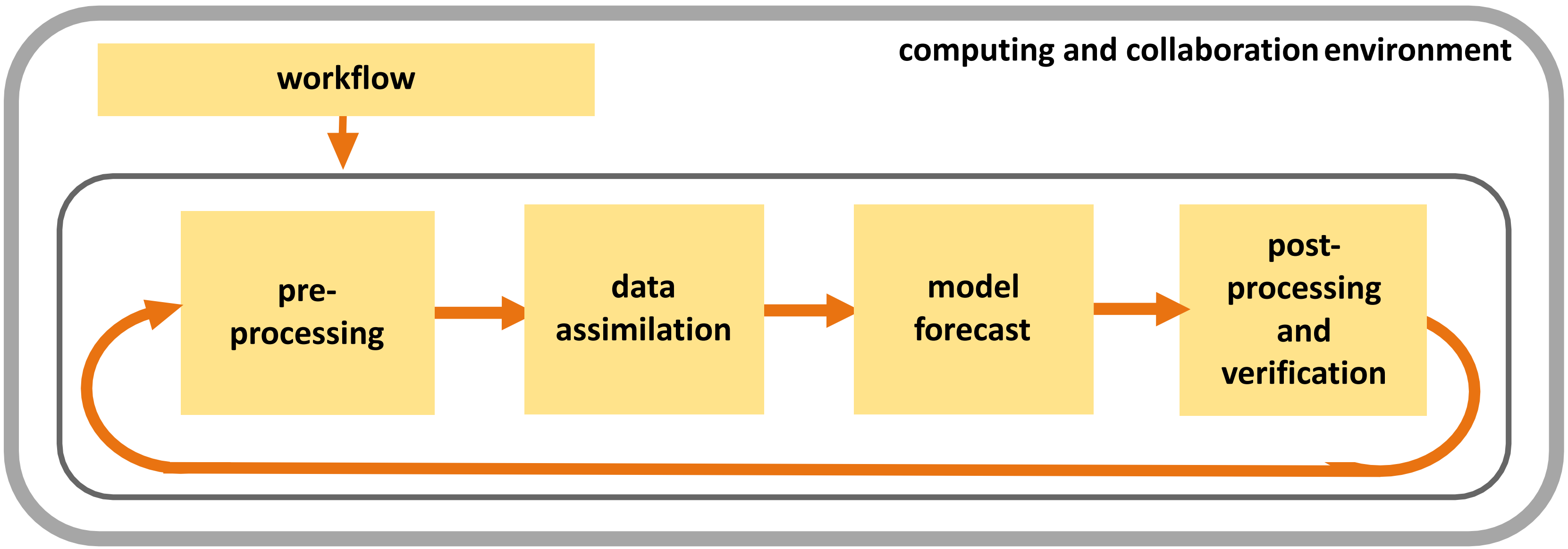
UFS applications span predictive timescales (less than an hour to more than a year) and focus on multiple spatial scales (local to global).

UFS Applications

UFS is configurable into multiple applications, each of which will have:

- A forecast target (numerical guidance for forecast products)
- Its own “umbrella” repository with links to common component and infrastructure code
- Lead(s), development plan, and test plan

Parts of a UFS Application



Pre-processing and data assimilation	• Stages inputs, performs observation processing, and prepares an analysis
Model forecast	• Integrates the model or ensemble of models forward
Post-processing and verification	• Assesses skill and diagnoses deficiencies in the model by comparing to observations
Workflow	• Executes a specified sequence of jobs
Computing and collaboration environment	• May be different for research (experiment focus) and operations (forecast focus) • Provides actual or virtualized hardware, databases, and support

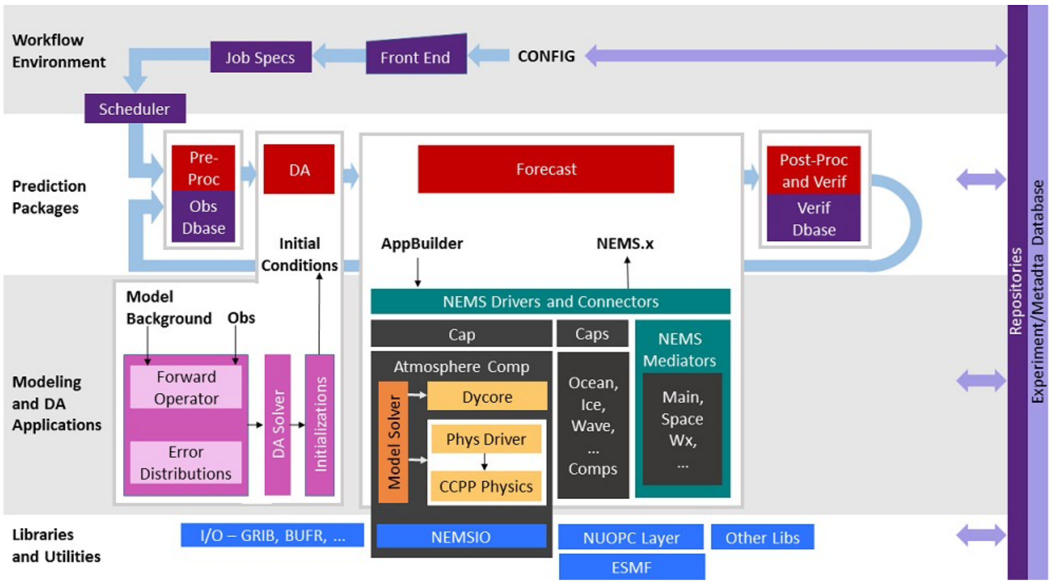
UFS System Architecture

Workflow

Prediction Packages

Modeling and DA Applications

Libraries and Utilities



Software engineering infrastructure: Repositories, Documentation

The Point: Complex system with differentiated functions. The functions are required to combine into end-to-end application systems. Requires data communication at the interfaces and communication among humans.

NCAR-NOAA Infrastructure MOA

- NCAR, NWS, and OAR Memorandum of Agreement focuses on synergistic development and use of infrastructure
- Builds on existing multi-agency community-developed infrastructure (NASA, Navy, NOAA, NSF, DOE…)
- UFS Working Groups are already engaged in seven work areas specified by the MOA
- Finalized January, 2019 (link)

NCAR-NOAA Infrastructure MOA
Work Areas

1. Coupling components
New ESMF/NUOPC mediator (CMEPS/NEMS)

2. Interoperable atmospheric physics
CCPP & CPF frameworks

3. Community-friendly workflow
CIME - CROW unification, CIME Case Control System

4. Hierarchical model development capabilities
Extensions of CIME data models, unit, and system testing

5. Forecast Verification: Comparison to Observations
Extension of METplus

6. Software Repository Management
NCAR manage_externals tool

7. User / Developer Support
DTC and CESM Capabilities

R2O: Description

- The goal of the UFS R2O transition is to move complex scientific software from a loosely managed research community to rigorously defined production software.
- The production software provides science-evaluated environmental forecasts on a repeating schedule.
- The R2O transition process requires, therefore, evaluation of software quality, computational performance, and scientific quality.

Compared with our past R2O practice the UFS:

- Is far more complex software
- Has a strong relationship with communities
  - Developers
  - End-users
- Has distributed, heterogeneous computational and information systems

- Even if what we have been doing was optimal, it would have to evolve, adapt, and extend to the UFS.
- EPIC is an opportunity to do this better.

[Organizing Research to Operations Transition]

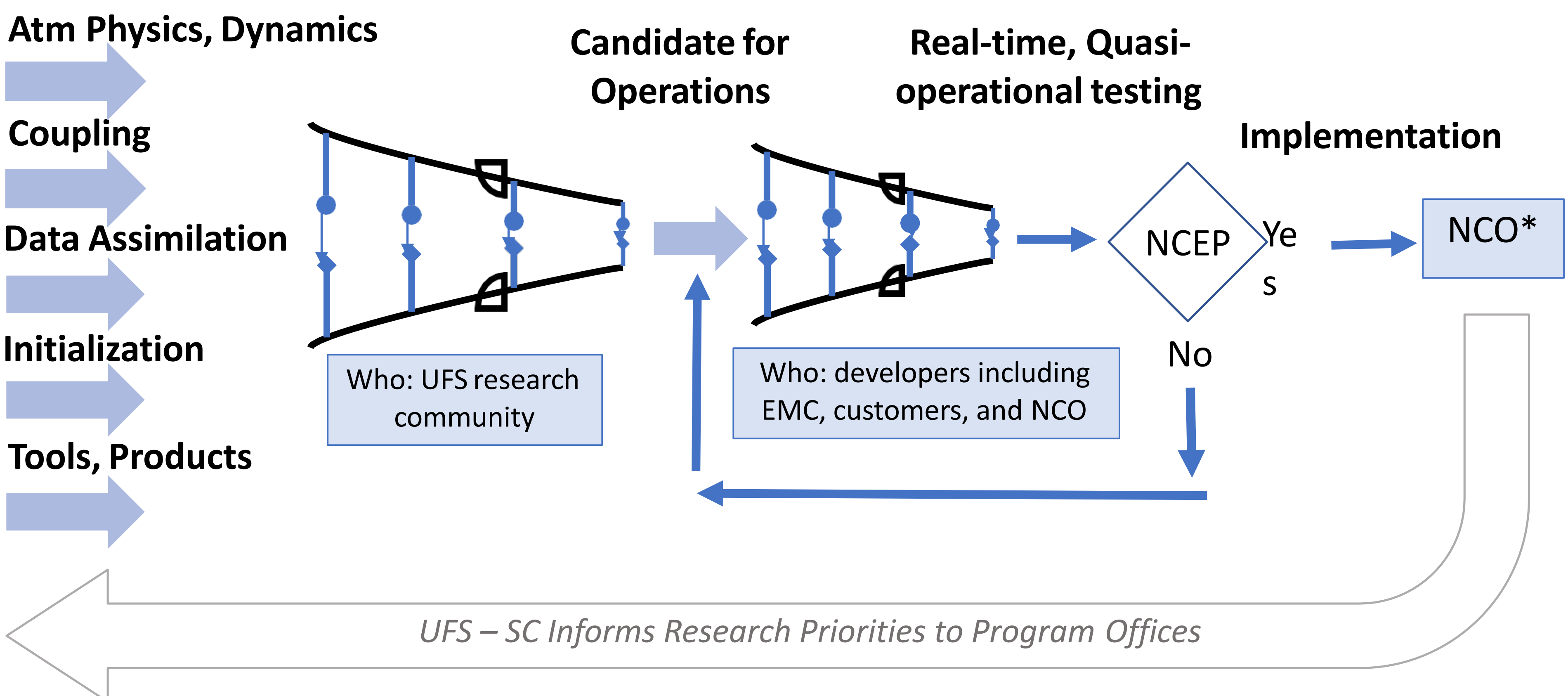
R2O: Major classes of functions

- Management and decision making
- Workflow
- Code Management
- Developer and User Support (Community Support)
- System Integration
- Testing, Verification, and Validation

[Organizing Research to Operations Transition]

R202R: Improving by Doing

- Use FV3-GFS release to increase community engagement, advance UFS plans (e.g. graduate student test), develop linkages across applications
- Use the two planned cycles of physics development and ongoing coupled system development to define and improve the R2O process



* Plus any NOAA entity with responsibility for the implementation (e.g. GSD, MDL, NOS etc.)

Shared Community Infrastructure

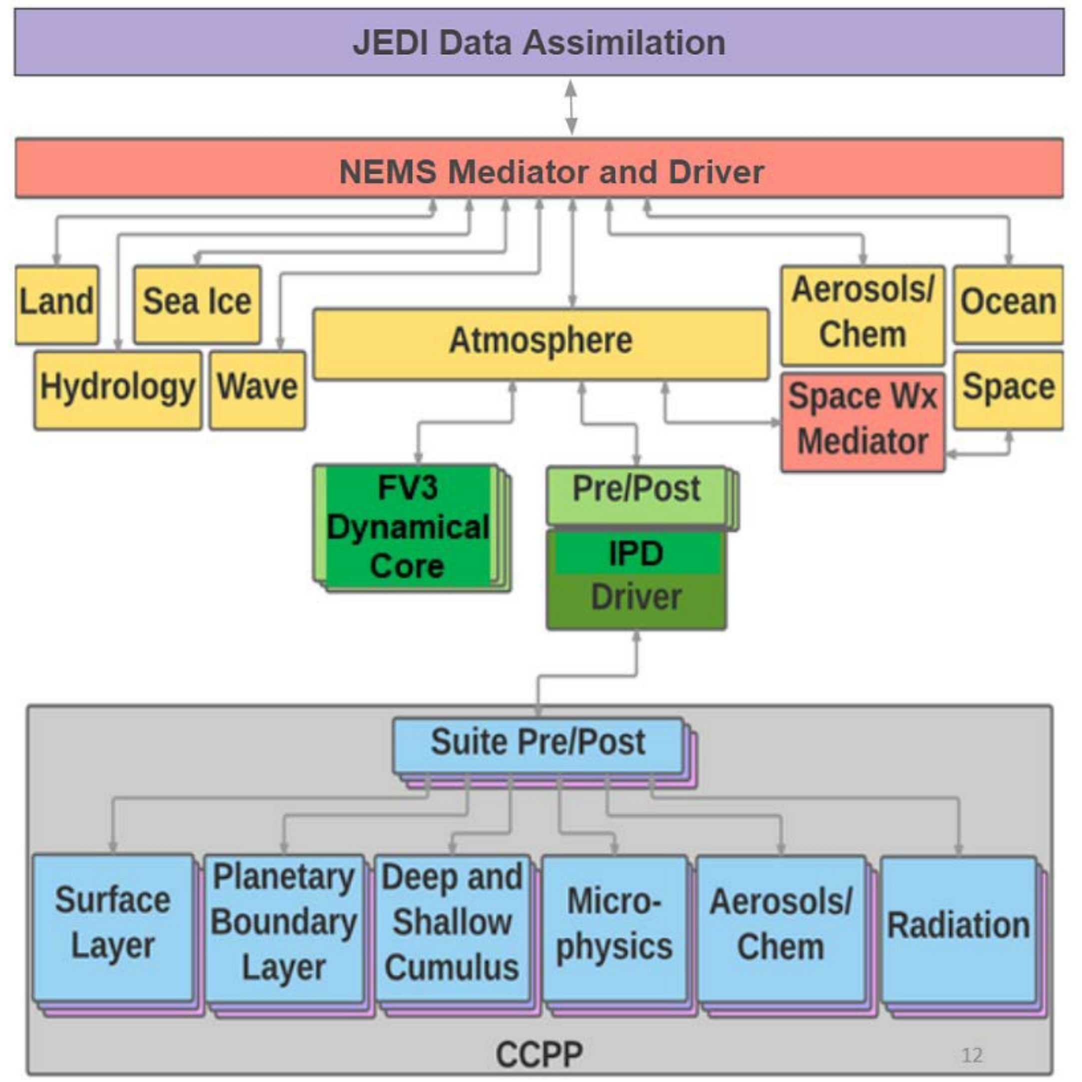
Infrastructure for data assimilation:
Joint Effort for Data assimilation Integration (**JEDI**)

Infrastructure for coupling models together:

- NOAA Environmental Modeling System (**NEMS**) coupler
- based on the Earth System Modeling Framework (**ESMF**)
- using National Unified Operational Prediction Capability (**NUOPC**) conventions

Infrastructure for interoperable physics:

- Common Community Physics Package (**CCPP**) framework



Take away

- We are in a much different and improved place than two years ago
  - Scientific basis
  - Convergence in both regional and global systems
  - Strategies for model coupling and alignment with forecast requirements is being incorporated into next phase of project
  - Stable planning and following the plan
  - Communications and coordination
  - Systems-wide description of barriers and initial solution paths
- Changes in approach to programmatic and line management
  - Leadership recognizes and aligns with the UFS activity
  - Commitment of NWS and OAR leadership to fund UFS activities in a strategic, systematic and integrated (NOAA with community) approach
  - Use of SIP planning process to guide a managed, project-based approach to UFS activities.
- Importance of alliances with federal, academic, and private-sector partners, the community, is recognized through
  - NCAR-NOAA Memo of Agreement
  - Use of ESMF, NUOPC, CCPP, JEDI community infrastructure
  - Use of surveys and focus teams to increase usability
  - Use of Federal Funding Opportunities to engage community in documented planning (e.g. SIP)
- UFS activity looks to EPIC to build from UFS progress and accelerate its successes.