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1.0 Overarching System Team Planning – NEMS/ESMF

1.1 State of the Science

The overarching system (OAS) team focuses on the overall software architecture of NGGPS modeling applications and coordination of software development. Areas of activity include improvements and extensions to high–performance coupling and utility infrastructure in response to NGGPS program needs; development of code management strategies that support multi-component modeling; and coordination of software infrastructure efforts across the teams involved in NGGPS and related activities at NCEP, NOAA, and the broader community.

The NGGPS program is leveraging the NOAA Environmental Modeling System, or NEMS. NEMS is a *coupled modeling system* designed to support environmental prediction across a range of time scales. Examples of other coupled modeling systems are the Community Earth System Model (CESM) and the Met Office Unified Model.

NEMS is associated with a collection of model components representing major Earth system domains and processes. In general, the interactions between model components are managed through the NEMS *mediator* (in other coupled modeling systems this is often called the "coupler").

NEMS can be configured to create multiple *modeling applications*. Modeling applications are associated with a purpose, like medium-range forecasting; a set of model components; and a set of parameters that represent a range of supported options, including grids and resolutions. Different NEMS modeling applications can have different types and numbers of model components. Also, the same physical domain may be represented by different model components in different modeling applications. For example, in some NEMS modeling applications the ocean component may be HYCOM and in others it may be MOM5.

The NGGPS program encompasses a set of modeling applications based on NEMS. NCEP has defined a NEMS-based Unified Global Coupled System, or UGCS, with predictive targets at 10-day, 6 week, and 9 month/seasonal timescales. UGCS is a convenient way to refer to several of the modeling applications that are likely to be associated with NGGPS. A first version of the UGCS Seasonal application (0.1) was delivered in June 2015 with coupled components GSM, MOM5, and the CICE ice model.

NEMS is built using the Earth System Modeling Framework (ESMF) infrastructure software. ESMF provides utilities like generation of interpolation weights and time-related classes, and also wrappers that create a standard component calling interface. This enables model components developed at different sites to be coupled more easily.

The National Unified Operational Prediction Capability (NUOPC) Layer adds additional rules about how ESMF models interact and increases their interoperability. The NUOPC Layer covers aspects from the level of build dependencies, to standardization of initialization phases, to standard names of the exchanged fields. ESMF-based software has been adopted in modeling applications at NASA, Navy, NOAA, NSF, and other centers.

1.2 Objectives

The OAS team has three main objectives.

1. **Provide a portable, high performance, unified software infrastructure for use in operational prediction models at NCEP.** Collaborate with component developers to transition NGGPS-relevant codes into this infrastructure in an efficient, coordinated manner. Implement coupling infrastructure without intruding into science codes and parallelization.
2. **Coordinate and provide to NCEP a document on code management for NEMS-based modeling applications and suites.** Provide guidance on strategies that support R2X and management of the complexity introduced by the many component types that NGGPS targets (e.g. atmosphere, ice, land, coast, ocean, chemistry, ionosphere) and the options for each type (e.g. prognostic, data, stub versions of components). Implement pilot projects and evaluate results.
3. **Promote communication and coordinated software development across the NGGPS teams and related efforts at EMC and NOAA.** These efforts include evolution of the coupling infrastructure, development of the atmospheric physics and dynamics interface, design of the atmospheric component (currently set up differently than other components), implementation of shared infrastructure for data assimilation, implementation of workflow suites, and interaction of NGGPS with seasonal modeling, regional modeling, and modeling at the National Water Center.

1.3 Milestones and Outcomes for Near-Term Objectives

- Define and deliver a sequence of increasingly capable coupled modeling applications following NGGPS requirements.
    - **Lead organization:** EMC, NESII/ESRL
    - **Activities:** Building on the UGCS Seasonal 0.1 application delivered in June 2015, work with NGGPS teams to define a sequence of modeling application deliveries.
    - **Milestones and deliverables:**
        - Past and planned deliveries for NEMS codes are shown in this spreadsheet: https://docs.google.com/spreadsheets/d/1RS-fTBYnfSIWrJYfalD2lAI-bUOGM0frNPEMIO_ND28/edit#gid=0
        - December 2015: Initial NUOPC/NEMS training offering in collaboration with NCAR DTC.
    - **Anticipated collaborating organizations:** CPC, GFDL, NRL, NCAR CESM, NCAR DTC, COLA.

- o **Priority (Low, medium, high):** High
- o **Duration:** 18 months
- o **Points of contact:** Mark Iredell, Cecelia DeLuca for infrastructure. Modeling application leads as identified at the URL under "Milestones and deliverables" above. Note some key modeling applications do not have identified leads. Internal and external component leads as identified at the same URL.

- Coordinate and deliver a document on code management strategies for NEMS-based modeling applications and suites. Implement pilot projects and evaluate.
  - o **Lead organization:** EMC, NESII/ESRL
  - o **Activities:** Develop code management document and approach through interactions with EMC and partner organizations (began 5/2015).
  - o **Milestones and deliverables:**
    - § September 2015: Review and complete first draft of document.
    - § March 2016: Complete implementation of initial pilot projects with VLab and the NCAR Common Infrastructure for Modeling the Earth (CIME) repository.
    - § June 2016: Initial implementation of code management strategy
  - o **Anticipated collaborating organizations:** NWS VLab, NCAR DTC, NCAR CESM, COLA
  - o **Priority (Low, medium, high):** High
  - o **Duration:** 12 months
  - o **Points of contact:** Mark Iredell, Cecelia DeLuca, Ligia Bernadet, Mariana Vertenstein

- Coordinate development of infrastructure software across NGGPS teams and activities.
  - o **Lead organization:** EMC, NESII/ESRL
  - o **Activities:** Promote communication and coordination across software development activities including evolution of the coupling infrastructure, development of the atmospheric physics and dynamics interface, design of the atmospheric component (currently set up differently than other components), implementation of shared infrastructure for data assimilation, implementation of workflow suites, and interaction of NGGPS with other modeling efforts at EMC (e.g. seasonal modeling) and elsewhere at NOAA (e.g. National Water Center modeling efforts).
  - o **Milestones and deliverables:**
    - § December 2015: Deliver coupled NEMS modeling application that includes separate land and hydrology components, in collaboration with NCAR RAL, GLERL, and National Water Center developers (funded by NSF).
    - § December 2015: Design and implement a strategy for the NEMS atmospheric component that is consistent with other model components, and allows at least one additional atmosphere besides GSM to be run coupled in NEMS.
    - § March 2016: Deliver updated version of physics interface following cross-team discussion.
    - § August 2016: Following cross-team discussion, implement initial demonstration of shared infrastructure for data assimilation (general observation operator).
  - o **Anticipated collaborating organizations:** NRL, NASA GSFC, NCAR RAL, GLERL, National Water Center
  - o **Priority (Low, medium, high):** High

- o **Duration:** 18 months
- o **Points of contact:** Mark Iredell

1.4 Milestones and Outcomes for Long-Term Objectives

- Deliver versions of NGGPS modeling applications ready for operational validation.
- Complete implementation of code management strategy for NEMS modeling applications and suites.
- Establish regular training opportunities for NUOPC/NEMS.
- Adapt NEMS to next generation processors.
- Evaluate and improve efficiency of NEMS infrastructure and NEMS modeling applications.
- Continue cross-team interactions on the physics interface and data assimilation.
- From EMC: Restructure code: separate algorithms from code; modularize dynamics and physics parameterizations; maximize code sharing; rationalize physics.