The Common Model Architecture of the National Unified Operational Prediction Capability

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Gerhard Theurich (ESMF Core Team/NESII/SAIC)
• **National Unified Operational Prediction Capability**
  - Consortium of U.S. operational weather and water prediction centers.

• Participants: NOAA, Navy, Air Force, NASA, and other associated modeling groups.

• Develop a Common Model Architecture (CMA) to:
  - Improve collaboration among agencies.
  - Accelerate the transition of new technology into the operational centers.

• NUOPC websites:
  → http://www.weather.gov/nuopc
  → http://earthsystemcog.org/projects/nuopc/
Basic Building Blocks:

- **Model**
  - Typically implements a specific physical domain, e.g. atmosphere, ocean, land, seaice, wave, ...

- **Connector**
  - Unidirectional connection from one component to another, e.g. Model-to-Model, Model-to-Mediator, etc.
  - Executes *simple* transforms (Regrid or Redist).

- **Mediator**
  - Custom coupling between *multiple* models (e.g. flux calculations, averaging, etc.).
  - Uses ESMF tools like Regrid and XGrid.

- **Driver**
  - Harness for Models, Mediators, and Connectors.
  - Coordinates initialization and run sequencing.
Simple ATM-OCN

Earth System Driver

ATM

OCN

Connector

Connector

PET
Simple ATM-OCN

Earth System Driver

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Additional CMA Features

- Explicit, Semi-Implicit, and Implicit Coupling
- Nested Domains
- Single- and Multi-Model Ensembles
- Component Hierarchies
Technical Aspects

- Component interfaces
  - Initialize/Run/Finalize (with phases)
  - Import State and Export State

- Initialization sequence
  - Resolve dependencies between Components
  - Resolve initialize data dependencies

- Run sequence
  - Support explicit, semi-implicit, implicit coupling
  - Support nested domains

- Timekeeping
  - Driver controls child components
  - Require a common and complete representation for timekeeping objects

- Grid and data representation
  - Structured and unstructured

- Metadata
  - On components and fields
  - Self-documentation
  - Human readable interaction CMA interactions (e.g. Connected, Updated, Timestamps, CplList)
NUOPC Layer

- Software layer that implements portions of the NUOPC CMA on top of ESMF:
  - Generic components (Driver, Model, Mediator, Connector)
  - Utility methods
  - Field dictionary (standard names for matching)
- Compliance checker
- A prototype has been in ESMF since v5.2.0r.
- The current version is available in ESMF v6.1.1.
- First “production” release is scheduled for later this year (2013).
Templating by Generic Library Code

Application

```fortran
...  
call lib_method()  
...  
end
```

Library

```fortran
subroutine lib_method()  
...  
...  
  call app_special()  
...  
end subroutine
```

subroutine app_special()  
...  
end subroutine
Generic Components
- Component Templates

Application

```plaintext
... call Comp.Initialize()
... end
```

```
subroutine Comp.Initialize()
...! do what goes beyond
...! generic NUOPC code
end subroutine
```

NUOPC

```
subroutine NUOPC_GenericComp_Init()
...! generic code, e.g. checking
call app_specific_Comp_Init()
...! generic code, e.g. time stamp
end subroutine
```

ESMF

```
subroutine Comp.Initialize()
... call NUOPC_GenericComp_Init()
... end subroutine
```
CMA elements provided by Generic Component Code

**NUOPC_Driver**

- **Generic Initialize:**
  - Creates child Components and their States
  - Attaches Component metadata
  - Sets up the default RunSequence
  - Drives the initialization sequence for its children

- **Generic Run:**
  - Validates incoming Clock against internal Clock
  - Takes parent timestep forward by driving children according to the RunSequence

- **Generic Finalize:**
  - Drives finalize for all children
  - Destroys all child Components and their States
CMA elements provided by Generic Component Code

**NUOPC_Model**

- **Generic Initialize:**
  - Sets the internal Clock
  - Checks that all the import Fields are connected
  - Timestamps the import and export Fields

- **Generic Run:**
  - Validates incoming Clock against internal Clock
  - Checks that all import Fields are at the current time
  - Advances model forward according to parent time step
  - Timestamps the export Fields

- **Generic Finalize:**
  - NOOP
CMA elements provided by Generic Component Code

**NUOPC_Mediator**

- **Generic Initialize:**
  - Sets the internal Clock
  - Checks that all the import Fields are connected
  - Timestamps the import and export Fields

- **Generic Run:**
  - Validates incoming Clock against internal Clock
  - Checks that all import Fields are at the current time
  - Timestamps the export Fields at the current time

- **Generic Finalize:**
  - NOOP
CMA elements provided by Generic Component Code

NUOPC_Connector

- **Generic Initialize:**
  - Constructs a list of matching Fields between its import State and export State
  - Pre-computes a RouteHandle for the paired Fields

- **Generic Run:**
  - Executes the RouteHandle
  - Updates the timestamps on the export Fields to match the timestamp on the import Fields

- **Generic Finalize:**
  - Releases the RouteHandle
Subjective look at different Template Techniques

- “Best practices” as a list of conventions and rules.
  - Cumbersome, error prone, difficult to enforce, requires code modifications as conventions change.

- Coding examples to be used as copy-and-paste templates.
  - Easy to introduce errors, actual code diverges from template, difficult to maintain compliance when templates change.

- Automatic code generation.
  - Actual code diverges from originally generated version, incorporating existing changes into re-generated code (e.g. new version) is difficult. Challenging for the user to debug the end result code.

- Generic library code with hooks for specialization.
  - Well established OOP concept (abstract classes). All of the logic visible in the call trace. Prepend actual Component name to all log messages. Compliance checker “visualizes” the Component interactions.
Adoption & Activities

- The Navy NOGAPS/NAVGEM and HYCOM coupled system
- The Navy COAMPS coupled system
- The NOAA Environment Modeling System (NEMS) from NOAA NCEP EMC
- The NOAA Climate Forecast System (CFS) from NOAA NCEP EMC
- The WaveWatch 3 model from NOAA NCEP EMC
- The MOM5 ocean model from NOAA GFDL and CICE sea ice model from DOE/Los Alamos
- The GEOS-5 atmospheric general circulation model from NASA Goddard Space Flight Center
- The Ionosphere Plasmasphere Electrodynamics model from the NOAA Space Weather Prediction Center
- The NASA Goddard Institute for Space Studies Model E
- The Community Earth System Model from NCAR/DOE (currently infrastructure)
Thank You!

http://earthsystemcog.org/projects/nuopc/

esmf_support@list.woc.noaa.gov