Minutes
for
WRF Executive Oversight Board (ExOB)[1]
Meeting 7 (2007-1)
NOAA/OAR/ESRL/GSD, Boulder, CO
31 July 2007

Attendees: Tim Killeen (NCAR), Simon Chang (NRL), Patrick Condray (AFWA), Robert Winokur (N7C), Louis Uccellini (NCEP), Steve Koch (ESRL), David Knapp (ARL), Stan Benjamin (FAA), Nelson Seaman, Robert Gall, Greg Mandt, Joe Klemp, Greg Holland, Sandy MacDonald, Daniel Rozema, Rich Wagoner, Louisa Nance, Sreela Nandi, and Fred Toepfer (via phone).

1. Briefing 1: Meeting Agenda and Objectives

Dr. Koch welcomed everyone to ESRL/GSD and opened the meeting. Dr. Seaman (PC) briefly reviewed the agenda for the ExOB meeting and introduced the primary objectives, as follows:

- ExOB provide guidance to DTC Director based on preliminary response to…

  (1) draft version of the new DTC Management Charter, and

  (2) proposal for a NOAA Cooperative Agreement to establish a path for transfer of resources from NOAA to NCAR for operating the DTC.

- Review and discuss implications of wider utilization of ESMF as per draft NUOPC MOA and other recent documents.

- ExOB provide guidance to Program Coordinator and DTC Director on recommended path forward to ensure WRF will remain responsive to the needs of both research and operations communities as ESMF matures and NUOPC recommendations are refined and implemented.

2. Briefing 2: Overview of NOAA/OAR Mission

Dr. Alexander MacDonald (OAR/ESRL) began by explaining NOAA's strategic plan, goals and programs, which span ecosystems, climate, weather/water, commerce/transportation, and mission support. NOAA/OAR supports the goals of NOAA by conducting environmental research, providing scientific information and leadership, and transferring research into products

[1] All acronyms used herein appear in list at end of these minutes.

and services to meet the economic, social, and environmental needs of the Nation. OAR is conducting extensive research on climate and climate forcing, including observations and analysis of the atmosphere and oceans. Climate modeling includes predictions and projections. Another major theme at NOAA/OAR is in weather and air quality research, where new science and technology is infused into environmental modeling. OAR also is participating in ocean observing, mapping and modeling to support tsunami research and warning capability.

Dr. MacDonald went on to explain ESRL's organization, which was created as part of OAR's recent reorganization. ESRL consists of 577 staff in four divisions and as of 2004, had a budget of $88 million. Innovative research in global modeling at ESRL includes a finite-volume system on an icosahedral geodesic grid. ESRL's goal is to be running 10-day weather predictions using this model at 15-km resolution by the end of 2007. ESRL contributes directly to the WRF project by hosting a node of the Developmental Testbed Center (DTC) and development of the Rapid Refresh WRF model scheduled to replace the RUC model in NCEP operations.

3. Briefing 3: Overview – WRF Program Status

Dr. Seaman began the overview by briefly reviewing chief successes of WRF. These include:

- development of two advanced NWP dynamical cores,
- development of the first versatile software framework designed specifically for NWP,
- establishment of a common code repository to facilitate management and support of shared end-to-end WRF codes,
- establishment of a shared Development Testbed Center,
- implementation of WRF versions in operations at two U.S. operational prediction centers, plus numerous government and commercial providers on four continents, and
- use of WRF codes by thousands of researchers worldwide.

Notable WRF system advancements were reviewed next. These include a lengthy list of new capabilities released in the WRF version 2.2 repository code in December 2006. Among these are four-dimensional data assimilation (nudging) in ARW, replacement of the old standard initialization (SI) code by a new WRF Preprocessing System (WPS) and a one-way nested version of NMM. Version 3.0 of WRF is planned for release about March 2008 and is expected to include a global capability for ARW, significant restructuring of the WRF software framework and numerous other additions. By Spring 2008, DTC also plans further release of a versatile Model Evaluation Tool (MET) for performing model verifications (for WRF and potentially other models as well). As WRF's capabilities grow, the community using WRF continues to expand. At present there are over 5000 registered users of WRF worldwide, with at least 15 nations running operational versions in N. American, S. America, Asia and Europe.

Several examples of recent WRF research developments and applications were presented, representing only a small part of the innovative ideas being pursued by the partnering organizations and outside researchers in the NWP community. The presentation demonstrated the value of WRF as a means of collecting new research codes and widely dispersing them across the science community to foster further testing and evaluation.

Next, the briefing reviewed the latest WRF implementations entering operations since April 2006. These include NCEP's implementation of WRF-NMM and WRF-ARW in the SREF (ensemble) system and replacement of Eta by WRF-NMM in the NAM domain. For hazardous weather prediction NCEP recently has made both WRF versions operational on large 4-km domains covering about three fourths of the CONUS. These high-resolution WRFs are run twice daily without convective parameterizations. Culminating from five years of experimental collaboration by researchers and operational forecasters testing and evaluating new versions of WRF at SPC, this new operational modeling capability demonstrates how WRF is accelerating the flow of new science and technology into operations. NCEP also introduced the initial version of a Hurricane WRF-NMM into operations on June 19, 2007. HWRF's capabilities are expected to grow over the next several years with the addition of advanced components for ocean modeling, wave modeling, storm surge, etc.

Meanwhile, in 2006 AFWA implemented WRF-ARW into operations in its classified domains. In the future AFWA will replace its numerous unclassified MM5 domains with a smaller number of WRF-ARW domains outside North America. Over North America AFWA will adopt and use NAM (WRF-NMM) datasets generated by NCEP, which is another example of how WRF allows operational centers to leverage each other's capabilities and conserve resources. At the same time, AFWA will use NCEP GFS (global) datasets to replace all 45-km MM5 domains. The timetable for transition of each AFWA modeling product currently generated by MM5 will depend on ensuring that output datasets contain all required variables, product delivery schedules are maintained and accuracy of products for the warfighter are at least as skillful as those being replaced. By requiring fewer WRF-ARW domains and expanding use of NCEP datasets over North America, AFWA will reduce its overall computational requirements for deterministic model solutions and thus help free resources for a future DoD joint ensemble prediction system.

Dr. Seaman finished the overview briefing by outlining key provisions of the plan developed by NCAR for managing the WRF code repository. The plan includes a new community-based Developers Committee to help regulate which codes are accepted as Contributed Code entering the WRF repository. Meanwhile DTC is developing a document to define requirements for elevating Contributed Code to become WRF Reference Code, based on documentation, assurance of interoperability with the rest of WRF, testing, evaluation, etc. Under the code management plan, joint WRF tutorials are now being held and WRF documentation will be unified to describe all repository codes in a single consistent set of documents. The ExOB expressed no objections to the code management plan. MMM and DTC will have responsibility for its implementation. (See action item in Section 9 below).

Lastly, Dr. Seaman described three challenges currently facing WRF:

- Need to review and execute agreements drafted to manage and resource the DTC in Boulder, including
    - NOAA Cooperative Agreement to define a DTC five-year plan and establish a means of transferring funds from government to NCAR, and
    - DTC management charter to provide oversight and to guide ongoing day-to-day operations;

- Need to implement all provisions of the WRF unified code management plan.
- Need to develop an effective plan for evolving the WRF modeling system as ESMF becomes more capable and widely utilized.

- *ExOB discussion related to overview of WRF program status*

Following the briefing, the ExOB raised some questions and offered comments. Dr. Uccellini pointed out that slide 10 showing an example from the 2007 SPC Spring Hazardous Weather Experiment should be modified to indicate the WRF-ARW also was used. Dr. Seaman will correct the slide.

Dr. Chang asked why hasn't the two-way moveable nested grid version of WRF-NMM, used in NCEP's operational Hurricane WRF, been installed in the WRF repository. Drs. Uccellini and Gall explained that the code for the two-way moveable nested WRF-NMM was developed over a period of months using WRFv2.0 as the base code. Meanwhile, the WRF repository was upgraded twice. It will take additional time and effort to modify the moveable nested-grid code to be compatible with the currently supported WRFv2.2 (as updated since its release), at which point it can be installed in the repository. Once in the repository it will be much easier to maintain the code when new WRF versions are created and released.

Col. Condray pointed out that AFWA's development of new WRF-ARW domains outside North America is done in conjunction with the Navy to minimize needless redundancies. Dr. Uccellini and Col. Condray then explained other ways in which interagency leveraging is taking place to optimize use of resources.

Dr. Uccellini said that the view sometimes expressed that WRF is a failed program is clearly contradicted by the many successes of WRF on display today. We have come a long way toward realizing the goals of WRF. Now we must guide WRF's transformation to be able to succeed in a modeling world where ensembles become the leading approach for forecasting. WRF provides the operations community a viable way to advance in lock step with the research community, achieving more rapid and efficient growth in capabilities, forecast skill and value to the customer. Col. Condray agreed with this assessment, saying we have already received great benefits from WRF. However, continuous attention will be needed to guide the WRF program, so we don't end up in a situation where each organization pursues its unique mission/goals in a way that leads us to work against each other's interests.

Dr. Koch noted that, in regard to development of agreements for governing the DTC, there is a need for an internal MOU covering ESRL/GSD's participation in the Boulder DTC. The proposal by NCAR for a NOAA Cooperative Agreement will only cover the NCAR node. This issue is captured as an action item (see below, Section 9).

4. Briefing 4: Report of the WRF Research Applications Board (WRAB)

Dr. Klemp explained the purpose of the WRAB is to represent the interests of the research community in WRF. This includes individuals from a wide range of organizations, including those in academia and the private sector, who are not represented on the ExOB.

The WRAB's focus has been to monitor WRF research activities and to identify opportunities where enhancement of WRF's modeling capabilities would provide further opportunities to advance research. This process is not designed to impose priorities on researchers, but to identify and prioritize model development work the research community indicates is needed to pursue its goals. The WRAB also promotes the formation and functioning of WRF working groups, provides input for annual WRF user workshops and acts as a voice for a wide range of researchers to express their concerns to the WRF partnership. The WRAB's work has culminated in a WRF research strategic plan developed in 2005-2006 and delivered to the ExOB in January 2007. Based on input from scores of researchers in labs, universities and the private sector, the strategic plan identifies the chief WRF development priorities and opportunities for research advancements using WRF over the next 5-10 years.

Dr. Klemp continued by describing the growing number of WRF users, now totaling over 5000 from 91 countries. At the 2007 WRF Users Workshop, 220 scientists from 25 countries took part. In addition to science presentations, posters and panel discussions, the workshop provided opportunity for 11 self-organized working groups to meet. These were very well attended and have stimulated active exchange of ideas and software to enhance research progress.

Next, a cross-section of recent WRF research was given, including new boundary layer parameterization approaches, vertical grid nesting, adaptive time steps and immersed boundary methods for use with steep terrain. Most of these applications have been developed initially in ARW, but can be transferred to NMM if found to have sufficient merit. The presentation also demonstrated applications of WRF at the NWS Marquette, MI, forecast office, where a version provided by Bob Rozumalski (COMET), called WRF Environmental Modeling System (EMS), has led to a creative merging of research and operational goals. Other notable WRF research applications were displayed from SPC's 2007 Hazardous Weather Testbed, NOAA/GSD's WRF-Chem model development, and NCAR's data assimilation development. For the 2007 hurricane season, NCAR plans to conduct modeling research in real time at resolutions down to 1.33 km using an EnKF for initialization. Additional work will test a 32 member tropical ensemble, while idealized studies will investigate eyewall structure with grids as fine as 0.185 km. NCAR is also testing a new global version of ARW which will be used for nested regional climate modeling, among other applications.

Lastly, Dr. Klemp explained plans to extend the WRF software framework to allow a "bottom-up" approach to coupling of "ESMF-ized" WRF components. Once completed, users will be allowed to selectively employ ESMF functionality based on their application requirements.

- *ExOB discussion following the WRAB report*

The WRAB report sparked an extensive open discussion. Dr. Winokur asked who has access to WRF codes and whether this might raise questions about information assurance (IA) and security. In further discussion the ExOB agreed that IA is a growing issue for all modeling systems used for military and civilian operations and by the research community as well.

Dr. Koch asked if the WRF EMS versions supported to the WFOs by COMET are able to maintain physics interoperability developed for the repository versions. Discussion concluded that physics interoperability is not assured in current EMS versions, since they were created by both extracting codes out to the repository and by importing other codes directly from NCEP. Dr. Gall said a priority for DTC will be to work with COMET to ensure future updated versions of the WRF EMS will have the physics interoperability desired by users.

Dr. Seaman pointed out the progress made over the past five years through the SPC Hazardous Weather Testbed is quite remarkable, leading to more advanced physics suites well-adapted to fine scales and without the need for parameterized deep convection. Only a few years ago, it appeared that operational implementation of models on large domains with 4-km resolution would not be feasible for many years, but WRF has enabled the process to be accelerated so that these models are now operational. This represents a notable success for WRF and the research-operations partnership.

Dr. Chang asked if the ARW hurricane forecasts tested by NCAR were conducted with observed BCs or forecasted BCs. Dr. Klemp replied that only forecasted BCs were used. Dr. Chang emphasized that evaluation of models for hurricane predictions requires running over multiple years because the tropical environment can change significantly from year to year. Dr. Klemp indicated this is NCAR's intent. For 2007 the ARW for hurricanes will be run with many enhancements (see above) and Dr. Holland confirmed that MMM will re-run all cases from the previous three years using this upgraded ARW.

In further discussion it was generally agreed that both deterministic and ensemble approaches would be necessary to improve tropical storm predictions in the future. This will require much research, particularly since there is a large gap in our knowledge of how to construct effective tropical ensembles. The multi-model "super-ensemble" approach used by Florida State University is a helpful indicator that tropical ensembles can work, but better approaches are needed to gain greatest value from them.

Dr. Killeen suggested that progress on tropical storm predictions could be accelerated by setting up a multi-year forecasting testbed similar to SPC's highly successful Hazardous Weather Testbed. Dr. Holland agreed, as did several others. A first step might be realized soon, since DTC is now hiring scientists to support and work with hurricane codes received from NCEP (HWRF) and NCAR (ARW for hurricanes). This can provide important infrastructure to assist in creating a tropical storm forecasting testbed.

Dr. Killeen also asked why slide 23 of the WRAB report called for expanded testbed facilities. Is DTC not able to handle the demand? Dr. Gall replied that with current resources DTC is able to conduct only one or two major evaluation experiments per year. Dr. Klemp added that one outcome of the WRAB strategic planning process was a growing recognition that many areas of

NWP require extensive evaluations involving large resources in order to accelerate progress. Thus, there is interest in having additional types of testbeds, besides those currently anticipated as being within the scope of DTC staff skills and resources. For example, an air-chemistry testbed has been suggested.

Dr. Holland told the ExOB experience has shown that WRF needs wider representation from different parts of the research community, including academia. Dr. Gall said the natural advocate for academia is NSF, which was invited to this meeting, but chose not to attend. Dr. Uccellini said NSF has steadfastly refused to support a community modeling system, even though they are clearly the right group to represent the research community on the ExOB. Dr. Killeen added that one of the problems making it difficult to engage NSF is the recent extensive personnel shakeups within that organization. He suggested that perhaps the ExOB could invite a respected senior academic leader to urge NSF to join the WRF partnership. Dr. Uccellini agreed with this recommendation.

Dr. Uccellini said he wanted to correct a misperception voiced during the WRAB presentation. Contrary to what was said, NCEP is not withdrawing from WRF or disengaging from the research community. NCEP is working closely with researchers in climate modeling, space modeling, global modeling and the data assimilation community, including a number of units at NCAR engaged in several of these fields to incorporate the NCEP model suite within the community-based Earth System Modeling Framework (ESMF). All the research teams are agreed to using ESMF, which is being developed chiefly by NCAR under the leadership of Cecelia Deluca. NCEP is not developing an independent software framework or another version of ESMF, but rather is contributing to the NCAR community-based version of the ESMF.

Dr. Holland suggested that perhaps it is time to bring the technical experts on software development together again to assess the way forward.

5. Briefing 5: DTC Status and Plans

[To help the meeting remain on schedule, Dr. Gall gave Briefing 6 next. To view the minutes in the order the meeting was conducted, advance to Section 6 and then return to Section 5.]

The briefing on status and plans of DTC began with a review of recent activities and accomplishments. Chief among these were WRF core intercomparisons conducted to support development of the Rapid Refresh WRF, implementation of a joint tutorial covering both cores and a wide range of physics options, release of new WRF verification software (Model Evaluation Tool, MET), and selection of successful 2007 proposals for the DTC visitor program. In addition DTC is developing a set of requirements for contributed code to be elevated to reference status. These include making sure the code is thoroughly tested for a wide range of regimes, maintains the interoperability of WRF components, and is adequately documented. As part of this process, DTC will develop WRF Testing Framework (WTF) software to make it easier to carry out the necessary testing of contributed codes.

Dr. Gall explained that the core intercomparisons in 2006 were based on 120 cases (30 per season) run for 24 h at a resolution of 13 km and with 50 vertical levels. The experiments were carefully designed to minimize differences between the models, such as the frequency at which physics was called, distribution of vertical layers and model domains. Results demonstrated the WRF cores performed nearly the same, with mostly small differences in statistical skill, sometimes favoring one model and sometimes the other. Statistical significance tests verified only a few differences, although in absolute terms they were quite small. For example, ARW had lower RMS errors for wind speed near the tropopause, while NMM had lower speed biases in the same region. DTC allows users to decide how to interpret its evaluation statistics according to the user's application requirements.

Dr. Gall also reported DTC is designing another round of core intercomparisons that will extend the forecasts to 60 h to better understand how the cores affect error growth in mid-range mesoscale predictions. In consultation with model development organizations, the new tests will further reduce potential sources of differences in model configurations, making the new tests the "cleanest" comparisons performed to date.

The Model Evaluation Tool (MET) was designed for WRF verifications by a team of DTC scientists from GSD and NCAR and constructed at the NCAR DTC. It includes the first version of object-oriented statistical verification tools supported to users for evaluating local precipitation features predicted by high-resolution models. MET supports the I/O modes used by NCEP and produces widely used standard (legacy) statistics used by many scientists in research and operations. Planning for future expansion of MET is underway, with the GSD DTC expected to lead the development.

Dr. Gall also summarized recent and projected growth in DTC staff and budget. DTC funding comes primarily from NOAA, AFWA and NCAR, with some additional resources provided by FAA and NSF. As resources grow, the top priority at DTC will be to establish user support for hurricane codes provided by NCEP and NCAR and to promote testing and evaluation of those codes. Components eventually will include the full end-state operational system: moveable nested-grid atmospheric model, an ocean model, a wave model and a storm surge model. Ultimately, as the expansion phase is completed, it is expected that DTC will level off around FY11-FT12 with 22 FTEs and a budget on the order of $5M/yr (contingent on available resources).

- *ExOB discussion following presentation of the DTC status briefing*

Dr. Uccellini wondered whether the MET verification system is designed to meet NWS needs. Dr. Koch said that further capabilities could be added to MET, but it's necessary to first identify who will be NOAA's chief customers for those capabilities. Dr. Uccellini replied that NWS actually has multiple customers who will need to be considered. Dr. Seaman pointed out that a desirable feature of MET is that it supports the standard statistics most commonly used in NWP, while adding new object-oriented precipitation verification statistics. This will provide ready access to new verification methods, allowing researchers and operational scientists to become more familiar with them over time.

Dr. Holland suggested that DTC's protocols for testing contributed WRF codes and elevating them to reference status could include examining the software for possible "rogue" codes. This would fulfill the need for information assurance expressed by all the organizations. Col. Condray agreed this would be very helpful, but the process employed for IA would need to be clearly defined and meet standards. DTC was asked to describe a current process for WRF code review for IA purposes. This will set the stage for DTC to institute a formal process for future WRF code review that will satisfy IA requirements being established by DoD and others.

Dr. Winokur asked what will happen to DTC's plans if the proposed Cooperative Agreement (in response to the NOAA Broad Agency Announcement) is not funded. Dr. Seaman replied that the NOAA funding shown by Dr. Gall already appears in NOAA's line-item budget projections, beginning in FY09, so the availability of the funds is reasonably assured. The Cooperative Agreement (CA) is necessary to establish an efficient method for transferring these funds directly to NCAR for DTC. Currently, NOAA must pass DTC funding through NSF, which subtracts a 5% service fee before forwarding to NCAR.

Dr. Killeen asked the DTC Director how the new funds would be spent. Dr. Gall referred to slides 38-39 of the briefing, which show the proposed five-year DTC budget and corresponding staff assignments. However, as described in the Charter, the DTC Executive Committee has authority to reset DTC priorities and staff assignments would be adjusted accordingly.

Dr. Uccellini asked how the larger number of staff and increased testing and code-support obligations might affect the visitor program. Would the academic community be gradually squeezed out from meaningful participation in the testing and evaluation process? Dr. Gall said that similar expansion of the visitor program depends on availability of funds. Each visitor requires about $20K. NCAR already provides significant funding for the visitor program, with some additional support directly from NSF. Dr. Seaman added this is why it's important for NSF to become an active participant in WRF and to increase its support for the visitor program, which primarily benefits university researchers. Dr. Uccellini recalled that NSF had asked if NOAA was going to support DTC in a meaningful way. Clearly, NOAA has done so and now the WRF partnership needs to apply pressure on NSF to do the same.

6. Briefing 6: DTC Charter – Review and Discussion

Dr. Gall began by saying the proposed DTC Charter has about the same level of specificity as the WRF Agreement in Principle (AIP), but directly addresses management and resourcing issues for the DTC, which are absent from the AIP. The briefing reviewed key background information, including establishment of the ExOB and DTC. It also summarized the four DTC strategic activities established by the ExOB at its April 2006 meeting: Management of WRF codes, support of those codes to the user community, testing and evaluation of contributed codes leading to their elevation as reference code, and administration. The new Charter will provide a management structure for agency oversight through an Executive Committee consisting of one senior executive from each organization signing the Charter. These executives are envisioned as also representing their agencies on the WRF ExOB. Additionally the Charter describes an internal management structure consisting of a Director and Deputy Directors and providing for

input from the signatory organizations (Management Board) and external community customers (Advisory Board). The role of each was described briefly.

The presentation concluded by explaining the Charter commits the signatories to a "good-faith best effort" to participate in providing oversight to the WRF DTC and resources to sustain it, contingent on availability of resources. This language is nearly identical to that in the WRF AIP.

- *ExOB discussion following presentation of the draft DTC Charter*

Dr. Killeen asked if the Charter creates a conflict of interest by having the Advisory Board appointed by the DTC Director, and then having the Advisory Board conducting a review of DTC performance (including performance of the Director). Drs. Gall and Seaman answered that there could be at least the appearance of a conflict. Dr. Killeen suggested the Charter define a different approach for selecting the Advisory Board members that would ensure its independence.

Dr. Killeen also asked if the code evaluations to be conducted by the DTC under the provisions of the Charter would include "bake-offs" (i.e., intercomparisons) of codes, such as alternative tropical prediction systems. Dr. Gall replied yes, as part of the process of ensuring codes attain Reference code status, DTC would conduct intercomparison tests on different WRF codes to identify their relative merits, but not for the purpose of rejecting particular codes. Dr. Koch agreed, saying this would become possible once HWRF and ARW hurricane codes are supported at DTC and suitable staff is available to conduct testing. Toward that end, GSD has advertised a position for an ocean modeler whose duties will include evaluation of alternative hurricane modeling strategies using WRF. Dr. Gall added that one of the chief purposes of DTC is to provide a neutral test facility that could be relied upon because it has no vested interest in any particular set of codes.

Dr. Uccellini said the DTC may be an ideal focal point for conducting test and evaluation studies for tropical storm predictions, both deterministic and ensembles, much the same way that SPC has been an effective focal point for conducting intercomparisons of severe-convection models. Dr. Seaman pointed out that the WRF working group on ensembles already has been active in collecting software designed for creating WRF ensembles. The WG is interested in passing these codes to DTC so they can be installed in the WRF repository as contributed codes and later be supported to the community. Such codes, along with operational ensembling codes, could become a useful basis for building an ensemble model testbed and for use in a tropical modeling testbed, as described by Dr. Uccellini. Dr. Killeen agreed it makes sense to use DTC as a focal point for a hurricane modeling testbed, similar to SPC's hazardous weather testbed encompassing both deterministic and ensemble approaches. Dr. Koch added that the Hurricane Research Division of NOAA/OAR in Miami has expressed interest in working with DTC to establish such a testbed.

Dr. Holland summarized the discussion by saying a hurricane modeling testbed would help address a critical national need for improved tropical warnings and so should be given a high priority. Dr. Gall said DTC will look to the proposed Executive Committee (a subset of the

WRF ExOB) for guidance in selecting the top priorities for extensive testing activities, such as the hurricane modeling testbed. Dr. Uccellini pointed out that it will be important to make sure DTC has the necessary resources to create and sustain an effective testbed.

[To view the minutes in the order the meeting was conducted, return to Section 5 before proceeding to Section 7.]

7. Briefing 7: WRF in the Era of NUOPC and ESMF – Implications and Possible Options

Lastly, Dr. Seaman gave a briefing to describe more fully the challenges to WRF raised by the emergence of ESMF as a preferred framework for many environmental modeling applications. It was noted that the NUOPC study group has recommended ESMF become the common framework used for operational global modeling in the U.S. Since most scientists and administrators expect global and regional models to gradually become unified over time, this raises questions about how WRF must adapt and evolve to remain relevant for the widest range of users. The science of the WRF system is not an issue in this case. Rather the suitability of the WRF software framework for meeting the requirements of the broad range of users, in view of the growing reliance on ESMF, must be considered. The many achievements of WRF and the many opportunities it provides for future advances in research and operations, so clearly displayed at this meeting, make it imperative that a workable solution be found that meets the requirements of both halves of the NWP community.

To assist the ExOB in addressing this issue, the briefing introduced several options and described some of the pros and cons for each. First, it was pointed out that maintaining two community code repositories, one based on the WRF framework and the other based on ESMF, would likely too complex and costly to sustain. As a starting place, three options were given for maintaining a single NWP code repository:

- Option 1: Abandon the WRF framework entirely and adopt ESMF now as the base framework for a new repository to manage all WRF science codes.
- Option 2: Retain the current approach in which the WRF framework is the basis for managing the WRF repository, with access to ESMF provided by an optional "wrapper" that allows WRF to appear as an ESMF-ready component for coupled model applications.
- Option 3: Extend ESMF's capabilities to allow it to provide the key functionalities of WRF, after which the WRF framework can be abandoned as the basis of a repository to manage WRF science codes.

Obviously, these are not the only options that could be proposed. In assessing these options Dr. Seaman addressed six critical questions:

-Can U.S. operations centers gain substantial leveraging opportunities among themselves by transitioning rapidly to an ESMF-only architecture (Option 1)? Yes

-Are there advantages for researchers to have continued access to the most important functions of the current WRF CMI:	Yes
-Can the existing "wrapperized" WRF-ESMF developed by MMM (Option 2) meet the requirements of U.S. operations centers?	No
-Can the existing ESMF alone (Option 1) meet the requirements of the mesoscale research community?	No
-Would collapse of the community infrastructure, including a managed and supported code system, and a DTC for testing and evaluation, lead to less efficient infusion of new science and technology into operations?	Yes
-If resources are made available, can the chief functions of the WRF CMI be replicated as options in a future version of ESMF (Option 3)?	TBD

The briefing concluded with the Program Coordinator's recommendation for addressing the WRF-ESMF framework issue. The recommendation is that the ExOB should appoint a team to:

- Identify the chief functional requirements of the current WRF science codes to be supported by a software framework, from the perspective of limited-area WRF users.

Based on these requirements, appoint a team consisting of technical experts and managers to:

- Determine the status of each desired function in the current ESMF and its development schedule.
- Analyze the potential to develop or to accelerate development of desired functions needed for ESMF to provide the required functionality for the WRF community.
- Develop cost and time estimates for all new functions.
- Report findings to the ExOB.

The goals of this recommended approach are to transition the WRF system into a software framework that preserves and extends the benefits of community modeling to users, accelerates adoption of an ESMF end state, and ensures a design that minimizes impacts to most current WRF users.

8. ExOB Discussion: ESMF Ramifications for WRF

Following Brief 7, the meeting was opened for discussion on how to address the software framework issue in view of ESMF developments and NUOPC recommendations.

Dr. Holland began by asking which ESMF is being discussed. More than one set of software is sometimes referred to as "ESMF." Dr. Uccellini answered that only the version under development at NCAR is under consideration. Dr. Holland objected that NUOPC has made its recommendation to adopt ESMF without any consultation with the research community about what is the best way to go. Dr. Uccellini replied that actually large segments of the research community already have adopted ESMF, including those in global, climate, space and coastal modeling. Dr. Holland emphasized that consultation and consensus building between research and operations is necessary for the mesoscale modeling community to advance in the ESMF era.

Col. Condray said that it is important to understand that most component models that will become part of the national unified operational system envisioned by NUOPC will use ESMF as their framework. The WRF program must adapt to that reality.

A question then was raised whether the ARW would need to be rewritten for it to use ESMF as its sole framework, including the capability for ARW to be coupled to other models via ESMF. Dr. Benjamin said he and Dr. Tom Black have investigated that. Yes, ARW would need significant changes, but there is a clear way to do it that does not appear very difficult. Col. Condray asked if the outcome would be similar to allowing ARW to be called as a subroutine. Dr. Benjamin said that is correct.

Dr. Holland expressed concern that the briefing on ESMF had implied that the WRF framework must be abandoned as a precondition and that only an ESMF-based solution was viable. He recommended that a team representing the research and operations communities be assembled to build a list of requirements for a future software framework with the necessary functionality needed by both groups. That set of requirements then can be examined by a team of technical software experts, who can report recommendations to the ExOB on how to best achieve the requirements. This is generally similar to the recommendation made by the Program Coordinator, but without imposing an ESMF-only approach as a pre-condition. After discussion Dr. Seaman agreed there was no necessity to assume *a priori* that Option 3 was the only solution.

Dr. Koch said there has been disconnect between research and operations about how to move toward an ESMF approach to modeling. However, top-level instructions from NOAA have directed the conversion to ESMF now underway. Navy and NCEP have made commitments to adopt ESMF for their operational models and NUOPC also has recommended the same direction. There is now a great deal of forward momentum behind the ESMF process. It's unlikely the impending change of administration in Washington in 2009 will alter that. It is time to recognize this disconnect cannot continue.

Col. Condray said he considers Option 3 to be the best direction, but we first need to understand the costs and timelines for moving forward. Dr. Seaman added that, given the momentum behind currently divergent approaches for frameworks being pursued by research and operations, the necessary re-alignment needs to begin as soon as possible to avoid making those costs even greater.

Dr. Klemp said he favors adding ESMF functionality to WRF using a bottom-up approach. This would be a fourth option. Dr. Seaman agreed that Dr. Klemp's proposal indeed could combine

the technical functionalities of the two frameworks, as in Option 3, but it would mean users still must deal directly with the WRF framework in order to use WRF science codes. Thus, in effect, it becomes a variation of Option 2.

Dr. Chang asked why it would not be feasible to adopt Option 1. Dr. Holland answered that ARW was written with the functionality of the WRF software framework in mind. As noted in the briefing, the current ESMF is not able to provide that range of functionality.

Dr. Killeen summarized by the discussion by saying it's clear that many of the requirements for WRF, such as portability, accuracy and scalability, exist in or must migrate to ESMF. Phase 1 of the merger (the current "wrapperized" WRF framework) took two years to produce and no functionality was lost along the way. We need to encourage continued convergence through a rational process.

The ExOB concluded that the recommendation made by the Program Coordinator, as modified by Dr. Holland to avoid pre-selecting Option 3, be pursued. The objective is to develop a rational pathway for further merging the frameworks (WRF and ESMF), beginning by defining requirements of WRF users as they are known today.

Dr. Killeen added that the provision in the draft DTC Charter for annual reviews by the Advisory Board is probably too demanding. Less frequent reviews would be more practical. Also the Charter needs to better explain the process for selecting and prioritizing major testing and evaluation activities (a "focus of the year"). Drs. Seaman and Gall agreed to make the requested changes to the draft.

Rich Wagoner pointed out that in the near future DTC will need to check the ITAR (International Traffic in Arms Regulations) requirements for information assurance. These can provide a basis for IA becoming part of a standard process by which contributed codes are modified, tested and evaluated on the way to becoming reference codes.

9. Request for ExOB Decisions: Action Items captured from Meeting 7 (2007-1)

Action Item 7.1-2007: DTC Director and NCAR/MMM Director – Implement the provisions of the **WRF unified code management plan**.

Action Item 7.2-2007: Program Coordinator – Modify slide 10 of Brief 3 to indicate WRF-ARW was also applied in the 2007 SPC Spring Hazardous Weather Experiment.

Action Item 7.3-2007: NOAA/OAR/ESRL/GSD Director – Oversee drafting of an internal NOAA MOU to define GSD's participation in the Boulder DTC and how NWS and OAR will cooperate to provide resources and oversight.

Action Item 7.4-2007: Program Coordinator and DTC Director – Modify the draft DTC Charter to **eliminate a possible conflict of interest** by redefining the method for selecting the Advisory Board members in a way that no longer involves the DTC Director.

Action Item 7.5-2007: Program Coordinator – Modify slide 10 of Brief 7 to indicate that the team assembled to identify functional requirements needed for WRF science codes and to recommended approaches for providing them in the ESMF era not be restricted to consider only Option 3.

Action Item 7.6-2007: Program Coordinator – Assemble a team to identify chief requirements (functions and attributes) for WRF science codes to be supported in a software framework. From these requirements, assemble a team consisting of managers and software technical experts to assess the current status of each function in ESMF, analyze the potential to develop or accelerate development of the desired functions needed for ESMF, and estimate **cost and time to construct a merged framework** having the required functions and attributes.

Action Item 7.7-2007: Program Coordinator and DTC Director – Modify the draft DTC Charter to **reduce the frequency of reviews** performed by the Advisory Board. Annual reviews are impractical and are unnecessary.

Action Item 7.8-2007: Program Coordinator and DTC Director – Modify the draft DTC Charter to better **describe the process for selecting and prioritizing** major testing and evaluation activities.

Action Item 7.9-2007: DTC Director – Lay out a current **process for WRF code review for information assurance (IA) purposes**. This action will set the stage for DTC to have a more formalized process of code review in the future that will address government requirements from an IA standpoint.

Glossary of Common WRF Acronyms
1 August 2007

AFWA	**A**ir **F**orce **W**eather **A**gency
AIP	**A**greement **I**n **P**rinciple
AO	**A**nnouncement **o**f **O**pportunity
ARL	**A**rmy **R**esearch **L**aboratory
AWRP	FAA's **A**viation **W**eather **R**esearch **P**rogram
BAMEX	**B**ow Echo **A**nd **M**CV **Ex**periment
BC	**B**oundary **C**ondition
CA	**C**ooperative **A**greement
COAMPS	**C**oupled **O**cean-**A**tmosphere **M**esoscale **P**rediction **S**ystem™
COMET	**C**ooperative Program for **O**perational **M**eteorology, **E**ducation and **T**raining
CONUS	**CON**tinental **U**nited **S**tates
COPC	**C**ommittee for **O**perational **P**rocessing **C**enters
DoD	**D**epartment **o**f **D**efense
DTC	**D**evelopment **T**estbed **C**enter
DWFE	**D**TC **W**inter **F**orecast **E**xperiment
EFF	**E**xperimental **F**orecast **F**acility
EMS	**E**nvironmental **M**odeling **S**ystem
EnKF	**E**nsemble **K**alman **F**ilter
ESMF	**E**arth **S**ystem **M**odeling **F**ramework
ESRL	**E**arth **S**ystem **R**esearch **L**aboratory
ExOB	**E**xecutive **O**versight **B**oard
FAA	**F**ederal **A**viation **A**gency
FSL	**F**orecast **S**ystems **L**aboratory
FTE	**F**ull-**T**ime **E**quivalent
FNMOC	**F**leet **N**umerical **M**eteorology and **O**ceanography **C**enter
GFS	NCEP **G**lobal **F**orecast **S**ystem
GPRA	**G**overnment **P**erformance and **R**esults **A**ct of 1993
GSD	**G**lobal **S**ystems **D**ivision of ESRL, formerly FSL
GSI	**G**ridpoint **S**tatistical **I**nterpolation
HWRF	NCEP's operational **H**urricane **WRF** model
IA	**I**nformation **A**ssurance
JAG/OCM	**J**oint **A**ction **G**roup for **O**perational **C**ommunity **M**odeling
JCSDA	**J**oint **C**enter for **S**atellite **D**ata **A**ssimilation
MCV	**M**esoscale **C**onvective **V**ortex
MET	**M**odel **E**valuation **T**ool
MM5	Penn State/NCAR **M**esoscale **M**odel, Generation **5**
MOA	**M**emorandum **o**f **A**greement
MOU	**M**emorandum **o**f **U**nderstanding
MMM	NCAR **M**esoscale and **M**icroscale **M**eteorology division
NAM	NCEP's **N**orth **A**merican **M**esoscale domain
NCAR	**N**ational **C**enter for **A**tmospheric **R**esearch
NCEP	**N**ational **C**enter for **E**nvironmental **P**redictions

NCOM	**N**avy **C**oupled **O**cean **M**odel
NOGAPS	**N**avy **O**perational **G**lobal **A**tmospheric **P**rediction **S**ystem
NOAA	**N**ational **O**ceanic and **A**tmospheric **A**dministration
NRL	**N**aval **R**esearch **L**aboratory
NSF	**N**ational **S**cience **F**oundation
NSSL	**N**ational **S**evere **S**torms **L**aboratory
NUOPC	**N**ational **U**nified **O**perational **P**rediction **C**apability
NWP	**N**umerical **W**eather **P**rediction
NWS	**N**ational **W**eather **S**ervice
OAR	NOAA/Office of **O**ceanic and **A**tmospheric **R**esearch
OST	NWS/**O**ffice of **S**cience and **T**echnology
OTC	**O**perational **T**estbed **C**enter
PC	**P**rogram **C**oordinator
POP	**P**rinceton **O**cean **P**rediction model
QPF	**Q**uantitative **P**recipitation **F**orecast
RAMS	Colorado State University **R**egional **A**tmospheric **M**odeling **S**ystem
RR	**R**apid **R**efresh version of WRF
RUC	**R**apid **U**pdate **C**ycle
RTVS	**R**eal **T**ime **V**erification **S**ystem
SPC	NCEP **S**torm **P**rediction **C**enter
SREF	**S**hort **R**ange **E**nsemble **F**orecast
TOR	**T**erms **o**f **R**eference
USWRP	**US W**eather **R**esearch **P**rogram
WFO	**W**eather **F**orecast **O**ffice
WG	**W**orking **G**roup
WJIP	**W**RF **J**oint **I**mplementation **P**lan of COPC
WPS	**W**RF **P**reprocessing **S**ystem
WRAB	**W**RF **R**esearch **A**pplications **B**oard
WRF	**W**eather **R**esearch and **F**orecast modeling system and program
WRF-ARW	**WRF A**dvanced **R**esearch **W**RF dynamical core
WRF-NMM	**WRF N**onhydrostatic **M**esoscale **M**odel dynamical core
WRF-SI	**WRF S**tandard **I**nitialization
WTF	**W**RF **T**esting **F**ramework