Final Report

From the

National Unified Operational Prediction Capability (NUOPC)

Interim Committee

on

Unified Ensemble Operations (UEO)

Final Version

1 October 2009

Produced by the NUOPC Unified Ensemble Operations Committee:

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FIGURES:

Revision Summary

Revision 1, 19 June 2009
(Note that thees page references may not map directly to the pages in the final version.)

Schedule and costs were revised to reflect changing the proposed model resolution upgrade schedule from FY2015 to FY2020 and shifting the originally planned FY2010 costs to FY2011 and beyond. The following describe the changes made to the original 8 May 2009 report:

1. Page 52, Section 9.1, Milestones for FY2010, Figure 18, FY2010 NUOPC Milestones. Delete two milestones, common post-processing toolbox software and agency-specific metrics scorecards. These will be shifted to FY2011 and moved to Section 9.2. Inserted Figure 18 Revision 1.

2. Page 53-56, Section 9.2, Milestones for FY2011, Figure 19, FY2011 NUOPC Milestones. Add text from Section 9.1 on the two milestones, common post-processing toolbox software and agency-specific metrics scorecards that were originally planned for FY2010 and moved to FY2011 because of budget concerns. Inserted Figure 19 Revision 1 the following milestones shifted from FY2010.

Complete joint design of common post-processing toolbox software	4Q FY11
Create agency-specific scorecards	4Q FY11

3. Page 64, Section 9.9.5, Metrics Scorecard. Shifted the NCEP FTE Costs by one year and delay the additional storage equipment by one year, from FY10 to FY11. Text in this section in this section was revised to reflect this change. Inserted Revision 1 Table

Metrics Scorecards	AFWA	FNMOC	NCEP	Timeframe	Total Costs
FTE	2	0.5	1	FY12, FY12, FY11	$560K
Other Costs	0	0	$100K	1QFY11	$100K

4. Page 65-66, Section 9.9.8, HPC Capabilities. Inserted Revision 1 Table to reflect extending the model resolution from the proposed original schedule of 0.5 degree in FY11, 0.25 degree in FY13 and 0.1 degree in FY15, to the revised schedule of 0.5 degree in FY12, 0.25 degree in FY15 and 0.1 degree in FY20.

HPC Capabilities	AFWA	FNMOC	NCEP	Timeframe	Total Costs
FTE	0	0	0		
Other Costs		$1.0M	$1.2M	FY12	$2.2M
Other Costs	$0.8M			FY12	$0.8M
Other Costs	$1.0M	$1.5M	$2.0M	FY15	$4.5M
Other Costs	$1.0M	$1.5M	$2.5M	FY20	$5.0M

5. Pages 67-68, Section 9.9.9, Ensemble Operations. Added text to describe the impact of extending the model resolution from the proposed original schedule of 0.5 degree in FY11, 0.25 degree in FY13 and 0.1 degree in FY15, to the revised schedule of 0.5 degree in FY12, 0.25 degree in FY15 and 0.1 degree in FY20. Inserted Revision 1 Table to show the changes in extending the model resolution upgrades to FY2020.

Ensemble Operations	AFWA	FNMOC	NCEP	Timeframe	Total Costs
FTE	0.5	2	3	2QFY11-2QFY20	$8.8M
Resources	0	0	0		

6. Page 68-69, section 9.9.10, Common Post-Processing Toolbox. Change the last sentence to reflect a one year slip: 2 FTEs will be at each Center from 2QFY11 to 2QFY15 with an additional 0.5 FTEs at each Center for software maintenance. Inserted Revision 1 Table to reflect this change.

FTE	2	2	2	Development 2QFY11-2QFY15	$3,840K
FTE	0.5	0.5	0.5	Maintenance 2QFY11-2QFY15	$1,440K

7. Page 69-70, section 9.9.11, Working Groups/Panels. Inserted Revision 1 Table in this section to reflect a one year shift in the starting dates for the three working groups/panels.

FTE IA & Network Operations	0.5	0.5	0.5	1QFY11- 1QFY17	$1,440K
FTE Ensemble Production	0.5	0.5	0.5	2QFY11- 1QFY17	$1,440K
FTE Ensemble Post-Production	0.5	0.5	0.5	1QFY11- 1QFY14	$720K

8. Page 70, section 9.9.12, Training. Inserted Revision 1 Table in this section to reflect a one year shift in the starting dates for the three working groups/panels.

FTE	1	1	1	1QFY11- 1QFY17	$2,880K
Other Costs	$10K	$10K	$10K	Travel Funds 1QFY11- 1QFY17	$180K

9. Page 71-72, Section 9.10, NUOPC Cost Summary, top of the page, insert Revision 1 Table with FTE Costs, and Other Costs to show the costs of extending the model resolution upgrades to FY2020 from the original FY2015.

Total Tri-Agency Costs for FY10-FY20	**FTE Costs**	**Other Costs**
GRIB2	$80K	
COPC JAG/CMM Enterprise-Enterprise Network	$1,600K	$4,620K
NAEFS IOC 1	$640K	$400K
NCDC Archive	$0.00	$7,000K
Scorecards	$560K	$100K
IA and ODAA	$1,680K	
6 D Data Base	$320K	$1,200K
HPC Capabilities		$12,500K
Ensemble Operations	$8,800K	$0.00
Common Toolbox	$6,240K	$0.00
Training	$4,800K	$300K
Community of Interest/Working Groups/Panels	$5,760K	$0.00
TOTAL	$30,480K	$26,120K

Note:In general, the increased costs of extending the model upgrade schedule to FY2020 reflect the increased FTE costs incurred for the extra 5 years, FY2015 to FY2010

10. Page 72, bottom of the page, table with Fiscal Year Total Costs ($K). Insert Revision 1 Fiscal Year Total Costs ($K) with the summary of costs for each fiscal year to show the impact of shifting cost shifts from FY10 to FY11 and beyond.

		FY10			FY11			FY12			FY13			FY14			FY15	
	AFWA	FNMOC	NCEP	AFWA	FNMOC	NCEP	AFWA	FNMOC	NCEP	AFWA	FNMOC	NCEP	AFWA	FNMOC	NCEP	AFWA	FNMOC	NCEP
Agency Costs (Less Training and Panels) per FY	$113.33	$293.33	$293.33	$1,066.67	$1,246.67	$1,666.67	$2,056.67	$2,256.67	$2,536.67	$866.67	$1,106.67	$1,266.67	$866.67	$1,106.67	$1,266.67	$1,980.00	$2,720.00	$3,380.00
Training per FY	$0.00	$0.00	$0.00	$170.00	$170.00	$170.00	$170.00	$170.00	$170.00	$170.00	$170.00	$170.00	$170.00	$170.00	$170.00	$170.00	$170.00	$170.00
Panels per FY	$0.00	$0.00	$0.00	$240.00	$240.00	$240.00	$240.00	$240.00	$240.00	$240.00	$240.00	$240.00	$240.00	$240.00	$240.00	$160.00	$160.00	$160.00
Tri-Agency Costs (less Training and Panels) per FY		$700.00			$3,980.00			$6,850.00			$3,240.00			$3,240.00			$8,080.00	
Training per FY		$0.00			$510.00			$510.00			$510.00			$510.00			$510.00	
Panels per FY		$0.00			$720.00			$720.00			$720.00			$720.00			$480.00	
Total Tri-AgencyCosts per FY		$700.00			$5,210.00			$8,080.00			$4,470.00			$4,470.00			$9,070.00	

11. Page 73, corrected an error in the original document's pagination to reflect the correct page number (the next page was 65, but should have been 70).

12. Page 74 inserted Revision 1 Spreadsheet to show the changes in funding caused by shifting costs from FY2010 to FY2011 and beyond and extending the model resolution upgrades to FY2020 from the original FY2015.

13. Page 75 inserted Revision 1 Figure 25, NUOPC Milestones and Costs (Part 1) to show the changes in funding caused by shifting costs from FY2010 to FY2011 and beyond.

14. Page 76 inserted Revision 1 Figure 26, NUOPC Milestones and Costs (Part 2) to show the changes in funding caused by shifting costs from FY2010 to FY2011 and beyond.

15. Page 77 inserted Revision 1 Figure 27, NUOPC Milestones and Costs (Part 3) to show the changes in funding caused by shifting costs from FY2010 to FY2011 and beyond.

16. Page 80, Section 12, Addendum. Revised to add a cost consideration point on extending the proposed model resolution from FY2015 to FY2020 and shifting the originally planned FY2010 costs to FY2011 and beyond.

Revision 2, 21 September 2009 (Responses to document reviews)

The following revisions were made in response to comments received from the report reviewers. All substantive revisions have been listed below. Several minor editorial changes were also made for Revision 2.

1. Page 45, comment added to Section 8.5 Data Flow, “Raw ensemble data will also flow to AFWA and the other centers for Step 4 post-processing.”

2. Page 50, added a comment to the end of Section 8.9.2 Scorecard Metrics, “As the centers participate in the review and coordination of proposed model changes, they must weigh the potential benefit of a proposed change with the delay in implementation caused by this level of coordination.”

3. Page 9, Section 5.2.1, corrected the statement to read that 1st Weather Group (1 WXG) is responsible for 3 CONUS Operational Weather Squadrons.

4. Page 24, Section 5.6.2 corrected the acronym IOOS for the Integrated Ocean Observing System.

5. Pages 83-89, Appendix 1, expanded the List of Acronyms to include all acronyms used in the document.

6. Page 29, Section 6, added the sentence, “While the following discussions refer to DoD and DoC, the intent of the Committee’s recommendations are limited to those parts of NOAA (NWS/NCEP), Air Force (AFWA), and Navy (FNMOC) that will be directly participating in NUOPC operations. For example, recommendations for increased IA protection apply only to those agencies within NOAA that will participate directly in NUOPC with the DoD agencies and will not apply to other sections of NOAA.

7. Page 34, Section 6.4.1, added the sentence, “To meet DoD concerns, any Foreign National programmers who provide code directly to the NUOPC DoD operational centers or computer systems, must have completed a satisfactory NACI investigation.”

8. Page 62, Section 9.9, added the sentence, “Most of the costs identified in this report by the UEO Committee are new costs that have not been included in current agency budgets. This report identified these unfunded requirements for agency consideration and future budget planning.”

1. Executive Summary

This summary discusses the purpose of the National Unified Operational Prediction Capability's (NUOPC) Unified Ensemble Operations (UEO) Committee. Subjects discussed will include the UEO Committee's tasks, findings, recommendations, milestones, schedules, and costs needed to achieve a National numerical weather prediction (NWP) ensemble forecast system, including recommendations for implementing NUOPC.

1.1 Purpose

To propose a Concept of Operations (CONOPS) for NUOPC Unified Ensemble Operations, and to define a plan and associated costs to implement this CONOPS.

1.2 Tasks

The UEO Committee approached its purpose by developing a series of six tasks that built upon each other. The committee formed Task Groups assigned to the six tasks and collected information from the representatives of the operational processing Centers, Air Force Weather Agency (AFWA), Fleet Numerical Meteorology and Oceanography Center (FNMOC), and National Centers for Environmental Prediction (NCEP), with additional assistance from committee representatives from the Naval Research Lab (NRL), the National Center for Atmospheric Research (NCAR), and Commander Naval Meteorology and Oceanography Command (CNMOC). The goals of the six tasks were:

- **Task 1 Overview of Agency Missions**

Identify how missions impact customer base, product suite, post processing, production/delivery schedules, etc., and information assurance issues.

- **Task 2 Proposed Information Assurance Approach**

Define Certification and Accreditation (C&A) requirements, processes, network security strategy at each Center, and restrictions on public release of NUOPC software and data.

- **Task 3 Definition of Unified Ensemble Operations Requirements**

Define Unified Ensemble Operations requirements (products, formats, post processing, bandwidth, etc.), and assess North American Ensemble Forecast System (NAEFS) application.

- **Task 4 Proposed Concept of Operations**

Describe how AFWA, FNMOC and NCEP will operate with each other on a daily basis to produce a global ensemble. Construct the "who, what, when."

- **Task 5 Implementation Plan**

Describe costs on a monthly basis using the "who, what, when" from CONOPS, construct the "how and how much."

- **Task 6 Final Report**

Inform the NUOPC Executive Steering Group (ESG) on how to best proceed with NUOPC implementation by summarizing the above results.

1.3 Findings, Recommendations, Milestones, Schedules, and Costs

- **Task 1 Overview of Agency Missions**

The Tri-Agencies have distinctly different missions with different customers, but these differences do not preclude cooperating jointly in a National Ensemble Prediction System.

- **Task 2 Proposed Information Assurance Approach**

The Tri-Agencies have many directives addressing Information Assurance (IA), so NUOPC does not pose unique IA requirements. While the Tri-Agencies' approaches are similar, the actual implementation of IA across each agency may achieve IA objectives differently. The processes of accepting software from external agencies, particularly the Research and Development (R&D) Community, exchanging software among the Tri-Agencies over dedicated Tri-Agency communications networks, like that proposed by the Committee for Operational Processing Centers (COPC) Joint Action Group for Centralized Communications Management (JAG/CCM), and distributing software to the public will require cooperation among the Tri-Agencies. Most likely this will require a "super" Office of Designated Approval Authority (ODAA) to direct both the Department of Defense (DoD) and Department of Commerce (DoC) agencies on the IA approach that must be adhered to by all. The National Polar-orbiting Operational Environmental Satellite System (NPOESS) is looking at similar IA challenges, and NUOPC should follow that program's lead on this issue. The use of software scanning tools to detect malicious code is a practice that should also be implemented at all three operational processing Centers

- **Task 3 Definition of Unified Ensemble Operations Requirements**

The Task Group agreed that both NCEP and FNMOC would produce 20 ensemble members for NUOPC. AFWA will serve as the primary NUOPC post-processing site. The Task Group determined the overall ensemble operations requirements that addressed

1. Standard Output Products
2. Standard Output Format
3. Overall Ensemble Configuration
4. Product Delivery Schedule
5. Post Processing
6. Product Storage/Archive
7. Ensemble Verification Metrics
8. Bandwidth between Centers

- **Task 4 Proposed Concept of Operations**

This Task Group determined that the major milestones for NUOPC in Phase II should include

- Exchange data using Gridded Binary Edition 2 (GRIB2)
- Use the proposed COPC JAG/CCM Enterprise-Enterprise Network for exchange of NUOPC products between Centers

- Achieve the NAEFS Initial Operating Capability (IOC)/NUOPC IOC1
- Establish a data archive at the National Climatic Data Center (NCDC)
- Implement Metrics Scorecards
- Implement common IA procedures directed by the Super ODAA
- Build a common (among all Centers) 6-Dimensional (6-D) Data Base (meteorological parameter – ensemble member – x – y – z –t)
- Upgrade High Performance Computing (HPC) capacities and capabilities to handle projected NUOPC workload
- Conduct Ensemble Operations
- Create a Common Ensemble Post-Processing Toolbox
- Form Necessary Working Groups and Panels for liaison between Centers
- Develop Ensemble Training

The Task Group established a schedule for accomplishing these milestones from FY10 through FY15.

- **Task 5 Implementation Plan**

Estimates for the costs of the milestones were made. A major cost driver is the increase in model resolution from the current ~1.0 degree latitude/longitude to ~0.1 degree latitude/longitude in 7 years. Costs for full-time equivalent (FTE) employees (government and/or contractor) and resources to support the milestones are summarized below:

NUOPC Milestone	**FTEs**	**Resources**
GRIB2 Implementation	**$80K**	
COPC JAG/CMM Enterprise-Enterprise Network	**$800K**	**$1,920K**
NAEFS IOC	**$640K**	**$400K**
Establish long-term archive at NCDC		**$5,500K**
Ensemble Metrics Scorecards	**$560K**	**$100K**
Super ODAA and Common FNMOC/AFWA/NCEP IA Policy	**$880K**	
6-D Data Base	**$320K**	**$1,200K**
HPC Capabilities		**$12,500K**
Joint Ensemble Operations	**$4,400K**	
Common Post-Processing Toolbox	**$5,280K**	
Working Groups and Panels	**$3,600K**	
Training	**$2,880K**	**$180K**
Totals	**$19,440K**	**$21,800K**

- **Task 6 Final Report**

The UEO Committee Final Report contains details for milestones, schedules, and costs described above.

1.4 Findings and Recommendations

The following are UEO Committee findings and recommendations for NUOPC as it moves forward into Phase II Implementation:

- AFWA, FNMOC and NCEP have distinctly different missions with different customers, but these differences do not preclude cooperating jointly in a National Ensemble Prediction System.
- Information Assurance (IA) issues are a concern, but appear manageable for NUOPC operations:
    - While each of the three agencies ultimately traces their IA policies back to the Federal Information Security Management Act (FISMA), the details of these policies and their implementations differ.
    - To address these differences, NUOPC should follow the lead of NPOESS in establishing a "Super ODAA" (Office of the Designated Approving Authority) to consolidate and direct Navy, Air Force and National Oceanic and Atmospheric Administration (NOAA) IA policy implementation at FNMOC, AFWA and NCEP.
    - NUOPC should monitor and encourage implementation of the National Agency Check with Inquiries (NACI) investigation requirement at NOAA.
    - To mitigate risks associated with possible acquisition of software from un-trusted sources, NUOPC should execute a Memorandum of Agreement (MOA) with the Air Force Software Assurance Center of Excellence (ASACoE) to acquire software scanning tools and requisite training in their use. NUOPC should establish uniform policies and procedures at AFWA, FNMOC and NCEP for use of these tools.
    - Procedures for identifying NUOPC software and data whose public distribution will be restricted should be implemented early in Phase II. This may involve designating certain operational NUOPC code as restricted, while releasing a research version that lacks the most current upgrades. Other NUOPC related software may be restricted from distribution, altogether.
    - The Enterprise-to-Enterprise Network Infrastructure proposed by COPC JAG/CCM as the replacement for Defense Information Systems Network (DISN) Asynchronous Transfer Mode Services – Unclassified (DATMS-U) network will nicely satisfy the NUOPC data exchange requirements.
        - COPC JAG/CCM should be encouraged to press ahead with the Enterprise-to-Enterprise DATMS-U replacement.
        - NUOPC must establish a liaison with COPC to ensure NUOPC communication requirements are included in the new Enterprise-to-Enterprise network.

- Consolidated Navy/Air Force/NOAA IA requirements, as defined by the NUOPC Super ODAA, must be folded into the design and implementation of this network.

✦ Construction of the NUOPC CONOPS requires clear tri-agency agreement on:
  - Production Center Roles and Responsibilities
  - Overall Ensemble Configuration
  - Standard Output Products
  - Standard Output Format
  - Product Delivery Schedule
  - Ensemble Post Processing
  - Product Storage/Archive
  - Ensemble Verification Metrics
  - Bandwidth Between Centers

✦ Major Milestones for achieving the NUOPC CONOPS include:
  - Form necessary Working Groups and Panels (Information Assurance and Network Operations; Ensemble Production; Ensemble Post-Production)
  - Upgrade data exchange format between the Centers to GRIB2
  - Achieve NAEFS IOC
  - Implement the COPC JAG/CCM proposed Enterprise-to-Enterprise Network as the replacement for DATMS-U
  - Establish Super ODAA and common FNMOC/AFWA/NCEP IA policy
  - Develop common post-processing toolbox software
  - Define and implement ensemble metrics scorecards
  - Build common 6-D database (parameter-member-x-y-z-t)
  - Establish long-term archive at NCDC
  - Upgrade HPC capabilities and capacities as needed
  - Conduct training
  - Commence NUOPC joint ensemble operations

2. Purpose

To establish and document the National Unified Operational Prediction Capability (NUOPC) Unified Ensemble Operations including the missions, Information Assurance and security, ensemble operations requirements, a CONOPS and Implementation Plan.

3. Introduction

NUOPC is an agreement to coordinate the activities of the Tri-Agency partners NOAA, U.S. Navy and U.S. Air Force) in order to accelerate the transition of new technology, eliminate unnecessary duplication, and achieve a superior National global numerical weather prediction (GNWP) capability. The NUOPC focus is on next-generation systems for GNWP, allowing for possible later expansion into other areas of numerical prediction, with Full Operating Capability (FOC) targeted for fiscal year (FY) 2015. This NUOPC

UEO CONOPS defines the process leading to the operation, maintenance, and management of a national ensemble forecast system across the Tri-Agencies. The NUOPC UEO Implementation Plan (IPlan) defines the roles and responsibilities of the cooperating and coordinating organizations in operating this national ensemble forecast system in terms of milestones, schedules, and cost. Portions of this CONOPS and IPlan will be refined and expanded during NUOPC Program Manager (PM) directed meetings/workshops during Phase II and Phase III of NUOPC (FY10-FY15) as the Tri-Agency's operational processing Centers implement a Nationally Unified Ensemble Prediction System.

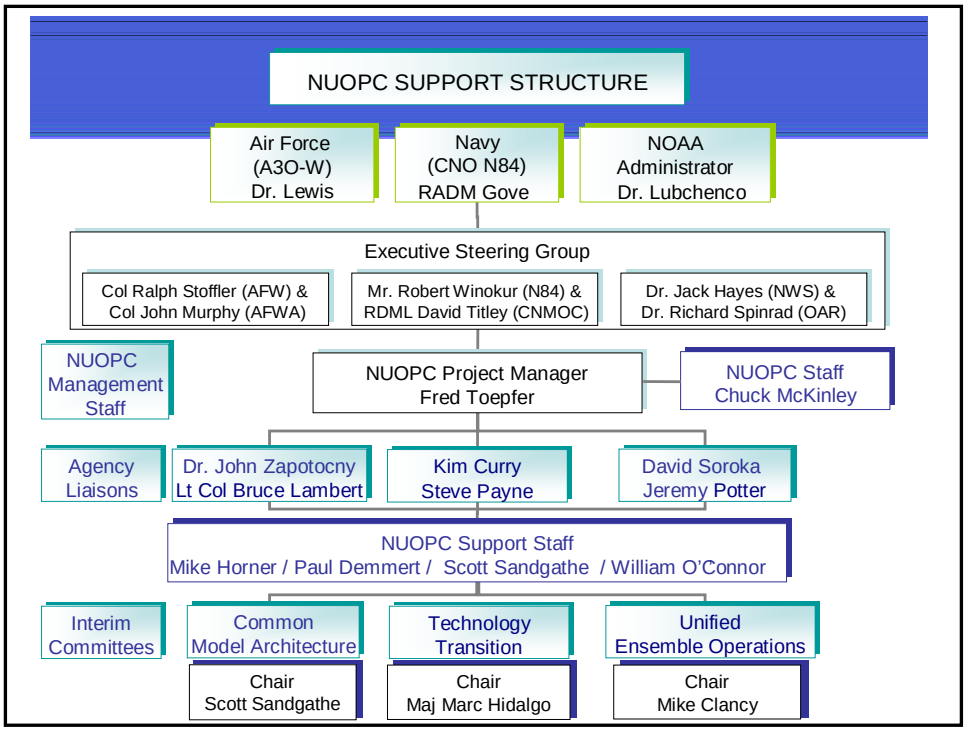

Figure 1. NUOPC Management Structure

3.1 Background

The Tri-Agencies established a NUOPC ESG to work towards achieving NUOPC FOC by FY2015. The NUOPC ESG seated a NUOPC PM to direct a NUOPC support staff and three interim NUOPC committees to complete Phase I of a three-phase NUOPC schedule (see Figure 2) by September 2009. The PM organized three interim NUOPC committees to develop UEO) Technology Transition Processes (TTP), and Common Model Architecture (CMA), respectively. The three committees were also tasked to construct IPlans to guide the Tri-Agency's efforts to produce a NUOPC FOC by 2015. Section 10, Revised NUOPC Phase II and III Schedule and Costs, contains a revised NUOPC Implementation Schedule based on the results of the UEO Committee milestones and costs.

3.2 UEO Task Format and Detail

In terms of format and level of detail, the UEO task deliverables took the form of PowerPoint briefs, with the information presented in an outline/bulletized form, plus any supporting information deemed necessary to clarify the meaning and intent of the information provided.

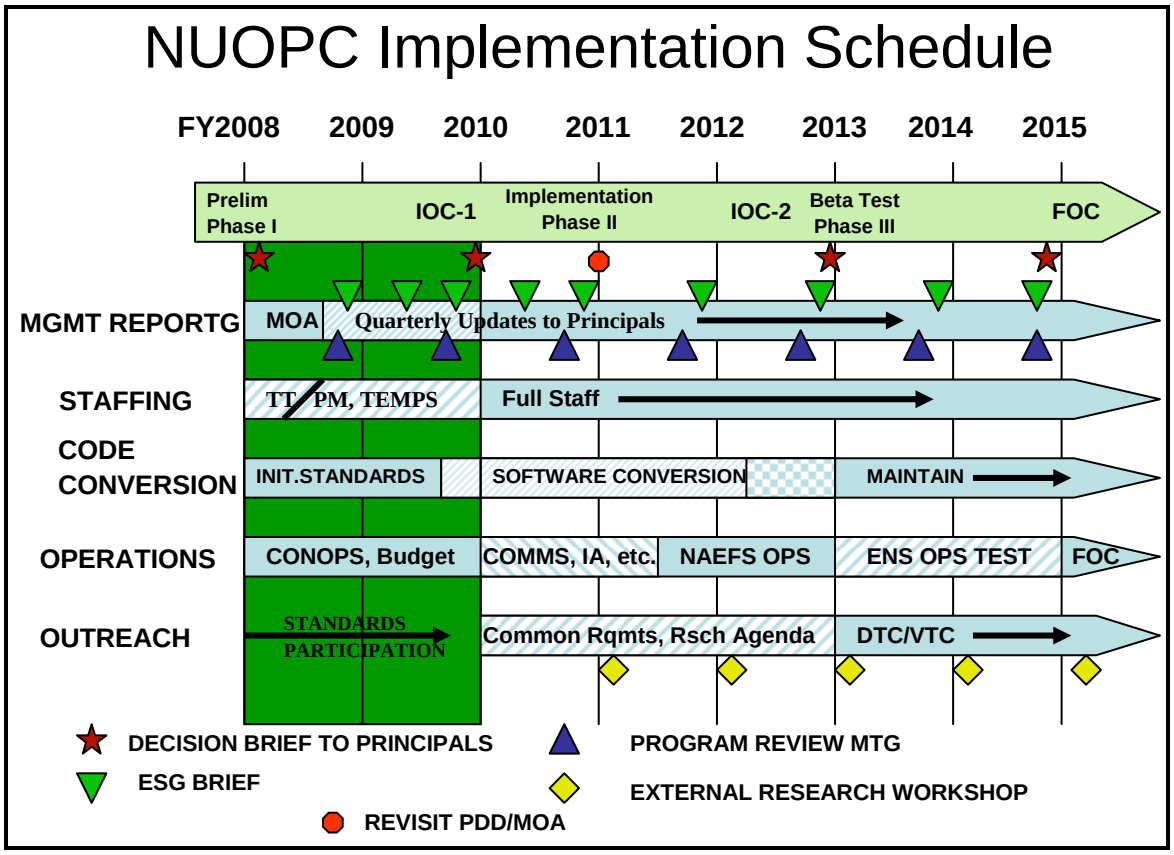

Figure 2. NUOPC Implementation Schedule

4. UEO Committee Tasks:

4.1. Overview of Agency Missions

Identify how missions impact customer base, product suite, post processing, production/delivery schedules, etc., and information assurance issues.

4.2. Proposed Information Assurance Approach

Define C&A requirements, processes, network security strategy at each Center, and restrictions on public release of NUOPC software and data. Involve CMA/TTP.

4.3. Definition of Unified Ensemble Operations Requirements

Define Unified Ensemble Operations requirements (products, formats, post processing, bandwidth, etc., and assess NAEFS application. Involve CMA/TTP.

4.4. Proposed Concept of Operations

Describe how AFWA, FNMOC and NCEP will operate with each other on a daily basis to produce a global ensemble. Construct the "who, what, when."

4.5. Implementation Plan

Describe costs on a monthly basis using the "who, what, when" from CONOPS, construct the "how and how much."

4.6. Final Report

Inform the NUOPC ESG on how to best proceed with NUOPC implementation by summarizing the above results.

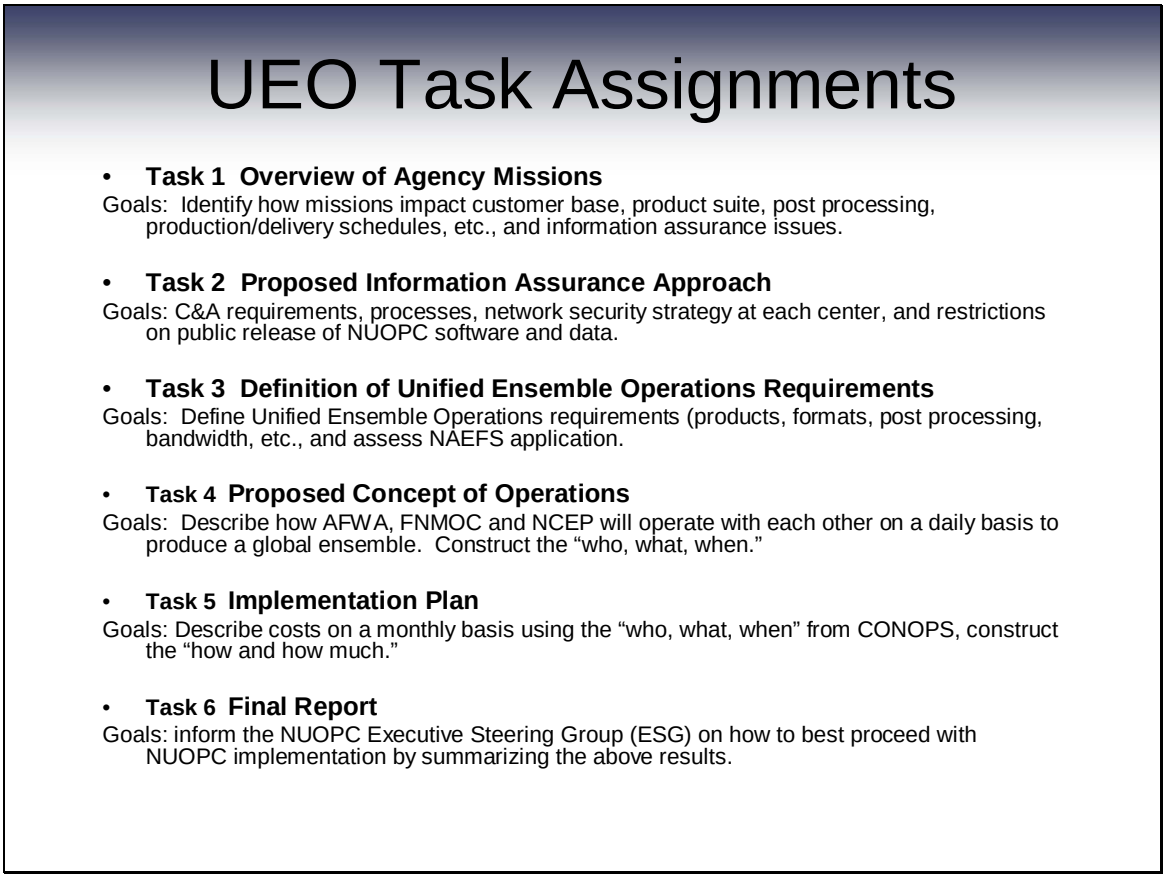

Figure 3. UEO Tasks and Goals

5. Task Findings and Recommendations

5.1 Mission Statements

5.1.1 AFWA

Maximizing America's Power through the Exploitation of Timely, Accurate, and Relevant Weather Information; *Anytime, Everywhere*

5.1.2 FNMOC

To provide high quality, relevant, and timely meteorological and oceanographic support to the Fleet.

5.1.3 NCEP

Deliver science-based environmental predictions to the Nation and the global community. Collaborate with partners and customers to produce reliable, timely, and accurate analyses, guidance, forecasts and warnings for the protection of life and property and the enhancement of the national economy.

5.2 Agency Introductions

5.2.1 AFWA

AFWA is the environmental intelligence Center for all Army and Air Force peace/combat operations around the world.

- 24x7 operations provide tailored support to unique warfighter needs
- Joint and Coalition support provided to Unified Commands
- On-demand support provided to Homeland Security Agencies
- Reachback support provided to all DoD warfighters

- AFWA consists of:
  - 1st Weather Group (1 WXG)—responsible for 3 CONUS Operational Weather Squadrons
  - 2nd Weather Group (2 WXG)—responsible for global reachback operations of AFWA
  - The Field Operating Agency "A" Staff
  - The Air Force Combat Weather Center (AFCWC)—responsible for fielding new equipment
  - Nine additional geographically separated units

5.2.2 FNMOC

Fleet Numerical is the Navy's Numerical NWP Center.

- Global and regional numerical weather and ocean prediction models

    - Weather satellite imagery products
    - Meteorological tactical decision aids, data, and data fusion products
    - 24x7 operational support of Naval, Joint, Coalition and National Missions worldwide via high-bandwidth communications
    - Scheduled and on-demand products
- Fleet Numerical is a 24x7 Global Operational Reachback Center
    - Tailored support to Naval, Joint, Coalition, and National Missions
    - Target Area Meteorology and Oceanography (METOC) (TAM) exploitation of National Technical Means (NTM) satellite imagery
    - Direct support for Submarine Enroute Weather Forecasting (SUBWEAX)
- Fleet Numerical is the Navy's Operational Supercomputing Center
    - ~30 Tera Floating Point Operations Per Second TFLOPS (10^{12} FLOPS) peak capacity as of September 2008
    - Hardened for crisis operations
    - Protected to DoD/Navy IA Standards
    - Able to support a wide variety of operational reachback applications

5.2.3 NCEP

The Office of the Director, National Centers for Environmental Prediction, gives overarching management to the nine Centers, which include the:

- Aviation Weather Center (AWC) provides aviation warnings and forecasts of hazardous flight conditions at all levels within domestic and international air space.
- Climate Prediction Center (CPC) monitors and forecasts short-term climate fluctuations and provides information on the effects climate patterns can have on the nation.
- Environmental Modeling Center (EMC) develops and improves numerical weather, climate, hydrological and ocean prediction through a broad program in partnership with the research community.
- Hydrometeorological Prediction Center (HPC) provides nationwide analysis and forecast guidance products out through seven days.
- NCEP Central Operations sustains and executes the operational suite of numerical analyses and forecast models and prepares NCEP products for dissemination.
- Ocean Prediction Center (OPC) issues weather warnings and forecasts out to five days for the Atlantic and Pacific Oceans north of 30 degrees North.
- Space Weather Prediction Center (SWPC) provides space weather alerts and warnings for disturbances that can affect people and equipment working in space and on earth.

- Storm Prediction Center (SPC) provides tornado and severe weather watches for the contiguous United States along with a suite of hazardous weather forecasts.
- Tropical Prediction Center (TPC) includes the National Hurricane Center and provides forecasts of the movement and strength of tropical weather systems and issues watches and warnings for the U.S. and surrounding areas.

5.3 Agency Infrastructure

The following sections describe the physical infrastructure present at the operational processing Centers.

5.3.1 AFWA

- 2nd Weather Group operates & maintains a 24x7x365 classified and unclassified production cycle
  - Ensures consistent/timely receipt and processing of global geostationary and polar orbiting satellite data availability for on-demand/subscription users
  - Ensures consistent/timely terrestrial meso-scale and space weather model runs available for tailored post-production & on-demand/subscription users
  - Ensures consistent/timely production of global cloud forecast guidance to warfighters and the National Intelligence Community for on-demand /subscription users
  - Collect/process/disseminate meteorological and space weather info
  - DoD lead agency for applied climatology and weather Modeling and Simulation (M&S)
  - Maintains Joint Air Force/Army Weather Information Network(JAAWIN)—warfighters reachback tool of choice
- Result
  - 800K products/day. With 13 million reach back web hits/month and 450 gigabytes (GB) downloaded/month

5.3.2 FNMOC

- Operations Center
  - Manned 24x7 by a team of military and civilian watch standers
  - Focused on operational mission support, response to requests for special support and products, and customer liaison for DoD operations worldwide
  - Joint Task Force capable
  - The Navy's Worldwide Meteorology/Oceanography Operations Watch
  - Operates at UNCLAS, CONFIDENTIAL and SECRET levels
- Sensitive Compartmented Information Facility (SCIF)
  - Extension of Operations (Ops) Center

- Operational communications (including secure video teleconferencing), tasking and processing elevated to the Top Secret-Sensitive Compartmented Information (TS/SCI) level if needed
- Includes significant supercomputer capacity at TS/SCI level

- Ops Run
  - Scheduled and on-demand 24x7 production
  - 6 million meteorological observations and 2 million products each day
  - 15 million lines of code and ~16,000 job executions per day
  - Highly automated and reliable

5.3.3 NCEP

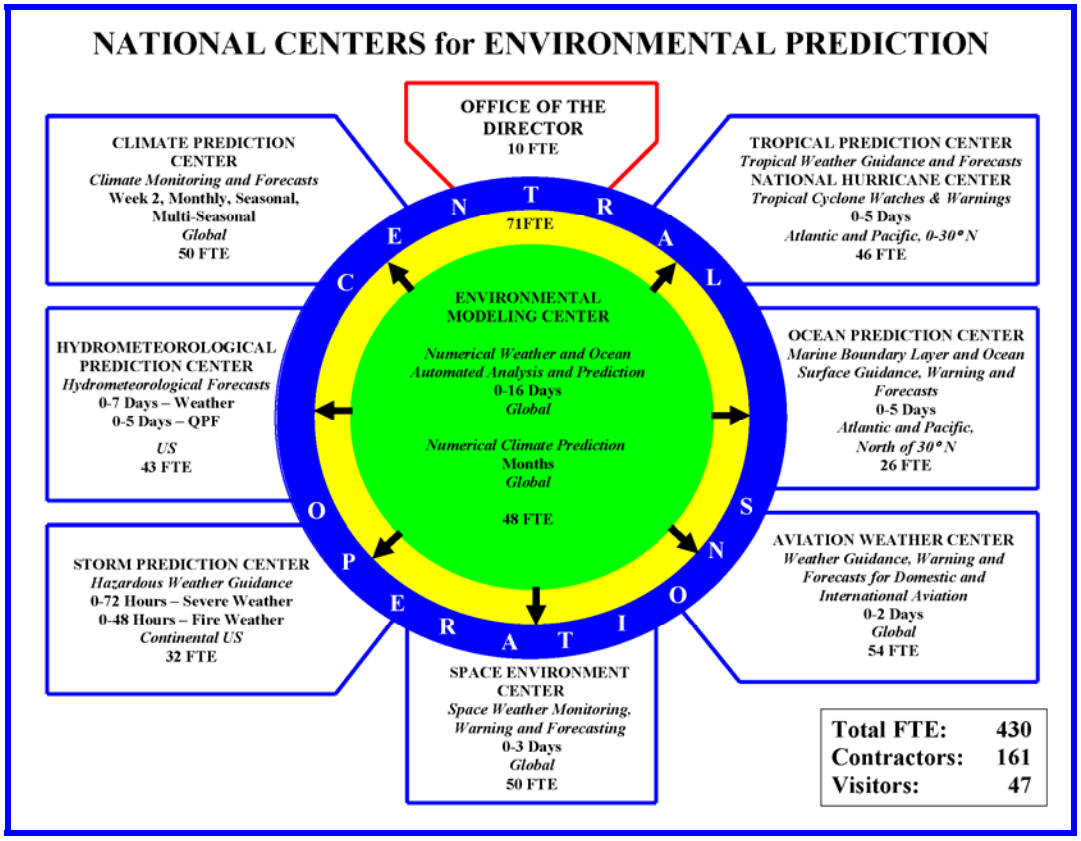

Figure 4. NCEP Organizational Infrastructure

5.4 Product Suites

5.4.1 AFWA Products

AFWA's product suite consists of terrestrial weather products, space weather products, climatology products, special products, Fifth Generation Meso-scale Model/Weather Research and Forecasting (MM5/WRF) model output, specialized model output, and space model output:

- Terrestrial Products

    - MM5/WRF Limited Area Numerical Weather Model
        - Tailored derived guidance for aviation weather, trafficability and surface movement, physical and human resource protection, and combat execution and planning
    - Global and Regional Cloud Model Forecasts
        - Diagnostic Cloud Forecast, Stochastic Cloud Forecast Model, Cloud Depiction and Forecast System II (CDFS II), World-Wide Merged Cloud Analysis (WWMCA)
    - Agricultural Meteorology Model
        - Tailored derived guidance for trafficability & surface movement, national intelligence, and combat execution & planning
- Space Weather Products
    - Electromagnetic Radiation, High-Energy Charged Particles Forecasts
    - Electrically-Charged Particle Clouds Forecasts
    - Geomagnetic Storms
    - Global space situational awareness & early warning guidance regarding SATCOM, Satellite Orbit, and Global Positioning System (GPS) accuracy—made possible by 5 geographically separated unit (GSU) locations worldwide
- Climatology Products
    - Advanced Climate Modeling and Environmental Simulation system
        - Global realistic simulated climatology for full spectrum of conflict planning guidance
    - Tailored climatological guidance for next generation weapon system design, engineering, and employment, and realistic modeling and simulation of the air and space natural environment for enhanced Tactics, Techniques, and Procedures (TTP) development
- Specialized Products
    - Worldwide Geostationary and Polar Orbiting Satellite imagery
        - Multi national/international platforms ingested and provided to all DoD agencies and national command authorities
    - Dust Transport Algorithm
        - Theater-specific guidance for reduction to visibilities due to lithometeors
    - Snow Depth (SNODEP) analysis Model
        - Guidance provided to NCEP and redistributed internationally
    - Infrared-based Geostationary Satellite-based Precipitation (GEOPRECIP) analysis Model
        - Planning guidance provided to National Intelligence Community and Air Force Tactical Applications Center (AFTAC)
- MM5/WRF
    - Runs up to 4 times/day on certain theaters

- Integrated to 72 hours (hrs) for 45 kilometers (km), 48 hrs for 15 km, and 30 hrs for 5 km domains
- Earliest windows start ~90minutes after cycle time with 6-hour spin-up at valid at t-6 hrs from cycle time
- Full forecast then runs to max forecast hour with 00hrs = current cycle time
- Minimum of 90 minute Maintenance and Recovery gap maintained between each cycle

- Specialized models
  - Global Cloud analyses runs every hour for global domain
  - Global Land surface model analyses runs every 6 hours
  - Global Surface Temp analyses run every 3 hours
  - Global Snow Depth analysis runs once per day
  - Global GEOPRECIP runs every 6 hours

- Space Models
  - Algorithm and Models run on own production platform
  - Algorithms/Models run as frequently as every 15 minutes to every 6 hours
  - Zero idle time on production system
  - Potentially 40 Algorithms/Models running at the same time during production

5.4.2 FNMOC Products

FNMOC's product suite consists of numerous model outputs, satellite products, and specialized services:

- Models:
  - Navy Operational Global Atmospheric Prediction System (NOGAPS); 239-wave, triangular truncation, 30 vertical levels (T239L30) global spectral model, at the Center of FNMOC production.
  - Coupled Ocean/Atmosphere Meso-scale Prediction System (COAMPS); regional meso-scale model, multi-nested to ~6 km resolution within NOGAPS. Re-locatable in minutes via the Centralized Atmospheric Analysis and Prediction System (CAAPS) Web graphical user interface (GUI), at classification levels up to TS/SCI.
  - Navy Atmospheric Variational Data Assimilation System (NAVDAS); three-dimensional variational (3D-VAR) data assimilation system for NOGAPS and COAMPS.
  - NAVDAS-Accelerated Representer (AR) four-dimensional variational (4D-VAR) data assimilation system, Weak Constraint system now testing on new A2 Linux Cluster HPC platform.

- Navy implementation of the Geophysical Fluid Dynamics Laboratory (GFDL) Tropical Cyclone (TC) model (GFDN); only movable-nest TC model operational in all ocean basins (critical part of 4-member CONW[1] and 5-member CONU[2] for extended TC forecasts). Nested within NOGAPS.
- WaveWatch III (WW3) spectral ocean wave model; global and regional implementations, driven by NOGAPS and COAMPS.
- Ensemble Forecast System (EFS) – NOGAPS-based global 18-member 10-day ensemble (part of NAEFS and AFWA's Joint Ensemble Forecast System (JEFS) collaborations); includes 18-member global WW3 ensemble. Does not currently involve any post-processing, but expect to include bias and spread correction in the next year.
- Navy Atmospheric Aerosol Prediction System (NAAPS); only operational global aerosol model. Atmospheric optical properties output feeds Target Acquisition Weapons Software (TAWS). Driven by NOGAPS.

- Satellite Products
  - Satellite Focus (SATFOCUS) Web Pages
    - Wide variety of on-demand satellite imagery products from meteorological satellites
    - Includes unique capability to display dust plumes from Moderate Resolution Imaging Spectroradiometer (MODIS) imager
  - Special Sensor Microwave/Imager (SSM/I) and Special Sensor Microwave Imager./Sounder (SSMI/S) products
    - Primary national production facility for SSMI and SSMI/S products
    - Important supporting data set for NWP models and maritime forecasters
  - Scatterometer Web Pages
    - Central site for distribution of scatterometer data to the Navy
    - Assimilation into NWP models and near real-time displays for operational forecasters
  - Tropical Cyclone Web Page
    - Multi-platform/multi-sensor satellite data fusion page
    - Global focus on tropical cyclones
  - Target Area METOC (TAM)
    - METOC products from NTM satellite imagery
    - Classified at the TS/SCI level

[1] CONW is an ensemble of ten global and regional models. Of these models, only four have forecasts available to 120 h. These are interpolations of the Navy Operational Global Atmospheric Prediction System (NOGAPS), the Geophysical Fluid Dynamics Lab – Navy version (GFDN), the NCEP Global Forecast System (GFS), and the United Kingdom Met Office (EGRI).

[2] CONU is an ensemble of nine global and regional models. Of these models, only four have forecasts available to 120 h. These are interpolations of the Navy Operational Global Atmospheric Prediction System (NOGAPS), the Geophysical Fluid Dynamics Lab – Navy version (GFDN), the NCEP Global Forecast System (GFS), and the United Kingdom Met Office (UKMO).

    - Tactically Enhanced Satellite Imagery (TESI)
        - On-demand satellite imagery products in geographic information system (GIS) formats
        - Primarily for TS/SCI users and applications
- Services
    - Naval Oceanography Portal (NOP); single Web presence and entry point for the entire CNMOC Enterprise.
    - Centralized Atmospheric Analysis and Prediction System (CAAPS); Web-based on-demand implementation of COAMPS.
    - Come and Get It Product Services (CAGIPS); principal service allowing customers to pull products from FNMOC.
    - Optimum Path Aircraft Routing System (OPARS); the Navy's automated flight routing system, driven by meteorological fields from NOGAPS.
    - Flight Weather Briefer (FWB); the Navy's weather briefing support system for safety of flight.
    - Automated Optimum Track Ship Routing (AOTSR); tools and data for automating and expediting the Navy's OTSR process.
    - Web-Based Search and Rescue (Web SAR); a reachback tool for support of at-sea search-and-rescue.
    - Chemical/Biological Agent Vapor, Liquid and Solid Tracking (VLSTrack)/ Hazard Prediction and Assessment Capability (HPAC) - Atmospheric transport and dispersion models driven by meteorological fields from COAMPS.
    - Contribution of Environmental Effects on Missile Systems (CEEMS); atmospheric support for maximizing the accuracy of ballistic missiles.
    - Weather Reentry body Interaction Planner (WRIP); special meteorological support for missile warhead reentry planning.
    - Advanced Refractive Effects Prediction System (AREPS); on-demand calculation of the refraction and ducting of electromagnetic energy in the atmosphere.
    - Target Acquisition Weather Software (TAWS); tactical decision aid for ordnance delivery accounting for the effect of slant-range visibility through the atmosphere.
    - Forecast of Atmospheric and Optical Radiative Properties (FAROP); calculation of slant-range visibility through the atmosphere for input to TAWS.
    - Automated Tropical Cyclone Forecast System (ATCF); tropical cyclone forecaster workbench.

5.4.3 NCEP

NCEP runs a complex suite of atmospheric and oceanic models on a fixed, 6-hour cycle:

- Global Atmospheric Models
    - Global Forecast System – Run four times per day to forecast hour (F)384 – T382L64[3] to F180, T190L64 to F384
    - Climate Model Runs – 120 members run over the course of a month – Forecasts at T62L64 out to 10 months
- Meso-scale Atmospheric Models
    - North American Meso-scale (NAM) – Run four times per day – Non-hydrostatic Meso-scale Model (NMM) in WRF infrastructure
        - 12 km Horizontal resolution run to 84 hours over North America
        - 4 and 5 km Horizontal resolution runs to 48 hours over CONUS, AK, Hawaii, and Puerto Rico grid domains
    - Rapid Update Cycle (RUC) model – Run hourly to F12 over CONUS at 13 km Horizontal resolution with 50 levels
    - Nested Grid Model (NGM)
        - To be retired from operations on 03 March 2009
- Ensemble runs at NCEP
    - Global Model Ensemble (Part of NAEFS)
        - Run four times per day – T126L28 resolution – forecasts to F384
        - 20 perturbed forecasts per cycle from ensemble transform technique (80 total per day)
        - Combined with 40 Canadian ensembles to create NAEFS product set.
            - Looking into use of FNMOC and European Centre for Medium-Range Weather Forecasts (ECMWF) ensemble data sets as well
    - Short Range Ensembles
        - Meso-scale over North America
        - Four unique modeling systems currently used
            - Eta (the model name is derived from the model's vertical coordinate known as the "eta" or "step-mountain" coordinate.), NMM, Advanced Research WRF (ARW), Regional Spectral Model (RSM)
        - Run four times per day to F87 at various resolutions (32-45 km horizontal)
    - Wave Ensembles
        - Run four times per day – 10 members – 1.25 x 1.0 degree horizontal resolution to F126
- Ocean Models at NCEP
    - Real Time Ocean Forecast System (RTOFS)
        - Coverage over Northern Atlantic ocean – variable 4-15 km horizontal resolution – 25 levels vertical – one run per day to F120

[3] T is the wave number, L is the number of horizontal layers in the model. T382L64 is approximately 35km resolution. T190L64 is approximately 70km resolution. T62L64 is approximately 200km.

    - Wave Models
        - Global and regional nested models run four times per day to F180
        - Global run is1.25 x 1.0 degree latitude/longitude (lat/lon)
        - 8 nested grids ranging from 30 feet (ft) to 4 ft resolution
        - deep ocean – 30 ft, off-shore – 10 ft, coastal – 4 ft
        - North Atlantic and North Pacific Hurricane (seasonal) – Separate run at .25 x .25 deg horizontal resolution – Run on demand on as many as four storms per cycle and four cycles per day – Forecasts to F126
        - Great Lakes wave model – 4 km horizontal resolution – Run four times per day to F84
- Hurricane Modeling
    - Hurricane WRF – Movable, two-way nested grid 9km inner; 27km outer – 42 levels – Run four times per day to F126
    - GFDL Hurricane Model – Coupled ocean-atmosphere with three nests (0.5, 1/6, 1/12 deg lat/lon) – 42 levels – Run four times per day to F126
- Air Quality Modeling
    - Model run for the EPA at 12 km horizontal resolution and 22 levels – Runs made twice per day at 06Z and 12Z – Forecasts to F48
- Dispersion Modeling
    - NOAA/Air Resources Laboratory (ARL) HYbrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) Dispersion Model – Run on demand

5.5 NWP Production Schedule

5.5.1 AFWA

AFWA's NWP production schedule, during and after transition from MM5 to WRF is shown in the figures below:

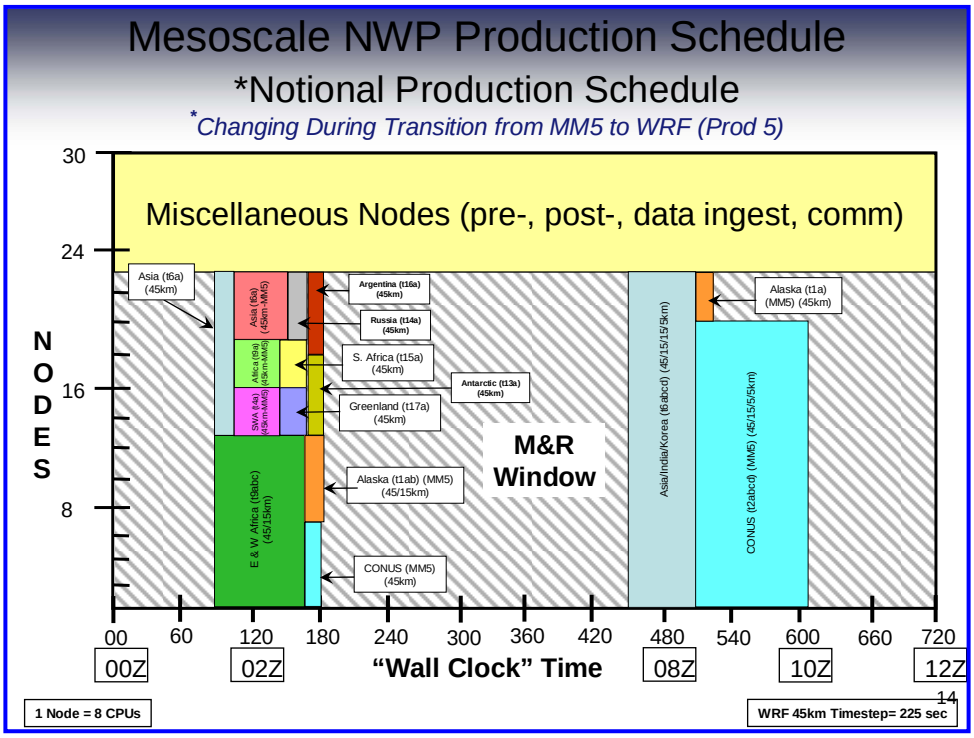

Figure 5. AFWA Production Schedule (Prod 5)

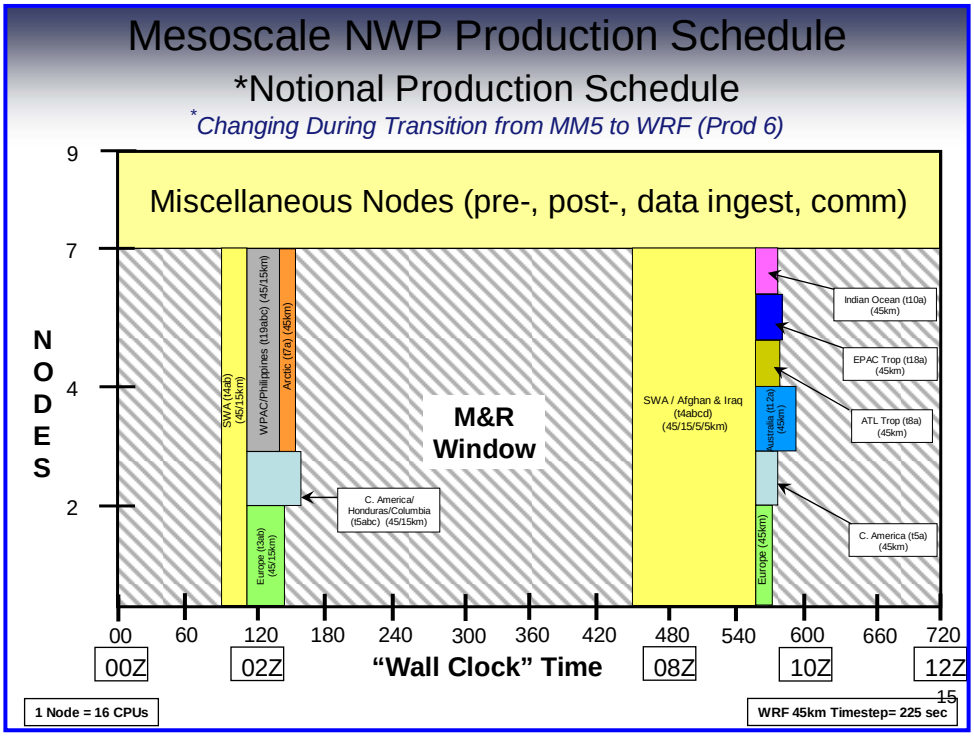

Figure 6. AFWA Production Schedule (Prod 6)

5.5.2 FNMOC

FNMOC's NWS production schedule is show in the figure below:

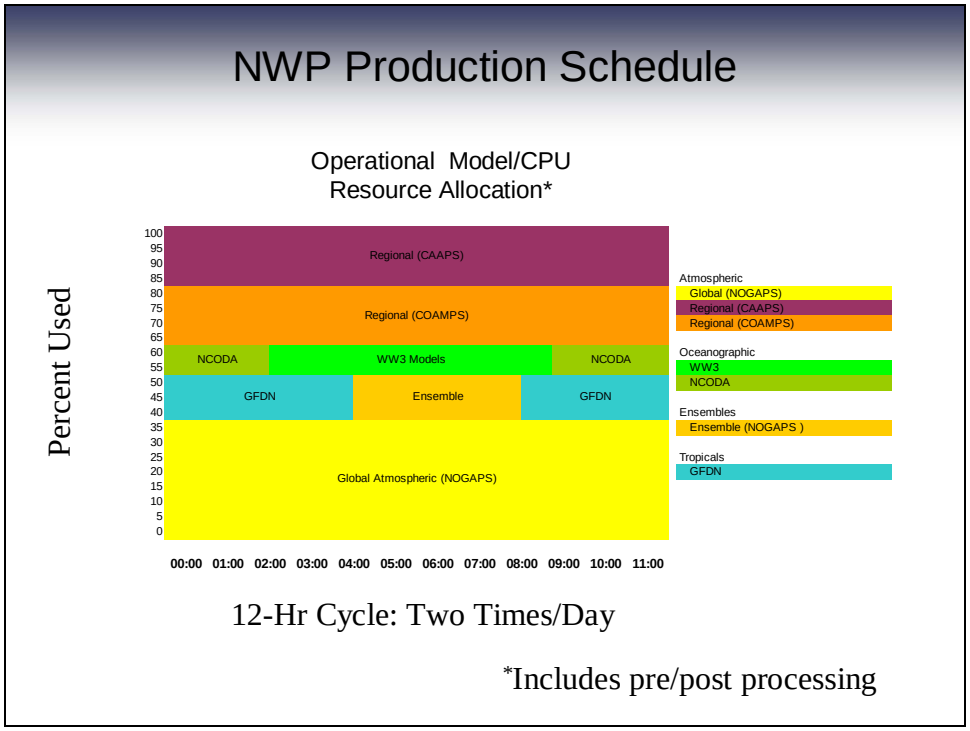

Figure 7. FNMOC NWP Production Schedule

5.5.3 NCEP

NCEP's current and future (Phase 4 2015+) NWP production schedule is shown in the two figures below:

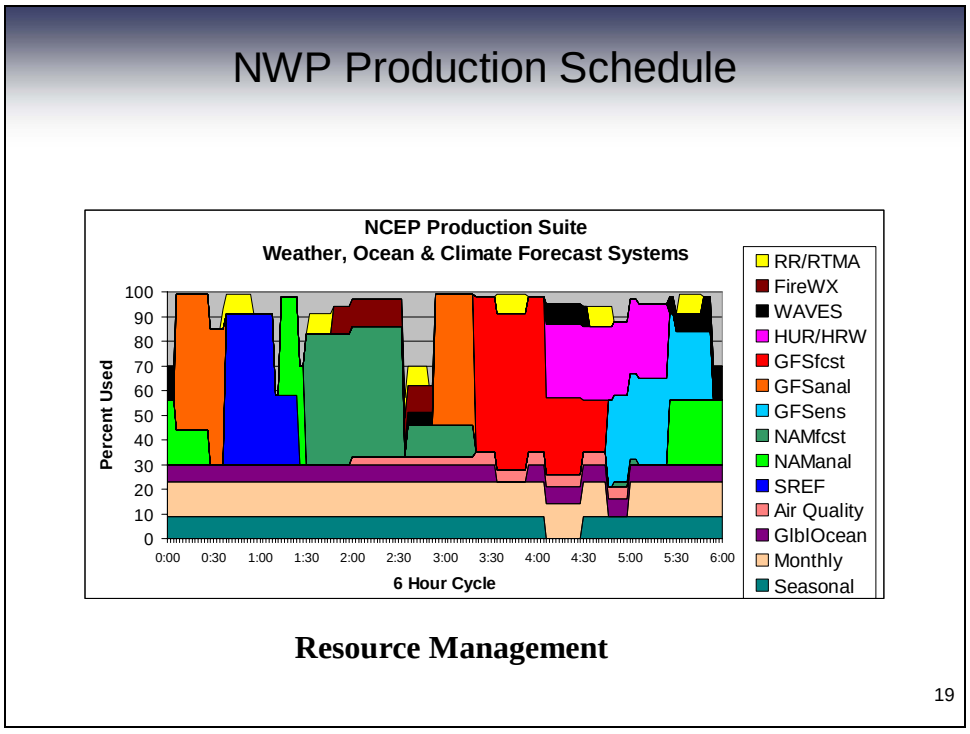

Figure 8. NCEP NWP Production Schedule-Current

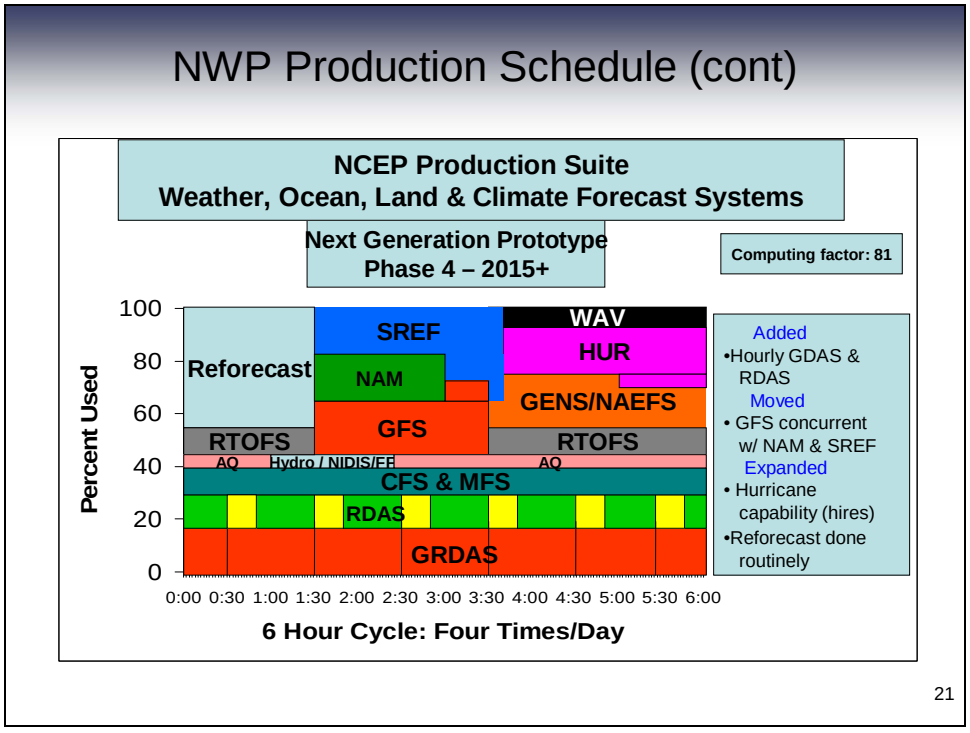

Figure 9. NCEP NWP Production Schedule-Next Generation Prototype

5.6 Customer Base

The following sections provide a review of the variety of customers the operational processing Centers serve on a daily basis.

5.6.1 AFWA's Customers

AFWA's customer base includes both DoD and NOAA agencies, plus several miscellaneous agencies:

- DoD/Joint
    - Army/Navy warfighters
    - Navy Fleet Numerical Meteorology & Oceanography Center
    - Unified Commands
    - Coalition/Joint Forces Commander, Coalition/Joint Forces Air Component Command Commander, and Coalition/Joint Forces Land Component Commander
    - North Atlantic Treaty Organization (NATO)
    - National Intelligence Community (NIC)
    - National Command Authority (NCA)
    - Defense Threat Reduction Agency (DTRA)
    - Joint Improvised Explosive Device (IED) Defeat Office
    - Joint Typhoon Warning Center (JTWC)
- Air Force
    - Worldwide Major Commands and all echelons lower
    - Air Force Tactical Applications Center (AFTAC)
- NOAA
    - National Centers for Environmental Prediction (NCEP)
    - National Environmental Satellite Data Information System (NESDIS)
    - National Space Weather Prediction Center (SWPC)
    - National Climatic Data Center (NCDC)
    - Joint Center for Satellite Data Assimilation (JCSDA)
- Miscellaneous
    - U.S. Department of Agriculture (USDA), U.S. Geological Survey (USGS), National Geospatial-Intelligence Agency (NGIA)
    - National Aeronautics and Space Administration (NASA)
    - Small Business Innovation Research projects
    - Defense Contractors

5.6.2 FNMOC's Customers

FNMOC's customer base includes DoD, intelligence community, NOAA, other Government, and miscellaneous agencies:

- DoD/Joint
    - JTWC

    - DTRA
    - U.S. Strategic Command (USSTRATCOM)
- Navy/Marine Corps
    - Naval Oceanographic Office (NAVO) and subordinate detachments and activities
    - Commander Undersea Surveillance (CUS) and subordinate detachments and activities
    - Naval Maritime Forecast Center (NMFC) Pearl Harbor
    - NMFC Norfolk
    - Naval Aviation Forecast Center (NAFC) Norfolk and subordinate detachments and activities
    - Naval Oceanography Special Warfare Center (NOSWC) San Diego and subordinate detachments and activities
    - Naval Oceanography ASW Center (NOAC) Stennis Space Center and subordinate detachments and activities
    - NOAC Yokosuka and subordinate detachments and activities
    - Strike Group Oceanography Team (SGOT) Norfolk and subordinate detachments and activities
    - SGOT San Diego and subordinate detachments and activities
    - Various individual customers of reachback services such as OPARS, AREPS, TAWS, etc.
    - NRL
    - Naval Postgraduate School (NPS)
- Air Force
    - AFWA
    - AFTAC
    - OPARS customers
- Intelligence Community
    - Central Intelligence Agency (CIA)
    - Defense Intelligence Agency (DIA)
    - National Security Agency (NSA)
- NOAA
    - NCEP
    - National Hurricane Center (NHC)
    - Aircraft Operations Center
    - Several Weather Service Forecast Offices
    - Pacific Fisheries Environmental Laboratory
    - Climate Program
    - GFDL
    - NCDC

    - National Marine Sanctuary Program
    - Integrated Ocean Observing System (IOOS) Community
- Other U.S. Government Agencies
    - Coast Guard
    - NASA
    - Drug Enforcement Administration (DEA)
- Miscellaneous
    - National Laboratories
    - Academia (dozens of colleges and universities)
    - Private Industry (dozens of value-added weather-related companies)
    - State and local emergency managers
    - General Public (users of products on FNMOC's Public Web Site, www.fnmoc.navy.mil)

5.6.3 NCEP

NCEP's customer base includes its internal agency users, Government agencies, and the international weather community:

- NOAA Partners:
    - NCEP Centers
    - AWC, CPC, EMC, HPC, OPC, SPC, Space Environmental Center (SEC), TPC
    - NWS Local Weather Offices and River Forecast Centers
    - NCDC, NESDIS, Earth System Research Laboratory's Global Systems Division (GSD)
- Government Agencies
    - DoD, Department of Homeland Security (DHS), Environmental Protection Agency (EPA), Federal Aviation Administration (FAA)
    - Foreign weather services
- Worldwide Weather Community
    - Aviation, emergency managers, ocean transportation, hydrology, recreation
    - Weather vendors and media outlets
    - University and research organizations
    - Private citizens

5.7 Information Assurance Issues

5.7.1 AFWA's Issues and Concerns

AFWA's IA issues and concerns as they relate to the NUOPC project include:

- Issues
    - Information Technology (IT) infrastructure must be built to National Institute of Standards and Technology (NIST) 800-53, DoD 8500.1, DoD Instruction

(DoDI) 8510.01 Department of Defense Information Assurance Certification and Accreditation Process (DIACAP) and Air Force Information Assurance (IA) standards. AF standards may be more stringent than the DoD standards, at times) and certified and accredited via the aforementioned standards.
  - Protected from outside intrusion by DoD-certified firewalls and access controls (such as Public Key Infrastructure (PKI) certificates)
  - Integrated Network Operations Security Centers (I-NOSC) controls boundary protection (to include ports/protocol permissions)
  - Internal access to hardware/software infrastructure granted only to U.S. Nationals holding at least a SECRET Security Clearance
  - Authority to Operate/Authority to Connect (ATO/ATC) from the Air Force Designated Accreditation Authority (AF-DAA) for systems connecting to AF infrastructure
    - Certifying official is the Commander Air Force Communications Agency (AFCA/CC); single DAA for <u>all</u> systems connecting to AF infrastructure
    - Process takes 6 – 9 months
    - May not reciprocate other services' approval to operate/connect
    - However, there is a process to accept systems granted ATOs from their respective DAA
    - Annual Federal Information Systems Management Act (FISMA) Requirements

- Concerns
  - Foreign National access to data/systems and code/software development
  - External agencies' network security policies that conflict with DoD/AF guidance
    - If a situation arises and one entity has to change—whose policies are going to govern?
  - Uniqueness of the AFWA Production/Development-Test computing environment
  - Highly dynamic nature of the hardware and software architecture, requiring essentially continuous C&A
  - Requirement for high-bandwidth Cross Domain Solution (CDS)
  - Requirement for efficient internal transfer of data between multiple specialized systems and subsystems
  - Network security policies that threaten production partnerships and supporting R&D relationships requiring operational exchange of data
    - Authentication of Server-to-Server data exchange
    - Differing Ports, Protocol and Service (PPS) policies

5.7.2 FNMOC's General Issues and Concerns

- General
  - IT infrastructure built to DoD IA standards
  - Protected from outside intrusion by DoD certified firewalls (Defense Information Systems Agency (DISA), Navy Network Warfare Command (NNWC) and access controls (PKI certificates)
  - Internal access to hardware/software infrastructure granted only to U.S. Nationals holding at least a Secret Security Clearance
  - In association with the 2002 FISMA:
  - Current Interim Authority to Operate (IATO) from NNWC and Interim Authority to Connect (IATC) from DISA set to expire 1 November 2008
  - Expect to submit request for ATO to NNWC September 2008

- Concerns
  - Uniqueness of the FNMOC HPC environment
  - Highly dynamic nature of the hardware and software architecture, requiring essentially continuous C&A
  - Requirement for high-bandwidth Cross Domain Solution
  - Requirement for efficient internal transfer of data between multiple specialized systems and subsystems
  - Network security policies that threaten production partnerships and supporting R&D relationships requiring operational exchange of data
    - Authentication of Server-to-Server data exchange
    - Differing PPS policies
    - Requirement for public-facing portal

5.7.3 NCEP's Security IT Management Approach

NCEP follows the Federal IT Security Management approach, which is driven by a Risk Management Framework:

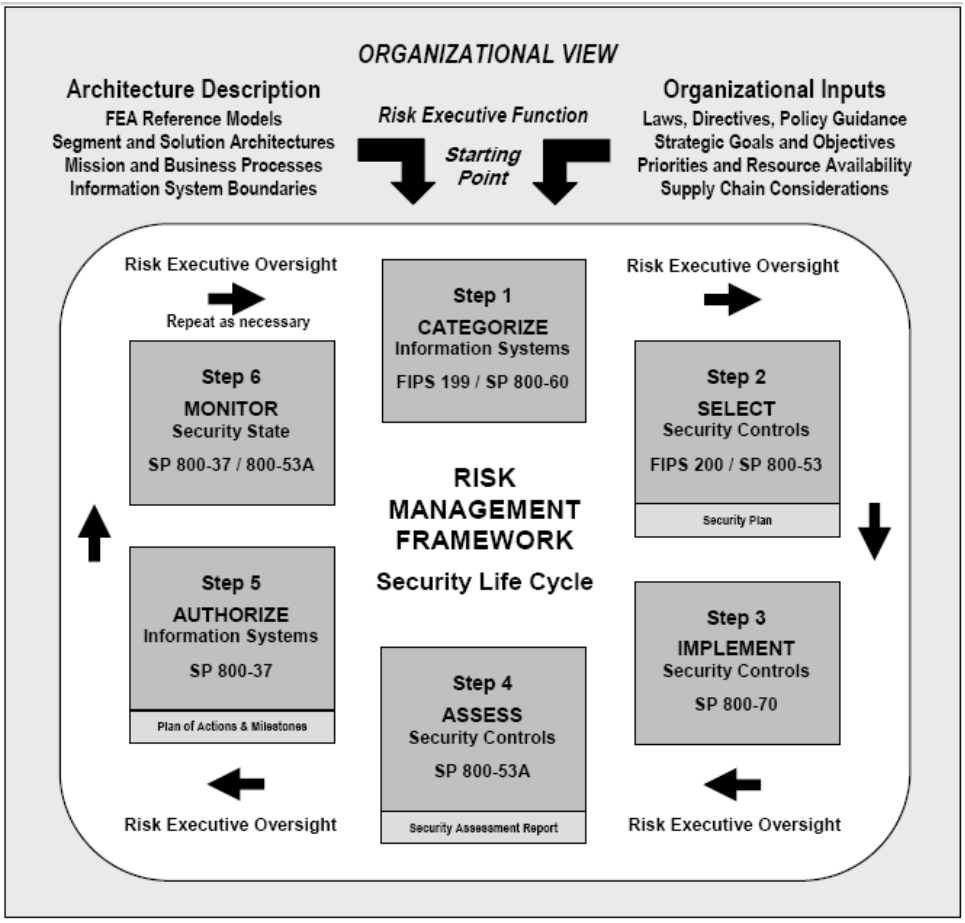

FIGURE 5: RISK MANAGEMENT FRAMEWORK

Figure 10. Risk Management Framework

- Information Systems Compromise and Security Requirements
  - Federal Information Processing Standards (FIPS) 199 – Categorize information and information systems according to their potential impact on an organization should events occur which compromise the information and information systems.
  - FIPS 200 – Specifies minimum security requirements for information and information systems supporting the executive agencies of the federal government and a risk-based process for selecting the security controls necessary to satisfy the minimum security requirements.

- Certification and Accreditation Process
  - NIST 800-37, Guide for the Security Certification and Accreditation of Federal Information Systems
  - The security C&A process consists of four phases
    - Initiation Phase

        - Security Certification Phase
        - Security Accreditation Phase
        - Continuous Monitoring Phase

- NOAA IT Security Policy and Related Regulations/Laws
    - NOAA Administrative Orders (NAO) 212-13 NOAA Information Technology Security Policy
    - Federal Information Security Management Act of 2002
    - Computer Security Act of 1987 (Public Law (Pub.L.) 100-235)
    - Computer Fraud and Abuse Act of 1987 (Pub.L. 99-474)
    - Office of Management and Budget Circular A-130, Appendix III, Management of Federal Information Resources
    - Clinger-Cohen Act of 1996, as amended
    - Executive Order 13011, Federal Information Technology
    - Privacy Act of 1974, as amended (Pub.L. 93-579)
    - The Department of Commerce Information Technology Management Handbook – Section titled “IT Security Program Policy and Minimum Implementation Standards."

5.8 Impact of NUOPC Unified Ensemble Operations

For AFWA, FNMOC, and NCEP the implementation of NUOPC and Unified Ensemble Operations will potentially impact the same areas in each agency:

- Additional computer resources.
    - HPC cycles
    - Disk storage and offline storage
- Additional internal and external networking.
    - Bandwidth sized to enable exchange of ensemble members with NUOPC partners
    - IA posture to allow required exchange of data
- Ops Run Scheduling.
    - Restructuring of Ops Run to ensure ensemble production schedule meets requirement for production of the Unified Ensemble
    - Restructuring of Ops Run to ensure that downstream applications and products dependent on global NWP are tied to the Unified Ensemble production schedule
- Operational Coordination with NUOPC Partners.
    - Joint approval/coordination of operational software changes
    - Coordinated software configuration management

- Implementation and operation of new software systems.
    - Post-processing of ensemble fields
    - Assembly of ensemble fields from the NUOPC partners into the Unified Ensemble
    - Visualization of ensemble products
    - Verification/validation of ensemble fields and products with agreed-upon metrics
- Modification of downstream applications and products to transition from deterministic to ensemble input, and to make full use of ensemble-based uncertainty.
    - Embedded regional models
    - Tactical Decision Aids and reach back services
    - Web portal
    - Visualization software
    - Viewers and forecaster toolkits
- Management of customer transition from deterministic to ensemble-based global NWP products.
    - Liaison
    - Training
    - Education
- Network connectivity and bandwidth.
    - Data volumes of ensembles and the nature of UEO processing dictate that large amounts of data be transferred reliably and with minimal delay

6. Proposed Information Assurance Approach

The Information Assurance Task Group reviewed four major areas: Certification and Accreditation, Public Release/Release to Foreign Nationals, Network Security, and Foreign National Programmer Threat and Malicious Code Mitigation.

While the following discussions refer to DoD and DoC, the intent of the Committee's recommendations are limited to those parts of NOAA (NWS/NCEP), Air Force (AFWA), and Navy (FNMOC) that will be directly participating in NUOPC operations. For example, recommendations for increased IA protection apply only to those agencies within NOAA who will participate directly in NUOPC with the DoD agencies and will not apply to other sections of NOAA.

6.1 Certification and Accreditation (C&A)

The Task Group recognized that there are different governing documents used by the DoC and DoD.

- Governing Documents

- DoD 5000.02, *Defense Acquisition Management System*
- DoD 8510.01 *DIACAP, DoD Information Assurance Certification and Accreditation Process*
- NIST SP 800-30, *Risk Management Guide for Information Technology Systems*
- NIST SP 800-37, *Guide for the Security Certification and Accreditation of Federal Information Systems*
- NIST SP 800-18, *Guide for Developing Security Plans for Federal Information Systems*
- NIST SP 800-53, *Recommended Security Controls for Federal Information Systems*
- FIPS 200, *Minimum Security Requirements for Federal Information and Information Systems*

Both DoD and DoC agencies follow very similar governing documents for C&A issues. As is the current procedure, the lead agency for a system is responsible for preparing/maintaining required documents, performing security test and evaluations (ST&E) and scans, and implementing required checklists and guides in accordance with the lead agency's requirements. For DoD, these requirements are dictated by the ODAA, while for DoC they are defined by the system owner. Pieces of an integrated system C&A solution owned by the other partner(s) also require C&A in accordance with their respective requirements, and the resulting C&A approval documents for these pieces should be provided to the lead agency for reference/inclusion in the final documentation packages.

6.1.1 "Super ODAA" Concept

The NPOESS Program has been pursuing a solution to C&A issues as they relate to the transfer of satellite data among the Air Force, Navy, and NOAA, similar to NUOPC's transfer of ensemble data among the Tri-Agencies. Specifically, there is concern that if one agency determines the level of IA protection needed for NPOESS, that the other agencies will independently implement a different level or levels of protection. The NPOESS Program has concluded that to ensure the definition of a system's criticality and the resultant level of protection needed will require a "Super ODAA", above the DoD and DoC approval authority levels, that can direct both departments to apply the same IA policy across all NPOESS systems. The NUOPC Project Management should closely monitor the groundbreaking efforts that the NPOESS Program is making and follow their lead in employing the same Super ODAA approach to direct and coordinate IA policy implementation at AFWA, FNMOC and NCEP.

6.1.2 C&A Conclusions

Conclusion: Because NUOPC will only deal with unclassified information (data and products), no onerous security classification requirements are expected to impact

NUOPC. Communications network C&A issues will be discussed in the Network Security section.
Recommendation: NUOPC Management should closely monitor the progress of the NPOESS Program in solving their C&A issues and in determining a "Super ODAA" to direct both DoD and DoC in the levels of IA protection needed for the NPOESS systems. By following the NPOESS Program's lead, NUOPC can implement a similar Super ODAA approach to ensure the Tri-Agencies agree on and implement a common IA policy.

6.2 Public Release/Release to Foreign Nationals

Not surprisingly, based on the nature of their basic missions, there is a basic difference in the approach to release of information between DoD and DoC agencies. DoD, of course, withholds release of information it considers sensitive, while DoC is generally much more open to release. The governing directives are quite detailed.

- Governing Documents
  - DoD Directive 5230.9, Clearance of Department of Defense (DoD) Information for Public Release
  - DoD 5200.1-R, Information Security Program Regulation
  - DoD Directive 5200.1, DoD Information Security Program
  - DoD Directive 5230.25, Withholding of Unclassified Technical Data from Public
  - Disclosure
  - DoD Directive 5400.07/5400.07R, DoD Freedom of Information Act Program (FOIA)
  - Department of Commerce Department Administrative Order (DAO) 207-12, Foreign National Visitor And Guest Access Program
  - NOAA Administrative Order NAO 207-12, *Technology Controls And Foreign National Access*, effective 5/11/06)

Essentially, the DoD has a more restrictive approach than the DoC in the public release of any information. However, both DoD and DoC will restrict any information if national defense or other national security interests would be significantly impaired by this release. The DoC has a separate category of information restriction called Deemed Export, which prohibits any release of technology (including software), subject to the Export Administration Regulations (EAR), to a foreign national within the United States. Such a release is deemed to be an export to the home country or countries of the foreign national. The EAR is administered and regulated by the DoC's Bureau of Industry and Security (BIS). For example, encryption technology, HPC technology, stealth technology and materials, satellites, aerospace technology, conventional military items, and dual use products are main areas of focus of the DoC export restrictions. Deemed Export controls

support national security by precluding sensitive information (in the form of source code or technology) from being transferred to foreign nationals who might use that information to the United States' disadvantage. The HPC designation encompasses a wide range of technologies, including supercomputers, bundled workstations, mainframe computers, advanced microprocessors, and software. HPC technology would include NOAA NWP software run on the supercomputers at NCEP.
To comply with the export restrictions and Deemed Export limitations, each NOAA facility has to maintain:

- Foreign National List (all foreign national guests in the facility)
- Controlled Technology Inventory (any designated controlled technology in the facility—i.e., computers, software, etc.)
- Deemed Exports License List (identifies foreign nationals and the controlled technology for which licenses are being or will be sought)

6.2.1 Public Release Conclusions

Both DoD and DoC have policies and procedures in place to address release of NUOPC information to the public, including Foreign Nationals. In the final analysis, any information that is designated as impacting national defense or other national security interests can and will be restricted by the Tri-Agencies. Procedures for identifying information that needs to be restricted should be implemented early in NUOPC Phase II, with the Tri-Agencies coordinating on what information will be restricted. This may involve, for example, designating operational NUOPC code as restricted, while releasing a research version of the code that lacks the most current implementations. Other NUOPC software may be restricted from distribution, altogether. Most likely this would involve DoD applications associated with generation of specific products.

6.3 Network Security

The task group reviewed network security from several perspectives: controlling access to the networks, the physical architecture of the networks connected to the processing Centers, and the network protocols used in the transmission of data across the networks.

6.3.1 Network Access

For all U.S. Government agencies, network access control is mandated by the Homeland Security Presidential Directive 12 (HSPD-12), and the Federal Information Processing Standards (FIPS) Publication 201, *Personal Identity Verification (PIV) Federal Employees and Contractors,* guidelines. For DoD, access control is mandated by regulations such as DoD 8500.2, *Information Assurance (IA) Implementation,* along with specific Air Force, Army, and Navy implementing directives.

Current DoD access controls to IT network and systems employ a combination of smart card technology, using the Common Access Card (CAC), and other control methods.

The CAC is used as a general identification card as well as for authentication to enable access to DoD computers, networks, and certain DoD facilities. Typically a DoD user must have a CAC, a user identification (ID) and a valid password to access the DoD IT network.

DoC is moving in a similar direction under HSPD-12:

- HSPD 12 governs logical (and physical) access to Government IT systems.
    - Under HSPD-12 DoC will employ a 3-factor authentication system in the near future for access to their IT networks:
        - Something you know (PIN)
        - Something you have (CAC card)
        - Something you are (fingerprint or other biometric identification).

6.3.2 Network Architecture

Physical aspects of Network Security related to the architecture of communications networks are a concern for NUOPC because of the nearly continuous transfer of model output and products among the Tri-Agencies. The circuits currently used for weather data and product transfer do not meet DISA requirements for a DoD point of presence (POP) at the NOAA and DoD operational processing Centers. Specifically, the existing DATMS-U network does not meet these requirements. This shortfall is being addressed by the Office of the Federal Coordinator for Meteorology (OFCM) COPC within the Working Group for Cooperative Support and Backup (WG/CSAB) JAG/CCM. The JAG/CCM has proposed an optical enterprise network connecting all the Tri-Agency operational processing Centers to a DoD POP and achieving a .gov to .mil gateway at AFWA. This proposed enterprise-to-enterprise network is precisely what is required to support NUOPC.

6.3.3 Network Protocols

Network protocol concerns, such as mandating use of secure file transfer protocol (FTP) in place of Transmission Control Protocol/Internet Protocol (TCP/IP), will have to be addressed when decisions are made. Of course, such decisions will affect all inter-agency communications, not just those associated with NUOPC.

6.3.4 Network Security Conclusions

Network Security policies and procedures of DoC and DoD are merging under the HSPD-12 requirements for physical and logical access to IT systems. Because of the ongoing efforts to upgrade the Tri-Agency network infrastructure, there do not appear to be any significant Network Security issues impacting NUOPC. Recommend that NUOPC Management monitor and encourage the COPC/JAG/CCM proposed enterprise-to-enterprise communications network to replace DATMS-U. NUOPC Management should monitor COPC's response to the emerging requirements to replace TCP/IP as the

approved network protocol to ensure that NUOPC communications requirements are supported. NUOPC Management must establish a liaison with COPC to ensure NUOPC communication requirements are fully included in the new enterprise-to-enterprise network.

6.4 Foreign National Programmer Threat and Malicious Code Mitigation

Significant Information Assurance/Information Security (IA/IS) concerns have revolved around NOAA's use of foreign nationals as programmers, because they have not been vetted by a DoD security investigation. A lot of research by the UEO Committee was focused on mitigating this risk and answering the concerns of the DoD agencies regarding foreign national involvement at NOAA. The recommended approach involves two separate steps: (1) ensuring all the NOAA foreign national programmers have completed a NACI investigation, and (2) employing software scanning tools at the Centers to mitigate the risk of malicious code.

6.4.1 Mandatory Security Investigations for Foreign Nationals

To meet DoD concerns, any Foreign National programmers who provide code directly to the NUOPC DoD operational centers or computer systems, must have completed a satisfactory NACI investigation. Use of NACI investigations is already part of DoC and NOAA policy, as documented for example in (1) NAO 207-12, *Technology Controls And Foreign National Access*, effective 5/11/06, and (2) DAO 207-12, *Foreign National Visitor And Guest Access Program*, effective 4/12/2006. These directives specify security procedures for foreign nationals working at or visiting NOAA facilities, based on the amount of time spent in these facilities as follows:

- VISITOR - Foreign Nationals accessing NOAA facilities 3 days or less, or attending conferences for 5 or fewer days.
- GUEST - Foreign Nationals accessing NOAA facilities more than 3 days including employees under contracts, grants, cooperative agreements.

Both VISITORS and GUESTS have to submit the following personal data to the DoC Office of Security (OSY).

Full name	Sponsoring Bureau
Gender	Facility number and location
Date of birth	Purpose of Visit
Place of birth	Arrival date
Passport Number and Issuing Country	Departure date
Citizenship and Country(ies) of Dual Citizenship (if applicable)	NOAA Department Sponsor (DSN) Name
Country of Current Residence	NOAA Department Sponsor (DSN) Email address

Figure 11. Required Personal Data

For VISITORS, the data in Figure 4 must be submitted to DoC/OSY 1 day prior to the visit. For GUESTS, the data must be submitted 30 days prior to the visit.

NOAA specifies "GUESTS are those foreign nationals accessing NOAA facilities for more than three days, including foreign nationals conducting work at a NOAA facility under a grant, contract, or cooperative arrangement or agreement, where such work requires access to NOAA facilities. GUESTS are subject to a security check *at the discretion* of the Director for Security. GUESTS *remaining beyond two years must undergo a security check* conducted by the servicing security office. The servicing security office will notify Departmental Sponsor/NOAA (DSN) when those guests are required to complete and sign the necessary paperwork (Standard Form 85 (SF-85), credit release, etc.) to conduct the check.

These policies contained an apparent loophole, between 3 days and 3 years, in that a foreign national GUEST could be employed *at the discretion of the Director of Security, without any security check* beyond the 12 items of personal data listed above for any visitor. However, because of the new requirement for NOAA Identification badges for facility access, similar to the DoD CAC, a NACI is now required for all employees and contractors:

- New Procedures for Issuing/Re-issuing NOAA ID Badges:

    - On October 11, 2005, the Department of Commerce implemented the requirements of *Homeland Security Presidential Directive (HSPD) 12 PIV-1: Policy for a Common Identification Standard for Federal Employees and Contractors*. This policy changed the requirements and process for issuance of ID badges (Personal Identity Verification cards). NOAA must obtain the results of a Federal Bureau of Investigation (FBI) National Criminal History

Check (fingerprint check) and initiate a NACI, or other suitability/national security investigation *for all new employees and contractors before issuance of a badge*.

- NACI is a National Agency Check (NAC) of the files of civilian applicants for employment by federal agencies, which includes written inquiries about the applicants. The Office of Personnel Management (OPM) conducts this check. It sends inquiries, covering the person's last 5 years before application, to law enforcement agencies, former employers, supervisors, references, and schools. The NACI investigation requires the applicant to complete and submit SF 85, which asks for (1) background information, including residential, educational, employment, and military histories, (2) the names of three references that "know you well," and (3) disclosure of any illegal drug use within the past year, along with any treatment or counseling received for such use. This information is then checked against four government databases: (1) Security/Suitability Investigations Index; (2) the Defense Clearance and Investigation Index; (3) the FBI Name Check; and (4) the FBI National Criminal History Fingerprint Check. Finally, SF 85 requires the applicant to sign an "Authorization for Release of Information" that authorizes the government to collect "any information relating to [his or her] activities from schools, residential management agents, employers, criminal justice agencies, retail business establishments, or other sources of information."

- From the Homeland Security Presidential Directive HSPD-12 PIV-1 *Implementation and Suitability Processing Policies & Procedures*, NOAA and Dept of Commerce (Revised September 21, 2007):
  - 11.1 PIV Credentialing Requirement for Current Employees in Need of NACIs. In accordance with HSPD-12, FIPS 201 to receive a PIV Credential, the agency *must verify that the employee has at a minimum a NACI investigation of record on file*. The Client Services Office Division (CSD) will in coordination with the Staff Office (SO) review employee listings to verify employee background investigation requirement.
  - 11.2 PIV Credentialing Requirement for Current Contractor Employees. In accordance with HSPD-12, FIPS 201 to receive a PIV Credential, the agency *must verify that the contractor has at a minimum a NACI investigation of record on file*. DoC Contracting Office Representatives (COR) will coordinate directly with the SO in the geographic region to verify contractor background investigation requirement compliance.

Clearly, implementation of HSPD-12-PIV-1 has closed the former security check loophole, in that <u>all employees and contractors</u> accessing a NOAA facility, <u>regardless of how long they intend to stay at the facility</u>, are subject a NACI investigation. It also withdraws from the facility security officer any discretion in determining if and when a NACI will be required for GUESTS staying less than 3 years.

NOTE: DoC and NOAA regulations (DAO 207-12 and NAO 207-12) exempted several categories of personnel from their Visitor and Guest Access Program:

- Lawful Permanent Residents or Protected Persons (both must present evidence of their status). This includes permanent resident alien or "Green Card" holders, and political refugees and political asylum holders,
- Foreign Nationals who are employees of DoC residing and working at DoC facilities outside of the United States.
- Foreign National diplomats and senior government officials at the ambassadorial or vice-ministerial level or above who visit DoC officials for the purpose of high-level policy dialogue.
- Foreign Nationals who visit DoC facilities during public events or activities, or in areas that are open to the general public (i.e., in circumstances that do not require visitors to pass through an access control point manned by security personnel, receptionists, or electronic screening devices).

There are no provisions for waivers or exemptions in HSPD-12 or in its implementing standards.

6.4.2 Malicious Code Mitigation

To further mitigate the threat of any employee, not just foreign national programmers, from injecting malicious code into the software exchanged among the participating NUOPC Centers, the Task Group recommends that software scanning tools be used at AFWA, FNMOC and NCEP to mitigate the risk of malicious code in NUOPC related software. Both DISA and the Air Force's Application Software Assurance Center of Excellence (ASACoE) offer software scanning tools at no expense. ASACoE will provide software tools and come to the operational Centers to conduct hands-on training at no cost to the agencies, and assist in conducting an initial screening. In addition, ASACoE will work with NUOPC to acquire and/or develop tools specific to the languages of greatest interest (e.g., Fortran, C++, etc.), and work with the NUOPC partners on their deployment and use.

6.4.3 Conclusions on Mitigating Threats from Foreign National Programmers and Malicious Code

The new DoC/NOAA requirement for NACI investigations for all Foreign National employees and contractors is encouraging from an IA perspective, and implementing software scanning tools for embedded malicious code at the operational processing Centers will further mitigate possible threats. Recommend NUOPC Management monitor implementation of the NACI investigation requirement at NOAA and the acquisition and implementation of scanning software at the operational processing Centers. This will involve executing a Memorandum of Agreement between the ASACoE and NUOPC and/or the operational processing Centers, in order to receive the desired software scanning tools and requisite training from ASACoE. Recommend NUOPC Management take action to establish uniform policies and procedures at the processing Centers to take advantage of these tools.

7. Definition of Unified Ensemble Operations Requirements

The UEO Requirements Task Group attempted to determine what things will be needed to make the NUOPC Ensemble Prediction System functional across the Tri-Agencies. This task included reviewing potential requirements for the numbers of ensemble output variables, where post processing will be performed, the timing of product delivery, and the size of the bandwidth needed to transmit ensemble products. The following specific findings of the UEO Committee in Figure 12 are recommendations for ensemble configurations based on the production of 20 ensemble members by both NCEP and FNMOC, with AFWA serving as the primary ensemble post-processing site. Based on available resources, the Tri-Agencies may have to adjust these recommendations. For example, the resolution of the ensembles will impact computer resources needed to process the ensembles, and the resulting size of the files produced will determine the communications bandwidth required to transfer these files. The increase in resolution from the current ~1.0 degree latitude/longitude to ~0.1 degree latitude/longitude in 7 years is the recommended path, as it allows NUOPC to close the gap with model resolution improvements at the ECMWF. By pushing the 0.1 degree resolution achievement out to 12 years, the increased in computer resources and communications bandwidth can be delayed by several years. In general, increasing model resolution by a factor of 2 requires an increase in computational resources of at least 8, and an increase in bandwidth of about 4.

Specifics of NUOPC Unified Ensemble Operations Requirements are summarized below in Figure 12.

Main Issues Under Review	Specific Findings
1. Standard Output Products	Variables (NAEFS will have 78 standard variables next year) NUOPC 118 variables, but may reduce numbers by calculating ceiling, visibility, vorticity, etc.
2. Standard Output Format	GRIB 2, plus investigate other compression options (Joint Photographic Experts Group (JPEG)2000, wavelets, Network Common Data Form (NetCDF), etc.)
3. Overall Ensemble Configuration	Multi-model (e.g., NOGAPS + Global Forecast System (GFS) + possible international models) Resolution Option 1: 2 year (yr) - 0.5º; 5 yr - 0.25º, 7 yr - 0.1º Option 2: 3 yr - 0.5º; 7 yr - 0.25º; 12 yr - 0.1º Number of U.S. ensemble members (20 at FNMOC and 20 at NCEP for total of 40) 4 times per day out to 7 days, 3-hourly output 2 times per day out to 30 days, 6-hourly output after 7 days (16 days supports DoD planning, NOAA expects products out to 30 days)
4. Product Delivery Schedule	Model run and bias correction +6 hrs, data exchange by +6.5, Center specific products by +7, combined products by +8. Drop dead time is a 0.5 hour past the above times. Explore speed-up through making runs available as they finish.
5. Post Processing	All Centers use same algorithms for bias correction and exchange bias-corrected fields. Ensemble calibration (i.e., second-moment correction) done at NCEP, with AFWA as backup. AFWA is the primary post-processing site for product generation, with backup and some Center-specific product generation capabilities at FNMOC and NCEP. All Centers share common Post-Processing Toolbox software.
6. Product Storage/Archive	Short term online storage for bias and spread correct (1month-x years). Long term archive of raw output and analysis—use NCDC to manage data archive.
7. Ensemble Verification Metrics	Common metrics used at all Centers plus Center-specific metrics make up the joint set of metrics. All metrics shared. Use a metrics scorecard to determine if a proposed model change impact will be positive or negative at each Center and then determine the schedule of the change based on the scorecard results.
8. Bandwidth between Centers	0.5 degree resolution: ~32.4 GB; bandwidth required ~162 megabits per second (Mbps) (millions of bits per second millions of bits per second) 0.1 degree resolution: ~810 GB; bandwidth required ~4050 Mbps Assumes 30 minute transfer of all fields at full resolution for all forecast times (TAU). May be able to exchange coarser resolution fields over longer timeframe for the longer forecast times with significant bandwidth reduction.

Figure 12. Unified Ensemble Operations Requirements

7.1 Standard Output Products

In 2009 NAEFS will have the 78 standard variables. Additional agency-specific variables include aviation weather forecast parameters (ceiling, visibility, icing, turbulence) and total cloud cover in an atmospheric column (TCDC), and cloud amount at pressure levels, a NOGAPS computed variable. Vorticity was also added as an aid to storm tracking and tropopause calculation. As a result the Task Group arrived at a total of 118 NUOPC variables, which are detailed in Figure 15. The operational Centers may decide to reduce the number of variables by using existing variables to calculate desired meteorological parameters. For example, algorithms may be used to compute ceiling and visibility, ceiling/visibility may be computed from the model microphysics and moisture, and vorticity computed from wind variables.

7.2 Standard Output Format

The standard output format is currently transitioning from standard GRIB to the newer GRIB2 format. GRIB includes an international, public, binary format used to efficiently store meteorological/oceanographic variables and the metadata that describe them. GRIB2 has a more complex set of header fields for the metadata than GRIB, and GRIB2 offers data compression that can significantly reduce file size. A GRIB data file typically consists of a collection of records. Each GRIB record contains a two-dimensional (2-D) longitude and latitude grid of data at a particular time and vertical level. A four-dimensional (4-D) GRIB data set is a collection of 2-D records covering a range of times and vertical levels. GRIB2 records may also contain ensemble information, creating a five-dimensional (5-D) data set. A GRIB record is a self-describing data object—each record contains not only the data, but also the metadata to describe the spatial grid, the valid time, the vertical level, and any ensemble metadata (for GRIB2 records). GRIB records may be concatenated together to form a single data set, but because each record is self-describing, the order in which they may be merged is arbitrary.

The Task Group also recognized the requirement for some form of data compression to limit the ensemble impact on communications bandwidth. A promising area is wavelet compression, which is well suited for storing images efficiently in a file. An example of a wavelet-based image compression standard is JPEG 2000, which supersedes the original JPEG standard created in 1992.

7.3 Overall Ensemble Configuration

The Task Group reached a consensus that the NUOPC Ensemble Forecast System would be a multi-model ensemble with each participating operational Center producing 20 ensemble members—20 at FNMOC and 20 at NCEP for total of 40 members. In addition, the integration of international members into the NUOPC ensemble would also

be considered, with NCEP serving as the interface with any and all foreign partners. Note that NAEFS sets a precedent for this.

The standard model cycle for the ensemble will be 4 times per day (every 6 hours) with forecasts out to 7 days, and the forecast output in 3-hourly increments. In addition there would be 2 cycles per day (every 12 hours) with long-range forecasts out to 30 days, with the forecast increments at 3 hourly increments for the first 7 days, extending to 6-hourly increments after 7 days. The long-range forecast period supports NOAA requirements to have products that extend the forecast period to 30 days, while the DoD agencies need forecast period of 16 days to support their planning timescales. The model resolution requirements respond to this rule of thumb: it takes an increase of at least 8 in computer resources to achieve a halving of the resolution. Recognizing this tradeoff, the Task Group arrived at two model resolution requirements:

- Option 1: 2 yr - 0.5º; 5 yr - 0.25º, 7 yr - 0.1º the option that puts us on track to close the gap with ECMWF
- Option 2: 3 yr - 0.5º; 7 yr - 0.25º; 12 yr - 0.1º this option maintains that status quo regarding model resolution deficit to ECMWF.

Task Group 5 (Implementation Plan) determined cost estimates for both of these model resolution options.

7.4 Product Delivery Schedule

Following the start of the model run, several processes will be performed before the model output is available for further post processing. Here are the estimates for the following processes: model run and bias correction +6 hours, data exchange by +6.5 hours, Center specific products by +7 hours, combined products available by +8 hours. "Drop dead time" or the time when, if new data is not available, the Centers should proceed with the data on hand, is 0.5 hours past the above times. The processing Centers will naturally explore speeding up these times by making runs available to the Centers as soon as the runs finish.

7.5 Post-Processing

All Centers will use the same algorithms for bias correction, and exchange bias-corrected fields. Common coding standards are needed to facilitate sharing algorithms/fields, and these standards are a concern for the Common Model Architecture Committee. Ensemble calibration (i.e., second-moment correction) will be done at NCEP, with AFWA as backup. AFWA will be the primary post-processing site for product generation. The Task Group considered the impact on data latency in passing model output to AFWA, but there will be a similar impact if the post processing is performed at FNMOC or NCEP, assuming equal bandwidth between all three Centers. Backup for

product generation and some Center-specific product generation will be done at FNMOC and NCEP. The Centers will share common Post-Processing Toolbox software to perform all aspects of ensemble post-processing.

7.6 Product Storage/Archive

The Task Group considered a variety of storage requirements: short-term on-line storage (~30 days in length) for bias and 2nd order corrections, hindcast on-line storage (~1 month to 5 years) for seasonal testing, and a long-term off-line archive for research and development. There was a desire to make all archives equally available to all participants. The Task Group observed that storage is cheap, but communications are expensive, so there is a desire to limit the amount of data that must be transmitted over the communications networks. NAEFS is planning to use The Observing System Research and Predictability Experiment (THORPEX) Interactive Grand Global Ensemble (TIGGE) for NAEFS off-line archive. In a similar manner, NUOPC recommends using the NCDC as the site for the long-term off-line archive. For all archives, the Task Group recommends storing both the data and the analyses, along with algorithms used to perform data corrections and analyses. Use of NCDC will entail the NUOPC Project forming an agreement with NCDC to establish the archive and pay for the data storage. As a result of their review, the Task Group recommends short term and hindcast online storage for bias and spread correction (1 month-several years) maintained at the Production Centers.

7.7 Ensemble Verification Metrics

There are several kinds of metrics that the Task Group considered: a common metrics scorecard used at all the Centers, Center-specific metrics or a Center scorecard, and the combination of the common plus the Center-specific metrics, making up the joint set of metrics. All metrics will be shared among the Centers.

The Task Group also addressed what metrics or metrics results would allow one Center to veto or deny another Center's proposed model change. The Task Group recommends that, with the NUOPC Common Metrics Scorecard defined as an agreed-to among all three agencies set of weighted metrics that capture the overall national value of the NUOPC Joint Global Ensemble, then one Center would not have veto power over a change made by another Center as long as the proposed model change has a net positive impact on this scorecard. However, if such a change has a detrimental impact on a Center's own specific scorecard, then that Center will have the option of using only its own ensemble members to support its specific applications that would be detrimentally affected by this change.

This will do two things: (1) allow Center A to ensure that its applications are not negatively impacted by a change that Center B might make, and (2) naturally motivate a

Center B to seek changes that will improve, or at least not degrade, Center A's specific metrics, as there will be less value perceived in Center B's contribution to the NUOPC if Center A is not making use of Center B's ensemble members for all of its applications.

7.8 Bandwidth between Centers

The required bandwidth between Centers depends on the final number of model parameters, number of levels, forecast times, model resolution, the number of ensemble members, and required delivery time. The Task Group calculated the bandwidth requirements using the two model resolutions:

- 0.5 degree resolution: ~32 GB per ensemble run; bandwidth required ~162 Mbps
- 0.1 degree resolution: ~810 GB per ensemble run; bandwidth required ~4050 Mbps

The bandwidth calculations assume 30 minute transfer of all fields and all forecast times. It may be possible to relax the 30 minute delivery constraint with significant bandwidth reduction. For example, perhaps only some of the parameters and/or some of the forecast times (e.g., first 7 days) really need to be transmitted within the first 30 minutes, with other parameters and/or longer forecast times not needed until later in the cycle. In addition, the fields for the longer forecast time might be exchanged at coarser resolution since forecast skill falls off rapidly at the finer scales. NAEFS may provide an example for how relaxed delivery constraints would translate into bandwidth savings.

8. Proposed Concept of Operations (CONOPS)

The UEO CONOPS Task Group focused on what actions will result in achieving the NUOPC End State in 2015. This end state will result in a nationally unified multi-model global ensemble with more members than could be run by any of the three U.S. NWP Centers alone. Moreover, the output from this ensemble will extend the range of U.S. weather forecasts and provide unprecedented insight into the probability of forecasts events and the overall reliability of global NWP products.

8.1 Purpose

The main purpose of the UEO CONOPS is to address the following:

- To establish and document the NUOPC Unified Ensemble Operations roles, responsibilities, procedures, and methods in operating, sustaining, and managing the NUOPC Unified Ensemble.
- To achieve greater diversity in initial conditions, model formulation, and model implementation than would be possible for each individual Center.

- To provide better skill of probabilistic forecast guidance products and estimates of forecast reliability than would be possible for each individual Center.

8.2 Vision

The NUOPC end state will result in the Centers utilizing the Unified Global Ensemble as the principal source for confidence and certainty in their products and guidance. To support special applications for their unique customers, any Center may opt to use a subset of the Unified Global Ensemble members. Any Center may opt to include additional ensemble components (e.g., international ensembles such as ECMWF, NAEFS, and others) beyond NUOPC requirements to meet Center-specific needs. Implementation of the Unified Global Ensemble will achieve a robust backup for U.S. global NWP because there will be no single point of failure: if one of the operational processing Centers is down, a Unified Global Ensemble will be available via the capabilities of the other processing Centers.

Each processing Center will run a global ensemble suite based on a NWP system configured to best meet their individual mission requirements and to achieve significant model diversity. NWP systems include forecast model, data assimilation system, and ensemble initialization technique. NWP system configurations that allow model diversity among the Centers are encouraged. International Global Ensemble members may be included, but their availability will not be required.

Additional long-term objectives of the Unified Global Ensemble include a commitment by all the Centers to support the COPC JAG/CCM proposed enterprise-to-enterprise communications infrastructure and bandwidth required for ensemble data exchange, including IA requirements. The Centers will invest in sufficient computational resources to ensure on-time delivery of their contributions to the Unified Global Ensemble. And, the Centers will coordinate HPC procurements to migrate to a more consistent or highly-compatible hardware architecture to achieve economy of scale in joint procurements, where feasible.

8.3 Production and Post-Processing Centers

FNMOC and NCEP will operate and maintain global ensemble forecast systems, and will thus be designated as the NUOPC Production Centers. NCEP will further perform ensemble calibration (i.e., second-moment correction) and serve as the interface and entry point for possible international ensemble members. AFWA will serve as the primary post-production site for product generation, validation, and the monitoring of overall ensemble verification metrics. AFWA will also serve as the backup for NCEP ensemble calibration. AFWA is thus designated as the NUOPC Post-Production Center. Product requirements and performance metrics will be provided by all three Centers. NCEP and

FNMOC will have the capability to backup the post-processing performed at AFWA, and will produce some Center-specific products.

8.4 Post Processing

Post processing consists of the following steps:

1. Bias correction of each Center's ensemble
2. Ensemble calibration (i.e. higher-moment corrections).
3. Combination of bias-corrected ensembles, including spread and higher-moment (calibration) corrections, to create the 6-D calibrated joint ensemble data base (variable, ensemble member, x, y, z, t). The resulting 6-D data base is shared among all three Centers.
4. Production of derived products from the 6-D data base and other information (e.g., Convective Available Potential Energy (CAPE) index, gale-force wind probability, joint probabilities, etc.).

Step 1 is performed at NCEP and FNMOC for their respective ensemble suites. Steps 2 and 3 are performed at NCEP, including the possible addition of ensemble members from international sources, with backup at AFWA. Step 4 is performed at AFWA, with mission-specific production and backup capabilities at NCEP and FNMOC.

Note that it is possible that other bias correction options may be considered. This is a research topic, and the bias correction approach might change in the future. While the UEO Committee assumed that all bias correction would be performed at the originating Center, it is recommended that NUOPC engage with the research community on the future direction for bias correction approaches.

8.5 Data Flow

Figure 13, Ensemble Data Flow, shows the expected data flow for the Unified Ensemble. In the figure at Step 1, the two Production Centers, NCEP and FNMOC, are responsible for producing their ensemble members and conducting their own bias correction. FNMOC provides their bias corrected data to NCEP who combines that data with their own bias corrected data (and possibly with bias corrected data from international ensembles). At Step 2 NCEP conducts second order calibrations, with AFWA capable of performing calibration as backup for this step. The resulting calibrated data are available for the 6-D calibrated joint ensemble data base (variable, ensemble member, x, y, z, t), and Center-specific subsets of data are also available for the respective Production Centers. At Step 3 AFWA conducts post-processing to derive certainty and confidence statistics, with both NCEP and FNMOC capable of performing the post-processing as backup for this step. The post-processing information is provided to the 6-D data base to better describe the calibrated output from Step 2, and subsets of post-processing data are

available to the specific Centers. In Step 4 AFWA performs validation and verification, providing these statistics back to the processing Centers. Both NCEP and FNMOC have the capability to perform validation and verification as backup. Raw ensemble data will also flow to AFWA and the other centers for Step 4 post-processing.

Post-processing software will be shared among the Centers as follows:

- Post-processing Step 1: software jointly developed and shared between NCEP and FNMOC
- Post-processing Step 2: software jointly developed and shared between NCEP and AFWA
- Post-processing Steps 3 and 4: software jointly developed and shared between all three Centers

Product dissemination and visualization will remain uniquely mission-specific, and therefore performed by each Center to satisfy its mission and customer requirements.

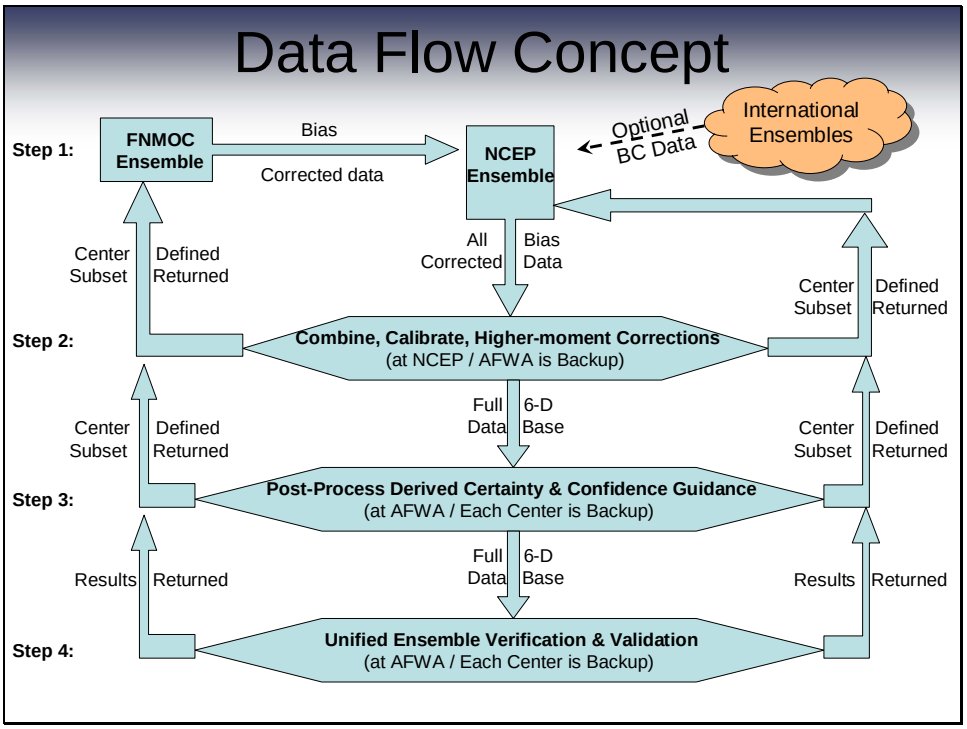

Figure 13. Ensemble Data Flow

8.6 Unified Ensemble Requirements

Both Production Centers, NCEP and FNMOC, shall meet the minimum requirements below by 2015:

- Output grid horizontal resolution: 0.1 degree latitude/longitude grid
- Output grid pressure levels
- Number of ensemble members: 20
- List of standard fields in common units
- 4 Cycles/day to 168 hours, 3 hr forecast intervals
- 2 Cycles/day 168 to 374 hours, 6 hr forecast intervals
- 1 Cycle/day 374 to 720 hours, 6 hr forecast intervals
- Common Production/delivery schedule
- GRIB2 files, compression to be determined

NAEFS Expanded Dataset (October 2008)		
Variables	NCEP: Pgrba file /CMC: naefs file	**Total 78**
GHT	Surface, 10, 50, 100, 200, 250, 500, 700, 850, 925, 1000hPa	11
TMP	2m, 2mMax, 2mMin, 10, 50, 100, 200, 250, 500, 700, 850, 925, 1000hPa	13
RH	2m, 10, 50, 100, 200, 250, 500, 700, 850, 925, 1000hPa	11
UGRD	10m, 10, 50, 100, 200, 250, 500, 700, 850, 925, 1000hPa	11
VGRD	10m, 10, 50, 100, 200, 250, 500, 700, 850, 925, 1000hPa	11
PRES	Surface, PRMSL	2
PRCP-NCEP	Categorical: APCP, CRAIN, CSNOW, CFRZR, CICEP	5
PRCP-CMC	Cumulative from 00hr: Rain, Snow, Freezing rain, Ice pellets	
FLUX (surface)	LHTFL, SHTFL, DSWRF, DLWRF, USWRF, ULWRF (CMC-cmltv, NCEP 6hr avg)	6
FLUX (top)	ULWRF (OLR) (CMC-cmltv, NCEP 6hr avg)	1
PWAT	Total precipitable water at atmospheric column	1
TCDC	Total cloud cover at atmospheric column (CMC instantaneous, NCEP 6hr avg)	1
CAPE	Convective available potential energy	1
SOIL	SOILW(0-10cm), WEASD(water equiv. of accum. Snow depth), SNOD(surface), TMP(0-10cm down)	4

Figure 14. NAEFS Dataset

The number of output parameters will be phased-in, starting with initial production based on the 78 NAEFS expanded dataset of variables shown in Figure 14. Additional biased-corrected and calibrated variables will be added, as needed, for calculating derived variables. Based on Tri-Agency requirements, the actual number of output variables, produced and calculated, is shown on Figure 15. Additional derived variables will be determined by emerging requirements. All derived variables will be calculated using common software, termed the Common Post-Processing Toolbox.

Standard Output Products

Variables	Details	Numbers of Variables
GHT	Surface, 10, 50, 100, 200, 250, 500, 700, 850, 925, 1000hPa	11
TMP	2m, 2mMax, 2mMin, 10, 50, 100, 200, 250, 500, 700, 850, 925, 1000hPa	13
RH	2m, 10, 50, 100, 200, 250, 500, 700, 850, 925, 1000hPa	11
UGRD	10m, 10, 50, 100, 200, 250, 500, 700, 850, 925, 1000hPa	11
VGRD	10m, 10, 50, 100, 200, 250, 500, 700, 850, 925, 1000hPa	11
PRES	Surface, PRMSL	2
PRCP (types)	APCP, CRAIN, CSNOW, CFRZR, CICEP (plus accumulated values).	5
FLUX (surface)	LHTFL, SHTFL, DSWRF, DLWRF, USWRF, ULWRF	6
FLUX (top)	ULWRF (OLR)	1
PWAT	Total precipitable water at atmospheric column	1
TCDC	Total cloud cover at atmospheric column, and cloud cover on pressure levels 10, 50, 100, 200, 250, 500, 700, 850, 925hPa	10
SENSIBLE WX	ceiling, surface visibility, surface winds (u*,v*), QPF	5
VORTICITY	10, 50, 100, 200, 250, 500, 700, 850, 925, 1000hPa	10
CAPE	Convective available potential energy	1
SOIL	SOILW(0-10cm), WEASD(water equiv. of accum. snow depth), SNOD(surface), TMP(0-10cm down)	4
TURBULENCE	10, 50, 100, 200, 250, 300, 400, 500hPa	8
ICING	10, 50, 100, 200, 250, 300, 400, 500hPa	8
TOTAL 2D FIELDS		**118**
NOTES	Possible to reduce number of fields by replacing diagnostics such as ceiling, visibility, and vorticity. Not all variables can be bias corrected because not all variables are analyzed.	

Figure 15. NUOPC Ensemble Standard Output Products

8.7 Common Production and Delivery Timelines

To permit scheduling output products at the three Centers, the Production Centers and the Post-Production Center will adhere to the following output delivery timelines:

- Ensemble initialization by cycle +4.5 hours
- Ensemble members / bias correction by cycle +6.0 hours
- Bias corrected fields to post-processing Center by cycle +6.5 hours
- Center specific products by cycle +7 hours (or whenever needed by Center customers)
- Spread corrected (post-processed) fields to production Centers by cycle +7.5 hours
- Combined products from all 3 Centers by cycle+8 hours
- Failover to own Center products if any step delayed by more than 30 minutes
- Sending raw fields to archive can be slower

The Centers will keep each other informed of any events that could jeopardize these timelines to permit action to reduce the adverse impacts of any production delays.

8.8 Configuration Management

To facilitate software exchange and interoperability of software components, the use of compatible Configuration Management (CM) tools and techniques across the Tri-Agencies is necessary. In addition, as defined by the Common Model Architecture Committee, the three Centers agree to common implementation of the Earth System Modeling Framework (ESMF) and use of common software coding and documentation standards. As part of NUOPC cooperation, the Centers will coordinate all changes to their global NWP systems, global ensemble suites and related post-processing software. Each Center will plan, manage and control all software changes through their existing change-control process and provide advance notification of changes to the other Centers. Each Center will encourage participation of the others in pre-implementation evaluation of major upgrades. The Common Post-Processing Toolkit software will be shared among the Centers, as described above in section 7.5, and all derived variables will be calculated using this shared software. In addition, the Centers will provide advance notification to the other Centers when changes to their underlying NWP system are needed. When two Centers propose changes at the same time, they will negotiate and preferably schedule staggered implementation and operational testing. This will avoid the complexity of problem identification with multiple simultaneous implementations.

8.9 Metrics

Under NUOPC, the Centers will use two kinds of performance statistics: routine NUOPC performance metrics (defined by the TTP Committee and based on best scientific practices) and a scorecard of statistics to be used for model update testing (defined individually by each of the Centers). To the extent possible, routine performance statistics for both the underlying NWP system and the resulting joint ensemble will use common algorithms and software. All Centers will contribute requirements to be included both in the routine performance statistics and in the scorecard metrics. Use of the metrics scorecard applies to “major” changes in the underlying NWP systems or the post-processing software.

8.9.1 Common Metrics

The Centers will use utilize common quality measures and common verification software to quantify NWP skill, such as: NWP system skill statistics, ensemble mean skill statistics, ensemble spread/skill statistics, and ensemble diagnostics. The Centers will use common performance metrics, such as: on-time product delivery, time of fail-over from primary to backup processing, cost of management per compute cycle, research-to-operations transition efficiency/effectiveness. Performance metrics will be calculated and published on a quarterly basis for the Unified Global Ensemble, each Center’s ensemble suite, and each Center’s underlying NWP system.

The goals of using common metrics include supporting the transition of R&D to operations, quantifying the value each Center brings to the Unified Global Ensemble, tracking changes to this value as each Center makes changes to its NWP system and ensemble suite, and identifying and prioritizing future R&D requirements.

8.9.2 Scorecard Metrics

Each Center will determine the content of its scorecard metrics. This is defined as the COMMON set of metrics, which when combined with the scorecards of the other Centers forms the JOINT set of verification metrics. The scorecard metrics will combine and summarize various quality measures important to the specific Center. The Centers will share all metric algorithms/codes. Used in conjunction with a pending model change, the scorecard metrics will produce a result that is positive, neutral, or negative:

- >0 -- significant increase in skill relative to operational baseline
- =0 -- no change in skill relative to operational baseline
- <0 -- significant decrease in skill relative to operational baseline

Each Center encourages participation of the others in pre-implementation evaluation of major upgrades. In preparation for a proposed model change, the Centers will test the impact of the upgrade using their COMMON set of metrics. The scorecard metrics will be applied to a version of the updated system in a beta or operational test mode with other Center fields isolated from their operational system. The Centers will report impact of change on the COMMON set as well as the JOINT set (i.e., consolidated individual scorecards). A net scorecard result that is positive indicates a proposed model update can be implemented in operations. Neutral or negative results will require further investigation that could revise or delay the pending implementation. If Centers disagree on proposed implementations, the issue will be discussed and resolved at the Center Director level or higher. As the Centers participate in the review and coordination of proposed model changes, they must weigh the potential benefit of a proposed change with the delay in implementation caused by this level of coordination.

8.10 Post-Processing

The Production Centers will use the same algorithm for bias correction and exchange bias-corrected fields. The Production Centers and the Post-Production Center will use the same algorithms, where applicable, to combine NUOPC ensemble output for the generation of derived products. All Centers will contribute to the development and implementation of a Common Post-Processing Toolkit that will contain all of the necessary algorithms and software to produce the full range of NUOPC post-processed products. The Post-Production Center will use this Toolkit software to generate a common set of derived products for use by all Centers. Each Production Center will have the capability to use the Toolkit software to backup the Post-Production Center, and may

generate additional derived products and downscaled products to fit the needs of their users. All Centers will share and jointly manage the configuration of the Common Post-Processing Toolkit software.

8.11 Archival

Both raw forecasts and bias-corrected and calibrated output will be archived. Raw forecasts from the Production Centers will be saved in the TIGGE archive, which is maintained at the NCAR's Computational and Information Systems Laboratory. The bias-corrected/calibrated 6-D data base will be archived at the NCDC, with retention period of up to 4 years. Archive of some derived products may be done at individual Centers. An estimate of the NUOPC data archival, described in Figure 16, is ~22Terabytes (TB)/day (10^{12} bytes/day), based on ensemble resolution of 0.1 degree and a total of 60 ensemble members (20 from NCEP, 20 from FNMOC and 20 from international sources).

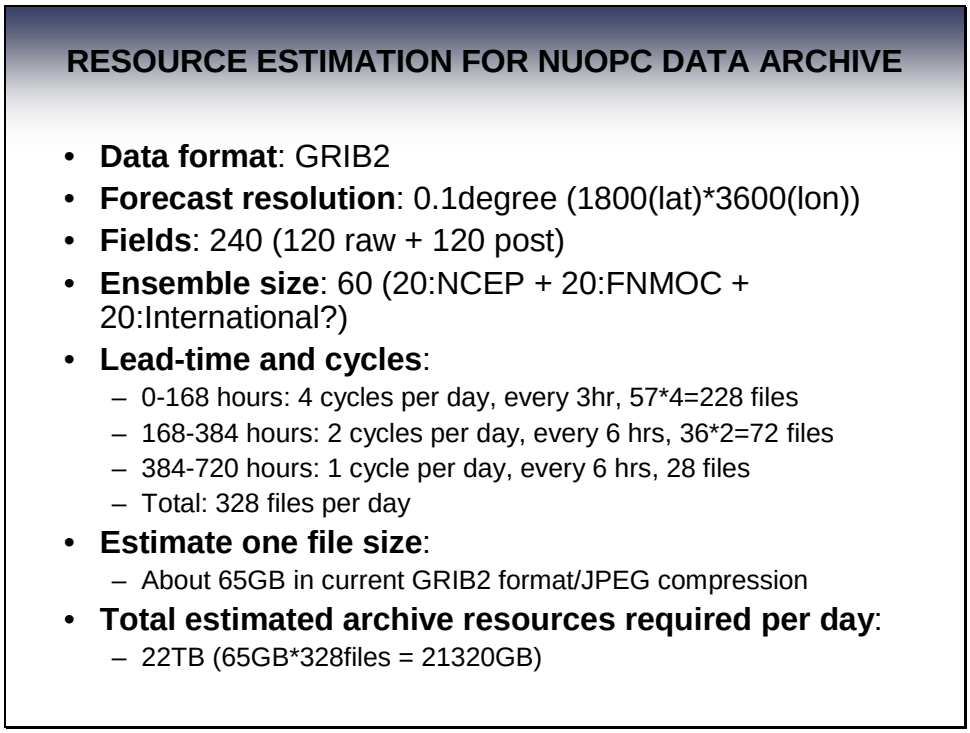

Figure 16. NUOPC Data Archival Estimate

8.12 Bandwidth

In order to estimate the bandwidth requirements for transferring NUOPC ensemble data for the NUOPC ensemble output, the calculations considered model resolution, ensemble size, and the number of variables. It was also assumed that all data have to be transferred in 30 minutes at full spatial resolution. Figure 17 shows the calculations for bandwidth, with an estimated transfer rate of 162 Mbps at model resolution of 0.5 degree

latitude/longitude. The transfer rate needed will increase to 4.05 Gigabits per second (Gbps) (10^9 bits per second) at model resolution of 0.1 degree. This represents a worst-case scenario, as fields at the longer forecast times could likely be shared at coarser resolution given the rapid fall off in forecast skill at the finer scales.

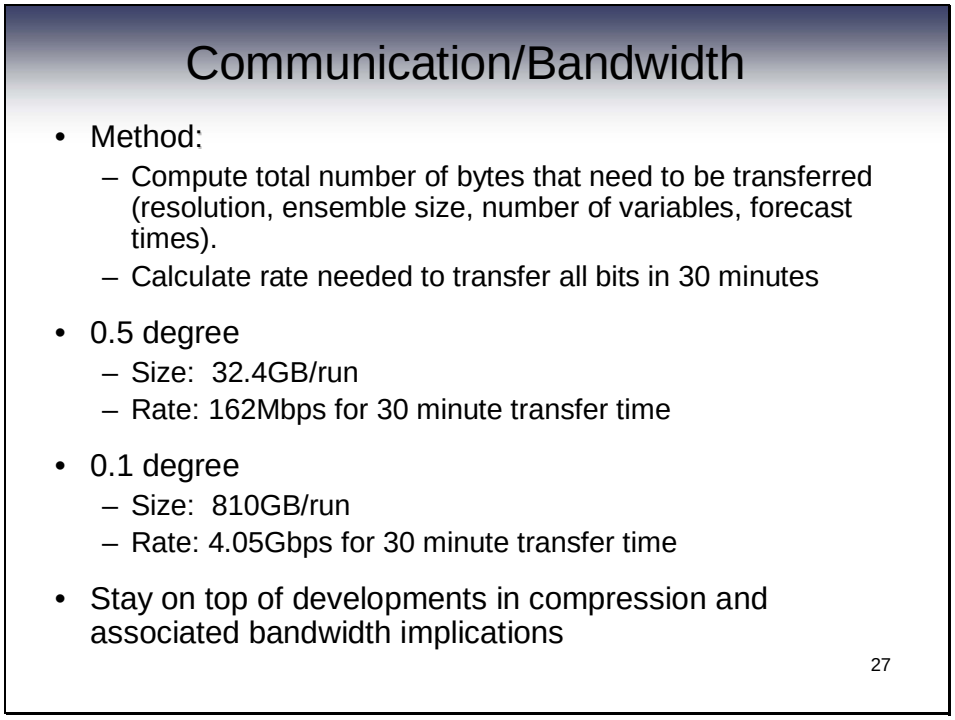

Figure 17. NUOPC Bandwidth Estimate

9. Implementation Plan.

The Implementation Plan Task Group considered capabilities described in the NUOPC CONOPS defined above, and arrived at a schedule of milestones to implement that CONOPS. Once the milestones and schedule were determined, the Task Group addressed the costs involved. The major cost drivers for the Implementation Plan were:

- Cost for expanding global ensemble production
- Cost for coordinating operational production
- Cost for expanded communications infrastructure and bandwidth required for ensemble data exchange
- Cost for online/offline and short/long term storage
- Cost for centralized assembly, generation, and dissemination of Unified Global Ensemble output
- Cost for standardization of software systems and infrastructure
- Cost to implement common performance metrics
- Cost to achieve a workable level of IA compatibility

9.1 Milestones for FY 2010

In Fiscal Year 2010, the major NUOPC milestones will involve data exchange using GRIB2, producing all 78 of the 78 NAEFS fields at NCEP and FNMOC, performing bias correction using common software at NCEP and FNMOC, establishing an IA liaison with the COPC JAG/CCM regarding the enterprise-to-enterprise network, designing the Common Post-Processing Toolbox software, arranging for the NUOPC archive at NCDC, and creating agency-specific metrics scorecards.

FY 2010 NUOPC Milestone	Date Competed
Achieve GRIB2 data exchange between FNMOC and NCEP	1Q FY10
Establish a NUOPC IA representative to liaise with COPC JAG/CCM	1Q FY10
FNMOC and NCEP ensure production of all required NAEFS IOC exchange fields (78) from their ensemble suites	2Q FY10
Implement Bias Correction at both FNMOC and NCEP with common software	2Q FY10
Implement GRIB2 processing capabilities at AFWA	4Q FY10
Complete agreement with NCDC for archive	4Q FY10

Figure 18. Revision 1. FY 2010 NUOPC Milestones

The use of GRIB2 is a natural progression from GRIB, which NCEP and FNMOC use currently.

Establishing a NUOPC link to the COPC JAG/CCM is needed to track the progress of the proposed enterprise-to-enterprise network and to ensure that all IA concerns are considered in the new network design.

The production and exchange of the 78 NAEFS fields is considered an essential first step to meet the NAEFS IOC/NUOPC IOC1.

To arrange for the future archival of NUOPC data at NCDC, NUOPC will need to fully document the archive requirements and execute an agreement with NCDC.

9.2 Milestones for FY 2011

In Fiscal Year 2011 the major NUOPC milestones will involve setting up the Super ODAA following the approach of the NPOESS program, creating and sharing the 6-D ensemble database, implementing the COPC/JAGCCM enterprise-to-enterprise network, commencing use of the common metrics scorecards, upgrading HPC capabilities and network bandwidth to meet 0.5 degree model resolution requirements, establishing the

NUOPC archive at NCDC, achieving NAEFS IOC, and obtaining and implementing software scanning tools from ASACoE.

FY 2011 NUOPC Milestone	Date Competed
Identify overarching ODAA for NUOPC IA issues, per NPOESS approach	1Q FY11
Create 6-D data base at NCEP	1Q FY11
Implement COPC JAG/CCM proposed enterprise-to-enterprise communications infrastructure	TBD, desired 2Q FY11
Begin use of common scorecard	2QFY11
Upgrade HPC capabilities to support 0.5 degree ensemble production	2Q FY11
Upgrade bandwidth of enterprise-to-enterprise network to support exchange of 0.5 degree ensembles	3 Q FY11
Share 6-D data base among all three Centers	3Q FY11
Establish archive at NCDC	4Q FY11
Achieve NAEFS IOC/NUOPC IOC1	4Q FY11
Obtain software scanning tools from ASACoE and implement at all three Centers	4Q FY11
Complete joint design of common post-processing toolbox software	4Q FY11
Create agency-specific scorecards	4Q FY11

Figure 19. Revision 1. FY 2011 NUOPC Milestones

Because IA concerns of the NPOESS Program are similar to those facing the NUOPC project, NUOPC will take advantage of the IA policies and procedures established by NPOESS. In particular, NUOPC will adopt the NPOESS solution for establishing a Super ODAA with authority to define and implement common IA policies and C&A criteria for AFWA, FNMOC and NCEP.

The establishment of a 6-D data base for NUOPC output will permit the ready access of ensemble output by operational customers as well as the R&D community. Sharing the 6-D data base among the Centers will facilitate backup procedures, permitting a Center that has lost its production or post-processing capabilities to access the production or post-processing output from the other Centers.

Implementing the COPC/JAG/CCM enterprise-to-enterprise network will support the additional bandwidth that NUOPC will require to transfer data among the three Centers.

Initiating the use of the metrics scorecards will involve initiating a change management process among the three Centers to review the impact of the proposed model changes as

shown by the individual Center's scorecard results. This process will include announcing a pending model change, collecting the scorecard metrics, analyzing the scorecards, assessing the impact of the proposed change (positive, neutral, or negative) based on the scorecard results, and determining among the Centers whether the proposed change should be implemented on schedule, delayed, or revised.

Preparation for model resolution upgrades from 1.0 degree to 0.5 degree latitude/longitude the following year will require commensurate increases in computer resources and communications bandwidth to support ensemble production and data transfer.

With the realization of the NAEFS IOC/NUOPC IOC1, ensemble output will be available to the Centers for use in forecast products, for population of the 6-D database, and for incorporation into the NCDC archive.

The Centers will begin the use of software scanning tools to mitigate the threat of malicious code being introduced into a Center from software obtained from the other Centers. Once NUOPC established an agreement with ASACoE, that organization will provide scanning tools and training to the Centers. The Centers will identify to ASACoE what software languages will need scanning, and ASACoE will provide or develop scanning tools for those languages.

The use of the same software in performing bias correction will establish the NUOPC concept of the Production Centers using standardized software. Using the same bias correcting algorithms at both Production Centers will result in consistent ensemble output from both Centers. Joint design of the Common Post-Processing Toolkit software also supports software standardization, and ensures consistent post-processing of ensemble output, regardless of which Center performs the post-processing.

To facilitate the implementation of projected model changes across the Tri-Agencies, each Center will determine the contents of its metrics scorecard. Contents of the individual scorecards will define the COMMON metrics, while the combination of all the scorecard metrics will define the JOINT set of verification metrics. The scorecards will evaluate the impact of a projected change and help the Centers determine whether a proposed change contributes value and is ready for implementation.

9.3 Milestones for FY 2012

In Fiscal Year 2012 the major NUOPC milestones will involve implementing 0.5 degree model resolution at the Production and Post-Production Centers, executing the first spiral development of the Common Post-Processing Toolbox, and producing bias-corrected and calibrated model variables needed for all derived parameters.

FY 2012 NUOPC Milestone	Date Competed
Implement 0.5 degree ensemble runs at Production Centers	1Q FY12
Upgrade HPC capabilities to support 0.5 degree ensemble post-production	2Q FY12
Implement Spiral 1 of common post-processing toolbox at all three Centers for initial testing	2Q FY12
Begin operational product generation using common post-processing toolbox [linked with stretch goals TBD]	4Q FY12
Produce all bias-corrected and calibrated model variables needed for derived parameters	4Q FY12

Figure 20. FY 2012 NUOPC Milestones

With the computer resources upgrades in place to support 0.5 degree model resolution ensemble production and post-production, the Production and Post-Production Centers will commence ensemble operations using the higher model resolution.

The Common Post-Processing Toolbox will require periodic upgrades as one Center identifies new algorithms that may be used by the other Centers. A spiral development process for the toolbox is a way to periodically develop, review, evaluate, and integrate new capabilities into it.

The addition of calibration (second-order and higher-moment corrections) to the post-processing bias-correction will permit the Post-Processing Center (AFWA, with the other Centers providing backup) to derive model certainty and confidence guidance for the ensemble members. Bias-correction and calibration will be performed on the ensemble output using the upgraded 0.5 degree model resolution, and will include computed and derived parameters.

9.4 Milestones for FY 2013

In Fiscal Year 2013, the major NUOPC milestones will involve employing agency-specific scorecards and common metrics at all the Centers, producing all required derived parameters, and upgrading HPC capabilities and network bandwidth to support 0.25 degree model resolution.

FY 2013 NUOPC Milestone	Date Competed
Implement agency-specific scorecards and common metrics across all Centers	1Q FY13
Derive all required parameters from bias-corrected and calibrated fields	2Q FY13
Upgrade HPC capabilities to support 0.25 degree ensemble production	2Q FY13
Upgrade HPC capabilities to support 0.25 degree ensemble post-production	3Q FY13
Upgrade bandwidth of enterprise-to-enterprise network to support exchange of 0.25 degree ensembles	3Q FY13

Figure 21. FY 2013 NUOPC Milestones

Individual Center metrics scorecards will be exchanged among all the Centers, and this will permit all of the Centers to see and understand the impact of a proposed change.

With all ensemble fields bias-corrected and calibrated, post-processing to derive all required parameters will be implemented.

Planned model resolution upgrades from 0.5 degree to 0.25 degree for the following year will require commensurate increases in computer resources and communications bandwidth to support ensemble production, post-production, and data transfer.

9.5 Milestones for FY 2014

In Fiscal Year 2014 the major NUOPC milestones will involve implementing 0.25 degree ensemble runs and completing the second spiral development of the Common Post-Processing toolbox.

FY 2014 NUOPC Milestone	Date Competed
Implement 0.25 degree ensemble runs at Production Centers	1Q FY14
Implement Spiral 2 of common post-processing toolbox at all three Centers for initial testing	2Q FY14
Begin operational product generation using Spiral 2 of common post-processing toolbox [linked with stretch goals TBD]	4Q FY14

Figure 22. FY 2014 NUOPC Milestones

With the computer resources upgrades in place to support 0.25 degree model ensemble production and post-processing, the Production and Post-Production Centers will commence ensemble operations using the higher model resolution.

Continuing development and implementation of the Common Post-Processing Toolbox will now enter Spiral 2.

9.6 Milestones for FY 2015 and FY 2016

In Fiscal Years 2015-2016 the major NUOPC milestones will involve upgrading HPC capabilities and network bandwidth to support 0.1 degree model resolution, and implementing 0.1 degree model ensemble runs.

FY 2015-2016 NUOPC Milestone	Date Competed
Upgrade HPC capabilities to support 0.1 degree ensemble production	2Q FY15
Upgrade HPC capabilities to support 0.1 degree ensemble post-processing	3Q FY15
Upgrade bandwidth of enterprise-to-enterprise network to support exchange of 0.1 degree ensembles	3Q FY15
Implement 0.1 degree ensemble runs at Production Centers	1Q FY16

Figure 23. FY 2015 and FY 2016 NUOPC Milestones

Planned model resolution upgrade from 0.25 degree to 0.1 degree latitude/longitude will require commensurate increases in computer resources and communications bandwidth to support ensemble production, post-processing, and data transfer.

With the computer resources upgrades in place to support 0.1 degree model ensemble production and post-processing, the Production and Post-Production Centers will commence ensemble operations using the higher model resolution.

9.7 Working Groups/Panels

The UEO Committee determined that NUOPC would benefit from standing up three working groups or panels that would be involved in issues related to IA and Network Operations, Ensemble Production, and Ensemble Post-Processing. Organizationally, these working groups/panels would be aligned with COPC, reporting to COPC on progress made on activities that facilitate NUOPC operations. The working groups/panels would have representation from all three Centers with expertise in NUOPC ensemble operations, and additional representatives who have expertise in the issues that the working groups/panels will be addressing.

The IA and Network Operations Working Group/Panel would be active from 1QFY10 to 1QFY16. Desired expertise would include IA, network operations, and software development. The major activities this working group/panel would be engaged in include:

- Liaison with COPC/JAG/CCM on the enterprise-to enterprise network

- Establishment of the Super ODAA
- Coordinating needed bandwidth upgrades
- Liaison with ASACoE

The Ensemble Production Working Group/Panel would be active from 2QFY10 to 1QFY16. Desired expertise would include ensemble processing, database structures, GRIB2, model resolution, and software change management. The major activities this working group/panel would be engaged in include:

- Producing required parameters/variables
- Implementing GRIB2
- Producing and sharing of the 6-D data base
- NAEFS IOC
- Ensemble configuration and resolution upgrades

The Ensemble Post-Production Working Group/Panel would be active from 1QFY10 to 1QFY13. Desired expertise would include ensemble post-processing, data archival, metrics, and software change management. The major activities this working group/panel would be engaged in include:

- Developing the Common Post-Processing Toolbox software
- Establishing the NUOPC archive at NCDC
- Developing common scorecards and metrics

9.8 Training (FY10-FY15)

The Tri-Agencies typically treat training as a function separate from operations. However, because of the paradigm change that ensemble NWP presents to the operational forecasters, training will be necessary for the success of NUOPC. The UEO Committee recommends that the Tri-Agencies collaborate in developing training focused on ensemble concepts, products, and interpretation of ensemble output. To this end, the Tri-Agencies should approach NUOPC training requirements by supporting the following activities:

- Collecting best training practices across the Tri-Agencies and interacting with users to identify ensemble training requirements (1QFY10-1QFY11)
- Planning for joint Cooperative Program for Operational Meteorology, Education and Training (COMET) modules on NUOPC, and designing Military Training School curriculum changes and NUOPC inputs to the AFW Knowledge Center (1QFY11-1QFY12)
- Designing Agency-specific training applications and modules (1QFY12-1QFY13)
- Cross feeding training developments for NUOPC (1QFY13-1QFY14)

The UOE Committee recommends ensemble training be elevated to the Tri-Agency level to ensure training tools are developed in parallel with the implementation of the NUOPC CONOPS.

9.9 Milestone Costs

The NUOPC operational milestones have significant costs associated with them. This analysis includes estimates for personnel costs (both government and contractor) and other costs (computers, communications bandwidth, archival services, disk storage, etc). In estimating the personnel costs, the UEO Committee used an average cost of $160K per FTE employee per year, regardless of whether the position was assumed to be filled by a contractor or a government employee.

Costs were binned to the following milestones:

- GRIB2
- COPC JAG/CMM Enterprise-Enterprise Network
- NAEFS IOC/NUOPC IOC1
- NCDC Archive at NCDC
- Scorecards
- IA and Super ODAA
- 6-D Data Base
- HPC Capabilities
- Ensemble Operations
- Common Toolbox
- Community of Interest/Working Groups/Panels
- Training

Most of the costs identified in this report by the UEO Committee are new costs that have not been included in current agency budgets. This report identifies these unfunded requirements for agency consideration and future budget planning.

9.9.1 GRIB2

The implementation of GRIB2 is well underway at both NCEP and FNMOC. AFWA will need to invest personnel resources to permit it to handle GRIB2 formatted data.

GRIB2	AFWA	FNMOC	NCEP	Timeframe	Total Costs
FTEs	0.5	0	0	1QFY10 to 1QFY11	$80K
Other Costs	0	0	0		

9.9.2 COPC JAG/CMM Enterprise-Enterprise Network

Cost of expanded communications infrastructure and bandwidth required for data exchange are anticipated approximate $100K/yr between 2010 and 2012, $540K/yr for 2013 to 2015. FNMOC is currently sending the NAEFS data set to NCEP and receiving about a tenth of that from NCEP. It is expected that FNMOC can receive all the NCEP grids within the current infrastructure, especially when GRIB2 files can be received and decoded. The NAEFS grids take about an hour to transfer at an effective transfer rate of 22 Mbps. Since the grid size for NUOPC is supposed to be 100 times NAEFS grids, even with better compression than the current GRIB2, NUOPC will require at least one dedicated OC-3 (155 Mbps) circuit to transfer all grids in 30 minutes (UEO Committee estimated 162 Mb/s transfer rate to transfer all grids in 30 minutes at 0.5 degree resolution). The cost of one OC-3 communication link plus switches, firewalls, support needed to connect to FNMOC network will initially cost about $100K per year to handle the model resolution of 1.0 degree to 0.5 degree; as bandwidth requirements increase with higher model resolution (0.25 degree to 0.1 degree), the communications costs are expected to escalate to $536K per year as transfer rates requirements increase to OC-48 (2.5 Gbps) or higher.

Personnel costs are estimated to one FTE, a network engineer with IA qualifications, at a cost of $160K per year, shared across the three Centers, or one third FTE per Agency per year.

COPC JAG/CMM Enterprise-Enterprise Network	AFWA	FNMOC	NCEP	Timeframe	Total Costs
FTEs	0.33	0.33	0.33	1QFY11-1QFY16	$800K
Other Costs	$33K	$33K	$33K	$100K 1QFY10-1QFY13	$300K
Other Costs	$180K	$180K	$180K	$540K 1QFY13-1QFY16	$1620K

Bandwidth calculations for NUOPC

Current 1.0 degree NAEFS
Observed transfer time averages 45 to 60 min, 30 minutes minimum, 90 minutes maximum
52 variables/levels
20 ensemble members
61 forecast times (0 to 360 hours at 6 hour intervals)

63440 grids/run
5.9 GB/run
Average GRIB file size of grids 590000000/63440 = 93.0 KB/grid
Ratio GRIB1 to flat binary grid 360*180*4/(5900000000/63440)=2.7
13.5 Mbps for 60 min average transfer time
27.0 Mb/s for 30 min transfer time

NUOPC 0.5 degree (IOC)
118 variables/levels from table in requirements document
20 ensemble members
148=57+91 forecast times (0 to 168 hrs at 3 hr intervals = 57, 174 to 720 hours at 6 hour intervals = 91)
349280 grids/run
0.5 degree grids are 4 times the size of 1.0 degree grids
GRIB2 compression to GRIB1 compression ratio expected 4.0
32.4 GB/run
13.5 Mbps for 6 hr transfer time
81 Mbps for 60 min transfer time
162 Mbps for 30 min transfer time

NUOPC 0.25 degree (FOC option 2)
0.25 degree grids are 4 times the size of 0.5 degree grids
129.6 GB/run
54.0 Mbps for 6 hour transfer time
324. Mbps for 60 min transfer time
648 Mbps for 30 min transfer time

NUOPC 0.10 degree (FOC option 1)
0.10 degree grids are 25 times the size of 0.5 degree grids
810 GB/run
337 Mbps for 6 hour transfer time
2025 Mbps for 60 min transfer time
4050 Mbps for 30 min transfer time

9.9.3 NAEFS IOC/NUOPC IOC1

The achievement of NAEFS IOC/NUOPC IOC1 will impact only FNMOC and NCEP. FNMOC and NCEP will ensure production of all required NAEFS IOC exchange fields from their ensemble suites. This effort will involve one FTE at each Center starting in FY10 until completion of IOC in late FY11. In addition, the implementation of bias correction at both FNMOC and NCEP with common software will involve additional disk storage, so both Centers estimated the disk costs to be $100K per year, also starting in FY10. Because NAEFS IOC is achieved in FY11, the requirements for 1 FTE at FNMOC and NCEP and the disk storage should only extend from FY10 to FY11. Should these costs continue out to FY16, the total costs would be $2.24M for personnel and $1.4M for disk storage.

NAEFS IOC/NUOPC IOC1	AFWA	FNMOC	NCEP	Timeframe	Total Costs
FTE	0	1	1	1QFY10-4QFY11	$640K
Other Costs		$100K	$100K	1QFY10-4QFY11	$400K

9.9.4 NUOPC Archive at NCDC

Once NUOPC completes an agreement with NCDC for archival of ensemble data, the costs of the archive will be based on the anticipated size of the data set to be stored. Because the incremental increases in data volume are aligned with the increases in model resolution, the major costs for archival services will be $0.5M in FY11, $1.0M in FY13, and $2.5M FY15. In addition, beginning in FY 11, costs for new disk storage will be $100K per agency per year.

NCDC Archive at NCDC	AFWA	FNMOC	NCEP	Timeframe	Total Costs
FTE	0	0	0		
Other Costs	$100K	$100K	$100K	1QFY11-1QFY16	$1.5M
Other Costs shared among the agencies	$0.5M	$1.0M	$2.5M	FY11, FY13, and FY15	$4.0M

9.9.5 Metrics Scorecards

Development of the metrics scorecards at the Centers will involve a software engineer with some expertise in the use of metrics. The Centers have projected that different levels of new software engineering support will be required: AFWA, 2 FTE in FY12, FNMOC, 0.5 FTE in FY12, and NCEP, 1.0 FTE in FY11. In addition, NCEP anticipated additional storage requirements costing $100K in FY11 to support the metrics scorecard efforts.

(Revision 1 Table)

Metrics Scorecards	AFWA	FNMOC	NCEP	Timeframe	Total Costs
FTE	2	0.5	1	FY12, FY12, FY11	$560K
Other Costs	0	0	$100K	1QFY11	$100K

9.9.6 IA and ODAA

Because of the importance of IA and its impact on NUOPC, the UEO Committee determined that it would be prudent for the Centers to devote 0.5 FTEs in FY11 and then reduce to 0.33 FTEs for FY12-FY16 to this effort. The FTE expertise would be in network operations with a background in IA. The main tasks would include following the efforts of the NPOESS program in establishing a Super ODAA, and applying a

similar solution to NUOPC IA issues. Tasking would also include coordinating the efforts to obtain software scanning tools and training from ASACoE and to implementing use of these tools as a standard practice at all three Centers.

IA and ODAA	AFWA	FNMOC	NCEP	Timeframe	Total Costs
FTE	0.5	0.5	0.5	1QFY11-1QFY12	$240K
FTE	0.33	0.33	0.33	1QFY12-1QFY16	$640K
Other Costs	0	0	0		

9.9.7 6-D Data Base

Creation of the 6-D data base at the three Centers will require software development by software engineers. At NCEP and FNMOC, that task will be done by existing personnel, while at AFWA this will require 2 FTEs in FY11. There will be costs at the Centers for additional disk storage to host the database. These costs are estimated to be $50K, $100K, and $250K in FY11, FY13, and FY15, respectively, to match the increased data volume caused by the increased model resolution.

6-D Data Base	AFWA	FNMOC	NCEP	Timeframe	Total Costs
FTE	2	0	0	1QFY11-1QFY12	$320K
Other Costs	$50K	$50K	$50K	1QFY11	$150K
Other Costs	$100K	$100K	$100K	1QFY13	$300K
Other Costs	$250K	$250K	$250K	1QFY15	$750K

9.9.8 HPC Capabilities

A major cost driver for NUOPC will be the anticipated increases in model resolution from 1.0 degree to 0.1 degree and their impact on HPC resources. While there are plans at all the agencies to increase HPC resources (see Figure 24), the projected NUOPC workload takes these requirements above and beyond existing agency plans. Estimated costs to acquire the HPC resources for the NUOPC workload are substantial and summarized in the following table for the original proposed model resolution upgrade to 0.1 by FY2015: 0.5 degree in FY11, 0.25 degree in FY13 and 0.1 degree in FY15. Estimated costs to acquire the HPC resources for the NUOPC workload are substantial and summarized in the following revised table for the extending model resolution upgrade to 0.1 from FY2015 to FY2020: 0.5 degree in FY12, 0.25 degree in FY15 and 0.1 degree in FY20

(Revision 1 Table)

HPC Capabilities	AFWA	FNMOC	NCEP	Timeframe	Total Costs
FTE	0	0	0		
Other Costs		$1.0M	$1.2M	FY12	$2.2M
Other Costs	$0.8M			FY12	$0.8M
Other Costs	$1.0M	$1.5M	$2.0M	FY15	$4.5M
Other Costs	$1.0M	$1.5M	$2.5M	FY20	$5.0M

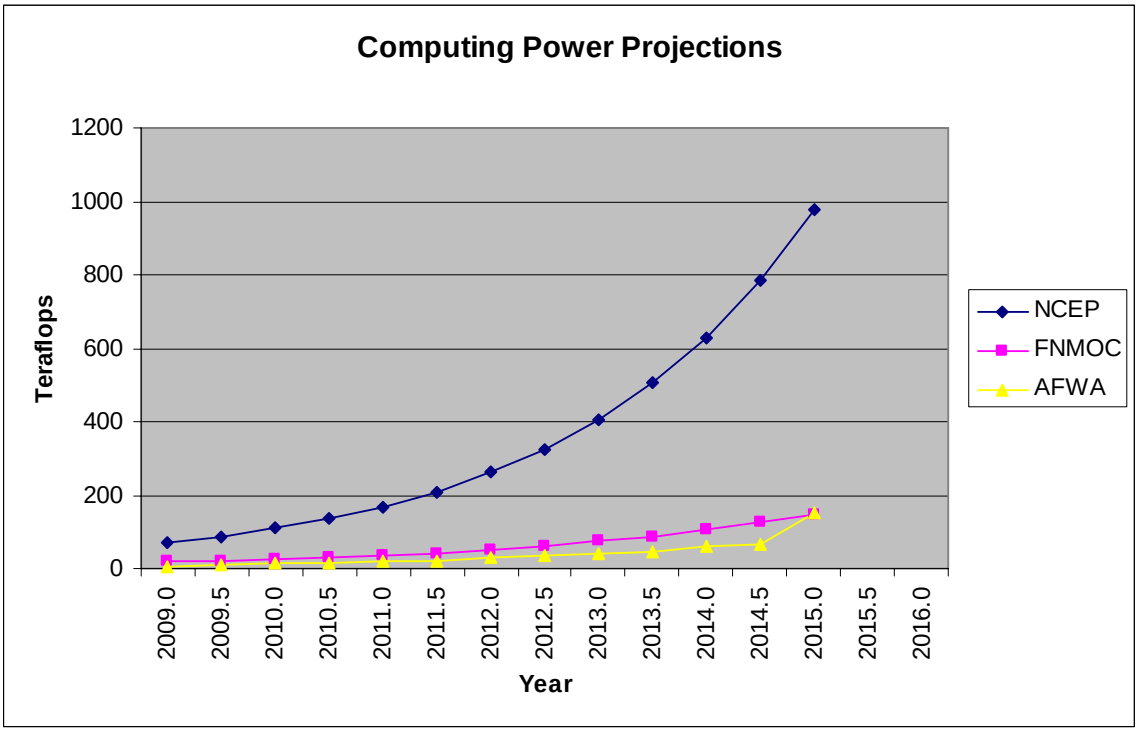

Figure 24. Tri-Agency Projected Computer Resources

9.9.9 Ensemble Operations

Beginning in early FY11 and continuing through FY16, the three Centers will need additional personnel to support ensemble operations. The various tasks these personnel will support include:

- Implementing 0.5 degree ensemble runs at Production Centers
- Producing all bias-corrected and calibrated model variables needed for derived parameters
- Producing all required derived parameters from bias-corrected and calibrated fields

- Implementing 0.25 degree ensemble runs at Production Centers
- Implementing 0.1 degree ensemble runs at Production Centers

The following revised table reflects the costs of extending the model resolution upgrades to 0.1 degree from FY2015 to FY2020.

(Revision 1 Table)

Ensemble Operations	AFWA	FNMOC	NCEP	Timeframe	Total Costs
FTE	0.5	2	3	2QFY11-2QFY20	$8.8M
Resources	0	0	0		

Note that the cost increase results from extending the FTEs for an additional 5 years (FY2015 to FY2020).

9.9.10 Common Post-Processing Toolbox

Under NUOPC, the Centers will use and share Common Post-Processing Toolbox software. This toolbox will include algorithms to derive parameters and generate products for specific requirements, applications and customers. The UEO Committee viewed this common toolbox as a continuing effort that would undergo a continuous Spiral Development effort, linked to improving model resolutions and emerging customer requirements. The development of the Common Post-Processing Toolbox will be a joint effort, and include development and testing of the software at all three Centers. The level of effort for developing the post-processing toolbox is expected to be 2 FTEs at each Center from 2QFY11 to 2QFY15, with an additional 0.5 FTEs at each Center for software maintenance 2QFY12 to 2QFY17.

(Revision 1 Table)

Common Post-Processing Toolbox	AFWA	FNMOC	NCEP	Timeframe	Total Costs
FTE	2	2	2	Development 2QFY11-2QFY15	$3,840K
FTE	0.5	0.5	0.5	Maintenance 2QFY11-2QFY17	$1,440K
Other Costs					

9.9.11 Working Groups/Panels

The UEO Committee recommended forming three separate working groups/panels, possibly under COPC, to facilitate tracking actions related to Information Assurance and Network Operations, Ensemble Production, and Ensemble Post-Processing. The UEO

Committee initially estimated that these groups would require 1-2 FTEs per panel. Upon further consideration, the assignment of personnel to these groups would likely draw in personnel from the Centers on a part-time basis, so the Committee reduced the new personnel for these groups to 0.5 FTEs per agency per panel. Note that the costs were adjusted downward for the Ensemble Post-Processing Panel because it will only run for 3 years, unlike the other two panels, that will run for the full 6 years.

(Revision 1 Table)

Working Groups/Panels	AFWA	FNMOC	NCEP	Timeframe	Total Costs
FTE IA & Network Operations	0.5	0.5	0.5	1QFY11-1QFY17	$1,440K
FTE Ensemble Production	0.5	0.5	0.5	2QFY11-1QFY17	$1,440K
FTE Ensemble Post-Production	0.5	0.5	0.5	1QFY11-1QFY14	$720K
Other Costs					

9.9.12 Training

Training will be essential to the success of introducing ensemble forecast techniques to the operational forecasters throughout the Tri-Agencies. The UEO Committee recognized that the Tri-Agencies treat training functions separately from operational functions, but wanted to identify the need to initiate a training development task that would result in a joint design of training material that could be included in the DoD military training curriculum for weather personnel and inclusion in COMET training modules for the DoC. This will require collecting the best training practices available across the Tri-Agencies, interacting with users to develop training requirements, curriculum design, cross feed of training developments as NUOPC implementation proceeds, and creating agency-specific training in the use of uncertainty, the most likely forecast outcomes, and the probability distribution of forecast outcomes. Applications may include Tactical Decision Aids and Risk Tables. Because of the amount of coordination that training development will require, an additional resource of $10K per agency per year was introduced for travel.

(Revision 1 Table)

Training	AFWA	FNMOC	NCEP	Timeframe	Total Costs
FTE	1	1	1	1QFY11-1QFY17	$2,880K
Other Costs	$10K	$10K	$10K	Travel Funds 1QFY11-1QFY17	$180K

9.10 NUOPC Cost Summary

(Revision 1 Table)

Total Tri-Agency Costs for FY10-FY20	**FTE Costs**	**Other Costs**
GRIB2	$80K	
COPC JAG/CMM Enterprise-Enterprise Network	$1,600K	$4,620K
NAEFS IOC 1	$640K	$400K
NCDC Archive	$0.00	$7,000K
Scorecards	$560K	$100K
IA and ODAA	$1,680K	
6 D Data Base	$320K	$1,200K
HPC Capabilities		$12,500K
Ensemble Operations	$8,800K	$0.00
Common Toolbox	$6,240K	$0.00
Training	$4,800K	$300K
Community of Interest/Working Groups/Panels	$5,760K	$0.00
TOTAL	$30,480K	$26,120K

Note that the cost increases in the Revision 1 Table above are a direct result of extending the FTEs and some specific resources for an additional 5 years (FY2015 to FY2020).

The table below shows the Tri-Agency costs for NUOPC for each fiscal year. Note that the cost totals on the table below are slightly different from the table above due to round off error.

Revision 1 Fiscal Year Total Costs ($K)

		FY10			FY11			FY12			FY13			FY14			FY15	
	AFWA	FNMOC	NCEP	AFWA	FNMOC	NCEP	AFWA	FNMOC	NCEP	AFWA	FNMOC	NCEP	AFWA	FNMOC	NCEP	AFWA	FNMOC	NCEP
Agency Costs (Less Training and Panels) per FY	$113.33	$293.33	$293.33	$1,066.67	$1,246.67	$1,666.67	$2,056.67	$2,256.67	$2,536.67	$866.67	$1,106.67	$1,266.67	$866.67	$1,106.67	$1,266.67	$1,980.00	$2,720.00	$3,380.00
Training per FY	$0.00	$0.00	$0.00	$170.00	$170.00	$170.00	$170.00	$170.00	$170.00	$170.00	$170.00	$170.00	$170.00	$170.00	$170.00	$170.00	$170.00	$170.00
Panels per FY	$0.00	$0.00	$0.00	$240.00	$240.00	$240.00	$240.00	$240.00	$240.00	$240.00	$240.00	$240.00	$240.00	$240.00	$240.00	$160.00	$160.00	$160.00
Tri-Agency Costs (less Training and Panels) per FY		$700.00			$3,980.00			$6,850.00			$3,240.00			$3,240.00			$8,080.00	
Training per FY		$0.00			$510.00			$510.00			$510.00			$510.00			$510.00	
Panels per FY		$0.00			$720.00			$720.00			$720.00			$720.00			$480.00	
Total Tri-AgencyCosts per FY		$700.00			$5,210.00			$8,080.00			$4,470.00			$4,470.00			$9,070.00	

The following page contains a spreadsheet of all the milestone costs allocated to each agency for each fiscal year, FY2010 to FY2015.

(Revision 1 Spreadsheet)

New Milestones March 18 2009	AFWA	FY10 Resource	FY10 FTEs	FY10 FTE Cost	FY11 Resource	FY11 FTEs	FY11 FTE Cost	FY12 Resource	FY12 FTEs	FY12 FTE Cost	FY13 Resource	FY13 FTEs	FY13 FTE Cost	FY14 Resource	FY14 FTEs	FY14 FTE Cost	FY15 Resource	FY15 FTEs	FY15 FTE Cost
GRIB2			0.5	$80.00															
COPC JAG/CMM Enterprise-Enterprise Network		$33.33			$33.33	0.333333	$53.33	$33.33	0.33	$53.33	$180.00	0.33	$53.33	$180.00	0.33	$53.33	$180.00	0.33	$53.33
NAEFS IOC 1																			
NCDC Archive					$100.00			$100.00			$100.00			$100.00			$100.00		
Establish archive at NCDC								$166.67									$333.33		
					-$166.67						-$333.33						-$833.33		
Scorecards									2	$320.00									
IA and ODAA						0.5	$80.00		0.333333	$53.33		0.333333	$53.33		0.333333	$53.33		0.333333	$53.33
6 D Data Base						2	$320.00	$50.00									$100.00		
					-$50.00						-$100.00						$250.00		
HPC Capabilities								$800.00									$1,000.00		
											-$1,000.00						-$1,000.00		
Ensemble Operations						0.5	$80.00		0.5	$80.00		0.5	$80.00		0.5	$80.00		0.5	$80.00
Common Toolbox						2.5	$400.00		2.5	$400.00		2.5	$400.00		2.5	$400.00		0.5	$80.00
			-2.5	-$400.00											-0.5	-$80.00			
Training					$10.00	1	$160.00	$10.00	1	$160.00	$10.00	1	$160.00	$10.00	1	$160.00	$10.00	1	$160.00
		-10	-1	-$160.00															
Community of Interest/Working Groups/Panels						1.5	$240.00		1.5	$240.00		1.5	$240.00		1.5	$240.00		1	$160.00
			-1.5	-$240.00															
COSTS (less Training and Panels) per FY		$33.33	$0.50	$80.00	$133.33	$5.83	$933.33	$1,150.00	$5.67	$906.67	$280.00	$3.67	$586.67	$280.00	$3.67	$586.67	$1,713.33	$1.67	$266.67
Training per FY		$0.00	0.00	$0.00	$10.00	1.00	$160.00	$10.00	1.00	$160.00	$10.00	1.00	$160.00	$10.00	1.00	$160.00	$10.00	1.00	$160.00
Panels per FY		$0.00	0.00	$0.00	$0.00	1.50	$240.00	$0.00	1.50	$240.00	$0.00	1.50	$240.00	$0.00	1.50	$240.00	$0.00	1.00	$160.00
			FY10			FY11			FY12			FY13			FY14			FY15	
Costs (less Training and Panels) per FY			$113.33			$1,066.67			$2,056.67			$866.67			$866.67			$1,980.00	
Training per FY			$0.00			$170.00			$170.00			$170.00			$170.00			$170.00	
Panel per FY			$0.00			$240.00			$240.00			$240.00			$240.00			$160.00	
			$113.33			$1,476.67			$2,466.67			$1,276.67			$1,276.67			$2,310.00	

New Milestones March 18 2009	FNMOC	FY10 Resource	FY10 FTEs	FY10 FTE Cost	FY11 Resource	FY11 FTEs	FY11 FTE Cost	FY12 Resource	FY12 FTEs	FY12 FTE Cost	FY13 Resource	FY13 FTEs	FY13 FTE Cost	FY14 Resource	FY14 FTEs	FY14 FTE Cost	FY15 Resource	FY15 FTEs	FY15 FTE Cost
GRIB2																			
COPC JAG/CMM Enterprise-Enterprise Network		$33.33			$33.33	0.333333	$53.33	$33.33	0.33	$53.33	$180.00	0.33	$53.33	$180.00	0.33	$53.33	$180.00	0.33	$53.33
NAEFS IOC 1		$100.00	1	$160.00	$100.00	1	$160.00												
NCDC Archive					$100.00			$100.00			$100.00			$100.00			$100.00		
Establish archive at NCDC								$166.67									$333.33		
					-$166.67						-$333.33						-$833.33		
Scorecards									0.5	$80.00									
IA and ODAA						0.5	$80.00		0.333333	$53.33		0.333333	$53.33		0.333333	$53.33		0.333333	$53.33
6 D Data Base								$50.00									$100.00		
					-$50.00						-$100.00						-$250.00		
HPC Capabilities								$1,000.00									$1,500.00		
					-$1,000.00						-$1,500.00						-$1,500.00		
Ensemble Operations						2	$320.00		2	$320.00		2	$320.00		2	$320.00		2	$320.00
Common Toolbox						2.5	$400.00		2.5	$400.00		2.5	$400.00		2.5	$400.00		0.5	$80.00
			-2.5	-$400.00											-0.5	-$80.00			
Training					$10.00	1	$160.00	$10.00	1	$160.00	$10.00	1	$160.00	$10.00	1	$160.00	$10.00	1	$160.00
		-$10.00	-1	-$160.00															
Community of Interest/Working Groups/Panels						1.5	$240.00		1.5	$240.00		1.5	$240.00		1.5	$240.00		1	$160.00
			-1.5	-$240.00															
COSTS (less Training and Panels) per FY		$133.33	$1.00	$160.00	$233.33	$6.33	$1,013.33	$1,350.00	$5.67	$906.67	$280.00	$5.17	$826.67	$280.00	$5.17	$826.67	$2,213.33	3.17	506.67
Training per FY		$0.00	0.00	$0.00	$10.00	1.00	$160.00	$10.00	1.00	$160.00	$10.00	1.00	$160.00	$10.00	1.00	$160.00	$10.00	1.00	$160.00
Panels per FY		$0.00	0.00	$0.00	$0.00	1.50	$240.00	$0.00	1.50	$240.00	$0.00	1.50	$240.00	$0.00	1.50	$240.00	$0.00	1.00	$160.00
			FY10			FY11			FY12			FY13			FY14			FY15	
Total Costs (less Training and Panels) per FY			$293.33			$1,246.67			$2,256.67			$1,106.67			$1,106.67			$2,720.00	
Training per FY			$0.00			$170.00			$170.00			$170.00			$170.00			$170.00	
Panel per FY			$0.00			$240.00			$240.00			$240.00			$240.00			$160.00	
			$293.33			$1,656.67			$2,666.67			$1,516.67			$1,516.67			$3,050.00	

New Milestones March 18 2009	NCEP	FY10 Resource	FY10 FTEs	FY10 FTE Cost	FY11 Resource	FY11 FTEs	FY11 FTE Cost	FY12 Resource	FY12 FTEs	FY12 FTE Cost	FY13 Resource	FY13 FTEs	FY13 FTE Cost	FY14 Resource	FY14 FTEs	FY14 FTE Cost	FY15 Resource	FY15 FTEs	FY15 FTE Cost
GRIB2																			
COPC JAG/CMM Enterprise-Enterprise Network		$33.33			$33.33	0.333333	$53.33	$33.33	0.33	$53.33	$180.00	0.33	$53.33	$180.00	0.33	$53.33	$180.00	0.33	$53.33
NAEFS IOC 1		$100.00	1	$160.00	$100.00	1	$160.00												
NCDC Archive					$100.00			$100.00			$100.00			$100.00			$100.00		
Establish archive at NCDC								$166.67									$333.33		
					-$166.67						-$333.33						-$833.33		
Scorecards					$100.00	1	$160.00												
IA and ODAA		-$100.00	-1	-$160.00		0.5	$80.00		0.333333	$53.33		0.333333	$53.33		0.333333	$53.33		0.333333	$53.33
6 D Data Base								$50.00									$100.00		
					-$50.00						-$100.00						-$250.00		
HPC Capabilities								$1,200.00									$2,000.00		
					-$1,200.00						-$2,000.00						-$2,500.00		
Ensemble Operations						3	$480.00		3	$480.00		3	$480.00		3	$480.00		3	$480.00
Common Toolbox						2.5	$400.00		2.5	$400.00		2.5	$400.00		2.5	$400.00		0.5	$80.00
			-2.5	-$400.00											-0.5	-$80.00			
Training					$10.00	1	$160.00	$10.00	1	$160.00	$10.00	1	$160.00	$10.00	1	$160.00	$10.00	1	$160.00
		-$10.00	-1	-$160.00															
Community of Interest/Working Groups/Panels						1.5	$240.00		1.5	$240.00		1.5	$240.00		1.5	$240.00		1	$160.00
			-1.5	-$240.00															
COSTS (less Training and Panels) per FY		$133.33	$1.00	$160.00	$333.33	$8.33	$1,333.33	$1,550.00	$6.17	$986.67	$280.00	$6.17	$986.67	$280.00	$6.17	$986.67	$2,713.33	$4.17	$666.67
Training per FY		$0.00	0	$0.00	$10.00	1	$160.00	$10.00	1	$160.00	$10.00	1	$160.00	$10.00	1	$160.00	$10.00	1	$160.00
Panels per FY		$0.00	0	$0.00	$0.00	1.5	$240.00	$0.00	1.5	$240.00	$0.00	1.5	$240.00	$0.00	1.5	$240.00	$0.00	1	$160.00
			FY10			FY11			FY12			FY13			FY14			FY15	
Total Costs (less Training and Panels) per FY			$293.33			$1,666.67			$2,536.67			$1,266.67			$1,266.67			$3,380.00	
Training per FY			$0.00			$170.00			$170.00			$170.00			$170.00			$170.00	
Panel per FY			$0.00			$240.00			$240.00			$240.00			$240.00			$160.00	
			$293.33			$2,076.67			$2,946.67			$1,676.67			$1,676.67			$3,710.00	

10. Revised NUOPC Phase II and III Schedule and Costs

The following three figures summarize Section 9 above, depicting the schedule and costs for the UEO Committee's milestones that would be accomplished during NUOPC Implementation (FY10-FY15). Note: these figures revise the information found in Figure 2, NUOPC Implementation Schedule.

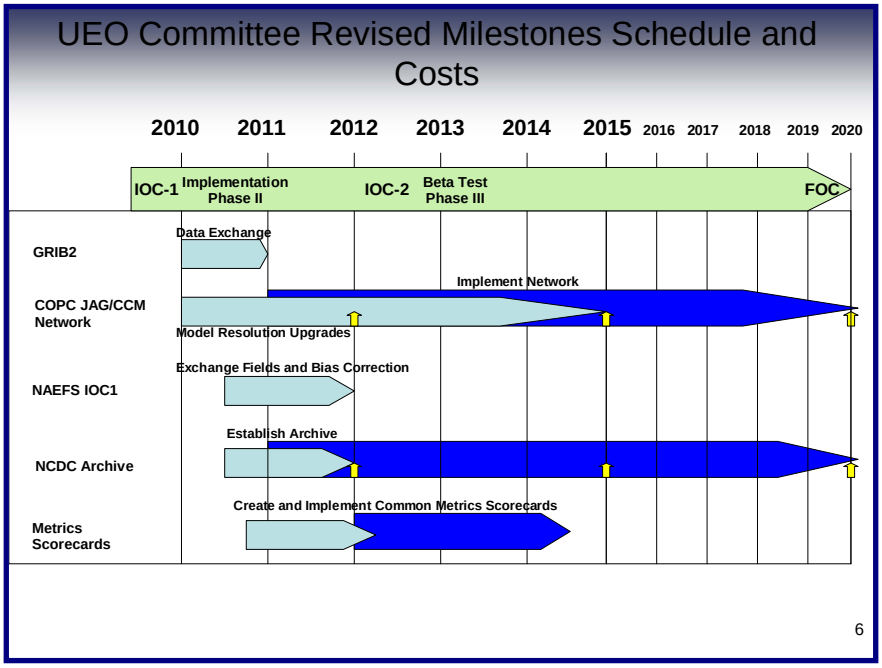

Figure 25. Revision 1. NUOPC Milestones and Costs (Part 1)

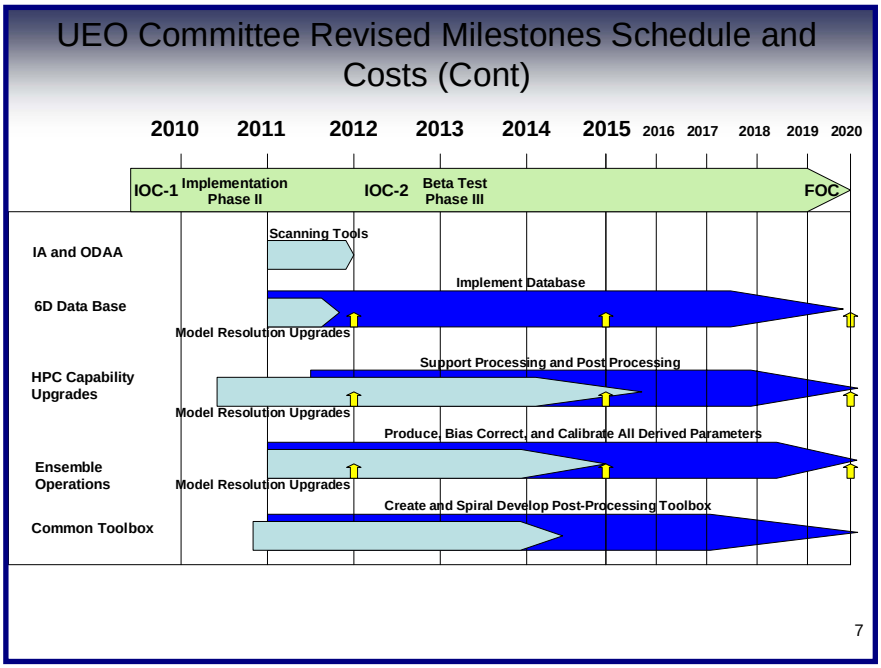

Figure 26. Revision 1. NUOPC Milestones and Costs (Part 2)

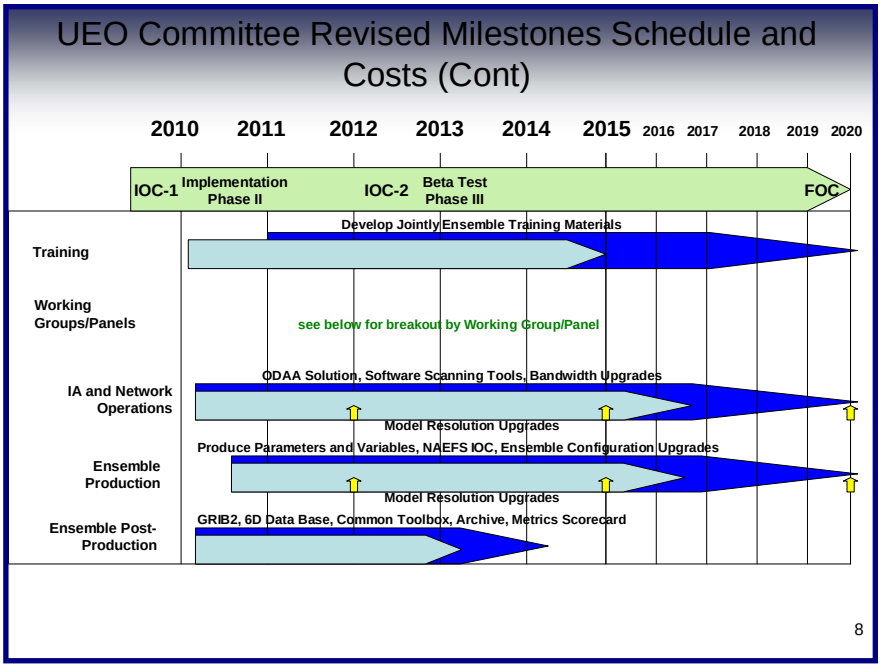

Figure 27. Revision 1. NUOPC Milestones and Costs (Part 3)

11. Summary of Committee Findings and Recommendations

The following are UEO Committee findings and recommendations for NUOPC as it moves forward into Phase II Implementation:

- AFWA, FNMOC and NCEP have distinctly different missions with different customers, but these differences do not preclude cooperating jointly in a National Ensemble Prediction System.

- Information Assurance (IA) issues are a concern, but appear manageable for NUOPC operations:
  - While each of the three agencies ultimately traces their IA policies back to the FISMA, the details of these policies and their implementations differ.
  - To address these differences, NUOPC should follow the lead of NPOESS in establishing a “Super ODAA” to consolidate and direct Navy, Air Force and NOAA IA policy implementation at FNMOC, AFWA and NCEP.
  - NUOPC should monitor and encourage implementation of the NACI investigation requirement at NOAA.
  - To mitigate risks associated with possible acquisition of software from un-trusted sources, NUOPC should execute an MOA with the ASACoE to acquire software scanning tools and requisite training in their use. NUOPC should establish uniform policies and procedures at AFWA, FNMOC and NCEP for use of these tools.

- Procedures for identifying NUOPC software and data whose public distribution will be restricted should be implemented early in Phase II. This may involve designating certain operational NUOPC code as restricted, while releasing a research version that lacks the most current upgrades. Other NUOPC related software may be restricted from distribution, altogether.
- The Enterprise-to-Enterprise Network Infrastructure proposed by COPC JAG/CCM as the replacement for DATMS-U will nicely satisfy the NUOPC data exchange requirements.
    - COPC JAG/CCM should be encouraged to press ahead with the Enterprise-to-Enterprise DATMS-U replacement.
    - NUOPC must establish a liaison with COPC to ensure NUOPC communication requirements are included in the new Enterprise-to-Enterprise network.
    - Consolidated Navy/Air Force/NOAA IA requirements, as defined by the NUOPC Super ODAA, must be folded into the design and implementation of this network.

✦ Construction of the NUOPC CONOPS requires clear tri-agency agreement on:
- Production Center Roles and Responsibilities
- Overall Ensemble Configuration
- Standard Output Products
- Standard Output Format
- Product Delivery Schedule
- Ensemble Post Processing
- Product Storage/Archive
- Ensemble Verification Metrics
- Bandwidth Between Centers

✦ Major Milestones for achieving the NUOPC CONOPS include:
- Form necessary Working Groups and Panels (Information Assurance and Network Operations; Ensemble Production; Ensemble Post-Production)
- Upgrade data exchange format between the Centers to GRIB2
- Achieve NAEFS IOC
- Implement the COPC JAG/CCM proposed Enterprise-to-Enterprise Network as the replacement for DATMS-U
- Establish Super ODAA and common FNMOC/AFWA/NCEP IA policy
- Develop common post-processing toolbox software
- Define and implement ensemble metrics scorecards
- Build common 6-D database (parameter-member-x-y-z-t)
- Establish long-term archive at NCDC

- Upgrade HPC capabilities and capacities as needed
- Conduct training
- Commence NUOPC joint ensemble operations

12. Addendum: Cost Considerations

The significant costs associated with implementing NUOPC, as defined by the UEO Committee, represent both personnel costs (FTEs) and other costs (mostly computer and communications hardware). There may be ways to decrease the impact of these costs by reprogramming old funding or by delaying NUOPC capabilities. For example:

- A major portion of the costs and are directly related to increased HPC workload, communications bandwidth and required data storage capacity caused by the higher-resolution models planned. In order to close the U.S. NWP gap with the Europeans, the UEO Committee looked at increasing the model resolutions for NUOPC ensemble members from 1.0 degree to 0.1 degree—doubling the resolution in FY11, FY13, and FY15. Resource costs associated with the increased model resolution are HPC hardware ($12.5M), network resources ($1.92M in hardware costs and $800K in communications engineering FTE costs), 6-D database ($1.2M in hardware and $320K FTE costs), and archival of NUOPC data at NCDC ($5.5M). Delaying the model resolution upgrades would produce significant savings, at the cost of failing to close the gap with or even falling farther behind the NWP capabilities of ECMWF. <u>These delays in model resolution upgrades are not recommended by the UEO Committee</u>.

- Other possible cost mitigations might include redirection of existing Agency Resources to cover some or all of the NUOPC costs driven by:
    - Software development
    - Ensemble operations
    - Working Groups and Panels
    - Training

- Revision 1 changes inserted into the original document deal with shifting costs that were originally programmed for FY2010 to FY2011 and beyond because significant NUOPC funds had not been budgeted by the Tri-Agency for FY2010. Shifting the costs does not have an effect on the overall NUOPC costs, the costs just appear in different years. Revision 1 also addressed extending model resolution upgrades from the original schedule of 0.5 degree in FY2011, 0.25 degree in FY2013 and 0.1 degree in FY2015, to the revised schedule of 0.5 degree in FY2012, 0.25 degree in FY2015 and 0.1 degree in FY2020. Note that extending the model resolution upgrades to FY2020 appears to increase the overall NUOPC costs only because the costs now appear over an additional 5 years. In reality, if the original NUOPC costs were extended to FY2020, the total NUOPC costs would be virtually identical regardless of when the model resolution upgrades are scheduled. Extending the model resolution

upgrades does help the Tri-Agency budget for the HPC costs by spreading these major resource investments out over an additional 5 years.

Appendix I – List of Acronyms

1 WXG	First Weather Group
2 WXG	Second Weather Group
2-D	Two Dimensional
3-D	Three Dimensional
4-D	Four Dimensional
5-D	Five Dimensional
6-D	Six Dimensional
3D-Var	Three-dimensional variational data assimilation system
4D-Var	Four-dimensional variational data assimilation system
AFCA/CC	Commander, Air Force Communications Agency
AFCWC	Air Force Combat Weather Center
AFDAA	Air Force Designated Accrediting Authority
AFTAC	Air Force Tactical Applications Center
AFW	Air Force Weather
AFWA	Air Force Weather Agency
AOTSR	FNMOC's Automated Optimum Track Ship Routing
APL-UW	Applied Physics Laboratory-University of Washington
AREPS	Navy's Advanced Refractive Effects Prediction System
ARL	NOAA/Air Resources Laboratory (ARL)
ARW	Advanced Research WRF
ASACoE	Air Force Software Assurance Center of Excellence
ATC	Authority to Connect
ATCF	Automated Tropical Cyclone Forecast system developed at the NRL
ATO	Authority to Operate
AWC	Aviation Weather Center
BIS	Bureau of Industry and Security
C&A	Certification and Accreditation
CAAPS	Centralized Atmospheric Analysis and Prediction System
CAC	Common Access Card
CAGIPS	FNMOC's Come and Get It Product Services
CCB	Configuration Control Board
CDFS II	AFWA's Cloud Depiction and Forecast System II
CDS	Cross Domain Solution
CEEMS	FNMOC's Contribution of Environmental Effects on Missile Systems
CIA	Central Intelligence Agency

CM	Configuration Management
CMA	Common Model Architecture committee
CNMOC	Commander, Naval Meteorology and Oceanography Command
COAMPS	FNMOC's Coupled Ocean/Atmosphere Mesoscale Prediction System
COMET	Cooperative Program for Operational Meteorology, Education and Training established by University Corporation for Atmospheric Research (UCAR) and the National Weather Service (NWS)
CONOPS	Concept of Operations
CONU	CONW is a NOAA ensemble of ten global and regional models
CONW	CONU is a NOAA ensemble of nine global and regional models
COPC	Committee for Operational Processing Centers
COR	Contracting Office Representative
CPC	Climate Prediction Center
CSD	NOAA's Client Services Office Division
CUS	Commander Undersea Surveillance
DAO	DoC's Department Administrative Order
DATMS-U	Defense Information Systems Network (DISN) Asynchronous Transfer Mode Services – Unclassified
DEA	Drug Enforcement Agency
DHS	Department of Homeland Security
DIA	Defense Intelligence Agency
DIACAP	Defense Information Assurance Certification and Accreditation Process
DISA	Defense Information Systems Agency
DISN	Defense Information Systems Network
DoC	Department of Commerce
DoC/OSY	DoC's Office of Security (OSY)
DoD	Department of Defense
DoDI	Department of Defense Instruction
DSN	Departmental Sponsor/NOAA
DTRA	Defense Threat Reduction Agency
EAR	Export Administration Regulations
ECMWF	European Centre for Medium Range Weather Forecasting
EFS	FNMOC's Ensemble Forecast System consists of 10 day forecasts produced by ten NOGAPS model forecasts (members) with varied initial conditions
EMC	NOAA's Environmental Modeling Center

EPA	Environmental Protection Agency
ESG	Executive Steering Group
ESMF	Earth System Modeling Framework
Eta	NWP model name derived from the model's vertical coordinate known as the "eta" or "step-mountain" coordinate
FAA	Federal Aviation Administration
FAROP	NRL's Forecast of Atmospheric and Optical Radiative Properties, a TAWS and the NAAPS visibility post-processor
FIPS	Federal Information Processing Standards
FISMA	Federal Information Security Management Act
FNMOC	Fleet Numerical Meteorology and Oceanography Center
FOC	Full Operating Capability
FOIA	Freedom of Information Act
ft	Feet
FTE	Full Time Equivalent
FWB	Flight Weather Briefer
FY	Fiscal Year
GB	Gigabyte
Gb	Gigabit
Gbps	Gigabits per second
GEOPRECIP	AFWA's Infrared-based Geostationary Satellite-based Precipitation model
GFDL	Geophysical Fluid Dynamics Laboratory
GFDN	Geophysical Fluid Dynamics Laboratory – model, Navy version
GFS	NOAA's Global Forecast System
GIS	Geographical Information System
GNWP	Global Numerical Weather Prediction
GPS	Global Positioning System
GRIB	Gridded Binary, a mathematically concise data format commonly used to store historical and forecast weather data
GRIB2	Gridded Binary edition 2, a newer generation of GRIB
GSD	Earth System Research Laboratory's Global Systems Division
GSU	Geographically Separated Unit
GUI	Graphical User Interface
HPAC	Hazard Prediction and Assessment Capability
HPC	High Performance Computing/Hurricane Prediction Center
hr	hour
HSPD	Homeland Security Presidential Directive
HYSPLIT	Hybrid Single-Particle Lagrangian Integrated Trajectory

	dispersion model
IA	Information Assurance
IATC	Interim Authority to Connect
IATO	Interim Authority to Operate
ID	Identification
IED	Improvised Explosive Devise
I-NOSC	Integrated Network Operations Security Center
IOC/NUOPC IOC1	Initial Operational Capability/NUOPC Initial Operational Capability One
IOOS	Integrated Ocean Observing System
Iplan	Implementation Plan
IS	Information Security
IT	Information Technology
JAAWIN	Joint Air Force and Army Weather Information Network
JAG/CMM	COPC's Joint Action Group for Centralized Communications Management
JCSDA	Joint Center for Satellite Data Assimilation
JEFS	AFWA's Joint Ensemble Forecast System
JPEG	Joint Photographic Experts Group
JPEG2000	A wavelet-based image compression standard created by the Joint Photographic Experts Group committee in the year 2000
JTWC	Joint Typhoon Warning Center
lat/lon	Latitude/Longitude
M&S	Modeling and Simulation
Mbps	Megabits per second
METOC	Meteorology and Oceanography
MM5/WRF	Fifth Generation Mesoscale Model/Weather Research and Forecasting model
MOA	Memorandum of Agreement
MODIS	Moderate Resolution Imaging Spectroradiometer instrument aboard the Terra Earth Observing System morning equatorial crossing time (EOS AM) satellite and Aqua the afternoon equatorial crossing time (EOS PM) satellite
NAAPS	Navy Atmospheric Aerosol Prediction System
NAC	National Agency Check
NACI	National Agency Check with Inquiry
NAEFS	North American Ensemble Forecast System
NAFC	Naval Aviation Forecast Center
NAM	North American Mesoscale model

NAO	NOAA Administrative Order
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NAVDAS	Navy Atmospheric Variational Data Assimilation System
NAVDAS-AR	NAVDAS-Accelerated Representer
NAVO	Naval Oceanographic Office
NCA	National Command Authority
NCAR	National Center for Atmospheric Research
NCDC	National Climatic Data Center
NCEP	National Centers for Environmental Prediction
NESDIS	National Environmental Satellite Data Information System
NetCDF	Network Common Data Form
NGIA	National Geospatial-Intelligence Agency
NGM	Nested Grid Model
NHC	National Hurricane Center
NIC	National Intelligence Community
NIST	National Institute of Standards and Technology
NMFC	Naval Maritime Forecast Center
NMM	Non-hydrostatic Mesoscale Model
NNWC	Naval Network Warfare Center
NOAA	National Oceanic and Atmospheric Administration
NOAC	Naval Oceanography ASW Center
NOGAPS	Navy Operational Global Atmospheric Prediction System
NOP	Naval Oceanography Portal
NOSWC	Naval Oceanography Special Warfare Center
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPS	Naval Postgraduate School
NRL	Naval Research Laboratory
NSA	National Security Agency
NTM	National Technical Means
NUOPC	National Unified Operational Prediction Capability
NWP	Numerical Weather Prediction
ODAA	Office of Designated Approval Authority
OFCM	Office of the Federal Coordinator for Meteorology
OPARS	FNMOC's Optimum Path Aircraft Routing System
OPC	Ocean Prediction Center
OPM	Office of Personnel Management
Ops	Operations

OTSR	FNMOC's Optimal Track Ship Routing
PIN	Personal Identification Number
PIV	Personal Identity Verification
PKI	Public Key Infrastructure
PM	Program Manager
POP	Point of Presence
PPS	Ports, Protocol and Service
Pub.L.	Public Law
R&D	Research and Development
RSM	Regional Spectral Model
RTOFS	Real Time Ocean Forecast System
RUC	Rapid Update Cycle model
SAIC	Science Applications International Corporation
SATFOCUS	Satellite focus
SCI	Sensitive Compartmented Information
SCIF	Sensitive Compartmented Information Facility
SEC	Space Environmental Center
SF	Standard Form
SGOT	Strike Group Oceanography Team
SNODEP	Snow Depth model
SO	Security Office
SPC	Space Prediction Center
SSM/I	Special Sensor Microwave/Imager
SSMI/S	Special Sensor Microwave Imager./Sounder
ST&E	Security Test and Evaluations
SUBWEAX	Submarine Enroute Weather Forecasting
SWPC	Space Weather Prediction Center
TAM	Target Area Meteorology and Oceanography (METOC)
TAU	Forecast hour period
TAWS	Target Acquisition Weapons Software
TB	Terabyte
TC	Tropical Cyclone
TCDC	Total cloud cover in an atmospheric column
TCI/IP	Transmission Control Protocol/Internet Protocol
TESI	Tactically Enhanced Satellite Imagery
TFLOPS	Tera Floating Point Operations Per Second (10^{12} FLOPS)
THORPEX	The Observing System Research and Predictability Experiment
TIGGE	THORPEX Interactive Grand Global Ensemble
TPC	Prediction Center

TS-SCI	Top Secret-Sensitive Compartmented Information
TTP	Technology Transfer Processes committee/ Tactics, Techniques, and Procedures
UEO	Unified Ensemble Operations committee
USAF	U.S. Air Force
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
USN	U.S. Navy
USSTRATCOM	U.S. Strategic Command
VLSTrack	Chemical/Biological Agent Vapor, Liquid and Solid Tracking
VSP	Visiting Scientist Program
Web SAR	Web-Based Search and Rescue
WG/CSAB	Working Group for Cooperative Support and Backup
WRIP	Weather Reentry body Interaction Planner
WW3	WaveWatch III spectral ocean wave model
yr	Year