# FY 2012 NCAR Program Operating Plan

## Table of Contents

1. **Executive Summary** .................................................. 1
2. **Planning and Decision Making** .................................. 3
3. **Budget Considerations** ........................................... 4
4. **Computational & Information Systems Laboratory (CISL)** 5
5. **Earth Observing Laboratory (EOL)** .......................... 20
6. **High Altitude Observatory (HAO)** .......................... 31
7. **NCAR Earth System Laboratory (NESL)** .................. 39
8. **Research Applications Laboratory (RAL)** .................. 73
9. **Advanced Study Program (ASP)** ......................... 86
10. **Integrated Science Program (ISP)** ...................... 90
11. **NSF Property Improvements** ............................ 93
FY 2012 NCAR Program Operating Plan

1.0 Executive Summary
The National Science Foundation (NSF) has been instrumental in aiding the U.S. research community’s ability to advance scientific understanding and enhance society’s ability to manage climate change, weather, and other aspects of Earth System variability. One effort toward this end was creation of the National Center for Atmospheric Research (NCAR). A federally funded research center, NCAR is devoted to service to the universities, and research and education in the atmospheric and related sciences. In addition to providing scientific facilities and resources to the wider research community, NCAR scientists are making important contributions to atmospheric and Earth System science. While NCAR’s roots lie within the core disciplines of atmospheric science, our own and our community’s programs and related facilities and support systems have evolved to take an interdisciplinary approach focused on Earth-system components, as well as the Earth’s system as a whole.

To meet the needs of atmospheric and Earth science researchers, NCAR has four laboratories, one observatory, and two center-wide programs. With frequent input from NSF, each serves the wider community and addresses NSF’s strategic goals of Discovery, Learning, Infrastructure, and Stewardship. Our labs, observatory, and programs include:

The **Computational and Information Systems Laboratory (CISL)** provides high-performance computers and networks, world-class data archiving and storage, research data sets, advanced mathematical tools, knowledge environments and visualization technologies, and a professional staff dedicated to advancing Earth-system science across broad fronts.

The **Earth Observing Laboratory (EOL)** develops and deploys observing facilities and data services that the research community needs to better understand the world in which we live.

**NCAR Earth System Laboratory’s (NESL)** research program addresses the complex scientific questions directly related to major environmental challenges. NESL’s research efforts – e.g., building climate, weather, and other atmospheric and Earth System models – are pursued both in partnerships with and on behalf of the wider scientific community.

**High Altitude Observatory (HAO)** research activities focus on developing a comprehensive, quantitative understanding of the coupled Sun-Earth System that ranges from investigating basic solar physics and activity and upper atmosphere structure and dynamics, to the influences of radiative, particulate, and magnetic outputs of the Sun on the Earth and its atmosphere and magnetosphere.

NCAR’s **Research Applications Laboratory (RAL)** conducts directed research that enhances fundamental scientific understanding, fosters knowledge and technology transfer for betterment of life on Earth, and supports applied research to expand the reach of atmospheric science.

The **Advanced Study Program (ASP)** prepares our community for the future, fostering early science career development in fields related to atmospheric science, as well as organizing and supporting new science initiatives, university interactions, and continuing education at NCAR.
The Integrated Science Program (ISP) integrates and facilitates cross-disciplinary and cross-institute collaboration and cooperation, focusing on Earth System/society interactions, hydrologic sciences, biogeochemistry, and building societal resilience to weather and climate hazards.

This FY 2012 Program Operating Plan addresses seven institutional Imperatives and Frontiers outlined in NCAR's Strategic Plan. Imperatives describe NCAR’s fundamental responsibilities; Frontiers are areas where new funding is being pursued to build out from/across existing programs and research activities. Taken together, Imperatives and Frontiers explain highest priority ongoing efforts and aspirations for program development and enhancement. Imperatives and Frontiers capitalize on recent scientific advances and address the challenges engendered, while continuing to provide first-rate scientific support, tools, and services to our research and educational community.

NCAR is focusing on several key priorities in FY 2012, including continuing to update community models, and providing facilities and services that allow the community to successfully pursue scientific endeavors. Toward this end, we expect NCAR-Wyoming Supercomputing Center construction to finish in FY 2012. The Earth Observing Laboratory will continue improvements to the NSF/NCAR GV, including work on the HIAPER Cloud Radar (HCR), NCAR’s Earth Systems Laboratory will continue efforts in enhancing its climate and weather models, and the Research Applications Laboratory along with NESL will continue research and support efforts related to wind-power generation. The Advanced Study Program continues to promote collaborations between postdoctoral Fellows, scientists and some of NCAR’s Historically Black Colleges and Universities (HBCU) partners. Similarly, the High Altitude Observatory’s Visitor Program continues its strong support of educational programs that integrate research and education both at HAO and within the wider atmospheric and space physics community. A new program within the Integrated Science Program and NESL uses NCAR’s oceanographic models to study marine ecosystem responses to changing climate.

In addition to these efforts, NCAR will continue a variety of programs that introduce community science to a wider population. Through programs such as the NCAR Journalism Fellowship, which invites eight to ten journalists to learn about atmospheric and Earth science, and our Communicating Science Program, which trains scientists and engineers to better communicate to the public. Several internships introduce undergraduate and graduate students to atmospheric science, engineering, and computing such as CISL’s Summer Internships in Parallel Computational Science (SIParCS), and EOL’s Summer Undergraduate Engineering Internship.
Program (SUEIP). Ongoing staff involvement in mentoring future scientists includes the High School Internships and Research Opportunities (HIRO), a program run for the first time in FY 2011, and UCAR’s Significant Opportunities in Atmospheric Research and Science (SOARS).

The tools, facilities and services highlighted above, along with our other research and support efforts, are described in detail in the following pages. Each laboratory, observatory and program provides an overview of FY 2012 efforts, including plans, milestones, and expected outcomes. Information on FY 2012 activities supported by non-base funds that leverage our base-funded work, key decisions that will impact lab/program efforts, as well as challenges likely to occur and major activities expected to run in the longer term are also provided below.

2.0 Planning and Decision Making

This program operating plan is based on a foundation of long-range planning and detailed review of laboratory and program priorities. To guide decision making at a high strategic level, NCAR relies on its Strategic Plan – developed with input from NSF and community partners – that sets the overall direction and priorities for the institution. Within this strategic framework, NCAR performs an annual budget review of its operating program to ensure progress toward meeting NCAR’s strategic goals. NCAR’s Annual Budget Review (ABR) provides for a comprehensive review of NCAR’s programs and priorities in the context of a range of funding scenarios. This review allows the NCAR management team to make informed decisions on NSF Base funding allocations.

The ABR process began at the end of November of 2010 with an initial NCAR Executive Committee (EC) discussion on NCAR’s highest priorities for FY 2012. Based on this initial discussion, the following priorities were unanimously agreed on as NCAR’s highest priorities for increments in FY 2012 regardless of funding levels:

- Support the transition to operations for the new NCAR-Wyoming Supercomputing center. This is considered NCAR’s highest priority for funding. $1.95M (current estimate)
- Sufficient capital budget for high performance computing to be housed at the NCAR-Wyoming Supercomputing Center $1.05M (increment in FY 2012 for a build up to $7.5M ongoing budget with additional $1M increment in FY 2013 to achieve this budget level).
- Protect and maintain a healthy level of support for the Postdoctoral Fellowship Program and related activities within the Advanced Study Program.
- Augment NCAR Director’s Reserves (e.g., to cover ladder track notices and to address emergency funding situations) $1M.
- Augment NCAR’s Core programs for inflation or Cost of Business. $0.67M.

To fund these activities, NCAR will need a $4.67M or close to a +5% increase to its budget. If an increase is not provided, NCAR would need to internally reprogram an equivalent amount. Based on this initial “above the line” list, UCAR and NCAR management met with NSF/AGS management on January 5, 2011 for input on NCAR’s priorities for FY 2012. NSF agreed with NCAR’s plans and subsequently instructed NCAR to plan at a level or 0% target increase within a -10% down to +5% up planning range.
The UCAR President, NCAR Director, NCAR Deputy Director, and NCAR Budget Director met with each individual laboratory/observatory/program director and administrator prior to the formal ABR presentations to review their proposals. In some cases, the group met with directors and administrators multiple times during the month of March 2011 to refine plans. The formal ABR presentations of lab, observatory and program plans were provided March 28 through March 30 and the NCAR EC met on April 12, 13, and 14 to review and prioritize actions for FY 2012. Proposed actions were ranked and prioritized at the NCAR-wide level that enabled the NCAR EC to “draw a line” depending on possible funding levels. In addition to the planning target of 0% (-5% with priority “above the line” items) as directed by NSF, NCAR also looked at -3% (or -8% with priority “above the line” items) for NCAR. Proposed programmatic actions at these two scenarios were presented to NSF/AGS Management on April 26, 2011 and to the UCAR Board on May 18, 2011. Specific planning and decisions are provided in the “Key Funding Decisions in FY 2012” sections of each laboratory, observatory, and program. A more detailed confidential report on proposed actions was provided separately to NSF.

3.0 Budget Considerations

In FY 2011, NCAR received $97.615M in NSF Base funds to operate the Center. This was a 2.1% increase or $2.0M above NCAR’s FY 2010 target. This increment was targeted for the NCAR-Wyoming Supercomputing Center operations ($0.7M), and for infrastructure support for the NSF Earth System Model Initiative (EaSM) solicitation ($1.3M). For purposes of this program operating plan, we will assume a level or 0% increase from FY 2011. As described in Section 2.0 above, NCAR will need to reprogram resources from lower priority areas to the “above the line” priorities. Table 1 details NCAR’s projected budget by organizational unit for this scenario.

Included in the “Net ABR Adjustments” column are priority or “above the line” increments, cost of business, and program reductions. The cost of business (cost of salary increases, non-labor inflation, and changes to indirect cost rates) for NCAR’s Base funded program is approximately 0.69% of NCAR’s budget, significantly lower than previous years which can average between 2% to 5% depending on indirect rate changes and the level of salary increases. In anticipation of declining or stagnant budgets, UCAR implemented, with UCAR Board approval, a salary freeze for FY 2012. This action provided significant savings to NCAR’s programs and is the primary reason for NCAR’s low cost of business in FY 2012. At a 3% salary increase, NCAR saves...
approximately $2.0M for a total of $4.2M for all fund sources due to the salary freeze. The benefit or fringe rate for regular employees is expected to drop from 51.0% in FY 2011 to 50.7% in FY 2012. This slight reduction is primarily due to prior year variances. NCAR’s indirect cost rate will slightly increase from 49.8% in FY 2011 to 50.5% in FY 2012. With the slight changes to indirect cost rates and no salary increases, the cost of business will have minimal impact to NCAR’s program.

In this budget context, we project NCAR’s staffing to remain fairly stable due to net increases in priority areas including non-Base projects which will be offset by staff departures or unfilled vacancies in lower priority areas. Table 2 below summarizes NCAR’s projected staffing by job category.

### Table 2

<table>
<thead>
<tr>
<th>Job Category</th>
<th>All Funds</th>
<th>NSF Base</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Person Yrs</td>
<td>Person Yrs</td>
</tr>
<tr>
<td>Ladder Track Scientists</td>
<td>126.7</td>
<td>89.7</td>
</tr>
<tr>
<td>Scientific Support (Including Project Scientists)</td>
<td>620.7</td>
<td>260.1</td>
</tr>
<tr>
<td>Other (Management, Administration and other categories)</td>
<td>128.8</td>
<td>12.4</td>
</tr>
<tr>
<td>Total</td>
<td>876.2</td>
<td>362.2</td>
</tr>
</tbody>
</table>

Additional budget and staffing tables are provided in the attached Appendix. The following program operating plan describes NCAR’s activities for FY 2012 within this budget context.

### 4.0 Program Operating Plan for the Computational and Information Systems Laboratory (CISL)

NCAR’s Computational and Information Systems Laboratory (CISL) supplies facilities, equipment, software, numerical methods, and intellectual resources to support the ever-expanding scientific goals of the atmospheric and related sciences research community. CISL is a computing laboratory that evolves with technology and scientific demands to provide targeted services; a science laboratory that integrates computer science, applied mathematics, and statistics with geosciences expertise; and an education laboratory that trains and mentors future scientists and engineers. The sections of this Program Operating Plan are determined by CISL’s Strategic Plan, and CISL’s plans are driven by overarching strategies.

#### 4.1 Program Activities

##### 4.1.1 Computing: Providing World-Class Cyberinfrastructure to Advance Science

CISL provides high-performance cyberinfrastructure (CI), Information Technology (IT), and services for more than 1,300 users at 76 UCAR member universities, NCAR, and the larger geosciences community. CISL balances these resources to increase simulation fidelity. CISL develops and curates research data sets, maintains user-centered online access to these data, and develops and maintains software tools to visualize and understand the data sets. By developing computing systems and services for the specialized requirements of Earth System modeling,
CISL nurtures model development and research in a controlled and responsive environment where researchers prepare complex models and perform the computationally demanding tests required to validate them. This modeling environment also offers on-demand resources to support the needs of urgent and other high-priority computing campaigns. Further, CISL operates a portfolio of resources for use by the TeraGrid’s broader science community.

4.1.1.1 NCAR-Wyoming Supercomputing Center (NWSC)
Working with NSF and State and University of Wyoming partners, CISL completed NWSC construction and is preparing to commission the facility in late FY 2011. Design work is being done through a subcontract with an architecture firm, and construction work through a construction subcontract. (NSF Base: $0.4M; NSF Special: $2.5M; NSF ARRA: $0.3M; Other: $1.4M)

**Milestones:** Finalize NWSC commissioning. Install and test High Performance Computing (HPC) system. Relocate NCAR data storage systems to NWSC. Transition from construction and commissioning to operations. Archive all NWSC project documents for CISL. Close NWSC Project Office in FY 2012.

**Expected Outcomes/Impacts:** Install and acceptance-test the first HPC system and relocate data storage systems to NWSC. Begin production computing operations in mid-FY 2012, initially producing 23-35 petabytes (PB) of data per year. The facility will set a new industry standard in data center energy efficiency. NWSC resources will integrate well with the CI of NSF’s TeraGrid eXtreme Digital program, the “Blue Waters” system, the DataNet program, and other federal and university computing facilities.

4.1.1.2 NWSC Transition to Operation
Transitioning from NCAR’s current computing facility to NWSC requires tight linkage between transition activities and the construction schedule. (NSF Base: $2M; NSF Special: $1.6M)

**Milestones:** Complete CI procurement and facility commissioning. Install, test, and accept all equipment. Execute NWSC Transition to Operations Plan led by CISL’s NWSC IT Transition Committee. Minimize the transition’s impact on scientific productivity by phasing in new facility operations, integrating NWSC into existing CI, optimizing NWSC services, and enhancing quality of services to the research community. Operate existing Mesa Lab (ML) equipment in parallel with NWSC for at least six months, and then decommission obsolete CI at ML.

**Expected Outcomes/Impacts:** Users will move from ML systems to NWSC’s new petascale resources.

4.1.1.3 Cyberinfrastructure for the Atmospheric Sciences
NCAR deploys and operates a comprehensive discipline-specific CI as a foundational element of its mission to provide the physical and virtual computational facilities of a robust, reliable, and secure end-to-end research environment. (NSF Base + Climate Simulation Lab: $15.9M)
4.1.1.4 Bluefire: NCAR’s 75-TFLOPS IBM Power 575 System
The Bluefire supercomputer is NCAR’s most capable and capacious HPC system.

**Milestones:** Bluefire will support users until mid-2012 when it will be replaced by NWSC resources. The Antarctic Mesoscale Prediction System (AMPS) will continue running on Bluefire until its workload is also migrated to NWSC.

**Expected Outcomes/Impacts:** Continue provision of computing tailored for the scientific community. Offer on-demand capability computing for dedicated or shared special computing campaigns.

4.1.1.5 NWSC-1 Procurement
The petascale NWSC-1 procurement process is managed by several teams, which consist of 40 people from a variety of disciplines and nine institutions that have expertise in technology evaluation, science requirements definition, and business evaluation. Driven by the science requirements of NCAR and the community, this procurement is shaped by input from the NCAR Strategic Plan science goals, the NWSC Science Justification, the CISL Strategic Plan, the NCAR-Wyoming Partnership, CISL user surveys, and a major workflow study conducted by CISL. The science team defined workload projections and scientific evaluation criteria. The procurement team established evaluation criteria, technical specifications, and benchmarks for the NWSC-1 Request for Proposals (RFP), which was released in December 2010. Four proposals were received by the 5 April 2011 deadline. To supplement funds being accumulated for NWSC’s equipment procurement, CISL will receive a $1.05M increment to its base budget. Additional funds from NSF were received in FY 2011 to support EaSM (Earth System Model) Climate Research Initiative awardees and the AMPS effort. These funds will be spent in FY 2012 for NWSC petascale resources. (NSF Base: $28M; NSF Special: $2.5M; Other: $2M)

**Milestones:** Request for best-and-final offers (BAFO) occurred in spring 2011, with evaluation completed in July. Subcontract negotiations will be completed by 1 September. NSF approval and award will occur by 30 September. Delivery of initial test equipment to the Mesa Lab will occur in November. Initial production equipment delivery to NWSC will occur in January 2012. Production computing operations at NWSC will begin in May-June 2012.

**Expected Outcomes/Impacts:** NWSC will be a world-class center for high-performance computing and data storage resources dedicated to advancing scientific knowledge, education, and society.

4.1.1.6 Transition to Next-Generation Archival Storage Resources
To meet growing demands for secure, reliable data storage with high-performance access, CISL evaluates and deploys the highest-performance, most cost-effective archive technologies available. CISL is preparing for petascale computing by evaluating and deploying new storage equipment, moving petabytes of data to the new equipment, and enacting a user transition plan.

After CISL completed a smooth transition to a new High Performance Storage System (HPSS) from its in-house tape archive system (Mass Storage System – MSS), the archive currently houses more than 12 PB of data for more than 800 users, and is accessed by more than 400
unique users every month. The HPSS provides up to 40 PB of data for the ML facility. HPSS will be distributed between NWSC and ML for data migration and disaster recovery purposes, and will hold hundreds of petabytes. HPSS transition time was minimized by converting and ingesting only MSS metadata; data movement was avoided by modifying HPSS to read MSS tapes. (NSF Base + Climate Simulation Lab: $3M)

**Milestones:** To reduce the number of new NWSC technologies coming online at the same time, CISL extended the Augmentation to the Mass Storage Archive Resources (AMSTAR) subcontract for two years to December 2014, when next-generation AMSTAR archival equipment delivery to NWSC and ML in November 2011 and data migration (“ooze”) of ML-resident data begins. In mid-FY 2012, before deploying the new supercomputer, CISL will release a fully operational HPSS system at NWSC to begin data ooze from existing HPSS resources at ML to the new system in Wyoming.

**Expected Outcomes/Impacts:** Extending the AMSTAR subcontract reduces risk of an NWSC HPSS deployment delay, by using existing tape library and similar tape drive technology, allowing two years of NWSC data management experience in the new environment to better determine future archive capacity and performance needs, and offsetting NWSC Archive procurement from the computing procurement by two years. This decision lets CISL prepare a data archival RFP that better represents NWSC requirements. The data ooze will convert data from NCAR MSS format to HPSS native format, transition the data to a new tape technology with five times more capacity, then reduce HPSS support risk by retiring the software modifications CISL developed for reading MSS tapes.

### 4.1.1.7 Unify CISL’s Data Services Architecture (GLADE)

The GLobally Accessible Data Environment (GLADE) provides centralized high-performance file systems spanning supercomputing, data post-processing, and data analysis and visualization (DAV). GLADE hosts NCAR’s data from the Research Data Archive (RDA), NCAR’s climate model projections for the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5), the NCAR-UCAR Community Data Portal, and all other user projects. This storage infrastructure allows user workflows to access data directly without first needing to move or copy it. Funds for this equipment are included in the NWSC-1 procurement.

**Milestones:** Refine GLADE architecture for NWSC use. Evaluate additional parallel file system offerings, refine allocation, charging, and management policies, and produce meaningful usage metrics.

**Expected Outcomes/Impacts:** Users can streamline data management processes through GLADE’s information-based workflows. These changes are critical for using NWSC’s larger resources. GLADE enables users to begin this process now, expediting rapid adoption of new resources at NWSC.

### 4.1.1.8 Strengthen NCAR Data Curation

NCAR’s Research Data Archive (RDA) is actively managed and internationally known for the quality of its content, long-term preservation, curation for research needs, accessibility, and growth. Each year, more than 7,000 users access the RDA for more than 260 TB of research data.
data. Users include people working in the CISL computing environment, those who access data through the web portal, and people who request and receive consulting and data prepared by CISL staff. (NSF Base: $1.5M; NSF Special: $0.15)

**Milestones:** RDA technical infrastructure was moved to GLADE, making data directly available to CISL supercomputers and the Internet. GLADE currently holds 188 TB of the most-used data sets for immediate access; roughly triple that amount is accessible from the HPSS. Growing at 0.5 TB/day in its fifth year, the THORPEX Interactive Grand Global Ensemble archive now has an access portal that supplements model forecasts with observational verification data. More than 60 RDA datasets are routinely updated, and major new datasets continue to be added.

**Expected Outcomes/Impacts:** The RDA will support more Earth System science researchers through ongoing enhancements, data content growth, and access improvements.

**Projected Metrics for FY 2011-2012:** Online RDA data will exceed 250 TB. NCAR usage will far exceed current GLADE access rates of more than 100 TB/week. Internet users will retain current workflows and benefit from increased data set availability and expanding data services. Scaling up will continue with more than 7,000 users accessing research datasets. The NWSC system will replicate the ML system on a much larger scale.

![RDA Data Online](image)

**4.1.2 Grid Cyberinfrastructure Development**

CISL develops Grid infrastructure and technology to support NSF’s strategic CI vision by participating in the TeraGrid and TeraGrid XD (XSEDE) programs; supporting the design, acquisition, deployment, and operation of novel Grid-facing computation, DAV, and data storage systems; and testing, evaluating, and developing new Grid software for scientific users. (NSF Base: $1.1M; Other: $0.2M)
Milestones: Participate in Extreme Science and Engineering Discovery Environment (XSEDE) in NSF’s TeraGrid XD program as an integral part of NCAR’s strategy for Grid CI development. CISL will devote 0.7 FTE to developing and supporting an XSEDE science gateway portal for the geosciences, including a science portal for climate education based on the Purdue portal. **Deploy and expand novel data-intensive CI** by expanding and operating Polynya, a data-intensive computing system that will be an architectural research testbed, as well as a data-intensive resource for XSEDE and university-facing projects. By combining evaluation of these new system designs with an exploration of Grid and cloud technologies, CISL will pursue the most promising solutions to transform community data workflows. **Feed data-intensive innovations into CISL production systems**, including architectural developments being migrated into NWSC’s central file system, DAV, and data mover components. GLADE and its community data transfer facilities will be used by science gateways formerly reliant on gateway-specific CI. **Science gateway development** will continue with Science Gateway Framework (SGF) and Earth System Grid (ESG) development. ESG development thrusts will include product service integration, aggregation support, and integration with evolving ESGF architecture. Developments most important to users include improved access to large volumes of files, improved search functionality, and simplified security. TeraGrid-supported work will integrate model execution workflows with the gateway and explore collaborative capabilities in the gateway context. **Data preservation** continues, with practical solutions under development for long-term data preservation issues through participation in the Chronopolis consortium.

**Expected Outcomes/Impacts:** Enhancing NCAR Grid CI supports the community’s increasingly complex, distributed workflows. Better, data-intensive system designs enable new capabilities like parallel DAV, large-memory applications, and multi-node accelerator-based simulations. Further SGF development will allow rapid prototyping and deploying new science gateways for the community, thereby broadening the Earth System data user base.

**4.1.3 Software Cyberinfrastructure Development**
CISL develops and supports software for use by the Earth System science community. This includes models and model components; data assimilation frameworks; software for accessing, comparing, and exploring data through science gateways; and DAV software for climate, weather, and turbulence applications. CISL developed three parts of today’s Community Earth System Model (CESM): the High Order Methods Modeling Environment (HOMME), the Parallel I/O (PIO) library, and ensembles in CPL-7 (CESM’s flux coupler). SGF provides a unified portal system for accessing and manipulating scientific data and improves high-performance CI usability for researchers. The Data Assimilation Research Testbed (DART) simplifies data assimilation for community researchers. DAV tools include NCAR Command Language (NCL) for 2D visualization and Visualization and Analysis Platform for Ocean, Atmosphere and Solar Research (VAPOR) for efficiently exploring enormous or complex 3D data sets.

**4.1.3.1 Community Earth System Model Improvement**
CISL will collaborate with partners in CGD and Department of Energy (DOE) SciDAC (Scientific Discovery through Advanced Computing) to develop key advanced capabilities for
CESM: high-resolution decadal-scale climate prediction and regional climate modeling. (NSF Base: $0.3M; Other: 0.2M)

**Milestones:** Add important capabilities to HOMME-CAM, a scalable community atmosphere model (CAM) in CESM based on the HOMME dynamical core; introduce and test telescoping grids for regional climate modeling capabilities; integrate Discontinuous Galerkin (DG) method to model fronts and similar phenomena better than HOMME’s current method. Further improve performance of the Parallel I/O (PIO) library developed collaboratively by CISL, CGD, Argonne National Laboratory, Lawrence Livermore National Laboratory, and Oak Ridge National Laboratory. CISL will add component-ensemble capabilities for sea-ice and the ocean components within the CPL-7 flux coupler framework – capabilities needed for climate data assimilation and for decadal prediction.

**Expected Outcomes/Impacts:** Better support for high-resolution, decadal-scale climate prediction and regional climate modeling capabilities in CESM.

### 4.1.3.2 Data and Science Gateways

CISL develops geoscience data and knowledge CI for national and international projects. The Community Data Portal (CDP), ESG, and the Cooperative Arctic Data and Information Service (CADIS) are three premier repositories for data, models, software, IPCC analyses, and more. CISL developed the SGF as a foundation for these services and future projects. SGF facilitates building new gateways that integrate data and knowledge management, modeling, analysis, visualization, and collaboration. Funding sources for CADIS, TeraGrid, and ESG end in FY 2011. New funding for CADIS and fractional new science gateway support will begin in FY 2012. NOAA support for Curator is expected to continue into FY 2012. Still seeking support for ESG, IPCC, and the Coupled Model Intercomparison Project Phase 5 (CMIP5). (NSF Base: $0.6M; Other $0.5M)

**Milestones:** Complete CDP migration to the SGF. Begin integrating Parvis’ new large-data and parallel NCL capabilities into ESG. Release new CADIS data management versions to the Arctic science community via OPERA/IADS (Organization of Projects on Environmental Research in the Arctic/Integrated Arctic Data Management Services) support. Complete North American Regional Climate Change Program (NARCCAP) data management project. Preserve more community collections using Chronopolis infrastructure. Prioritize production data services for CESM and CMIP5/IPCC in the context of uncertain ESG funding. Continue work to provide cloud data services via Globus Online, as funding permits. Explore reanalysis data product service enhancements in ESG. Pursue new partnerships and funding sources that are strategically valuable.

**Expected Outcomes/Impacts:** Continue providing critical data services to a growing international community of more than 23,000 researchers and educators worldwide: World Climate Change Research Programme Coupled Model Intercomparison Project (WCRP CMIP), IPCC AR5, Arctic Observing Network (AON) and other polar science, CESM, World Meteorological Organization (WMO) programs, and many more.
4.1.3.3 TIGGE: An International Data Archive and Access System
TIGGE was established by WMO to accelerate improvements in high-impact weather forecasts. The NCAR archive is an ensemble forecast data collection from 10 Numerical Weather Prediction centers, and it is growing at more than 0.5 TB per day. The primary archive is supplemented with ensemble tropical cyclone tracks, a low-volume weather data product. (NSF Base: $0.1M; Other: $0.2M)

**Milestones:** Integrate the new observational verification data portal with the TIGGE forecast data portal. Online data storage capacity is now 30 days (45 TB) on GLADE, with the full archive (400+ TB) available from the HPSS. Both changes will improve user access.

**Expected Outcomes/Impacts:** Research on weather forecasts will be improved by the directly connected verification data interface linked to the RDA’s key observational datasets. The number of verification datasets will be expanded, and user-selected subsets from the TIGGE archive will be created using HPC.

4.1.3.4 Data Analysis and Visualization Tools
CISL provides open source DAV tools targeted for Earth System sciences: VAPOR, NCL, and NCL’s PyNGL and PyNIO interfaces. These powerful tools support data processing, analysis, and qualitative and quantitative visualization. Critical CI for our community, these tools enable analysis that underpins scientific progress and discovery. They require the long-term development and support that only a national center provides. (NSF Base: $1.2M; Other: $0.1M)

**Milestones:** Continue work on Parvis, a DOE-funded joint project with ANL to parallelize NCL’s file I/O components and streamline computational algorithms for effective analysis of next-generation ultrascale climate datasets. Complete an NCL/Java GUI, support new data formats in NCL and PyNIO, upgrade the display model to allow more fluid use of color tables and transparency, extend support for complex grid topologies, integrate NCL as a data product web service for ESG, and support international requirements driven by efforts such as CESM. Complete NSF-funded work on VAPOR: re-factor its architecture for extensibility; deploy data readers for VAPOR’s multi-resolution data format in VisIt and ParaView; and deliver parallel Application Programming Interface for writing VAPOR data sets directly from a numerical simulation code. Extend VAPOR’s capabilities to support global ocean circulation model data. Complete all planned VAPOR enhancements aimed at better supporting numerical weather models.

**Expected Outcomes/Impacts:** CISL’s DAV tools now have 10,000+ users throughout the global scientific community. Researchers analyzing the IPCC AR5 and CMIP5 simulation results will use NCL to publish their findings, and NCL has become a mainstay of the CESM and Weather Research and Forecast (WRF) communities. VAPOR’s user base will continue to expand, particularly in the weather modeling community, and features planned for ocean model data will also increase its user base. Benefits for VAPOR users include enhanced scientific productivity and improved handling of significantly larger data sets.
4.1.4 Science: Physical Modeling, Computational Methods, and Data Analysis

CISL’s science thrusts support scientific computation, numerical methods, geophysical modeling, and the analysis of data and models. This work leads the Earth System science community in adopting new computational methods and mathematical tools that enhance scientific research and clarify human impacts, vulnerability, and adaptation options.

4.1.4.1 Numerical Methods for Improving Geophysical Models

Simulating geophysical processes with numerical models is vital to understanding complex Earth System relationships. Model development depends on efficient numerical methods, and as models become more complex, their algorithms must be continually improved. This activity leverages the scientific development of weather and climate models at NCAR and its links to geophysical communities for disseminating software. CISL identifies numerical methods research that will address outstanding or anticipated modeling problems. Much of this research is built on software testbeds. (NSF Base: $0.5M)

**Milestones:** Geophysical and Astrophysical Spectral element Adaptive Refinement (GASpAR) efforts include final modifications of the two-level preconditioner for 3D conforming meshes and for 2D adaptive meshes using Dirichlet and periodic boundary conditions. For the Geophysical High Order Suite for Turbulence (GHOST), CISL will develop a Boussinesq solver; develop interfaces for CUDA-based FFTs and test performance on multi-GPU systems. Develop a surface quasi-geostrophic solver, a shallow water solver, and test axisymmetric spectra for anisotropic flows. For the CAM/HOMME Framework, a low-order DG version in HOMME for non-hydrostatic benchmark tests will be prepared. Radial Basis Functions (RBF) algorithms that exploit the geometric flexibility, computational effectiveness, and high accuracy of the method for solving complex 3D fluid flows with multiscale features will be created. For the Adaptive Mesh Refinement, we will implement a 2D stacked shallow water model in the vertical plane, and apply it to examination of orographic flow.

**Expected Outcomes/Impacts:** More accurate algorithms for simulating global atmospheric flows and transport of trace constituents will be created. Scalable algorithms for massively parallel global models will be generated. Efforts will improve information for policy/decision making, and, by extending parallelization beyond 20,000 processors, better petascale-ready tools.

4.1.4.2 Inferences and Prediction from Numerical Models and Observations

Numerical models make predictions on different geophysical scales. Research in this area includes data assimilation methods (combining observational data with numerical models) and statistical methods for summarizing and interpreting model output. DART was developed in CISL’s Institute for Mathematics Applied to Geosciences (IMA Ge) as an assimilation environment for community atmosphere models. Statistical software for paleoclimate reconstruction and for analyzing regional models is contributed in “R,” an open source statistical environment. (NSF Base: $0.5M)

**Milestones:** Scalable data assimilation: Scale DART to large numbers of cores. Remote sensing assimilation: Add and test ability to assimilate radiance observations in WRF,

Expected Outcomes/Impacts: Better quantification of error in simulations using ensemble spread and statistical techniques can improve policy decisions by weighting a prediction with other information. Improving graphical tools to visualize transport in turbulent flow and quantify coherent patterns makes complex simulations easier to interpret, aids in discovery of new features, and improves geophysical models.

4.1.4.3 Producing High-Resolution Research Data for Climate Change Studies
The Regional Integrated Science Collective (RISC) collaborates with a broad range of public and private laboratories and universities. RISC generates high-quality regional-scale scenarios of projected climate change and develops tools and methods for analyzing impacts, vulnerability, and adaptation options. RISC primarily produces climate projections over North America through NARCCAP using both global and regional models. RISC also maintains and develops the Weather and Climate Impacts Assessment Science Program (WCIASP) that investigates uncertainty in climate change research, studies extreme weather and climate events, and runs the Climate and Health Workshop series. (NSF Base: $1.1M)

Milestones: Complete a high-resolution WRF scenario over the U.S. West using boundary conditions from NARCCAP’s 50-km WRF model. Derive probabilistic measures of climate change using Bayesian hierarchical modeling and on a balanced set of global/regional model pairings. Establish differential “credibility” collaboratively using careful process-level evaluation of model simulations.

Expected Outcomes/Impacts: Develop methods that incorporate uncertainty into assessments of regional impacts and evaluations of adaptation strategies; publish journal articles describing these new methods.

4.1.4.4 Simulation and Modeling of Multi-Scale Processes
Processes that drive climate and create weather occur at many spatial and temporal scales. A challenge for traditional modeling is to represent behavior at scales that are physically relevant but too small to be resolved explicitly in a model. One solution is to simulate simpler processes in great detail and study the patterns and physical relationships by which scales are connected. This takes advantage of NCAR’s rich scientific expertise in turbulence and climate processes and a national center’s perspective when building collaborations among geophysicists, statisticians,
and computational scientists. In addition to numerical models, statistical models are being developed from observational data to quantify how field correlations change at different distances and locations. (NSF Base: $0.2M)

**Milestones:** Study flow properties with or without magnetic fields or rotation and linkages with conservative systems. Analyze simulations of geophysical turbulence with rotation. Study stratified turbulence and tracer transport under rotation. **Multiresolution Statistical Models:** Combine lattice models with wavelet bases and test on regional climate model output and reanalysis data products.

**Expected Outcomes/Impacts:** New results on scaling flows in the presence of rotation and magnetic fields will inform modeling of the Sun’s corona, atmospheric mixing at the Earth’s surface, and intense storms. Representing multiscale covariance functions will provide more accurate models of field variability over space for interpolation and prediction. Advances in representing multiscale processes will produce more accurate characterizations of processes in the Earth-Sun system and broaden impact on society's use of this information. Access the three-dimensionality of flow at small scales by resolving the Ozmidov scale.

**4.1.4.5 Petascale Computational Science Research**

Application developers must employ massive levels of parallelism to exploit petascale systems, so CISL is advancing these community capabilities. The HOMME dynamical core framework provides a scalable platform for algorithm development that is showing impressive numerical results using up to 96,000 processors. Expertise gained from HOMME has been used to improve CESM. (NSF Base: $0.1M)

**Milestones:** Enhance CESM with CPL-7 flux coupler, CAM, river-routing algorithms, and I/O subsystem components. Validate DG version of HOMME/CAM in idealized climate simulations. Validate the conservative semi-Lagrangian multi-tracer transport scheme in HOMME/CAM climate simulation tests.

**Expected Outcomes/Impacts:** Conservative advection capabilities in HOMME are needed for climate system models with scalable atmospheric components. New methods for petascale systems will enable climate and weather models to run efficiently and produce more accurate simulations.

**4.1.5 Education, Outreach, and Training**

In its role as an education laboratory, CISL teaches the mathematical and computational science concepts and skills necessary for effectively using advanced cyberinfrastructure, and CISL encourages young people to embark on careers in supercomputing and the computational sciences.

**4.1.5.1 HPC Workforce of the Future, SIParCS, RSVP, GTP, and TOY (Cultivate Next-Generation Computational Scientists)**

A variety of programs are in place to train new talent in computational science. Among these is the Summer Internships in Parallel Computational Science (SIParCS) program, which provides experience for graduate and undergraduate students in computational science, applied
mathematics, and geostatistics. CISL’s Research and Supercomputing Visitor Program (RSVP) sustains collaborations between CISL staff, the university community, and researchers at peer centers. The Geophysical Turbulence Program (GTP) supports workshops and visitors at NCAR to investigate multiscale and nonlinear processes. IMAGe’s Theme-of-the-Year (TOY) workshops focus on mathematics applied to the geosciences to advance research and education between the mathematical and geosciences communities. CISL’s HPC training classes at NCAR integrate research and education for interns and new supercomputer users. (NSF Base: $0.3M)

**Milestones:** SIParCS targets outreach to under-served individuals and communities. Increasing intern salary will improve competitiveness in attracting quality candidates. Ten interns will be supported by core funds; educational partners and NCAR Director’s diversity funds may support more. RSVP will invite visitors and trainees to collaborate with CISL, particularly those from under-served groups. GTP plans include hosting a workshop on gravity waves and boundary layers (principal organizer Jielun Sun, MMM). The May 2012 TOY will focus on rotating stratified turbulence (principal organizer Baylor Fox-Kemper, CU; co-organizer Keith Julien, CU). HPC training will provide classes in ten essential HPC skills at NCAR, primarily in summer.

**Expected Outcome/Impacts:** SIParCS will prepare students for careers in computational sciences by involving them in atmospheric science-related research projects. RSVP brings national and international visitors to NCAR to supplement CISL research. GTP and TOY entrain researchers and students in mathematics and geosciences in interdisciplinary collaborations. HPC training improves skill and efficiency of HPC users.

**4.1.5.2 VisLab Outreach: Telling NCAR’s Story**
CISL’s Visualization Lab (VisLab) fosters public awareness and understanding of Earth System sciences through outreach to thousands of student, corporate, scientific, and government visitors. The VisLab’s stereo 3D platform creates and presents compelling visuals about our science, supports collaboration with high-definition video-conferencing capabilities, and serves as a venue for broadcast film crews to interview scientific staff. The VisLab is a collaborative education and outreach effort among CISL, the UCAR Public Visitor Program, and the UCAR Office of Government Affairs. (NSF Base: $0.2M)
**Milestones:** Continue VisLab partnership with UCAR Office of Government Affairs and UCAR Public Visitor Program to expose K-12 students through VIP visitors to NCAR’s scientific visualization capabilities. Provide expertise to establish AV communication between Boulder and Cheyenne campuses. Provide videoconferencing for meetings and classes. Augment library of digital media to communicate science and expand its impact through social networking sites.

**Expected Outcomes/Impacts:** Engage broad and diverse communities (50-75% of VisLab’s 2,000+ users are student, corporate, and government visitors). Increase awareness and understanding of science, HPC, and environmental issues. Help NCAR embrace green technologies and reduce its environmental footprint by supporting collaboration technologies and tools between NWSC and other NCAR campuses.

### 4.1.5.3 Training in Scientific DAV

CISL’s NCL team partners with CGD staff to teach four-day training workshops in scientific DAV. These courses enhance the knowledge and skills of university students and scientists to meet research challenges in the geosciences. About four workshops per year include local courses, a fully CISL-funded course at a qualified UCAR-member university, and one for another institution or international organization. CISL routinely receives international requests with offers of financial support; these are engaged as time and priorities allow. NCL workshops support and enhance geoscience education at universities.

**Milestones:** Host two local workshops, one at a UCAR-member university, plus one at the Max-Planck Institute for Meteorology in Hamburg to train staff to host future workshops. Develop short training modules for NCL on YouTube. Provide funding for under-served students to attend local workshops. Consider current workshop requests from Australia, Switzerland, Canada, Germany, China, and Finland.

**Expected Outcomes/Impacts:** Connect with scientific users and provide them with software and skills to improve the quality of research. Teach scientific data analysis basics to graduate students and post doctoral students (about 70 per year with a heavy concentration in climate and weather). This builds community capacity and strengthens ties with and service to the academic community and other stakeholders.

### 4.2 NSF Special and Non-NSF Funding Supporting Computational Efforts

CISL receives support in addition to NSF core funds to pursue complementary research and foster collaboration. **NSF Special funds** support **PetaApps: New Coupling Strategies and Capabilities for Petascale Climate Modeling**, which examines coupling strategies to improve high-resolution climate models on petascale systems. Also funded by an NSF PetaApps award, the **Multiscale Unified Simulation Environment** is developing a petascale model to address atmospheric science issues. The **CCSM Gateway with Purdue** provides science gateways for climate research using TeraGrid resources. The **TIGGE** project has two major foci: improve data access to the RDA and supplement weather research with analyses and observations to validate forecasts. The **Stochastically Robust Resource Allocation for Computing** project applies and evaluates resource allocation techniques for shared high-performance computing environments. In the NSF **High End Computing University Research Activity**, NCAR evaluates the “Quality
of Service” approach within the disk I/O subsystem of several important multi-agency climate models. The Multiresolution Lattice Model effort studies regional climate change where complex models are coupled to simulate climate at local scales. Interactions Between Changing Climate and Technological Innovations in Agricultural Decision-making develops spatio-temporal stochastic models of daily weather variables. Fast Algorithms for Radial Basis Function Methods on Arbitrary Geometries integrates radial basis functions into multiscale geoscience modeling. Models, Tools, and Analysis for Studies of the Magnetosphere and Upper Atmosphere develops an encompassing framework for estimating calibration parameters in complex computer models. Robust Capacity-Constrained Scheduling and Data-Based Model Refinement for Enhanced Collision Avoidance in Low-Earth Orbit applies atmospheric data assimilation to better predict satellite orbits. Integration of decadal climate predictions, ecological models and human decision-making models to support climate-resilient agriculture in the Argentine Pampas develops novel statistical methods to model possible regime shifts on annual-to-decadal time scales in weather extremes. Analysis and Modeling of Rotating Stratified Flows develops phenomenological and numerical models for helical rotating stratified flows at high Reynolds numbers. Informing Climate-Related Decisions with Earth System Models develops measures of future climate uncertainty based on high-resolution NARCCAP simulations for use by U.S. water and land managers; it also helps determine if such high-resolution information affects adaptation planning.

Non-NSF funds support the VAPOR Collaboration with the Texas Advanced Computing Center received TeraGrid funds in FY 2010 to enhance VAPOR for the TeraGrid’s broad scientific community and to prepare for petascale computing. To improve predictions of tropical storm intensity, the National Oceanographic Partnership Program provided funds for Achieving Superior Tropical Cyclone Intensity Forecasts by Improving the Assimilation of High-Resolution through a sub-award from the University of Wisconsin. The EPA funds Providing Products and Focused Analysis of Global and Regional Climate Model Results Produced or Used in NARCCAP to run simulations for the National Water Quality Assessment. Funded by the University of Wisconsin, the Impacts of Climate Change Extremes on Human Morbidity in Wisconsin uses statistical models to study human morbidity in extreme temperatures. DOE-funded Parallel Analysis and Visualization produces advanced climate-model visualizations.

4.3 Key Funding Decisions for CISL in FY 2012
Consistent with the NCAR Strategic Plan and in keeping with the strategy of previous budget reviews, guidance from the NCAR Directorate, and priorities proposed in the UCAR proposal to manage NCAR, the CISL Council agreed that the highest priorities are to maintain the budgets for NWSC operations and capital equipment at current levels, even in a -10% scenario. Providing computing services to the atmospheric and related sciences community remains CISL’s highest priority. When NWSC construction is completed, CISL will need additional funds (as identified in the proposal and budget scenarios) to operate the facility. CISL’s second priority is to ramp up the capital available to procure Track-2-scale CI for NWSC and integrate it with other national resources. Third, returns on CISL’s investments in Education, Outreach, and Training are so positive and significant that we are committed to preserve and enhance them, but this is threatened by potential staff reductions.
4.4 Challenges and Opportunities for CISL in FY 2012

Our $30M HPC procurement is among our most complex ever because it will occur at the same time that we transition users from computation-centered to data-centered workflows. This new paradigm improves the critical balance of scientific productivity with computing systems and services. Our first challenge is to procure the optimal mix of resources, then integrate them for improved scientific productivity. CISL also needs to balance staffing priorities between HPC system support and services, software infrastructure development, and scientific research, all at a time when CISL’s human capital has been significantly downsized. CISL needs to continually glean economies through adroit synergies and by consolidating its operations and R&D activities wherever possible. Finally, CISL must continue improving the “user experience” of its facilities to further enhance scientific collaboration while maintaining IT security.

4.5 Long-Term Plans (FY 2013–2016)

CISL managers face technical, budgetary, and workforce challenges. The technical challenges include ultrascale computing, data and system management, and federating and virtualizing HPC systems and services. The increasing complexity of both science and CI will increase staffing needs, and this will introduce budgetary challenges. Finally, the future workforce must be trained with the right skills. These challenges are also opportunities for CISL to lead the community toward practical solutions.

Ultrascale parallel computing will require new skills and interdisciplinary approaches. CISL’s collaborative efforts in scalable numerical schemes and parallel algorithms currently offer effective applications for ultrascale systems. These must be enhanced and extended. CISL is also collaborating with vendors to explore accelerator-card-based technologies and development environments to improve scientific productivity while protecting NCAR’s software investment. We have to prepare for ultrascale demands that may change the way jobs are run and how codes are validated and verified for correctness.

Increasing needs for larger and heterogeneous datasets will require interoperable and highly parallel tools, robust infrastructure, and flexible policies. CISL’s tools for visualization and data assimilation, and its innovative workflow paradigms like the GLADE CI need ongoing development to support parallelized science and efficient storage management at the ultrascale. Virtual environments like science gateways and cloud environments can increase scientific productivity by minimizing process details. CISL must learn to provide a new layer of virtualized services to support research communities on a fixed budget.

Ultrascale systems and science problems will likely require more staff to support them. The ratio of science output to staffing expenses might be improved through savings from automated operations, increased productivity, more system virtualization, and further automating compilers and optimization.

To develop the workforce for future HPC and computational science needs, CISL trains people to work in diverse interdisciplinary teams. To meet future technical needs, CISL uses targeted education, outreach, and training via internship programs, visitor programs, and contacts with minority-serving institutions.
5.0 Program Operating Plan for the Earth Observing Laboratory (EOL)

The ability to make observations of our atmosphere, Earth System, and Sun is fundamental to achieving science goals of NSF, NCAR, and the community. When established, NCAR was charged with providing observing facilities and services for the community of atmospheric scientists, with emphasis on large and expensive facilities best supplied centrally rather than by a single university group. EOL’s mission to develop and deploy observing facilities and provide data services needed to advance scientific understanding of the Earth System aligns with this goal as well as an NCAR Strategic Plan Imperative. EOL facilitates operational, technical, logistical, and data support to effectively drive progress on many fronts of atmospheric research.

The NSF-funded Lower Atmospheric Observing Facilities (LAOF) that EOL manages include research aircraft, ground-based and airborne remote sensing systems, sounding systems, in situ sensing systems, and many instruments that can be deployed with these.

EOL’s planning and preparation for the FY 2012 Annual Budget Review included extensive discussions within EOL’s Management Advisory Committee, NCAR’s Directorate and Executive Committee, and discussions between the NCAR Directorate and NSF/AGS. EOL’s Strategic Plan (2009-2014) and overarching mission played a major role in clarifying budget priorities. The plans provided below are consistent with this strategy.

5.1 Program Activities

5.1.1 Maintain EOL facilities deployed using NSF “deployment pool” funds so they are ready for reliable and safe operation in anticipated field programs.

The development and verification of weather, climate, and chemistry models depend on accurate observations and measurements. Central to EOL’s mission, and its first Imperative, is maintenance of NSF-funded LAOF for research in atmospheric science. This ties to NCAR’s Strategic Imperative to provide capabilities for more accurate prediction and attribution of changes in climate, severe weather, and air quality.

Fulfillment of these Imperatives drives day-to-day efforts to preserve and consistently improve NSF LAOF resources that are entrusted to NCAR, and maintains readiness for a vigorous deployment schedule. In the run-up to each field campaign, all instruments undergo exhaustive testing by EOL engineers and technicians to ensure optimal campaign performance. After the field phase commences, it often becomes necessary to make adjustments or upgrades to overcome difficult or unforeseen environmental conditions in order to meet scientific objectives.

FY 2011 saw completion of major GV modifications and almost all HAIS (HIAPER Aircraft Instrument Solicitation) instruments delivered and tested. An ongoing challenge therefore will be supporting the higher number and sophistication-level of GV instruments. EOL’s model for this effort is multi-faceted and follows HIAPER Advisory Committee recommendations. It includes assigning EOL staff to a subset of HAIS instruments, maintaining sufficient in-house expertise to manage and operate these instruments, supplying funding for continuing hardware upgrades and basic maintenance, and providing financial support to other divisions within NCAR to assist in HAIS support. Additionally, EOL maintains modest reserves to support outside investigator participation and cooperative arrangements with outside instrument developers. We are working with NSF and future users to accommodate critical instrument-support needs during field campaigns and have conducted instrument-specific planning to address future needs.
EOL has enhanced security measures to ensure continued ability to participate in global field campaigns. To this end, EOL has implemented a Safety Management System (SMS) – a positive identification (badge) system – at the Research Aviation Facility (RAF) that will be certified by an audit in the near future. A certified SMS will soon be mandatory for international flights, which drives this effort. In addition, EOL/RAF’s Technology Control Plan (TCP), which assures compliance with U.S. export law, requires us to control access to certain technical data (e.g., data collected about the C-130, a military aircraft) by non-U.S. persons. Policies and procedures to pass this audit based on industry standards described by the International Standard for Business Aircraft Operations (IS-BAO) are under development.

In addition to base funding, EOL received American Recovery and Reinvestment Act (ARRA) funding. In FY 2012 this will be used for GV improvements, including work on the HIAPER Cloud Radar (HCR), and continuation of our airborne radar capabilities. (NSF Base: $7M; ARRA: $10.7M to be spent by FY 2012)

Milestones:

- The HCR, a unique wing pod-based airborne Doppler 3-mm (95 GHz) weather radar, will be mounted on the NSF/NCAR GV. In FY 2012, EOL will complete Phase-A development of a scanning W-band radar mounted in an under-wing pod. This effort will culminate with delivery of a tested airborne system. Phase B, adding polarimetric capabilities and pulse compression, begins in FY 2013 and will finish in FY 2014.
- EOL will continue using ARRA funding through end-FY 2012 to advance our airborne radar capabilities, colloquially referred to as “the next ELDORA.” EOL will upgrade ELDORA (ELectra DOppler RAdar) hardware to refurbish and extend lifespan through 2016; upgrade and extend lifetime of the Weather Avoidance Radar Data System (WARDS); enhance automatic navigation correction and develop real-time dual Doppler capability; and partner with the Massachusetts Institute of Technology’s (MIT) Lincoln Labs (LL) to reduce major risks involved in development of next-generation C-band (to mitigate attenuation at X-band), polarimetric (improved microphysics characterization), and airborne phased array radar (improved scanning). Specific to FY 2012, activities planned for ELDORA include completing upgrades to the onboard aircraft science display, improvements to WARDS and the real-time 150 dual-Doppler wind display software development.
- Planned activities for the remainder of FY 2011 and early FY 2012 for the GV’s large view ports include pressure testing of the windows and interface structures along with FAA certification of the windows for use on the aircraft. The windows will be used for deployment of the L-VIS, a high-altitude, laser altimeter during NASA’s IceBridge mission (a six-year airborne survey of Earth’s polar regions) in October 2011 and for deployment of the High Spectral Resolution Lidar (HSRL) aerosol lidar for the Tropical Ocean Troposphere Exchange of Reactive halogen species and Oxygenated VOC (TORERO) project in January 2012.

Expected Outcomes/Impacts: Highest quality, high-resolution HCR data collected from an unprecedented altitude of 50,000 feet offers unique observations on interactions between aerosols and clouds, and on the formation and evolution of clouds. HCR will be carried in one of the GV large wing stores. Phased-array technology applications will help advance
science in several areas related to mesoscale meteorology, and higher temporal and spatial resolution measurements are needed to investigate detailed storm structures and evolution.

5.1.2 Support observing needs of research programs at a level that serves NSF, university, and NCAR program needs.

Field-program planning and implementation is a critical community service, and EOL’s efforts here tie to an NCAR Strategic Imperative to provide observational facilities that meet the science community’s needs. EOL employs and trains project staff, assists PIs with project planning and preparation, supports observing programs by operating facilities and instruments, and preserves quality of collected data for decades in support for research and field programs worldwide.

In FY 2012, EOL will support five research missions, and awaits NSF approval for five additional missions. (NSF Base: $6.7M; NSF Deploy: $5.7M; NSF Spec: $0.3M; Other: $1.2M)

Milestones:

- In October 2011, Instrument Development and Education in Airborne Science (IDEAS) IV will provide testing opportunities on the C-130 for airborne instrumentation created for geosciences research.
- NASA’s IceBridge mission will use airborne altimetry to monitor key, rapidly changing areas of ice in the Arctic and Antarctic; support of IceBridge will be done on a cost-recovery basis with the NSF/NCAR GV in Punta Arenas, Chile in October 2011.
- EOL will provide field project coordination and deploy the NSF/NCAR S-Pol Radar and Integrated Sounding System/ GPS Advanced Upper-air Sounding system (ISS/GAUS) in support of Dynamics of the Madden-Julian Oscillation (MJO) (DYNAMO) from September-December 2011.
- Tropical Ocean Troposphere Exchange of reactive halogen species and oxygenated VOC (TORERO) will use the GV to investigate presence of oxygenated VOC (OVOC) and reactive halogen species (RHS) in the free troposphere over the Eastern Pacific Ocean in January-February 2012.
- From January-March 2012, AgI Seeding of Clouds Impact Investigation (ASCII) will explore precipitation enhancement effectiveness by glaciogenic cloud seeding.
**Expected Outcomes/Impacts:** IDEAS IV tests community-created instruments and helps university students develop skills in airborne observational science, which in process, strengthens ties between NCAR and the university instrument development community. An ongoing NASA mission, IceBridge monitors key, rapidly changing Arctic and Antarctic ice, sustains the long-term observation record, improves glacial dynamics understanding, and improves predictive models of sea level rise and sea ice cover. DYNAMO will enhance understanding of key MJO initiation processes over the Indian Ocean and efforts to improve MJO model simulation and prediction; global models are currently unable to produce the MJO, which degrades seasonal to interannual predictions. TORERO research will shed light on the role of deep convective clouds in transporting VOC and RHS from the marine boundary layer into the upper-most free troposphere at tropical latitudes, provide insights on the possible role of OVOC and RHS to form and grow Aitken mode-sized particles to cloud condensation nuclei (CCN) active sizes, and map the horizontal and vertical distribution of OVOC and RHS over biologically active upwelling areas. ASCII research feeds into the broader question of how concentrations of cloud-active aerosols affect clouds’ precipitation efficiency, thereby influencing the climate system’s latent and radiative heat forcing.

5.1.3 Anticipate future needs due to changing priorities, aging equipment or emerging opportunities, and develop new technology (instrumentation, software, and infrastructure) to meet those needs.

Community priorities and technological opportunities call for ongoing development to ensure that EOL’s observing systems and support matches evolving community needs. Climate studies are of particular emerging importance and it will be important for EOL to expand service in this area. The shift toward an emphasis on studies that support climate research on both local and global scales can be well served by new or developing EOL facilities such as the now fully operational GV, the planned CentNet sensor array, and Front Range Observational Network Testbed (FRONT). Movement in this direction will feature increased aircraft use in collection of global-scale observations, longer-term deployment of observing systems and sensors, repeated observations to cover seasons and broader areas, networks that provide a larger number of measuring stations, and development of reliable, easily deployable sensors. This Imperative calls for a healthy development effort and for retention and training of staff that can conduct required research and development. It also requires the development of life-cycle and end-of-life plans for major facilities and instruments. (NSF Base: $3.8M; NSF Spec: $0.17M; Other: $0.6M)

**Milestones:**

- Leverage the autonomous dropsonde launch system designed for NASA’s Global Hawk unmanned aircraft system (UAS) research aircraft in FY 2011 as EOL replaces the current GV dropsonde launch system in FY 2012. EOL will design a semi-automated dropsonde launch system for the GV with 50-100 sonde capacity; this allows eight sondes to be airborne at any given time, as opposed to the current four.
- Completion of FRONT site preparations to accommodate the S-Pol radar; remote operations capability to be added post-DYNAMO, with support for 20-hour educational projects to begin about eight months later. Plans include enhancing the centralized data archive (including Colorado State University (CSU)/CHILL, Denver and Cheyenne NEXRAD data), upgrading S-Pol’s digital receiver, and expanding/refining S-Pol’s remote operations capability; integration of S-Pol remote operations begin October 2012.
• EOL, in collaboration with NOAA’s Earth System Research Laboratory (ESRL) and the University of Oklahoma, is developing an innovative modular 449-MHz wind profiler network to expand and replace the 915-MHz boundary-layer wind profiling capability. As a basic boundary-layer wind profiler, the new system will probe higher and be simpler to deploy. Its modular architecture allows antennas to be configured to form a large network of boundary-layer profilers, or fewer profilers that probe higher into the atmosphere to match a given experiment’s needs. In 2012, EOL will refine the design and construct modules for a 7-antenna configuration capable of probing up to mid-tropospheric altitudes.

• The Laser Air Motion Sensor (LAMS), reconfigured to enable retrieval of 3-dimensional wind speeds, will be completed in early FY 2012 (pending budgetary and staffing issues). If complete, the 3D version will be flown during IDEAS-IV campaign, otherwise the 1D version will be used. Subsequently, data analysis will be performed to identify improvements and/or modifications.

• Responding to input from the 2007 Adaptive Sensor Array workshop, EOL is designing and prototyping CentNet, a deployable 100-station network for surface exchange research; to make this number of stations manageable, CentNet is designed to minimize set up and maintenance time. The network will include redundant measurements to identify sensor problems, have automatic cleaning systems to minimize field maintenance of sensors, and a data system with 2-way communications to sensors. Tower infrastructure is being designed to be lightweight, easily deployable, with minimal footprint. In FY 2012, EOL will concentrate on evaluation of surface-flux sensors and complete a small network of three prototype stations. Plans include improving network infrastructure flexibility (sensor interfaces, communication and power options). EOL will submit a construction proposal by late FY 2012 to build the network.

• EOL will explore partnering with Montana State University (MSU) to develop a cost-effective, easily-deployable eye-safe diode laser-based micro-pulse differential absorption lidar (DIAL) for water vapor and aerosol profiling in the lower troposphere. Should this partnership proceed, some near-term FY 2012 goals include modifying the existing DIAL to permit autonomous operation and to evaluate its performance in the field. After successful proof of concept and with agreement from NSF, the long-term goal is to develop an NSF Major Research Instrumentation (MRI) Program Solicitation to create a system comprised of a 10-instrument network, designed to withstand the long-term rigors of multiple deployments under a range of conditions.

Expected Outcomes/Impacts: Since the 1990s, the atmospheric research community has relied on NCAR’s GPS Dropsondes to provide targeted, precise in situ atmospheric measurement in remote areas of the globe. The semi-automated dropsonde launch system will allow operators to be either on the plane or on the ground. FRONT will provide a rich set of radar observations across a wide spectrum of weather, and offers a framework for local field campaigns, hands-on educational opportunities, and a long-term mesoscale test bed for testing new instruments’ networking capabilities and data quality procedures, studying sensor integration technologies, and validating numerical models. As an example, deployment of cloud radars and lidars at the FRONT will offer unique measurements of the life cycle of precipitation events. The configurable 449 MHz Profiler Network will advance state-of-the-art deployable wind profiler capabilities and serve the atmospheric science community’s
need to measure winds over horizontal spatial scales and to altitudes not currently available (see Section 3, NSF Special and Non-NSF Funding Supporting the Lab). Accurate wind speed and direction measurement is important for virtually all GV atmospheric field experiments; this has historically been accomplished with a 5-hole radome gust probe that measures differential pressure at the aircraft radome’s surface. However, air flow around the GV radome and fuselage, which are not symmetrical, are expected to result in significant errors in wind-velocity estimates. **LAMS** is designed to make accurate wind velocity measurements using a continuous-wave laser focused in undisturbed air about 20 meters ahead of the aircraft. The ability to deploy a large sensor network, such as **CentNet**, which facilitates research in the biogeosciences, hydrology, and urban meteorology over seasons, is a capability that supports climate science. CentNet addresses many research topics including understanding turbulent flow over complex terrain, predicting convective initialization, and characterizing the exchange of trace gases within a vegetative canopy. The MSU eye-safe, low-cost, water vapor **DIAL** profiler will fill a national long-term observing facility gap and greatly benefit studies of micro- and meso-scale meteorology, water cycle, carbon cycle and, generally, biosphere-hydrosphere-atmosphere interaction research at weather and climate variability time scales.

### 5.1.4 Provide Comprehensive Data Services, Open Access, and Long-term Data Stewardship

NSF policy requires data set preservation and availability to users pursuing research questions apart from those that justified the original project, and data sets collected in EOL-supported field campaigns and preserved by EOL have value that extends far beyond immediate project-team use. Modern data-access mechanisms increase the importance and utility of data set preservation, and improve data access by the scientific community. Leveraging these mechanisms, EOL has enlarged the scope of its data services to include service provision from mission planning stages, to data collection and quality control and long-term archives. EOL also provides stewardship for a select set of data not collected by our observational facilities. These efforts directly feed into NCAR’s Strategic Plan Imperative to develop and provide state-of-the-art data services that meet needs of NSF, NCAR, and our science community. (NSF Base: $2.3M; NSF Spec: $1.3M; Other: $0.2M)

**Milestones:**

Existing tools will continue the migration to the new EOL Metadata Database and Cyberinfrastructure (EMDAC) schema in FY 2012. In FY 2012, EOL will also begin development of a next-generation field catalog, a tool in high demand by the research community. Expected FY 2012 enhancements include design of a single code-base, Google Earth integration and direct data access.

Several significant EOL/Computing, Data and Software (CDS) facility software systems will see application in new areas in FY 2012. Components such as the NCAR In-situ Data Acquisition System (NIDAS), EOL’s implementation of Field Programmable Gate Array-based hardware developments, and the Software Defined Digital Down-Converter (SD3C) suite, are complex and highly capable packages already deployed on multiple EOL platforms. Their use has expanded to additional observing systems such as the S-Pol Ka band system, the Integrated Sounding System, the 449 MHz profiler, and the HCR.
Remote monitoring of EOL software systems using Nagios will expand in FY 2012, and will include the S-Pol radar system and Integrated Sounding System. System monitoring allows sending of prompt alerts to engineers via text message or email and assists reliable remote operation of EOL platforms. This work builds upon prior experience of Nagios use in EOL's airborne and ground-based systems.

In FY 2012, use of centralized software management will expand. Standardized packaging of application support libraries and utilities and deployment from a central repository will alleviate routine software administrative tasks that currently impact software engineers.

**Expected Outcomes/Impacts:** The EMDAC schema will streamline metadata entry, reducing duplication of effort, providing better consistency among EOL tools, and meet future metadata needs. Field catalog refactoring will include architecture changes for more efficient maintenance using state-of-the-art web development frameworks, and will include addition of new features requested by the community. The new design will allow EOL to propagate improvements to prior catalog versions and provide a foundation for expansion of new capabilities in the future. EMDAC's long-term archive relies on CISL hardware but certain project datasets are hosted on EOL servers for rapid, interactive access. EOL data are accessible through CISL’s Community Data Portal and a majority of the archive is stored on CISL mass storage hardware. Expertise about the datasets, tracking of quality control and revisions, data and metadata formatting and access to high-demand datasets remains EOL’s responsibility while the longer-term physical storage of datasets and management of mass store hardware are CISL’s responsibility.

Through common, **cross-platform software development** and management, EOL expects many research community benefits. Among these: efficient use of limited software engineering resources by calling on the variety of expertise areas offered by EOL’s software engineers (e.g., software architecture, real-time data acquisition, signal processing, web application frameworks); a team-developed code ensures EOL can recover in the event that an individual software engineer is not available; multi-platform (e.g. Linux, Mac, and Windows) development lets EOL meet software needs of a broad community; using common tools to manage the software engineering process reduces overhead required for functions such as revision control, bug tracking, and software packaging; and by sharing software libraries across the Lab, EOL leverages extensive testing that occurs and uses the most reliable, proven software in our observing systems.

**5.1.5 Education, Outreach, and Training:** Attract and inspire new generations of scientists, engineers, and the general public to atmospheric science, conveying the excitement and intrinsic value of observational research.

EOL’s commitment to both continuing and expanding the Laboratory’s portfolio of education and outreach (E&O) contributions is reflected in EOL’s Strategic Plan Imperative V. This Imperative aligns with NCAR’s goal to attract a diverse group of university students and early career scientists and engineers, to provide exciting educational and professional opportunities. EOL’s mission and activities offer an excellent basis for fostering education and training opportunities for undergraduate and graduate students interested in observational meteorology, and the integration of traditional engineering fields with areas of science. Bright students in
science and engineering can be motivated to pursue careers in observational meteorology through exposure to NSF observational facilities and instruments and to EOL development activities. The public can better understand observational atmospheric science value through demonstrations of direct atmospheric measurements combined with explanations of what scientists learn from such observations. (NSF Base: $0.44M; NSF Deploy: $0.1M; NSF Spec: $.04M)

**Milestones:**

- EOL’s Summer Undergraduate Engineering Internship Program is a continuing FY 2012 priority, focusing EOL’s outreach efforts on the engineering community in a manner analogous to what other programs in UCAR/NCAR currently do for young scientists. EOL typically receives resumes from mechanical, electrical and computer, aerospace, optical, environmental, chemical, and industrial engineering students, three of four of whom are chosen to spend the summer working with EOL engineers on a variety of projects. EOL closely coordinates SUEIP activities with UCAR’s SOARS program, including joint social and networking events for students and mentors.

<table>
<thead>
<tr>
<th># of Visits by Length of Visit</th>
<th>FY09</th>
<th>FY10</th>
<th>FY11</th>
<th>FY12 Proj.</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 Months - 1 Year</td>
<td>3</td>
<td>8</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>3-6 Months</td>
<td>21</td>
<td>28</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>1-2 Months</td>
<td>10</td>
<td>6</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>15-30 Days</td>
<td>8</td>
<td>4</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>8-14 Days</td>
<td>7</td>
<td>5</td>
<td>18</td>
<td>17</td>
</tr>
<tr>
<td>1-7 Days</td>
<td>1</td>
<td>7</td>
<td>20</td>
<td>21</td>
</tr>
</tbody>
</table>

- EOL was awarded funding for its Diversity Proposal called "Careers in Science" from the NCAR Directorate. This program will conduct a targeted education and outreach program that exposes students from a subset of carefully chosen and accredited postsecondary minority-serving institutions to career opportunities in the areas of science and science support. Working closely with career counselors, science instructors, and a select number of university PIs, EOL staff will conduct two multi-day visits to areas in the south and southeastern U.S. in fall 2011 and early spring 2012. Efforts will be made to combine these visits with hands-on demonstrations of a mobile NSF observing facility (e.g., Doppler on Wheels (DoW), Mobile GPS-Advanced Upper Air System) to entice students to consider careers within a scientific environment.
EOL is collaborating closely with NSF, NCAR, NOAA, DOE, Office of Naval Research, and the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) to coordinate DYNAMO field campaign E&O component. Efforts will include comprehensive field project web sites, educational videos, scientist interviews on the Earth & Sky radio show, online radar activities for teachers, and outreach events.

The EOL Technical Support Internship Pilot Program will be initiated, consisting of three semester-long internships for students focused on science support from 2-year colleges and vocational/technical institutions in the Boulder/Denver area. The objective is to establish connections with students and faculty, spark interest in technical careers in the geosciences, and create EOL/student mentoring relationships that will foster the students’ academic advancement and careers. It will provide opportunities for a small number of students to work side-by-side with technicians, instrument makers, mechanics, and other technical support staff. In the long-term, EOL plans to work with college faculty to establish hiring pipelines and help formulate curriculum enhancements that complement support staff needs in the geosciences.

EOL staff will continue involvement with the new High School Internships and Research Opportunities program. The project pairs high school juniors and seniors with research scientists, engineers and web developers to assist with research or projects.

EOL will continue deploying instrumentation in support of education through NSF’s Deployment Pool; funding for this is $100K per year. EOL is actively soliciting proposals from minority-serving institutions for these funds. One educational deployment under consideration by NSF is for the Center for Severe Weather Research’s DoW platform.

**Expected Outcomes/Impacts:** The mechanisms EOL provides to support and inspire high school students and teachers, undergraduate and graduate students and faculty will ensure the field of atmospheric science becomes even more diverse and vibrant well into the future.

### 5.2 NSF Special and Non-NSF Funding Supporting Observational Research Facilities and Services

Miniaturization of dropsondes and remote deployments of soundings using the driftsonde are instrumental in developing next-generation GV and Unmanned Aircraft System (UAS) dropsonde systems. Development of UAS requires substantial progress on autonomous operations using a web-based interface. NSF Base funds are being used for this effort, along with NASA, U.S. Air Force, and NSF’s Office of Polar Programs funds.

**NSF ARRA Funds ($10.7M, received in late FY 2009 with work continuing through FY 2012):** In FY 2012, EOL will use ARRA funding to continue investigation into phased-array radar for airborne radar capabilities (“the next ELDORA”). The tasks planned for FY 2012 will extend availability of ELDORA for the scientific community through 2016 with the following enhancements: safe operation of radar without an escort aircraft and real-time dual Doppler winds (see Section 5.1.1 for further information). EOL will continue converting the HCR from a ground-based to an airborne system, with plans to add polarimetric capabilities and pulse compression to the instrument in FY 2012 (see Section 5.1.1).

**NSF Special One-Time Funds** will be used in FY 2012 to refine the design of the 449 MHz Profiler Network and to construct at least four additional modules to provide a system capable of
probing up to mid-tropospheric altitudes. EOL also anticipates receiving NSF Special Funds for tasks associated with approved DYNAMO and TORERO deployment projects, and potentially for the DC3 and Southeast Asia Composition, Cloud, Climate Coupling Regional Study (SEAC4RS) campaigns as well, should these be approved by NSF.

5.3 Key Funding Decisions for EOL in FY 2012
Facing a budget reduction in FY 2011 and in preparation for a flat budget in FY 2012, EOL made the strategic decision to no longer support the Technology Development Facility (TDF) and the associated personnel with new base funds. This decision will eliminate what was originally intended to be a centralized incubator for future developments in EOL, and will leave gaps in future HAIS support and in scientific and research engineering development leadership in EOL, thus impacting the ability to address some of EOL’s Strategic Frontiers.

However, EOL’s analysis of its program revealed this action to be the least disruptive to continued support of Strategic Imperatives. EOL then analyzed its remaining Program and Strategic Plan, conducted a State-of-the-Lab Assessment, and an online survey to identify other lower-priority activities for FY 2012 action. Mindful that the highest priorities are to maintain, support, and deploy observational facilities that are in the NSF Deployment Pool, and that data services and long-term data stewardship have grown in importance in EOL over the past five years, along with a long-term, focused strategy, EOL has chosen to reduce service to the community in some areas given funding projections for FY 2012. EOL’s FY 2012 key funding decisions will allow support of instrumentation and platforms requested for NSF-approved field campaigns. They will also allow continued incremental progress on the development of next-generation instrumentation and will support HAIS instruments as much as possible. We will not, however, be able to augment our Long Term Equipment Reserve Fund (LTERF) with new funds in FY 2012, and would channel unanticipated flexibility to the LTERF should the opportunity arise. More detailed impacts in FY 2012 are provided in a separate, confidential report to NSF.

5.4 Challenges and Opportunities for EOL in FY 2012
As EOL looks toward the future, we must rethink existing capabilities, scientific foci, and methods of support in light of the evolving funding environment and technologies. Areas of opportunity include development of new capabilities such as radars, lidars and profilers to observe high-impact weather and extreme events; characterization of aerosol concentration, cloud formation and microphysical processes; characterization of fractional cloud coverage and radiative properties of clouds; turbulence characterization in the boundary layer, including measurement of water vapor flux; improved wind sensing and flux measurements on research aircraft; and characterization of the tropopause’s structure.

Any shifts in emphasis are naturally accompanied by challenges. Operational and support challenges arise from new platforms and instruments (such as the GV and Driftsonde) and new technologies (such as real-time communications). Some of our challenges and EOL’s planned courses of action are outlined below.

- Healthy LTERF and EOL Reserves: Both will be implemented based on funding availability and future use.
• HAIS PI involvement and support: continue negotiations with NSF and PIs on an instrument-by-instrument basis.
• FRONT operation: EOL plans to have the FRONT site established in spring 2012 and will re-assess ongoing costs, operational requirements, and potential partnerships once the radar is sited.
• ELDORA deployability on the Naval Research Laboratory (NRL) P3: EOL requires approximately eight months of spin-up time, including new hires and/or retasking existing staff, and significant non-labor funds to meet any future requests due to the need to replace the aircraft data systems and a number of key sensors. EOL is investigating the details of this process, however, does anticipate ample notice of any potential deployments since they would be considered a large deployment request. ARRA funds were received for data system and software upgrades for ELDORA but did not include the data system and sensor needs for the NRL P3.
• Continued HCR development: EOL is devoting personnel and non-labor to HCR and, if funds are available, would augment HCR non-labor in FY 2012 to make progress on the second wavelength.

5.5 Long-Term Plans (FY 2013–2016)
Focusing on EOL’s mission to “develop and deploy observing facilities and provide data services needed to advance scientific understanding of the Earth System,” EOL envisions the overarching long-term plan to be continued support of NCAR’s Imperatives. EOL will make resource and programmatic adjustments among their imperatives as needed, dependent upon final funding allocations. Long Range Plans for 2013-2016 include:

• Continue fostering partnership between CSU (CHILL) and EOL (S-Pol) for FRONT.
• Reconfiguring the current GV system by taking advantage of the Global Hawk development, including autonomous operations and smaller sondes.
• Continued development of the 449 MHz profiler system through construction of additional arrays and testing, and expansion to a full tropospheric or boundary layer network capability.
• Enhanced CGD collaboration (longer-term measurements, multi-year field campaigns).
• Continued development of CentNet infrastructure to support climate science.
• Continued modernization of the C-130; an upgrade to 8-bladed C-130 propellers to improve aircraft performance is being evaluated.
• Building on CONCORDIASI, we will discuss the future of driftsonde with NSF.
• Continue exploring a partnership with National Ecological Observatory Network (NEON) on sensor technologies for ecological research.
• Continue NOAA and NASA partnerships on aircraft platform usage and instrumentation.
• Investigate collaborations with MSU on improvements to their DIAL instrument.
• In collaboration with community stakeholders, EOL will develop a project plan outlining development ideas and resource needs for an ELDORA replacement. ARRA funds were received for initial evaluation of phased array radar technology.
• Explore phased-array radar technology for use on the C-130.

In addition to these strategic foci, EOL will continue lifecycle management planning for instrumentation, so it is positioned to meet emergency needs, technological changes, and science
requirements. Such planning is critical to the continued renewal and development of the NSF LAOFs of which EOL is a steward, so that the Lab can maintain its measurement and deployment capabilities.

6.0 Program Operating Plan for the High Altitude Observatory (HAO)
The High Altitude Observatory FY 2012 research program is guided by the HAO 2011-2015 Strategic Plan, which focuses on six Imperatives. Imperatives include efforts to promote innovation and creativity within HAO and across the solar-terrestrial physics community; provide capabilities for more accurate prediction and attribution of changes in solar output and impacts of such changes; advance world-leading numerical models of the atmosphere and Sun-Earth System, make them widely available, and support their use by the scientific community; develop and provide state-of-the-art observational facilities that meet the needs of NSF, NCAR, and the solar-terrestrial physics community; develop and transfer scientific applications, technology, and information products that address societal needs; attract a diverse group of university students and early-career scientists and engineers to solar-terrestrial physics, and provide them with exciting opportunities for educational and professional development.

This POP also outlines several activities that further HAO’s program Frontiers as described in the Strategic Plan, namely to investigate onset and development of magnetic flux transport through the chromosphere, and the impact of its short-term variability on the Sun-Earth System; to investigate impacts on terrestrial and space climate of solar variability on decadal time scales; to determine how small-scale structures are produced in the Earth’s upper atmosphere and their effects on global dynamics; and link dynamo models to simulations of flux emergence.

Section 6.1 corresponds to HAO Imperative 1, although some elements are covered in Section 6.6. Sections 6.2-6.6 correspond to HAO Imperatives 2 to 6, respectively. In each of these sections, the main milestones correspond to bullets under the Imperatives in the HAO Strategic Plan. HAO notes that development by a consultative process within HAO of an implementation and delivery plan for the 2011-2015 Strategic Plan is not yet fully reflected in this program operating plan. That development will result in a prioritized list indicating where new or reprogrammed resources will be put to best deliver our strategic vision; this will be in place in next year’s program plan.

6.1. Scientific Innovation and Discovery
HAO conducts a comprehensive program of solar-terrestrial physics, encompassing solar physics, physics of the heliosphere, study of geospace and space weather, and the physical processes of Earth’s magnetosphere and upper atmosphere. The main research activities include theoretical and observational research on solar dynamo using state-of-the-art numerical models; investigation of magnetic fields and plasma properties and motions in the Sun’s photosphere and chromosphere; research into the structure, energetics, and dynamics of the corona and the solar wind; and investigation of Earth’s upper atmosphere’s response to variable solar output and its coupling to the lower atmosphere. (NSF Base: $2,868K. Non-NSF: $4,500K)

Milestones:
- Carry out theoretical and observational studies of solar-stellar magnetic activity cycles, focusing on magnetic flux transport processes by meridional circulation, as well as
turbulent transport mechanisms, along with a survey of solar-like bright stars in the Southern Hemisphere.

- Conduct numerical simulations to underpin dynamical processes in the near-surface shear layer, and explore the theory of meridional circulation at the polar cap based on low-latitude observations.
- Continue basic studies of ion-neutral physics of the solar chromosphere and fundamental magneto-hydrodynamic (MHD) theory of magnetic helicity and current sheet formation.
- Conduct observational studies and MHD simulations of the development of Coronal Mass Ejections (CMEs) and their precursor structures, focusing on determining the magnetic field evolution of realistic CME events.
- Continue comparative studies of solar minima to characterize properties of the coupled Sun-Earth System during the latest solar minimum in contrast to past solar minima.
- Conduct numerical and observational investigations of dynamical and electrodynamical response of the thermosphere-ionosphere-magnetosphere system to forcing from the Sun and the lower atmosphere.

**Expected Outcomes/Impacts:** These efforts will provide new physical insights into fundamental processes that cause solar disturbances, and will contribute to a better understanding of the Sun’s role in driving space weather. This program of theoretical, numerical, and observational research is core to HAO’s scientific program to understand the behavior of the Sun and its impact on the Earth. For example, numerical simulations and theoretical and observations studies will elucidate the role of large-scale interior flows in the workings of the solar dynamo.

**6.2 Capabilities for Prediction of Changes in Solar Output and their Impacts**

An HAO Imperative is to enhance capabilities for the study and more accurate prediction and attribution of changes in solar output and their impacts on Earth, from short-term space weather to long-term solar-cycle modulation. (NSF Base: $1,704K. Non-NSF: $62K)

**Milestones:**

- Collect critical measurements and develop appropriate diagnostic tools: daily observations (weather permitting) using a suite of instruments at the Mauna Loa Solar Observatory (MLSO), including the recently deployed Coronal Multi-channel Polarimeter (CoMP) instrument; measure magnetic free energy in the corona from spectro-polarimetry observations in the chromosphere and at the coronal base using ground-based instrumentation; expand Community Spectro-polarimetric Analysis Center (CSAC) capabilities by developing new software packages for the polarimetric data inversion, validating inversion strategies, and obtaining and distributing ProMag data to the community via CSAC.

- Carry out analysis and forward modeling of multi-wavelength observations from the Hinode, Solar Dynamics Observatory (SDO), and Solar Terrestrial Relation Observatory (STEREO) satellites and ground-based instruments at MLSO and National Solar Observatory (NSO) to advance understanding of the 3D structure and evolution of CMEs and their precursors (e.g., prominences and coronal cavities).

- Work toward creating a comprehensive model of interactive processes throughout the Earth’s upper atmosphere: quantify variability of thermospheric/ionspheric temperature,
density, and winds to changes in solar UV and X-ray radiance and other external forcing; investigate the influence of ionosphere ion outflow on magnetospheric dynamics using the Coupled Magnetosphere-Ionosphere-Thermosphere (CMIT) model; analyze effects of a new gravity-wave parameterization on the quasi-biennial oscillation (QBO) and the middle-atmospheric circulation at mid- and high latitudes in the Whole Atmosphere Community Climate Model (WACCM).

**Expected Outcomes/Impact:** This work advances a central element of HAO’s vision, namely to “perform world-leading science to understand fundamentally and with predictive capability the sources and nature of solar and geospace variability.” Daily observations at the MLSO will provide unique data sets for community use. Forward modeling of multiple observables will shed new light on the formation of solar prominences and coronal cavities. Development of comprehensive global numerical models will greatly improve the understanding of various dynamical and electrodynamical processes that affect the upper atmosphere.

### 6.3 Community Model Development

HAO plays a major role in leading and supporting development of state-of-the-art models for the community, including research models for solar and heliospheric research and community models in the atmosphere, ionosphere and magnetosphere (AIM) area. HAO leads and develops large-scale numerical models that support community research in the upper atmospheric, ionospheric, and magnetospheric physics. Community models include the NCAR Thermosphere-Ionosphere-Electrodynamics General Circulation model (TIE-GCM), the CMIT model, and the upward extension of the WACCM-X. CMIT development is a joint effort with the Center for Integrated Space Weather Modeling (CISM), led by Boston University; WACCM is part of the Community Earth System Model, and is a joint effort among ACD, CGD, and HAO. Though the Thermosphere-Ionosphere-Mesosphere-Electrodynamics General Circulation model (TIME-GCM) does not meet all requirements of a “community model” (e.g., an openly accessible source code), it is widely used by the upper atmospheric community. In particular, university researchers and students collaborate with HAO staff to use it for basic research because the model incorporates comprehensive aeronomical, dynamical, and electrodynamical processes that are appropriate for the mesosphere-thermosphere-ionosphere regions (NSF Base: $700K, NSF Special: $167K, Non-NSF: $460K)

**Milestones:**

- Lead and support development of space-weather community models: complete a community-wide release of the latest TIE-GCM version and update the user guide for this version; continue CMIT development (such as coupling with the Rice Convection model developed at Rice University, improving auroral parameterization, incorporation of ion outflow), utilization, and community support.
- Develop new community modeling systems and components: continue to upgrade TIE-GCM and TIME-GCM (with regard to grid resolution, parallelized dynamo, calculation of geomagnetic perturbations, plasmasphere interactions, high-latitude auroral and electrodynamic inputs, energetic-particle parameterization), including documentation, scientific utilization, and community support.
• Develop and merge WACCM-X in the CESM main trunk, and develop and test WACCM-X’s vertical plasma transport module.

• Lead and support modeling efforts for the solar dynamo and flux emergence: further enhance sunspot modeling capability by extending the computational domain of a typically observed active region both horizontally and vertically to more realistically simulate flux emergence into the chromosphere; improve MHD simulation realism for initiation of CMEs using observational input to constrain the lower boundary driving conditions and carry out simulations of actual CME events; develop and implement an Ensemble Kalman Filter (EnKF) data assimilation scheme in the flux transport dynamo model to improve solar cycle prediction.

**Expected Outcomes/Impact:** The research community directly benefits from this work through release of up-to-date AIM model versions that incorporate improved physical processes related to Sun-Earth System interactions. Simulation runs by state-of-the-art models of flux emergence and sunspot formation and evolution also benefit the community and wider society.

### 6.4 Observational Facilities

Observational research is central to HAO’s vision and mission. To fulfill this Imperative, HAO will maintain its observing facilities and seek opportunities to develop and upgrade existing observational technology and instruments. Major efforts in FY 2012 include completing transition of CoMP to routine operations in its synoptic mode, constructing the K-coronagraph as a component of the Coronal Solar Magnetism Observatory (COSMO) project, and enhancing HAO’s data service capability for the community (NSF Base: $550K, NSF Special: $1,161K)

**Milestones:**

• Complete the K-coronagraph’s final design, and complete instrument fabrication by FY 2012 end.

• Take the Visible Spectro-Polarimeter (ViSP) instrument through to a successful critical design review (CDR), subject to obtaining the contract from Advanced Technology Solar Telescope (ATST) in early FY 2012.

• Develop partnerships and begin a detailed design phase for COSMO, and develop a roadmap to get to a COSMO preliminary design review (PDR).

• Enhance data service capability through complete development and implementation of a pipeline to retrieve CoMP data rapidly from MLSO, and continue to collect and process new Coupling and Energetics of Atmospheric Regions (CEDAR) data sets, providing the community with easy access to the archived data.

**Expected Outcomes/Impact:** These developments will significantly enhance the solar and space-weather research communities’ research capabilities. The new K-coronagraph will be able to provide high-cadence, high-sensitivity CME measurements. Combined with CoMP’s synoptic coronal magnetic field measurements, these observations will yield unprecedented insight into coronal eruptive processes that often cause space weather disturbances at Earth.
6.5 Research to Application
HAO’s mission includes fostering and transferring knowledge and technology from its origins in fundamental research for society’s benefit. In partnership with NASA’s Community Coordinated Modeling Center (CCMC), the Space Weather Prediction Center (SWPC) at NOAA, and CISM, HAO will continue to develop, test, and transfer our numerical models for space weather applications. (NSF Base: $62K, NSF Special: $27K, Non-NSF: $114K)

Milestones:
- Develop, test and transfer models to operational agencies: Transition code from the latest TIE-GCM version to the CCMC; Transition CMIT to the CCMC, and help validate CCMC’s “runs-on-request” model outputs; leverage SWPC collaboration to implement and validate the CMIT (if selected) for space weather prediction. Work with SWPC to model how COSMO coronal magnetic field measurements might be used as an effective boundary condition on SWPC’s heliospheric model used for space-weather prediction.
- Transfer updated user guides/documentation for TIE-GCM and CMIT to CCMC.

Expected Outcomes/Impact: These efforts will further development of HAO’s first principles physics models to become more efficient and accurate, and to explore predictive capabilities in order to meet the challenge of space weather application. The efforts will also support government agencies to develop better national strategies toward space weather prediction and mitigation.

6.6 Education, Outreach, and Training
HAO is committed to a vibrant visitor program, allocating sizable base funds to the program despite the very tight FY 2012 budget. Funds support postdoctoral visiting scientists, graduate students and Research Experiences for Undergraduates (REU) undergraduate students, as well as senior and other short-term visitors (NSF Base: $801K. Non-NSF: $370K)

Milestones:
- Increase effectiveness of advertising of opportunities at HAO for graduate and postdoctoral appointments, in particular advertising graduate studentships widely in order to draw from a more geographically diverse pool of potential students.
- Support 10 postdoctoral scientists with a mix of base and non-base support, selecting new postdoctoral appointees with regard to their scientific excellence and potential, and their strategic fit to HAO’s programmatic needs.
- Support three graduate students with a mix of base and non-base support.
- Conduct educational programs that integrate research and education at HAO: work with CU-LASP (Laboratory for Atmospheric and Space Physics) toward a successful renewal of the REU grant; support two to three REU students in summer 2012; work with UCAR’s Education and Outreach department to attract more Significant Opportunities in
Atmospheric Research and Science (SOARS) students and help improve diversity in the solar-terrestrial area.

- Encourage and support visits by at least 2/3 of HAO Affiliate Scientists, and seek to create new Affiliate Scientist positions in areas that support our 2011-2015 Strategic Plan.
- Host about 90 short-term visitors, seeking to use this resource as strategically as possible to support HAO’s highest programmatic priorities.

6.7 NSF Special and Non-NSF Funding Supporting HAO Research and Modeling

- The High-altitude Interferometer WIND (HIWIND) is a NASA-funded balloon project to measure upper atmosphere winds. The instrument, a Fabry-Perot interferometer (FPI), was constructed and tested in FY 2011, with a science flight running in June 2011 in Kiruna, Sweden. Scientific data analysis and data dissemination will be carried out in FY 2012.
- Continue operation of ground-based FPIs in Resolute Bay, Canada, and at Palmer Station, Antarctica.
- Continue the efforts of Hinode spectro-polarimeter level 1 and level 2 data preparation and distribution. Integrate azimuth disambiguation into pipeline.
- Continue SDO data analysis and study of Alfvénic motion and dynamic energy release in the lower atmosphere coupling into the corona.
- The Interface Region Imaging Spectrograph (IRIS) is a new NASA satellite mission to be launched in December 2012. As a team member, HAO will develop spectral diagnostics of the upper chromosphere and transition region, and will focus on Mg II spectral modeling and time-dependent ionization processes affecting instrument emission lines.
- Continue scientific activities related to the Integrated Modeling of the Atmosphere-Ionosphere System, which is a collaborative effort with NCAR/ACD and CU/CiRES (Cooperative Institute for Research in Environmental Sciences) and supported by NASA’s Living With a Star (LWS) Strategic Capability program.
- Other externally funded efforts that are highly relevant to HAO’s strategic objectives will continue, including those supported by NASA’s LWS Targeted Research and Technology (TR&T) program, the Heliophysics Guest Investigators program, the Solar and Heliospheric

6.8 Key Funding Decisions for HAO in FY 2012
HAO completed its Strategic Plan through an inclusive staff and community development process in Fall 2010. This Strategic Plan, which is strongly aligned with NCAR’s Strategic Plan, has guided the plans and actions presented here; these plans and actions have been developed and discussed with HAO Executive members, and with HAO Section Heads.

HAO’s planning priorities are to protect HAO’s capacity to deliver on strategic imperatives and, where resources permit, to support activities that will drive forward COSMO and HAO’s highest-priority program frontiers. Specifically, HAO protects the capacity to deliver on community facilities and models.

Based on this strategy, HAO has proposed several actions to meet a flat budget for NCAR in FY 2012. Several research and service areas were impacted.

6.9 Challenges and Opportunities for HAO in FY 2012
The anticipated FY 2012 flat budget for NCAR would result in an approximate 5% reduction in HAO base funds because of the need to support new, high-priority NCAR areas with reprogrammed funds. This poses significant challenges to HAO programs. In anticipation of this, and in line with implementation elsewhere in NCAR, planning priorities were undertaken in FY 2011 as discussed in Section 6.8 above.

Other challenges include:

- End of CISM in one year’s time. This means some elements of WACCM and CMIT model development and support may have to be picked up by Base funds; we are currently working to secure non-base funding opportunities.
- Likely end of NASA Hinode funding in a few years. Hinode funds currently provide partial support to two staff members. HAO is seeking alternative ways to support these staff, including switching one to other projects, with the other taking phased retirement.
- Maintaining critical mass in the area of spectro-polarimetry. The imminent retirement of a senior scientist will leave a critical gap in this area that needs to be filled as soon as possible.
- Uncertainty over ViSP/ ATST contract award. HAO successfully presented ViSP for PDR in January 2011, but uncertainty remains regarding if and when HAO shall be awarded a contract to build ViSP due to cost overruns within the ATST project. Without an early contract, HAO may have to take staff actions in the Instrumentation Group; however once awarded, the $6M+ ViSP contract will be a major project for HAO for the next three years.
- On a smaller scale, some current external grants supporting a critical staff member will expire in the coming year, which may mean HAO has to support the individual on Base funding. This would be entirely justified given the strong role the individual plays in HAO (including leading the Lower Solar Atmosphere [LSA] section and our highest priority program frontier).
Several new opportunities have been identified as the follows:

- HAO’s Strategic Plan composes four program Frontiers that are prioritized, should additional resources become available. This Strategic Plan offers the flexibility to allow Frontier activity to be carried out opportunistically, should funding for a particular area arise. Each Frontier working group is actively seeking external resources through competitive proposal processes and through expanded collaborations with the community.

- The COSMO instrument suite is capable of providing unprecedented measurements of coronal magnetic fields over a large field-of-view at the spatial and temporal resolution required to address outstanding problems pertaining to fundamental solar physics. Efforts will continue to find a funding path for COSMO.

- ViSP is a spectro-polarimeter designed at HAO for NSF’s ATST. The instrument PDR was conducted in January 2011. Once a final decision is made by the ATST project to go ahead with ViSP, work on final design and fabrication will begin.

- Finalize science questions motivating the ChroMag (Chromosphere Magnetometer) concept, identify spectro-polarimetric and plasma dynamic science requirements for the ChroMag proposal based on CoMP and Prominence Magnetometer (ProMag) data, as well as archived observations from space- and ground-based instruments.

- Following the successful balloon flight of the first Sunrise project in 2008, a second flight (Sunrise-II) has been planned by the international consortium of partners. If a NASA proposal to support the project is funded, HAO’s involvement in Sunrise-II will proceed in FY 2012, with balloon flight anticipated in 2012-2013.

- Solar-C is a next-generation Japanese solar physics satellite and successor to Hinode; mission concept is currently under development. HAO will actively seek to position itself to partner with U.S. and Japanese collaborators to design, bid, and build the optical focal plane package for Solar-C as a NASA-funded project. Some uncertainty exists over whether NASA will adopt Solar-C as a bilateral mission, however. Launch will likely be no earlier than 2018.

**6.10 Long-Term Plans (FY 2013-2016)**

HAO’s long-term plans are guided by the HAO Strategic Plan. HAO is currently developing an implementation and delivery plan that will be a roadmap for how to deliver this strategic vision. Plan for implementation is likely to include the following elements:

- Ensure critical mass in spectro-polarimetry to maintain HAO’s leading position in this field following a recent retirement so as to be in a strong position to continue CSAC development and support, and to exploit spectro-polarimetric data from existing and future instruments such as ViSP (Imperatives 2 and 4).

- Ensure critical mass in state-of-the-art AIM modeling so as to be able to develop and support existing and new community models (Imperative 3).

- Advance COSMO through CDR and into a construction phase either in the United States (our preferred option) or internationally, with U.S. and international collaborators (Imperative 4).

- Develop and deploy ChroMag to monitor the spatial and temporal evolution of the chromosphere’s magnetic field (Frontier 1).

- Develop the capability to forward-model complex chromospheric spectro-polarimetric signals to develop and test inversion strategies in the context of CSAC (Frontier 1).
• Continue WACCM-X development to enable studies of long-term atmospheric effects of solar variability (Frontier 2).
• Continue CMIT development to enable studies of how the magnetosphere and its coupling with the ionosphere depend on long-term changes in the solar wind, atmosphere, and geomagnetic field (Frontier 2).
• Develop a high-resolution ionosphere/plasmasphere module for WACCM-X to study cross-scale interactions and sources of ionospheric irregularities (Frontier 3).
• Explore the possibility of deploying an FPI and all-sky camera at MLSO to observe gravity waves and neutral winds at low latitudes for better understanding of how small-scale structures such as gravity waves affect the ionosphere (Frontier 3).
• Develop large-scale 3D dynamo models to study different aspects of longitude- and latitude-dependent solar cycle features, including the emergence, evolution, and dynamics of active regions produced from the dynamo-generated magnetic flux (Frontier 4).
• Expand the Finite-difference Spherical Anelastic MHD (FSAM) code by adding convection, rotation, and a tachocline (Frontier 4).

7.0 Program Operating Plan for NCAR’s Earth System Laboratory (NESL)
The mission of NCAR’s Earth System Laboratory (NESL) is to advance understanding of weather, climate, atmospheric composition and processes, provide facility support to the wider community, and apply the results to benefit society. NESL performs fundamental studies of the Earth’s system dynamics across spatial and temporal scales, from understanding and predicting high impact weather and air quality to assessing how natural forcing processes (and human-driven changes) affect the evolution of the Earth’s system and ultimately the habitability of our planet. NESL maintains a strong disciplinary science program, while reaching out actively to other disciplines to enable the interdisciplinary research required to respond to societal needs. Our programs include exploratory research, model development, use, and analysis, instrument development, observations and analysis, and community support and services through provision of facilities, scientific collaboration, and education and outreach.

The activities described below show how the NESL research program is advancing Earth System knowledge. These programs are defined by the NESL Strategic Plan, which is consistent with NCAR and NSF strategic goals and was developed through numerous interactions with NESL staff, division management, and the NESL Advisory Panel made up of community members. This research is accomplished within the divisions, through substantial cross-division interactions, collaboration with other NCAR Labs and the Observatory, and collaboration with the international research community. NESL’s research also has broader impacts through strong community participation in developing and using community modeling and next-generation instrumentation, and a robust visitor program. NESL research and facilities provide support for national policy decisions and for improvements in predictions of weather with a high societal impact. The importance of these contributions has been recognized by the NSF Site Review Team who commented: “The Site Visit Team (SVT) considers NESL’s community modeling effort, culminating in the CESM, the WRF, and the WACCM to be among NCAR’s greatest achievements in its nearly 40-year history.”
7.1 Program Activities

7.1.1 Atmospheric Chemistry Division (ACD)

Improvements in community models require detailed study of “processes.” One particular study is that of gas-phase chemical reactions, particle formation and growth, and biogenic emissions at the leaf/plant level. Such research makes ample use of various chamber and related facilities housed in ACD and involves significant collaboration with universities and national and international agencies to provide the underpinning for development of detailed models. These process studies also form the basis for parameterizations of relevant processes in community models such as the Weather Research and Forecast (WRF) model coupled with Chemistry (WRF-Chem). Other process-related studies resulting from participation in field experiments using airborne and ground-based instrumentation, and satellite platforms are described in Section 7.1.7.

Milestones:

- Laboratory studies of gas-phase oxidation of oxygenated volatile organic compounds (OVOCs) will be conducted in ACD’s environmental chamber on representative OVOCs.
- Laboratory studies of the oxidation of, and new particle formation from Biogenic Volatile Organic Compounds (BVOCs), which include use of a flow tube system to investigate isoprene and monoterpene oxidation schemes, including in low NOx environments, and their impact on HOx, and use of the ACD bioaerosol chamber to investigate new particle formation and growth processes associated with BVOC, and studies of the chemistry of nitrate compounds formed from isoprene. A BVOC emissions study will use ACD’s plant growth chamber to investigate the processes controlling BVOC emissions including stress (drought, heat, insects, and air pollutants).
- A “Laboratory Campaign” to study particle formation from nitrogen chemistry will be carried out in late FY 2011/early FY 2012.

Expected Project Outcomes/Impacts: These process studies form the basis for parameterizations of relevant processes in community models such as WRF-Chem and CAM-Chem (Community Atmosphere Modeled, coupled with Chemistry).

7.1.2 Climate and Global Dynamics Division (CGD)

NESL’s Climate and Global Dynamics (CGD) Division continues discovery-oriented research in each of its three strategic priorities – community modeling, decadal climate predictions, and model development. The major focus for CGD’s community modeling is on discovering climate responses, interactions and feedbacks as revealed by the recently completed Community Climate System Model (CCSM4) and Community Earth System Model (CESM1) integrations performed under the CMIP5 protocol as a contribution to the IPCC AR5.

Milestones:

- Preliminary results and descriptive papers will appear in two special Journal of Climate issues.
- A continuing focus is explicitly and consistently representing small-scale variability in parameterizations (25-km and less) in CAM.
- There will be an increasing emphasis on decadal climate predictability and predictions. A key ingredient will be greater understanding of natural variability so it can be initialized
in models to maximize the predictability it contains. Decadal predictions are also boundary value problems and efforts will intensify to provide better climate forcing, including terrestrial signals such as land-use change and other human interactions arising from integrative assessment modeling such as population growth, urbanization, energy strategies and economic factors. An important question is: how long do initial conditions dictate predictability before the forcing becomes first an equal then a dominant factor?

• With completion of the AR5 simulations, CGD will transfer from production mode into a period of model development aimed at reducing biases and imperfections for the physical atmosphere, ocean, land and sea-ice components of CESM, and for biogeochemical cycles, ocean ecosystems, land ice and atmospheric chemistry.

Expected Project Outcomes/Impacts: Preliminary CCSM4/CESM1 results will establish a baseline for more extensive and creative analysis aimed at testing various climate change hypotheses. Regional-scaling of CAM will allow interactions with detailed process models in both the land and atmosphere. The CCSM4 and CESM1 AR5 simulations reveal significant biases in the simulated climate, as well as the newly-examined relationships and correlations between climate variables. These will be more fully explored to reduce model imperfections.

7.1.3 Mesoscale and Microscale Meteorology (MMM)
NESL’s Mesoscale and Microscale Meteorology Division has the mission of advancing understanding of meso- and microscale aspects of weather and climate, and applying this knowledge to benefit society. Achieving this end is reflected in FY 2012 efforts related to boundary layers and turbulence, physical meteorology, mesoscale dynamics, data assimilation, regional climate research and societal impacts.

Milestones:
• MMM plans to ascertain the importance of anisotropic production of subgrid-scale momentum and scalar fluxes in high-Reynolds large eddy simulations (LES) of turbulent flow near rough boundaries utilizing observational data and truncated equations for subgrid-scale fluxes.
• The upcoming Ice in Clouds Experiment-Tropical (ICE-T) field campaign will provide microphysical process measurements in tropical maritime convective clouds, focusing on super-cooled regions.
• Extensive retrospective hurricane simulations and idealized numerical simulations will be run.
• Development and support of the WRF model will continue, with annual releases and model physics improvements; an improved boundary-layer parameterization will be developed to include wind-farm effects.
• A prototype capability will be developed to assimilate satellite radiances for WRF with the Data Assimilation Research Testbed (DART).
• The Nested Regional Climate Model (NRCM) will be improved to include a fully coupled atmosphere-ocean-wave model, and simulations will be run to investigate hurricane statistics in future climate scenarios. For the first time, advanced statistical techniques for extreme events to diagnosis model output will be available to the research community.
• Data from surveys and in-depth interviews of forecasters, broadcast media, emergency managers, and members of the public will be analyzed to identify ways to improve communication of hurricane and flash flood forecasts and warning information.

Expected Project Outcomes/Impacts: The subgrid-scale momentum and scalar flux research will increase the fidelity of LES solutions and their ability to accurately predict fluxes in a wide variety of complex flow regimes. ICE-T outcomes will support evaluation of cloud condensation and ice nuclei properties, and the role of dust in ice nucleation, entrainment and glaciation processes – understanding that is critical to meteorological and climate studies. Retrospective hurricane runs will help ascertain major controls on tropical-cyclone intensity and track forecasts, and improve real-time experimental forecast accuracy. Similarly, NRCM improvements will assist hurricane output diagnoses. WRF’s user community has come to rely on model updates and expanded capabilities, making WRF an important research tool for many in our science community. DART/WRF efforts related to satellite radiances will significantly improve real-time Advanced Research WRF (ARW) hurricane prediction. Improved communications in the case of extreme events provide obvious societal benefits.

7.2 Major Cross-Cutting Initiative: Prediction Across Scales
Society is becoming increasingly vulnerable to weather and climate events, especially those at the severe and high-impact end of the spectrum. This has been demonstrated by recent bursts of Atlantic hurricane activity, heat waves, droughts and flash flooding. Yet uncertainty over potential climatic changes in these high-impact events severely hampers capacity to plan for, adjust to, and mitigate impacts. The Prediction Across Scales Initiative will develop advanced predictive techniques that will improve society’s capacity to mitigate, respond and adapt to effects of high-impact weather and climate on scales from hours to decades. This effort provides special focus on advancing community modeling facilities, and ties to several NCAR Imperatives, including providing capabilities for more accurate prediction and attribution of changes in climate, severe weather, air quality and solar output, and impacts of such changes on ecosystems and human well-being; working with collaborators to advance world-leading numerical models of the atmosphere and Earth System; and promoting scientific innovation and creativity within NCAR and across the research community.

Milestones: By nesting the well-developed ARW model into CCSM, high-resolution prediction with existing computing infrastructure can be further explored. In the next stage of this effort, CESM will be extended using high-end computational power to further develop the capacity to predict climate (and weather) at the regional and, soon, local scale.

Expected Project Outcome/Impact: Traditional grid scales used for climate (on the order of 10s to 100s of km) are insufficient to constrain process-based representations of the climate system and to generate weather statistics and extreme event probabilities that are critical for impact assessment. NESL is initially addressing these aspects using the NRCM approach.

Developing cyber-infrastructure is enabling the move toward a full capacity for prediction across all scales, both temporally and spatially. In the next stage, CESM will be extended using high-end computational power to further develop the capacity to predict climate (and weather) at
regional and, soon, local scales. These programs, on scales of 10s of km and less, will enable further progress in evaluation of cloud-scale processes (aerosol activation, cloud microphysical and dynamical interactions) that affect regional and global climate sensitivity, and estimation and assessment of impacts using self-consistent models to produce statistics of weather and extreme events to drive impact assessment models (e.g., of the hydrological cycle). Ultimately, NESL will move toward a full capacity for nonhydrostatic modeling on the sphere, a goal that has its foundations in the current development of the Model for Prediction Across Scales (MPAS).

This major initiative thus involves a wide range of scientists and disciplines within and outside NCAR. It includes CCSM/CESM, WRF and its components (CESM, NRCM, WACCM, WRF-Chem, WRF-Fire, and AHW), next-generation MPAS development, the Regional Climate Prediction Program, and incorporation of human dimensions and communication into modeling-system predictions. These component programs are described in the following sections. Notably, Prediction Across Scales provides a core theme running through many of NESL’s programs and activities listed in this document.

7.3 Community Models
7.3.1 Community Earth System Model
NCAR has a proud and unique tradition of collaboration with scientists from universities, national laboratories, and other research organizations to develop, continuously improve and support scientific use of a comprehensive Earth modeling system that is at the forefront of international efforts to understand and predict the behavior of Earth's climate. The community-created, NSF/DOE-funded Community Earth System Model provides additional physical processes and new capabilities that will allow the research community to address a wider range of pressing scientific questions. The CESM code base has more than 1,500 registered downloads, with several thousand others accessing CESM data for use in the large variety of climate studies. Simulations performed with CESM will make major contributions to the IPCC AR5.

Most CESM project funding comes from NSF; DOE is also a major funder and key partner. CESM provides NSF- and DOE-funded communities, as well as partners in the overall U.S. Global Change Research Program, with a core modeling system for multiple purposes, including studies of past and current climate, and projections of future climate change. Importantly, CESM continues to involve a significant part of the climate community in its development and application, and there is community governance of all its activities. The governance of the scientific direction of the CESM activities, for instance, occurs through a scientific steering committee with more than half of its members coming from universities or other government laboratories. Model development takes place at NCAR and at many collaborating institutions, including several other national laboratories, and data from major experiments are shared with all users and analyzed at a variety of institutions. Future directions are discussed and decided in a community process. An annual CESM workshop allows hundreds of scientists to gather, discuss their work, and plan future activities; FY 2011 had more than 400 workshop participants. Twelve model working groups meet during the year to discuss model development progress and future plans. All components and major model data sets are made available on the web or through data portals (e.g., the Earth System Grid).
Collaborators are allocated computer time through a community-based governance process, and NCAR/NESL supports several liaison personnel to facilitate interactions with these scientists. A significant amount of the CESM project success is attributable to contributions by these outside collaborators. CESM will continue to be used as a facility by scientists from across the United States and around the world. Also of note, Marika Holland became CESM Chief Scientist as of 1 September 2011; the CESM chief scientist is a critical NESL team member. (NSF Base: $4.7M; Other: $4.16M)

**Milestones:** Overarching development priorities are directed toward the next major update and community release of CESM, while production priorities relate to major simulations to be performed with CESM and made available for community analysis during FY 2012.

**Development priorities include:**

- Coupling across components and understanding interactions focusing on evaluating model performance against observations, understanding the behavior and refining representation of physical processes, and expanding capabilities for coupling across components.
- New parameterizations and processes to address improving simulation of climate change radiative forcing by greenhouse gases (CO₂, ozone, and methane) and aerosols (secondary organic aerosol), as well as improving treatment of climate change feedbacks involving greenhouse gases, aerosols, clouds, and the cryosphere. High-resolution and new dynamical core development will also be a focus, with major efforts to include testing and evaluating the CAM and coupled CESM performance (with and without chemistry) at resolutions up to 0.25° using the finite-volume dynamical core; testing and evaluating CAM performance (with and without chemistry) at resolutions up to 0.25° using the Higher-Order Method Modeling Environment (HOMME) dynamical core; and carbon cycle simulations at 0.5° resolution.
- Addressing biases and other known CESM shortcomings are critical. Toward this end, FY 2012 will be focused on reducing CESM biases related to the double inter-tropical convergence zone (ITCZ) and an excessive tropical water cycle.
- Lastly, a CESM Workshop will convene in Breckenridge, Colorado; tutorials and training will be provided to early career scientists and graduate students on using CESM.

**Production Priorities include:**

- Coordinating modeling and assessment activities in support of CMIP5; the Geo-engineering Model Intercomparison Project (GeoMIP); the Paleoclimate Model Intercomparison Project (PCMIP); and the Coupled Carbon Cycle Model Intercomparison Project (C³MIP). The CESM project will also participate in international projects designed to assess short-term behavior of climate models when they are run in weather forecast mode, and will participate in CLIVAR Climate Process Team (CPT) activities as well as the international CLIVAR Coordinated Ocean-Ice Reference Experiments (CORE).
- Benchmark simulations that will involve both control (e.g., pre-industrial and present day) and transient climate change experiments; these will be made available to the research community for analysis and assessment.
- Climate variability and predictability experiments to characterize CESM’s representation of past climate and projections of future climate, including (for example) spread of climate predictions generated by internal variability, the role of polar processes in determining climate sensitivity, and the role of oceanic surface temperature patterns in generating atmospheric variability.

**Expected Project Outcome/Impact:** Development activities will result in new CESM capabilities and improved versions. These versions will be thoroughly tested, and control simulations will be performed. All significant model updates, along with control data sets, will be made available to the community, with a goal of releasing CESM1.5 by FY 2012 end. The research community continues to have free and open access to a comprehensive set of CESM production simulations, as outlined above. For example, results from the CMIP5 simulations will be thoroughly and openly documented in two special collections in the *Journal of Climate* and software engineering advancements will be featured in a special issue of the *International Journal of High Performance Computing Applications*.

**7.3.2 The WRF Model and Data Assimilation System**
The WRF-system effort in MMM supports an extensive user community that includes academic, operational and commercial interests. WRF-supported activities include: provisioning of help for WRF and the WRF data assimilation (WRFDA) systems; delivery of multiple tutorials each year; organizing and hosting the annual WRF Users’ Workshop (more than 220 attended in FY 2011); oversight of the WRF Developers’ Committee; testing and incorporation of community-
based code contributions for new or improved WRF capabilities; and oversight of the WRF Release Committee and WRF releases, including issuance of bug-fixes and updates. To ensure WRF code-improvement and upgrade-accessibility, MMM maintains a single-source code repository. The WRF team also undertakes model-based research and development, provides support for field projects with real-time WRF forecasts, and conducts fundamental research on algorithms and techniques for ensemble data assimilation. The WRF-Chem model will be used for field program analysis, air quality forecasting and analysis, and investigating meteorology/chemistry interactions. (NSF Base: $2.2M, Other: $1.5M)

**Milestones:**
- Conduct WRF system tutorials in Boulder, CO; Edinburgh, UK; and Pusan, Korea.
- Conduct a WRF Users' Workshop in Boulder.
- Prepare and distribute the 2012 major WRF release (WRF V3.4 or higher).
- Run real-time WRF from analyses from WRF/DART in support of the 2012 Storm Prediction Center Spring Forecast Experiment.
- Run real-time WRF in support of the U.S. Antarctic Program.
- Run real-time WRF from WRF/DART analyses for the 2012 Atlantic hurricane season.
- Develop initial capabilities for assimilation of satellite radiances with WRF/DART.
- Run real-time WRF for the Deep Convective Clouds and Chemistry campaign (Spring 2012), with inclusion of chemical tracers.
- Continue development of WRF-Chem with activities focused on updating the Model of Emissions of Gases and Aerosols from Nature (MEGAN) biogenic emissions module, adding secondary organic aerosol gas and aqueous phase chemistry, and refining other parameterizations in WRF-Chem. In collaboration with the University of Arizona, continue to develop chemical data assimilation (WRF-Chem/DART).
- Analyze WRF-Chem simulations for field project preparation/analysis and for chemistry-climate studies. Among the simulations and analyses planned/underway: BEACHON field campaign analysis and preparation (to study aerosol production and aerosol-cloud interactions); preparatory simulations and real-time forecasts for DC3; regional-scale chemistry-climate simulations for North America; regional-scale chemistry-climate simulations for Asia; analyses of North American monsoon simulations; analyses for the Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS) field campaign; Shanghai and Xi’an, China, field campaign air quality analyses; simulations investigating interactions between dust and anthropogenic aerosols; and simulations for the United States in support of NASA’s Geostationary Coastal and Air Pollution Events (GEOCAPE) mission.

**Expected Project Outcomes/Impacts:** Continued WRF system success and growth (including the WRFDA component) is based on keeping the model cutting-edge, while providing scientific and numerical weather prediction (NWP) communities with the most advanced tools available. Continued development of data assimilation techniques in WRFDA and WRF/DART assist in improving mesoscale analyses and predictions and provide a critical path to identifying and correcting areas for improvement in WRF. Mesoscale modeling is critical to scientific innovation and can reduce societal vulnerability to high-impact weather. WRF-Chem development will lead to improvements in the community version of WRF-Chem – specifically, the updated MEGAN emissions module will give
better predictions of BVOCS, which impact air quality through ozone and aerosol production. Conducting mesoscale chemistry simulations allows for analysis and forecasting of air quality and chemistry-climate impacts at scales appropriate for society, with population aggregated primarily in cities. These scales are also appropriate for field program analysis to evaluate the ability to predict tropospheric composition.

7.3.3 The Whole-Atmosphere Community Climate Model (WACCM)

WACCM is a comprehensive numerical model, spanning the range of altitudes from the Earth's surface to thermosphere. WACCM development is an inter-divisional collaboration that unifies aspects of HAO’s upper atmospheric modeling, the middle atmosphere modeling of ACD, and the tropospheric modeling of CGD, using CESM as a common numerical framework. Model development and validation occurs with extensive community collaboration. (NSF Base: $0.60M; Other: $0.4M)

**Milestones:**
- Perform numerical simulations using WACCM coupled to an interactive ocean (CESM1-WACCM) in support of GeoMIP.
- Update WACCM to make it consistent with CAM5 (to be released Fall 2011) and evaluate the HOMME dynamical core.
• Release a WACCM version with an extended altitude (WACCM-X).
• Integrate bin microphysical model Community Aerosol and Radiation Model for Atmospheres (CARMA) into WACCM.
• Examine the quasi-biennial oscillation (QBO) structures (self-generated from the new inertial gravity wave module) in WACCM. Extend the inertial gravity wave module to middle and high latitudes, and evaluate the impact on middle atmosphere dynamics; conduct a simulation using WACCM-X with new QBO module to study the upper atmosphere QBO modulation.
• Include ambipolar diffusion and field-aligned transport of ionospheric plasma for WACCM-X.
• Continue field program support, including Airborne Tropical Tropopause Experiment (ATTREX) and the Southeast Asia Composition, Cloud, Climate Coupling Regional Study (SEAC4RS) project, by performing integrations using Specified Dynamics WACCM (SD-WACCM).

Expected Project Outcome/Impact: A core set of WACCM simulations will be completed by 2012 so as to participate in GeoMIP and in support of ATTREX/SEAC4RS. GeoMIP, in an effort to educate and inform the public and policy makers, examines how climate model consensus may predict climate effects of geoengineering. Both ATTREX and SEAC4RS will improve scientific understanding and our ability to predict future changes in stratospheric ozone, climate forcing, chemical composition, water vapor and air quality associated with changes in atmospheric composition. Migrating WACCM to use physics based on CAM5 will improve many model aspects, in particular the handling of radiative transfer and aerosols. Evaluating and tuning the model for the HOMME core will ready WACCM for running on the NWSC1. Lastly, extending the inertial gravity wave module to higher latitudes may improve stratospheric dynamics.

7.4 Regional Climate Prediction Program
The Regional Climate Prediction Program forms part of the Prediction Across Scales Initiative. This effort is responsible for simulating a wide range of physical and dynamical phenomena with associated physical, biological and chemical feedbacks that collectively cross the traditional weather-climate divide. Such simulations and predictions are essential to a society that is becoming much more sophisticated in its requirements for weather, air quality and climate predictions, and that is able to make useful economic and social use of such improvements. The importance of this work is demonstrated by the considerable industry interest in, and support for the program. Among the NCAR Imperatives addressed in this effort are provision of capabilities for more accurate prediction and attribution of changes in climate, severe weather, air quality, etc., and working with collaborators to advance world-leading numerical models of the atmosphere and Earth System, making them widely available and supporting use by the scientific community.

7.4.1 Nested Regional Climate Model (NRCM)
The enabling tool for much of the Prediction Across Scales research is the community NRCM. The NRCM combines extensive NCAR weather and climate expertise and systems, with goals of providing a testbed for gaining experience in support of the next-generation approach to seamless weather/climate modeling, enabling development and testing of new physical and
dynamical core approaches, development of new components including chemistry and air quality, coupled atmosphere-ocean processes and land surface processes, discovering remote impacts of local processes (upscaling), and providing initial assessments of regional climate changes to societal groups. Further, the NRCM program directly supports several high priority NCAR Frontier programs, including informing climate change adaptation and mitigation, water resource availability, vulnerability and adaptation planning in western North America, and development of new methods to more accurately assess regional climate. (NSF Base: $0.7M; Other: $0.76M)

Over the past year, NRCM simulations have been completed at 12-km grid spacing for current and future climate scenarios for all of the North Atlantic and North and Central America, with more detailed simulations conducted at 4-km grid spacing for periods of interest over the United States. This work is being carried out under continuing collaborations with DOE, the Research Partnership to Secure Energy for America, and Willis Re, and is providing assessments of regional climate variability and change over North America.

**Milestones:**

- Continue to pursue full coupling of the NRCM to a 3-dimensional regional ocean model.
- Develop improved statistical downscaling techniques to augment NRCM results utilizing statistical inference of weather extremes from modeled large-scale conditions, extreme value theory to fill out the extreme tail of the distribution, and combinations of dynamical and statistical inference.
- Analyze existing and planned NRCM simulations in collaboration with societal groups to ensure societal applicability and enable NESL to provide interim results to societal partners as research and development proceeds.
- Further develop the atmospheric chemistry and air quality module and build capability to produce high resolution (<50 km) NRCM-Chem simulations describing air quality and weather under recent past, present and future climate, including population vulnerability.

**Expected Project Outcome/Impact:** The NRCM brings together weather and climate expertise in development of an advanced tool with which to investigate regional climate impact on society. It has gained widespread interest among a variety of societal groups including the insurance, offshore energy and wind energy communities, and the U.S. Western Governors’ Association. University collaborations abound, and many others exist through the Willis Research Network. NRCM has been released under WRF 3.3 for community use and is in the process of being utilized by many academic and governmental groups including Bjerknes Centre for Climate Research, the National Centre for Atmospheric Science, UK and the Coordinated Regional Downscaling Experiment (CORDEX) program.

**7.4.2 Model for Prediction Across Scales (MPAS)**

MPAS is a next-generation modeling system being developed that will be suitable for weather, regional climate, climate and Earth System research and prediction. It is designed to simulate interacting small- (e.g., clouds, small hydrologic basins, and small estuaries) and large-scale

---

1 Reinsurance Broker division of global insurance broker Willis Group Holdings Limited.
(e.g., planetary atmospheric waves and Earth-ocean circulations) phenomena. A critically important component of this project is to develop MPAS components (atmosphere, ocean, land surface models, etc.) that scale well on new computer architectures, and can simulate all necessary scales for NCAR and community research and production applications. (NSF Base: $0.5M)

**Milestones:**
- Complete development of a 3-D nonhydrostatic global model within MPAS based on icosahedral grids (hexagons) for discretizing the sphere.
- Complete implementation of appropriate atmospheric physics suites for weather, regional climate and climate applications of MPAS.
- Begin applications tests for the nonhydrostatic core for weather and regional climate applications.
- Implement the nonhydrostatic MPAS dynamical core into the CAM/CESM climate modeling system.
- Evaluate computational efficiency for the unstructured solver on available computer architectures.
- Implement data assimilation capabilities using the Ensemble Kalman filter in DART.
- Initial “friendly-user” release of the MPAS atmospheric simulation system.

**Expected Project Outcome/Impact:** The FY 2012 activities will allow full evaluation of the viability of the MPAS nonhydrostatic atmospheric dynamical solver formulation on hexagonal grids. It also will allow initial assessment of the system’s cloud-resolving and local refinement capabilities, and begin assessment of the solvers’ ability to simulate nonhydrostatic structures in these locally refined regions. Full cycling NWP tests without the need for lateral boundary conditions will begin, and implementation in CAM/CESM will allow testing to begin for climate applications on MPAS. A friendly-user release will let community users begin applications testing and research, and will significantly accelerate MPAS system testing and development.

### 7.5 Connecting Past, Present, and Future Climates
Connecting past, present, and future climates is a NESL priority, and will be carried out by CGD. The IPCC/CMIP5 integrations were completed in FY 2011, and analysis will continue throughout FY 2012 with the goal of discovering the relative roles of the stratosphere, tropospheric chemistry, the terrestrial carbon-nitrogen cycle, land ice, and ocean ecosystems in future climate. In parallel, the roles of these elements of the climate system will be assessed for past and present climate by comparison to observations. A critical activity will be development and evaluation of suitable observational, including proxy, data sets. Comparisons are expected to reveal biases that will then direct further model development in these and other areas. An example of a specific activity is the recently developed land-ice modeling (Community Ice-Sheet Model, CISM) capability, which will be exploited in studies of glacial inter-glacial transitions, present day imbalances of the majority of glaciers, and the role of glaciers in projected sea-level rise. Near-future climates will be a focus centered on decadal predictability and predictions. As with the CESM project, the objectives of the topics below include extensive national and international collaborations with multiple universities and laboratories.
7.5.1 Past Climates
Paleoclimates offer a unique perspective to understanding Earth's climate sensitivity and stability. CESM is the first full GCM able to transition from a warm interglacial period like today's to a glacial period by changing the orbital forcing only. This provides strong support for the Milankovitch hypothesis, which states that orbitally-induced reductions in Northern Hemisphere summer insolation led to a reduced melting of winter snow, and thus an increased albedo, which further amplifies reduced insolation. The magnitude of this change is comparable to what NESL expects from future greenhouse gas forcing; therefore this result builds trust in the ability of CESM to anticipate future climate change. (NSF Base: $0.68M; Other: $.0.27M)

**Milestones:** Using CESM, scientists will address atmospheric CO₂ drawdown during ice age inception. Work is under way to replace the current fixed diapycnal diffusivity in POP with an energy and stratification-based one as part of an NSF-funded Climate Process Team (CPT). Once this new mixing parameterization is finalized, the inception experiment will be repeated with a full carbon cycle, with the expectation of reproducing the observed CO₂ drawdown.

**Expected Outcomes/Impacts:** The inception project will answer the question of what controls the natural carbon cycle; it will also drive and direct model development and lead to improved ocean physics.

7.5.2 Present Climates
A major element of CGD research will be devoted to characterizing the structure and generating mechanisms of the intrinsic variability of the climate system’s atmosphere/ocean/sea ice components on seasonal, interannual, and decadal time scales, as well as longer-term trends. Such variability shapes year-to-year fluctuations in the statistics of weather, contributes substantially to the evolution of climate on decadal time scales, and is an important factor in the uncertainty of climate projections. Characterizing intrinsic variability and contrasting it to climate variations produced through imposed forcing contributes to NESL’s ability to understand and attribute past climate fluctuations, aids in interpretation and assessment of confidence in future climate projections, and assists in rigorous testing of numerical models. Both data analysis and numerical experimentation will be used in this effort, which will encompass a broad range of phenomena that are of special interest to the scientific community and pertinent to society’s needs. (NSF Base: $0.88M; Other: $0.96M)

**Milestones:**
- Diagnose and attribute variations and trends in tropical sea surface temperatures and Arctic sea ice and the associated global climate impacts through data analysis and GCM experiments.
- Use reanalysis data, numerical experimentation and theoretical models to understand a high latitude zonal wave number three intrinsic mode of tropospheric variability that appears to be important for multi-decadal fluctuations and trends, and strive to determine why it is misrepresented in climate models.
- Examine the role of natural variability in the uncertainty of projected climate change and systematically assess and compare CMIP5 models’ predictability.
• Begin development of an informed guide to climate data sets with relevance to Earth System model evaluation.

**Expected Outcomes/Impacts:** Among the outcomes is expected improvement in attribution of past Arctic and tropical variations and trends and attendant impacts on climate worldwide, and greater understanding of factors that contribute to the poor representation of decadal time scale intrinsic modes of variability in climate models. These efforts will quantify the uncertainty in climate projections resulting from chaotic behavior and natural variability. They also provide a community forum for expert-user guidance on existing climate datasets, which enhances their utility in observational and model evaluation studies.

### 7.5.3 Future Climates

Interaction between chemistry and future climate is a combination of changes in anthropogenic emissions (including ozone-depleting substances) and climate conditions, with overall response expected to vary significantly between the various Representative Concentration Pathways (RCPs). Currently only very basic features of changes in atmospheric composition have been studied; significant aspects of regional air quality and its potential changes (intensity and duration of surface ozone and particulate matter) need to be studied in more detail. In addition, potential solar-reduction management techniques, such as those defined by GeoMIP, could lead to major modifications of tropospheric and stratospheric chemistry conditions. NCAR’s future climates effort includes performing a suite of CESM simulations (1°) with interactive chemistry to tackle these issues. In particular, this work will include running companion simulations to the CMIP5 decadal prediction experiments. (NSF Base: $1.32M; Other: $0.51M)

**Milestones:**

- Conduct long-term (2005-2100) simulations with CESM1 (interactive chemistry) using the various RCPs.
- Conduct medium-term (2005-2030) simulations with CESM1 (interactive chemistry) following the decadal prediction experiments.
- Conduct medium term (2020-2070) simulations with CESM1 (interactive chemistry) following GeoMIP.

**Expected Project Outcome/Impact:** Analysis and quantification of changes and their drivers in regional air quality, and analysis of potential impacts of solar-reduction management techniques on tropospheric and stratospheric chemistry will be among the outcomes. Both analyses will expand understanding of possible future conditions and provide informed choices by policy makers about strategies related to atmospheric composition and regional air quality.

### 7.6 Human Activity in an Earth System Hierarchy

A critical component of fulfilling NCAR and NSF’s goal of pursuing science in service to society, is considering atmospheric and geophysical research as it relates to societal issues and needs. Major NESL projects that integrate effects of human activity and Earth-system research are highlighted below. (NSF Base: $1.05M; Other: $0.175M)
7.6.1 Integrated Assessment Modeling (IAM)
Integrated Assessment Modeling is a partnership with the NCAR Integrated Study Program that links knowledge across a wide variety of disciplines in a quantitative framework that can inform decisions regarding response options for the climate change issue, including both emissions mitigation and adaptation to expected impacts. As a model-based area of applied research, it fits naturally within CGD, and within NCAR more broadly as a complement to larger-scale modeling efforts in other fields. For example, IA models can both directly link to Earth System Models (ESM) by providing inputs and/or using outputs and indirectly inform ESM efforts by prioritizing research directions and identifying interesting scenarios to explore. The IAM group, along with outside collaborators, created the Integrated-Population-Economy-Technology-Science (iPETS) model to consider future demographic changes (urbanization, aging, and population growth) could have on energy use and emissions. Model code is publicly available, and the team continues to build on this work in several ways.

Milestones
• NESL will complete work on integrating a spatial land use model into iPETS, allowing linkages to land surface models such as NCAR’s Community Land Model (CLM) and the Integrated Science Assessment Model (ISAM) developed at the University of Illinois in order to investigate the interactions between future changes in the demand for land, resulting emissions, and climate change (and its feedback on land use decisions).
• A set of global urbanization projections for use in emissions, mitigation, and impact studies will be completed; the model developed to produce these projections will form one component of a Community Demographic Model currently under development.
• The IAM team will contribute to a broader effort by the integrated assessment and impacts, adaptation, and vulnerability (IAV) communities to develop a new set of socio-economic scenarios for use in climate change research and assessment.

Expected Project Outcome/Impact: The IAM group provides global urbanization scenarios for use by the community in climate change research; results will be part of the process of scenario development that will feed into assessment in IPCC AR5. Along with members of the IAM and IAV communities, this team will provide socio-economic scenarios for use by the wider climate change research community, and will organize a workshop at NCAR as part of a series of meetings facilitating scenario development. Milestones will contribute to key improvements to model capacity that will enable exploration of new questions related to the role of land use and of socio-economic development in climate change emissions, mitigation and impacts.

7.6.2 Climate Change and Marine Ecosystems (CCME)
Climate Change and Marine Ecosystems is a new Integrated Science Program (ISP) supported research direction that integrates climate change research at NCAR with marine ecosystem studies. CCME builds on the decades-long record of global oceanographic modeling as well as on growing efforts in regional oceanographic modeling. Studies of biological and ecological consequences of climate change are increasing, but few have utilized climate system model output. Moreover, most ecosystem studies associated with NCAR’s climate modeling effort are designed to understand the carbon cycle and/or climate feedbacks rather than ecosystem impacts. Decision makers involved in marine fisheries management and marine conservation, however,
are very interested in planning for future climate change and ocean acidification. CCME research falls within two parallel tracks: using NCAR’s oceanographic models for studying ecosystem responses, and ensuring that modeling efforts provide high quality information relevant to ecological research. CCME’s projects include a joint NCAR-Rutgers project to use the Regional Ocean Modeling System (ROMS) in the Coral Triangle Region (includes collaborators from UC-Berkeley and The Nature Conservancy) with a goal of mapping differences in coral reef vulnerability to bleaching as a function of exposure to extreme sea surface temperature, sensitivity to those extremes, the probability that reefs will be reseeded via larval dispersal. The second effort is oriented toward improving the marine CaCO3 cycle in the CESM ocean biogeochemistry (BGC) model. This work begins Fall 2011 as part of research proposed by a new ASP postdoctoral fellow.

Milestones:
- ROMS Coral Triangle runs will be validated against observations; a ROMS simulation for years 2000-2030 will be completed and used in a regional vulnerability assessment (bleaching projections, larval connectivity assessment).
- The CaCO3 cycle, both biological calcification as well as CaCO3 dissolution, will be explicitly addressed in the ocean BGC model, with improvements to representation of CO2-system parameters; these improvements will be tested against observations of the depth distribution of various related CO2-system parameters (e.g. total alkalinity, pH).

Expected Project Outcome/Impact: Coral Triangle Modeling Project results will be integrated into ongoing planning efforts within the Coral Triangle Initiative (a large multinational initiative to safeguard the marine and coastal biological resources of the Coral Triangle). The ROMS modeling effort will likely spawn multiple spin-off projects, not only in understanding marine ecosystem response to climate change, but in better understanding what controls the high marine biodiversity in this region, as well as improvements high
resolution modeling can offer in terms of climate simulations. Results from CaCO3-cycle research will improve the ability of the ocean biogeochemistry model to simulate depth profiles of total alkalinity and other important carbon-cycle parameters. This work will not only improve the applicability of the BGC model to ocean acidification research, it will help progress understanding of vertical carbon transport in the oceans.

7.7 Community Instrumentation – Development and Deployment

7.7.1 NESL Atmospheric Chemistry Observing Facility

NESL will create a new Atmospheric Chemistry Observing Facility, modeled loosely on the current CESM and WRF Modeling facilities housed within NESL. The new Observing Facility, to be developed in consultation with NSF, NCAR EOL, and the wider atmospheric chemistry community, will integrate existing NESL/ACD field and laboratory-based instrumentation, facilities and expertise into a single cohesive unit. (NSF Base: TBD upon development)

Milestones:
- With input from NSF and NCAR EOL, NESL will further develop the concept (“white paper”) of the Facility and develop an implementation plan and timeline.
- ACD will host a community-wide workshop in the first half of FY 2012. The workshop will include NESL staff, EOL, the academic community, NSF program managers, and representatives from agencies such as NASA, NOAA and the Environmental Protection Agency (EPA). Workshop goals include prioritizing instrumentation needs within the wider community, and creating a plan for developing, collaboratively, an atmospheric chemistry observing program of highest utility to the wider community.
- Rollout of the new Facility will occur in late FY 2012.

Expected Project Outcome/Impact: The Facility’s goal is developing a stronger, more visible, better supported, and more collaborative atmospheric chemistry observing program capable of leading and supporting community observational science into the future.

7.7.2 Field Campaign Deployments

In close coordination with NCAR’s Earth Observing Laboratory, NESL participates in field campaigns each year through the provision of instrumentation or scientific leadership. NESL’s planned activities in field campaigns are described below. (NSF Base: $2.3M; Other: $1.1M)

7.7.2.1 Biosphere-Atmosphere Exchange of Aerosols within Cloud, Carbon, and Hydrologic Cycles, including Organics & Nitrogen (BEACHON)

BEACHON’s goal is to improve predictability of Earth System behavior based on better measurements and understanding of the coupling between water, energy, and biogeochemical cycles in observational, process studies, and multi-scale modeling frameworks, and to expand the range of societal-environmental options available to policy and decision makers. To support this goal, BEACHON continues to develop novel observational approaches and modeling tools and conduct integrated laboratory, field and modeling studies. These efforts focus on NCAR’s Imperative to develop and provide state-of-the-art observational facilities that meet the needs of NSF, NCAR, and the atmospheric and related science communities.
Milestones:

- Analyze results from 2011 Manitou Forest Observatory (MFO) BEACHON-ROMBAS (Rocky Mountain Biogenic Aerosol Study) campaign, and assess long-term observational infrastructure and augment with observations that will maximize use of this site by university investigators.
- Enhance partnerships with scientists in Brazil and Korea to conduct long-term observations and intensive campaigns.
- Complete modifications of key BEACHON instrumentation including airborne Proton transfer Reaction Mass Spectrometer (PTRMS) and Time of Flight (TOF)-PTRMS.
- Conduct laboratory studies of atmospheric and ecological drivers of biogeochemical cycling and quantify the impact on atmospheric distributions of trace gases and aerosols.
- Complete operation of the GLObal Biogenic Organic Emissions Network (GLOBOENET), adding additional sites in tropical forest and boreal forest biomes. Factors controlling temporal and spatial variations in BVOC emissions will be investigated using Relaxed Eddy Accumulation (REA) and eddy covariance above canopy flux systems.
- Continue efforts to compare models of different scales (e.g., LES 1-D and regional model) and develop strategies for integrating with field measurements to advance land-surface model parameterizations and improved biogenic emission, aerosol formation and growth, and cloud microphysics in WRF.
- Isoprene oxidation and HOx recycling will be investigated in a remote region of the Amazon, as part of the BEACHON-Amazon Field Campaign. A suite of instruments will be deployed, including several that have not previously been deployed in the tropical forest (TOF-PTRMS, OH/Sulfuric Acid Chemical Ionization Mass spectrometer).

Expected Project Outcome/Impact: BEACHON will provide a comprehensive suite of ecological, hydrological, atmospheric, and chemical measurements, and will develop and evaluate improved CESM components, including the land-surface model, biogenic emission module, secondary aerosol production and growth model, cloud condensation nuclei activation representation, and cloud properties model. This will improve understanding of biosphere-atmosphere forcings and feedbacks and inform environmental decision making.

7.7.2.2 Megacities

More than half of the world’s population now resides in urban areas, and megacities are appearing and growing rapidly, particularly in the developing world. ACD, through its focus program Megacities Impacts on Regional and Global Environments (MIRAGE), is providing internationally recognized leadership to study how megacities affect the composition of the atmosphere at large scales.

Milestones:

- Observational data from recent field campaigns will be used to evaluate and improve regional (WRF-Chem) and global Model for Ozone and Related Chemical Tracers (MOZART) chemistry-transport models. Specific studies will include: detailed evaluation of key predicted oxidants by comparison between observed and model-predicted photochemical dependencies; representation of the evolution of organic aerosols and calculation of their regional radiative forcing; representation of the
perturbations to UV radiation by aerosol and clouds, and consequences for photochemical processing including production of ozone and hydroxyl radicals. A central aspect will be assessment of the relative contributions of anthropogenic, biogenic, and biomass burning emissions. The field campaigns being analyzed include urban-dominated air (2006 MIRAGE, 2009 Shanghai) as well as mixed biogenic-urban environments (2010/2011 BEACHON, 2010 CalNex, and 2010 CARES (Carbonaceous Aerosols and Radiative Effects Study).

- Evaluation of the performance of WRF-Chem in the Shanghai region to include analysis of 2009 Shanghai Campaign measurements, and publication preparation for a special issue of *Atmospheric Chemistry and Physics*.
- During August 2011, ACD will participate in a first-ever intensive measurement program in Xi’an, China, an emerging megacity in central China. Measurements will include emission and deposition fluxes and vertical gradients for several pollutants. A key objective for FY 2012 will be establishment of the WRF-Chem model in the Xi’an region, with evaluation using the observations. NESL scientists will continue to pursue partnering opportunities with international research institutes, particularly in Asia (e.g., China, India, and Korea), with a long-term goal of developing a future major field intensive in an Asian megacity.
- An overview paper on North American Megacities will be prepared.

**Expected Project Outcome/Impact:** MIRAGE’s long-term goal of examining several selected megacities and surrounding regions has the obvious benefits of improving emissions data from major source regions and allowing the implementation, evaluation, and improvement of chemistry-transport models (e.g., WRF-Chem, CAM-Chem) in different environments. A continuing focus will be on understanding production and fate of secondary organic aerosols (SOA), which are of importance because of their significant health effects, their impacts on cloud formation and precipitation, and their impacts on climate.

### 7.7.2.3 Upper Troposphere/Lower Stratosphere (UTLS) Dynamics, Chemistry and Microphysics

As a NESL cross-divisional project, the UTLS program focuses on climate-relevant process studies in the upper troposphere and lower stratosphere using both models and observations. A core component of the UTLS program is to plan and conduct focused field campaigns, using the GV aircraft, optimized with the integration of global satellite data and a suite of NCAR models. During FY 2012, the UTLS group will participate in the NASA/NSF field campaign, SEAC4RS. Preparation before the field phase will focus on developing climatologies of regional transport behavior using satellite data and NCAR models. Significant effort will be put into developing forecasting and flight planning tools.

**Milestones:**

- Develop composites of key tracers, convective signatures, and dynamics from satellite observations and analysis systems.
- Provide simulations of a full suite of tracers using a chemical climate model with specified dynamics.
- Analyze relationships between key tracers, convective signatures and dynamics to identify regions of interest for addressing key SEAC4RS science questions (convection,
UTLS transport, and aerosols).
- Preparation and verification of the WRF model that Taiwan’s Central Weather Bureau runs for forecasting during the SEAC4RS campaign.
- Participate in the field phase and contribute to scientific planning and flight operations.

Expected Project Outcome/Impact: The SEAC4RS campaign should obtain in situ observations of chemical composition and cloud microphysical properties over the Southeast Asian region that, when coupled with meteorological behavior, will generate a wealth of information for investigation of chemistry-climate coupling.

7.7.2.4 Deep Convective Clouds and Chemistry (DC3)
The DC3 field campaign will investigate the impact of summertime continental convective clouds on upper tropospheric composition and chemistry. DC3 objectives are to characterize the physical, chemical and transport behavior of deep convection within the first few hours of active convection, and quantify changes in chemistry and composition 12-48 hours after convection. The field campaign, under consideration for May-June 2012, will use extensively instrumented aircraft platforms and ground-based facilities. FY 2012 activities focus on preparing for and conducting the 2012 campaign.

Milestones:
- Campaign infrastructure preparations include selecting an aircraft and operations base, designing aircraft flight plans, assembling products for weather and convective outflow location forecasting, refining communication plans between the various DC3 facilities and refining the decision-making process, and finalizing the GV payload.
- Conduct a community workshop in early 2012 to prepare for the field campaign, continue preparations of campaign instrumentation for deployment, and analyze high-resolution WRF model simulations conducted in May-June 2011.

Expected Project Outcome/Impact: The DC3 field experiment will provide a comprehensive suite of chemical measurements within the context of high-quality kinematic, microphysical, and electrical ground-based measurements. Results will be used to improve understanding of how convection affects tropospheric composition, especially ozone, which acts as a radiatively active greenhouse gas in the upper troposphere. Measurements may improve model parameterizations of convective transport, production of nitrogen oxides from lightning, and wet deposition of chemical species.

7.7.2.5 Optical Techniques Project/Network for the Detection of Atmospheric Composition Change (NDACC)
The Optical Techniques Project studies evolution of trace gas concentrations using infrared spectroscopic techniques from airborne and ground-based instrumentation. Its primary focus is operation of two Fourier transform infrared spectroscopy (FTIR) instruments at Mauna Loa Observatory, Hawaii and at Thule, Greenland. From the daily, high-resolution solar spectra obtained, information on vertical distribution and total column amounts of more than 20 trace gases are retrieved and analyzed on diurnal, seasonal, annual and decadal timescales. The group also maintains an airborne Fourier Transform Spectrometer (FTS) instrument for deployment aboard NASA and NCAR aircraft.
**Milestones:**
- Finalize the network-wide retrieval harmonization project.
- Publish results of an Arctic tropospheric chemistry and pollution events study of the last decade conducted using MOZART4.
- Complete a network-wide study of Cl and F multi-decadal trends for the Quadrennial Ozone Assessment.
- Participate in a global NDACC Infrared Working Group network study on ozone trends.
- Complete the network-wide validation of SCanning Imaging Absorption SpectroMeter for Atmospheric CHartographY (SCIAMACHY) Methane (CH4).
- Continue synergistic studies with in situ data from NOAA ESRL and in situ trace gas measurements from HIPPO over-flights (Mauna Loa Observatory and Boulder).
- Restart daily observations at MLO after FTIR system upgrades are complete.

**Expected Project Outcome/Impact:** Ongoing, high-quality atmospheric composition measurements provide a unique data set for community use and are key to evaluating a changing atmosphere and climate. These data are sources for long-term analyses of trends and variability, and may help establish links between climate change and atmospheric composition. Also used for satellite validation, they improve both theoretical models and source inversion modeling. Further benefits are expected as constituent vertical profile uncertainties are reduced; for example, upper tropospheric water vapor may become a standard data product, and is crucial to evaluating climate change feedbacks at the tropopause.

**7.7.2.6 Additional Field Projects for FY 2012; Data Analysis Activities from Previous Campaigns**

This section describes field campaigns, in addition to DC3/SEAC4RS, in which NESL will participate and highlights some data analysis activities associated with previous campaigns.

**Milestones:**
- NESL scientists will deploy two instruments in the upcoming TORERO field campaign, to be conducted in early 2012; see Section 5.1.2 for additional project details.
- NESL scientists will continue to participate in the NASA-led DISCOVER-AQ (Deriving Information on Surface Conditions from Column and Vertically Resolved Observations Relevant to Air Quality) campaign, which is focused on improving the ability of satellites to measure air quality-related parameters near the Earth’s surface.
- NESL scientists will participate in the Gases and Aerosols in Megacity-Biosphere-Atmosphere Interactions (GAMBAI)-Korea campaign, which will focus on how anthropogenic pollutants can modify the impact of BVOCs on SOA and ozone. A small intensive measurement campaign will be conducted in Pittsburgh, Pennsylvania to develop mechanistic understanding of atmospheric nucleation and new particle growth.
- Ongoing Oceanic & Atmospheric Scientific Information System (OASIS) [Barrow 2009] data analysis will include assessment of aerosol physical, chemical and optical properties, fluxes/gradients of NOx and OVOCs from the snowpack, analysis of the Peroxyacetyl Nitrate (PAN) budget, analysis of radical budgets and impact on ozone levels, and analysis of both OASIS and ARCTAS data, focusing on the impact of changes in ozone
column, albedo and aerosol loading on actinic flux and photolysis frequencies. Updating and implementation of a detailed box model, and adaptation and implementation of a 1-D model to further understanding of these and other OASIS issues will also occur.

- Four special issues of *Atmospheric Chemistry and Physics* (ACP) have been organized to highlight results from recent NCAR-ACD field programs including 2009 MIRAGE-Shanghai, 2011 MIRAGE-Xian, and 2010 and 2011 GAMBAI-Korea studies, the 2010 BEACHON-ROCS study and 2011 BEACHON-ROMBAS study, Community Atmosphere-Biosphere INteractions EXperiments (CABINEX), and the 2011 California Airborne BVOC Emission Research in Natural Ecosystem Transects (CABERNET) study, as well as other recent biosphere-atmosphere studies.
- Nanoparticle composition data obtained with the Thermal Desorption-Chemical Ionization Mass Spectrometer system (TD-CIMS), and its high resolution follow-on, at various sites over the last few years will be analyzed and published.

**Expected Project Outcome/Impact:** Participation of NESL scientists in these and other (often university-led) campaigns contributes not only to the objectives of the specific campaigns and to NESL scientific goals, but to a stronger, more connected research community, to improved instrumentation for studying problems in atmospheric chemistry and related sciences, to the education and training of the next generation of atmospheric scientists, and to the availability of detailed datasets to improve models.

### 7.7.3 Instrument Development Activities
ACD has a long heritage of making high quality observations of atmospheric composition, in collaboration with members of the wider atmospheric chemistry community. Among the instruments housed and maintained within ACD are a group of OFAP-requestable instruments, a group of HIAPER/HAIS instruments; and a large number of additional instruments available to the community through collaborative research activities. This collection of instruments, and the science driven by their deployment, will be a major feature of the observing facility mentioned earlier, and currently under development. Planned activities related to further development of this suite of instruments are outlined below. (NSF Base: $0.8M ; Other: $0.7M)

**Milestones:**
- A new NO2 photolysis cell better suited for higher-altitude use will be built for NO/NO2 LIF detection systems to be used during DC3/SEAC4RS on the GV. NOAA P3 aircraft cell modifications will likely occur for the next Deriving Information on Surface Conditions from COlumn and VERtically Resolved Observations Relevant to Air Quality (DISCOVER-AQ) deployment (and/or for the DC-8 in DC3/SEAC4RS, if funded).
- Based upon DC3 Test Flight campaign results, extensive laboratory tests will be performed in to optimize performance of the TOGA-HIAPER for the TORERO and DC3/SEAC4RS field campaigns. Also, full characterization of TOGA’s ability to measure formaldehyde, including determination of detection limits and precisions, will be performed.
- Lessons learned in the bullet above will be applied to the TOGA-NASA instrument. Additional updates and repairs will be conducted to prepare for future field deployments (including SEAC4RS, if funded), and will include building a new catalytic air generator/calibrator.
• Improvements to a primarily ground-based HOX CIMS instrument will include an added inlet to enable HO2+RO2 measurements, replacement of a radioactive source with non-radioactive corona discharge source, and implementation of an improved approach for calibrating and accounting for background signals.

• Assess and implement new approaches (i.e., different reagents, inlets, etc.) to extend the suite of compounds that can be identified and quantified with time of flight-proton transfer reaction mass spectrometer (TOF-PTRMS).

• Determine feasibility and best approach for using CIMS to measure organic acids. If funding is available, development of a new instrument may be initiated.

• The High-Resolution Thermal Desorption Chemical Ionization Mass Spectrometer (HR-TDCIMS) will undergo additional lab testing using primary and secondary aerosol standards.

• The PAN-Thermal Desorption CIMS instrument is being modified to expand its mass range from 180 to 350 amu, to make measurements of halogens and halogen oxides. This effort will continue in 2012; some limited instruments tests are planned.

• Upgrades of the open path tunable diode laser hygrometer (OPLH) will be tested; and first aircraft deployments are expected to occur.

• The recently-assembled GV-Scanning Mobility Particle Sizer (GV-SMPS) will be modified to improve sensitivity and accuracy during rapid changes in ambient pressure.

• With NASA funding, improvements in the accuracy of UV-B measurements obtained by the Charged-coupled device Actinic Flux Spectroradiometer (CAFS) will be made, and wavelength range extended to > 600 nm.

**Expected Project Outcome/Impact:** A new instrumentation program will be established over the next year, combining the current diverse efforts with revised priorities established in collaboration with NSF and the community. These new priorities combined with continued development, upgrading, and maintenance of the atmospheric chemistry instruments housed in NESL/ACD ensures availability to the community of a comprehensive, scientifically-relevant, high-quality, and modern suite of instruments for deployment on ground-based and aircraft platforms.

### 7.7.4 Observations from Satellite Platforms: Satellite Observations of the Troposphere, Chemical Weather, and Data Assimilation

Remote sensing of atmospheric composition provides a powerful method for quantifying and understanding processes that impact atmospheric composition and related issues on regional to global scales, including intercontinental transport of pollutants, megacity and biomass burning emissions, and convective processes. NESL scientists are engaged in a range of remote sensing activities that provide key data for quantifying these and other regional/global-scale phenomena, and for furthering development of global models such as CAM-Chem and WACCM. (NSF Base: $0.1M; Other: $3.1)

#### 7.7.4.1 Measurements of Pollution in the Troposphere (MOPITT)

MOPITT is an instrument flying on NASA’s Earth Observing System Terra spacecraft measuring tropospheric carbon monoxide (CO) on a global scale. MOPITT measurements enable atmospheric scientists to analyze distribution, transport, sources and sinks of CO, a trace gas...
produced by methane oxidation, fossil fuel consumption and biomass burning. Operational since March 2000, MOPITT continues to provide high quality measurements.

**Milestones:** The MOPITT team will evaluate, refine and reprocess new 'Version 5' CO products, exploiting both near-infrared (NIR) and thermal-infrared (TIR) MOPITT observations, with a focus on improved surface level CO retrievals.

**Expected Project Outcome/Impact:** NIR MOPITT radiances significantly improve sensitivity to CO in the lower troposphere, where major anthropogenic sources lie. MOPITT is currently the only satellite instrument able to observe CO in both TIR and NIR spectral bands. Applications of the new MOPITT products should yield improved chemical weather forecasting, and improved quantitative CO emissions estimates.

**7.7.4.2 Chemical Weather - Data Assimilation**

NESL scientists have been working on melding modeling and observations across different spatial and temporal scales for analyzing chemical weather. Operational monitoring of air quality (AQ) is mostly performed by ground networks, which provide very detailed but highly localized information. As recent research has shown, surface AQ is not only impacted by processes at the surface but also by transport aloft, which often happens over large distances. For this reason, the integrated application of models and observations on multiple scales is crucial. Observations of tropospheric constituents from satellites are of special importance in this regard as they complement surface data by providing the larger scale picture, albeit with limited vertical information.

**Milestones:**
- A chemical weather analysis framework that links the global CAM-Chem and regional WRF-Chem models is nearing completion. This framework accounts for interactions between biological, physical, and chemical processes over multiple scales.
- The chemical weather system has been/will be used for: assessing the efficacy of current satellite products in chemical weather research; determining the role of regional, intercontinental and global pollution transport on local air quality over North America and quantifying contributions from wildfires and biogenic sources versus anthropogenic sources; and instrument design and observation system simulation experiments (OSSEs) for quantifying needs and potential impact of future satellite measurements, particularly those from the NASA GEOCAPE mission on chemical weather prediction.
- Daily global forecasts of CO, O$_3$ and other tropospheric constituents will continue to be provided on the NESL/ACD/ACRESP (Atmospheric Composition, Remote Sensing & Prediction) web site, which will be used to support the DC3 and SEAC4RS experiments.

**Expected Project Outcome/Impact:** A chemical weather analysis system allows for quantification of the effects of local anthropogenic emissions and wildfires, and of long-range pollution transport on tropospheric composition and air quality. The work will lead to significant improvements in community models and in data assimilation techniques, thus benefiting the wider research community. Use of current satellite data in chemical weather research will help identify priorities for future instrument needs and designs. This system will also be used to assess feedbacks between climate change and future air quality.
7.7.4.3 High Resolution Dynamics Limb Sounder (HIRDLS)
HIRDLS is a 21-channel infrared limb-scanning radiometer flying on the Aura satellite. A malfunction introduced an obstruction into the optical path at launch, however the HIRDLS team has developed algorithms to partially correct for some of the resulting effects, allowing distributions of temperature, ozone, nitric acid, chlorofluorocarbons cloud and aerosol extinction, and geopotential heights, plus new products (zonal means of nitrogen dioxide (NO2) and dinitrogen pentoxide (N2O5), and maps of stratospheric columns of daytime NO2), to be recovered. These data are unique in having global coverage at 1-km vertical resolution.

Milestones: Ongoing refinement of the correction algorithms will enable recovery of additional species; these efforts are aimed specifically at water vapor and nitrous oxide retrieval. Release of another new version of retrieval results is expected, with an aim being to focus on analysis of water vapor distributions in the UTLS region.

Expected Project Outcome/Impact: Improved understanding of observed behavior in the UTLS, including cross-tropopause transport, will provide strong constraints on the calculation of transports of radiatively active gases in climate models.

7.8 Information to Support Mitigation and Adaptation Strategies
As society is requesting objective information on environmental change and related impacts primarily at the regional scale, models developed by NESL scientists in collaboration with RAL, ISP, and external groups as outlined below will be extensively used to address questions posed by decision makers in the public and private sectors. Addressing such questions is becoming increasingly critical to ensure an adequately prepared society for future weather and climate risks. Examples of the work being undertaken include:

- NCAR membership in the Willis Research Network, through which NESL communicates with the insurance and re-insurance sectors findings on climate and high-impact weather of concern to providing quality and cost-effective insurance coverage for the public.
- Discussions with the Western Governors’ Association on climate change impacts on snowpack, snow melt and ecological issues. Related to this is a PACE (Postdocs Applying Climate Expertise) doctoral fellow from NOAA and the USGS who is developing new ecological modeling approaches suited to NRCM application.
- Working with DOE and the Offshore Energy Industry assessing changing impacts of hurricanes on offshore facilities arising from climate variability and change.

Expected Project Outcome/Impact: NESL has improved planning and mitigation strategies that reduce risk and cost of weather impacts for the American public. The efforts in this area are in broad support of NCAR and NESL Imperatives to develop and transfer scientific applications, technology, and information products that meet societal needs, and developing state-of-the-art data services that drive advancement of the atmospheric and related sciences.

7.8.1 The Hurricane Forecast Improvement Project (HFIP)
NESL is a contributor to HFIP, a NOAA-led initiative to improve hurricane forecast skill, with an emphasis on hurricane intensity and structure. HFIP involves a combination of operational and research efforts, including NCAR, universities, NOAA, and the Naval Research Laboratory.
Program goals are to conduct resolution tests to determine if higher resolution models systematically improve intensity forecasts, and implement new models into a quasi-operational framework, in addition to models run operationally at NCEP. The retrospective effort is coordinated through RAL’s Developmental Testbed Center. (NSF Base: $0.1M; Other: $0.2M)

**Milestones:** Analyze retrospective simulations to uncover systematic model errors and report on these, and perform real-time forecasts for the 2011 hurricane season.

**Expected Project Outcome/Impact:** HFIP work focuses on bringing advanced hurricane-simulation research into operations, and providing the first high-resolution operational hurricane forecasts. It will also help scientists better understand the sensitivity of hurricane intensity forecasts to various aspects of modeling systems, including physics and initialization.

### 7.8.2 The Antarctic Mesoscale Prediction System (AMPS)
AMPS is a real-time, experimental WRF system run at high resolution over Antarctica in support of the U.S. Antarctic Program (USAP). This activity provides guidance for USAP weather forecasting and for various scientific and logistical efforts over the continent. This work is vital to USAP activities, as the weather forecasters depend on a well-maintained, robust, tailored, and upgraded system. AMPS, supported primarily by NSF’s Office of Polar Programs, also offers support to international scientific activities across Antarctica. (NSF Base: $0.1M; NSF-Special: $0.4M)

**Milestones:**
- Provide NWP guidance for the USAP forecasters through the 2011-2012 field season.
- Improve and develop new forecast products based on user input.
- Work with CISL on procurement of new AMPS computing hardware for ultimate installation at the NWSC.
- Update polar modifications in WRF used in AMPS.
- Contribute to or host at NCAR the Antarctic Meteorological Observation, Modeling, and Forecasting Workshop.

**Expected Project Outcome/Impact:** These efforts support the NSF-funded Antarctic Program, improve high-latitude WRF capabilities and forecasting products, and advance model evaluation and model-based research over Antarctica.

### 7.8.3 Renewable Energy: Wind Energy Research
The importance and potential impact of wind energy research has been growing in recent years, yet wind remains among the most difficult weather variables to forecast. To address this, NESL scientists, in close collaboration with RAL, are conducting basic research underlying wind energy. (NSF Base: $0.06M)

**Milestones:**
- Attend meetings, give presentations, and write proposals toward developing relationships with university collaborators, government research facilities, and industry partners.
- Depending on the available resources:
o Undertake advanced simulations of atmospheric turbulence to explore problems ranging from large scale (where should wind turbines be placed?) to very small scales (characterizing the wind field within which a turbine’s blades operate).

o Work in collaboration with NCAR scientists and community researchers to simulate extreme wind, wind shear, and turbulence events that stress turbines, with the goal of improved turbine design.

o Develop, test, and implement observational strategies and techniques to improve wind energy resource predictive skill.

o Leverage ongoing or future NRCM simulations to determine wind resource response to evolving climate.

**Expected Project Outcome/Impact:** This effort will lead to better understanding of how surface characteristics such as surface heterogeneity introduced by land-use, orography, vegetation, ocean waves and turbulence, and the turbines themselves interact with the diurnally-varying atmosphere to influence local wind speed, direction, turbulence characteristics, precipitation and clouds. This information can benefit society by providing data that will help wind farms optimize wind-farm location and turbine spacing, which can lead to enhanced energy capture and community acceptance.

**7.8.4 Improving Communication of the Implications of Weather and Climate**

NESL conducts research to understand and enhance the communication, interpretation, and use of weather-related information, in the context of weather forecasts and warnings, and climate variability and change. The research aims to address major gaps in current understanding of how weather messages are generated and communicated and how they are interpreted by various audiences and used in decisions. It also seeks to understand people’s perceptions of weather risk and underlying vulnerabilities and other contextual factors that influence weather-related decision making. It emphasizes application of social science concepts and methods to atmospheric science issues, facilitating interdisciplinary work by the broader research community. This effort is partially funded by NCAR’s ISP in addition to research grants from NSF and NOAA. The work is performed in collaboration with the Societal Impacts Program in RAL and with researchers at various universities. (NSF Base: $0.4M; Other: $0.2M)

**Milestones:**

- Analyze mental model interview data from Boulder, Colorado by comparing how different expert groups conceptualize and communicate flash flood risk and identifying gaps in how members of the public conceptualize flash flood risk and interpret warning communications.

- Analyze interview data from Miami, Florida that examines strengths and gaps in how National Weather Service forecasters, broadcast media, and local emergency managers interact to communicate hurricane risk with the public.

- Begin analysis of data from a survey and focus groups in Miami, Florida examining how members of the public (including more vulnerable populations) obtain, interpret, and use hurricane forecast and warning messages.
**Expected Project Outcome/Impact:** This work is focused on advancing knowledge of weather-related decision making and on collaborating with stakeholders to improve usability of weather and climate risk information, enhancing its societal benefits.

### 7.9 Earth System Modeling (EaSM) Infrastructure

NESL is partnering with CISL, NSF, DOE, and the U.S. Department of Agriculture on a series of accelerated climate research initiatives (CRI) that will allow broadening of interdisciplinary research and support to a much larger audience. With the number of successful non-NCAR EaSM proposals, NESL realizes that the number of community users who will now rely on and use NESL model codes and data is likely to grow. With additional NSF Base funding, NESL is able to build an infrastructure to support these new CRI users who are from a variety of disciplines with varying levels of modeling and data analysis sophistication. (NSF Base: $0.915M)

**Milestones:**
- Release latest software configuration on a near annual basis, including documentation and validation of portability of codes.
- Respond to help requests through augmentation to CESM and WRF help response staff.
- Conduct tutorials and training.

**Expected Project Outcomes/Impacts:**
By augmentation of NESL CESM and WRF support staff and creation of an infrastructure, non-NCAR EaSM researchers will be able to successfully access the models’ codes, receive training, run model simulations and analyze data.

### 7.10 Communicating Science Program

Society is in an era of rapidly changing communication media that requires a marked evolution in the modes of communicating science. Scientists are required to assume increasing responsibility for translating their scientific findings and calibrating their communications to non-technical audiences, a task for which they are often ill prepared, especially when it comes to controversial societal issues such as tobacco, evolution, and most recently climate change. Such issues can be highly politicized and prone to being hijacked by ideological belief systems, often to the detriment of constructive dialogue.

If scientists start from a sound scientific finding with general scientific consensus, then the primary emphasis moves from the *science* to the *art* of communication. This art must address a number of factors that influence community decisions from the policy to the personal level, including: immediacy, economics, culture, community leaders and elders, emotional conditions, and ideological filters. The art cannot have free reign, however, as there remains a strong science requirement for objectivity, honesty, consistency in message, and a resistance to advocating particular policy positions.

NESL has collaborated with NSF, ISP, UCAR E&O, the UCAR Communication Unit and a number of communications specialists over the past year to establish a new communicating science program aimed at developing:
- Improved approaches to communicating science, with an emphasis on targeting specific societal and commercial groups in a manner consistent with their values and beliefs.
- Providing scientists with new and improved communications skills.
- Developing and nurturing a new cadre of young scientists who see communicating science as part of their future career aspirations.
- Establishing initial community targets to further develop our skills and approaches to science communication.

( NSF Base: $0.16M )

**Milestones:**
- Completion of a white paper, “Communicating Science in an Era of Mass Communications” which is being readied for formal publication.
- Developing a joint working ethos with the UCAR education and communications units.
- Scheduling of a major media training program, developed by NSF, to provide 2-day training to scientists on all aspects of mass media: TV, Radio, Blog, Web.
- Support for several sessions at AGU to further develop the theme of science communication and promote further work in this area.

**Expected Project Outcome/Impact:** Provide scientists with new, better communication skills. Develop and nurture a cadre of young scientists who see communicating science as part of their future career aspirations and establish initial community targets to further develop skills and approaches to science communication.

### 7.11 Education, Outreach, and Training
In FY 2012, NESL plans to continue its tradition of hosting a wide-range of visitors from all over the world and, as funding permits, target new visitors from a variety of disciplines to the programs in order to continue expanding collaborative efforts throughout the community; this is essential to the health and vitality of NESL’s scientific programs. The Visitor Program within NESL has expanded to include students and post docs, as well as hosting several ASP Graduate Student Program awardees, and numerous ASP postdocs. Also, NESL scientists and staff are active in the UCAR SOARS program. Many of these efforts tie to NCAR’s Imperative to provide students, early career, and other scientists with exciting opportunities for educational and professional development. ( NSF Base: $0.52 M; Other: $0.32M )
NESL continues to place a strong emphasis on community interactions and collaborations, modeling facilities, such as CESM and WRF, feature widespread contributions and collaboration from NCAR’s science communities. Additionally, NESL staff members have contributed to community outreach and service in a variety of areas, which are shown in the above table for FY 2009 and FY 2010.
7.12 NSF Special and Non-NSF Funding Supporting NESL

In FY 2011, NESL was awarded numerous Decadal and Regional Climate Prediction Using Earth System Models (EaSM) funds of both Type I and Type II for regional climate studies, and climate modeling. These projects are highly collaborative (and often led) with the university community, and also provide a scientific opportunity to bridge the weather and climate divide and enable predictions of regional climate and high-impact weather statistics on decadal time scales. Through NSF’s EaSM support, NCAR will be well positioned to address future research linking societal impacts and regional modeling.

Weather prediction research has been accelerated through NSF-Special funds supporting data assimilation, fire modeling, hurricane forecast communications, polar climate studies, and Antarctic weather prediction. The Air Force Weather Agency (AFWA) continues to support WRF data assimilation, forecasting, and joint ensemble research. NASA provides funds for field participation and subsequent data analysis to support research related to ice and cirrus cloud programs including GRIP (Genesis and Rapid Intensification Processes) and MACPEX (Mid-latitude Airborne Cirrus Properties Experiment). It also supports research related to retrieval of ice cloud properties from space-borne cloud radar and microwave radiometry (PRECIP/GPM). NASA, along with the Office of Naval Research, DOE, and several universities, funds severe weather, boundary layer, cloud and precipitation forecasting research. Funding from NASA, NOAA, and DOE to the physical meteorology program supports research related to hurricane lifecycles, convective bursts and ice microphysics. NESL participates in the Colorado Renewable Energy Collaboratory, and has developed collaborations with industry and DOE laboratories interested in wind and solar energy research. Support from NOAA makes it possible for NESL to continue research and real-time simulations for the Hurricane Forecast Improvement Program. NESL is also studying aviation impacts on climate through Federal Aviation Administration (FAA) funding.

FY 2011 was the final year of a $3M, one-time special climate fund grant received from NSF in FY 2009. Positions supported by this funding make fundamental contributions to all of NESL/CGD’s strategic priorities, as well as support some of the simulations planned in FY 2012 as CESM contributions to the IPCC AR5 and CMIP5.

DOE is a significant contributor to development of the next-generation CESM; that support continues to grow through a variety of DOE programs. NASA supports climate science at NCAR in a number of ways: partnering to fund evaluation of global satellite data sets for Earth System observations, supporting development of gravity wave parameterizations for WACCM and CAM, as well as supporting software engineering standards and protocols that are incorporated into CESM. NOAA funding provides support to NCAR’s climate programs; this funding is primarily directed at data set development and evaluation, diagnostics of climate variability and change, and assisting with CCSM development. The regional climate program will continue its momentum in FY 2012 through support from NSF, NASA, the Willis Research Network, and the Research Partnership to Secure Energy for America (RPSEA); these efforts will focus on hurricane activity, convective scale transport, global circulation and NRCM development.

NSF-sponsored programs in atmospheric chemistry are augmented by both NSF-Special and Non-NSF funding. Modeling, including development and support of community models such as
WACCM and CAM-CHEM, is supported by NASA and DOE. Research on the troposphere, including satellite-based studies to quantify pollution, aerosols and transport is funded by NASA. Development of instruments and support for community field campaigns for aerosol formation/composition, photochemistry and biogenic emissions measurements is supplemented by NASA, EPA, and NSF-Special funds. Two major satellite programs, MOPITT and HIRDLS, are supported by NASA. The HIRDLS project began to wind down in FY 2011; at this time we anticipate it will continue to be funded over the next several years at a reduced level.

7.13 Key Funding Decisions for NESL in FY 2012
Last year NESL developed a comprehensive Strategic Plan that closely aligns with NSF and NCAR strategic goals and encompasses major aspects from divisional plans. This plan lays out six, laboratory-wide Imperatives that guide NESL’s role and commitments within a national laboratory. In addition, as part of the NSF review process, NESL’s core activities were refined within these Imperatives, with the core being major modeling (especially CESM and WRF), instrumentation facilities, and community service; NESL’s Annual Budget Review priority setting and funding decisions are based on these foundations. Additional considerations arise from joint decisions by ISP and program management agreements, and from the reality that most base funds go to salaries and are disproportionately used to support ladder-track (LT) staff salaries in NESL.

NESL’s plan for FY 2012 is thus based on protecting core activities within its Imperatives, with the central core being NESL’s major modeling and instrumentation facilities, and community service. Other considerations taken into account include:

- Close to 90% of base funding goes to salaries, and around 70% of the salary component goes to LT salaries. NESL support/LT ratio on base funds is far below optimal and most support staff on Base are stretched to maintain critical maintenance and development of core facilities, maintenance that urgently requires more, not less, support.
- NESL is no longer a stovepipe organization. The traditional vertical sections remain, but these are increasingly management and reporting streams, with projects occurring in multi-disciplinary and multiple-component teams spread horizontally across sections and into the community. As a result, few staff are involved in a single program.
- A number of one-person programs within NESL do exist, some arising through attrition of once, more robust programs, others from personal choice.
- Many programs are now substantially supported by non-Base resources.

7.14 Challenges and Opportunities for NESL in FY 2012
NESL is close to a 50/50 level of NSF Base to other funds and is at a crossroads that has been inexorably approaching for several years, continually reviewing our position and ensuring outside-funded activities align with the Lab and NCAR Strategic Plans.

In FY 2011, NESL received funds to provide infrastructure support related to EaSM activities. In FY 2012, NESL will complete hiring of planned staff supported by those funds. In the long term, potential downstream liabilities exist based on using carryover and other one-time funds to ameliorate NESL’s budget shortfalls. NESL will continue to analyze other funding opportunities moving forward. A major concern is the loss of the $1.2M-per-year NSF Special Climate Funds
that support a Scientist III, a Scientist II, a Project Scientist I/Scientist I, a Project Scientist I, a Software Engineer II, and an Associate Scientist III. This support was a catalyst to enabling the transition from CCSM to CESM and is essential for continued model development. NESL estimates being able to support these staff through FY 2012 at about the $1.0M level (the SE II position will shift to EaSM infrastructure support) by supporting the Scientist II with DOE funds, and covering the remainder with projected carryover funds. Recently a NESL Senior Scientist accepted the NESL Lab Director position, and NESL expects that the senior scientist position will not be filled, so the associated NSF Base funding can be re-allocated to help support the remaining five Climate Fund positions on an on-going basis. This leaves an unfunded shortfall of around $725K in FY 2013 and beyond. ACD potentially faces significant issues in FY 2013 and beyond related to funding HAIS and community instrument support staff. A number of these staff are partially supported from non-NSF funds, and they will be supported in preparation for and during DC3/SEAC4RS due to one-time carryover and NASA funding.

In addition to the specific EaSM community support, the overall success of our community modeling and instrumentation facilities and growing need to properly maintain these facilities for the community, and provide community liaison are putting an increasing strain on resources, a concern raised by NSF’s Site Visit Team (SVT). The SVT also raised concerns that some basic community model development is being supported by non-NSF funds and questioned what would happen should these research funds dry up. NESL has already started working with NSF to initiate action aimed at reducing these issues.

A particular SVT concern relates to declining support for atmospheric chemistry instrumentation. As discussed earlier, NESL is embarking on revitalizing this instrumentation, especially in-situ measurements, in response to these concerns. Plans include a new facility structure bringing all instrument and laboratory expertise and development activities under a single leader. NESL plans to involve EOL, NSF, and the broader atmospheric chemistry community while proceeding down this road. Among the anticipated efforts are an instrument development and maintenance priorities workshop to assess how NESL can better include the community explicitly into our strategic planning process.

The SVT also noted a need to ensure an adequate voice is heard from NESL divisional sciences at the NCAR Executive level. NESL will work with the NCAR Director to respond to this concern.

Another major challenge outside NESL’s control is the potential for catastrophic loss of federal climate funds. The current political environment may be heading down this path, with resulting funding impacts coming not only from NSF, but from DOE and NASA. NESL needs to be aware that this would mean loss of core imperatives if the worst case occurs.

Multidisciplinary research and collaboration holds great opportunities for everything from innovative research to development of the complex modeling systems required in the future, and to the ways in which we interact with society. NESL places a priority on developing these areas, which will be achieved through a combination of modest hiring of expertise and a major effort to engage other disciplines within the community to work with NESL on mutual priorities. Here there are a number of genuine opportunities that NESL can leverage, including:
• Regional climate prediction and provision of systems suitable for the climate services community are a major growth area with considerable demand already being experienced. Here, NESL has developed a number of new partnerships and collaborations with other scientific sister organizations and with key societial, governmental, and commercial organizations, which will be expanded.

• Renewable energy is a growth area, both commercially and in government funding. Here, NESL has already developed collaborations with commercial groups and with DOE Laboratories and plans to develop these further.

• Urban quality of life and especially urban air quality is affected by growth of megacities, with great stress placed on the local (and often also on the remote) environment. NESL is well placed to engage in activities to identify problems and help with their amelioration.

• Participating in NASA’s Earth Venture-2 program planned for FY 2012 is a strong possibility. At this writing, NESL is likely to submit two proposals to the recently announced solicitation. Only one proposal of all submitted will be awarded, though.

7.15 Long-Term Plans (FY 2013-2016)
NESL's long-range plans remain as per its Strategic Plan with the following goals:

• Maintenance and enhancement of existing Imperative areas with key activities including:
  o Enabling and supporting innovation and creativity.
  o Continued development of major modeling systems.
  o Maintenance of modeling systems for community use, an ever-increasing burden given the phenomenal growth in these areas.
  o An increased priority on maintaining instrument and field experimental areas, which have been under great financial stress for some time. This includes support for HIAPER, and satellite instrumentation.
  o Continued priority on education and outreach, on mentoring, and on encouraging bright new scientists into NESL fields.
  o Further developing and managing the successful diversity program.

• Development of major new strategic directions, including:
  o Development of the Prediction Across Scales initiative, through:
    ▪ Growth of the Regional Climate Prediction Program into a major NCAR flagship.
  o Utilization of the above developments to further enhance and develop capacity for:
    ▪ Regional climate prediction on decadal scales.
    ▪ Water systems and availability assessment.
    ▪ Renewable energy applications.

• Consolidation and finalization of a number of initiatives under the NESL reorganization, including full implementation of a Program Management Structure to facilitate and enable collaborations across divisions, with other Laboratories, and with the community.

• Development of improved methods of communicating science to societal groups, including:
  o Communication of the information in weather forecasts in a way that ensures informed responses.
  o Engaging in debates on major scientific issues (such as the current one on climate change) in a manner that maximizes information exchange but also protects the integrity of the science and the overall scientific process.
Considerable progress has already occurred with implementing the NCAR Workforce Management Plan and this will continue as opportunity and funds permit.

Working with CISL and other collaborators on ensuring continued access to computer power and data storage, analysis, and visualization required to support our future scientific programs.

8.0 Program Operating Plan for the Research Applications Laboratory (RAL)

The Research Applications Laboratory’s (RAL) mission is to conduct research that contributes to the depth of fundamental scientific understanding, to support technology transfer that expands the reach of atmospheric science, and foster transfer of knowledge and technology for the betterment of life on Earth. This mission is clearly consistent with NCAR’s Imperative to develop and transfer scientific applications, technology, and information products that address societal needs. The Lab’s research and development activities are primarily funded by a variety of federal and state agencies, foreign governments, and commercial entities via contracts, grants, cooperative agreements, and inter-agency transfers through the NSF. Because NSF base funding is limited, detail on non-NSF funding that supports base programs is also included here.

Base funds are allocated by the RAL Director and Executive Committee to provide research support for early career scientists, to conduct a visitor program, for education and outreach activities, and to support high-priority efforts such as the Societal Impacts Program, Short-Term Explicit Prediction program, and Developmental Testbed Center (DTC). In prioritizing use of base funds, RAL management looks closely at on-going programs, and at RAL and NCAR Imperatives and Frontiers. A formal internal review of the full RAL program is also conducted each spring. In several follow-on meetings, RAL’s Executive Committee reaches consensus on funding priorities to be presented as part of NCAR’s Annual Budget Review.

Research Frontiers identified in the NCAR and RAL Strategic Plans are high-priority focus areas for the Lab. These include water resources in the U.S. West; renewable energy; climate applications, with emphasis on connections between climate, weather and health; and integrated regional assessments of the impacts of climate change. With fewer base dollars available to support these activities, leveraged funding from outside sources will continue to be critical.

8.1 Program Activities

8.1.1 Numerical Systems Testing and Evaluation

RAL’s Joint Numerical Testbed (JNT) provides an independent facility for testing and evaluating numerical weather prediction systems, facilitates transfer of research capabilities to operational prediction centers, and develops and implements new methods and tools for forecast evaluation. This work focuses primarily on the Weather Research and Forecasting (WRF) model and real-time 4-dimensional data assimilation strategies used in mesoscale models. New areas include testing of hurricane and ensemble forecasting systems. NSF funding for work conducted by the DTC, a distributed program with efforts in the JNT, and for development of new verification methods and tools is described below; other efforts to test, evaluate and verify tropical cyclone, hydrometeorology, and ensemble forecast systems grew substantially in FY 2011 with funding from NOAA and the Air Force Weather Agency (AFWA). These are described in Section 8.2.5.
8.1.1.1 Developmental Testbed Center (DTC)
NSF funding continues to support the DTC in its role as a facility that developers and the operational community can rely on for unbiased assessment of numerical weather prediction (NWP) systems, as well as for evaluating and verifying new additions to or new components of those systems. In addition to testing and evaluation efforts, the DTC conducts a number of workshops and tutorials each year, providing users with training, access to code, documentation and user support. The DTC also supports a visitor program that provides researchers with the opportunity to test new forecasting and verification techniques, models, model components, and data assimilation approaches, and explore ways to introduce new developments into community codes. (NSF: $0.325M; Non-NSF: $3.6M)

Milestones:
- Second year of enhanced DTC Visitor Program, which will support an extended visit by a graduate student for the first time.
- Community WRF tutorials and support, data assimilation, and verification packages.
- Increased testing and evaluation of new model capabilities and tracking of performance of model reference configurations.

Expected Outcomes/Impacts: Continuation of the expanded visitor program will bring additional new capabilities to meet scientific objectives for model improvements and help train new generations within the modeling community. Community support will facilitate expanded development of new modeling capabilities. Reference configuration and other model testing will enhance knowledge of model capabilities and potential improvements.

8.1.1.2 Advanced Verification Techniques and Tools
Evaluation of system performance is essential to all developers and NWP operational users and other forecasting systems. It is increasingly important to utilize verification approaches that are relevant for high-resolution forecasts, are user-specific, and provide information about forecast quality relative to purposes for which forecast information is used. NSF funding supports the research effort needed to develop and improve verification of model-based forecasts, particularly with regard to high-resolution, spatial forecasts of precipitation and forecasts of extreme weather events. Spatial verification research has recently been published in a special edition of *Weather and Forecasting* and will be included in an upcoming new edition of a verification text book. NSF funding also supports an annual workshop that gives members of the national and international verification community a collaboration opportunity. Research output continues to be made available to the community through development and release of the Meteorological Evaluation Tools (MET) software package, which is primarily funded by AFWA. (NSF: $0.355M; Non-NSF: $1.2M)

Milestones:
- Extend spatial verification methods to new areas and to ensembles.
- Release of MET 4.0 with new spatial and temporal object-based verification methods.
- Implement new data analysis tools to utilize NASA’s “A-Train” satellite observations for evaluation of NWP products.
- Develop new tools for evaluation of tropical cyclone forecasts.
• Publish information about MET in *Bulletin of the American Meteorological Society* (BAMS).

**Expected Outcomes/Impacts:** Continued growth in the verification community and its engagement with new research methods and tools as evidenced by positive feedback and constructive advice from MET users, and positive response to research presented in journal articles (*Weather and Forecasting, BAMS*) and text books. Engaged participation in annual workshops and collaborative working relationships emerging from those interactions.

### 8.1.2 National Security Applications

One-time funding from NSF is supporting investigation of the use of graphical processing unit (GPU) technology taken from the gaming industry for acceleration of scientific applications. Project activities in this project transitioned to the acceleration of the algorithm used for analog-based ensemble forecasts by porting it to GPUs. (NSF Special: $0.2M)

**Milestones:**
- Port existing Matlab-based code to GPU.
- Run GPU-based code against a reference dataset to ensure answers from the basic GPU port are equivalent (within machine tolerances) to those from the Matlab-based code.
- Explore algorithm optimizations, including a more efficient sorting routine, optimized I/O, and methodology to work on full gridded fields with a million grid points or more.
- Explore improved methods to find closely matching forecasts, e.g., consider the slope of the local trend in the distance metric.

**Expected Outcomes/Impacts:** Increasing processing speed of the forecast algorithm using GPUs will reduce computing costs and aid in a successful technology transfer from NWP research into applied forecast capabilities.

### 8.1.3 Hydro-Meteorological Applications

The main goal of RAL’s Hydrometeorological Applications Program is to provide relevant information to high-impact weather, flood warning, and water resource decision makers through directed and basic research and development in hydrometeorology, aerosol-precipitation...
interactions, very short-term precipitation nowcasting, cloud microphysical modeling, and winter weather.

8.1.3.1 Short-Term Weather Forecasting
RAL is an active participant in NCAR’s Short-Term Explicit Prediction (STEP) program, which works to improve short-term forecasting of high-impact weather such as severe thunderstorms and hurricanes. The program includes research into basic understanding of high-impact weather systems, development of forecast techniques, real-time testing of forecast systems, verification, and interaction with users. This collaborative effort involves national and international scientists, engineers, and operational personnel from universities, government institutions and the private sector. RAL scientists will continue to make major contributions to a number of STEP projects including: 1) Front Range polarimetric quantitative precipitation estimation for hydrology; 2) nowcasting convective precipitation over the complex terrain of Taiwan; 3) land-surface modeling using International H2O Program (IHOP) retrospective period data, AmeriFlux data, and simulations by the WRF/Noah model to examine the role of the land surface on convective initiation and development; 4) extension of the Method for Object based Diagnostic Evaluation (MODE) to include the temporal dimension; 5) development of improved nowcasting techniques; and 6) improvement and verification of microphysical schemes. These efforts will continue into FY 2012. Funding for this work is heavily leveraged with the FAA-funded storm prediction program. (NSF: $475K; Non-NSF: $1M)

Milestones:
• In partnership with EOL, establish the Front Range Observational Network Testbed (FRONT) to improve precipitation forecasts and flash-flood nowcasts.
• Improve nowcasting of precipitation in complex terrain through analysis of data acquired in the WMO-sponsored Research Development Project for the 2010 Vancouver Olympics.
• Improve statistical evaluation techniques for mesoscale weather such as MODE.
• Improve treatment of the land surface in mesoscale models using Ameriflux data to improve model coupling between land surface and the atmosphere.

Expected Outcomes/Impacts: Progress in understanding precipitation processes in complex terrain will improve nowcasts of hazardous summer and winter weather.

8.1.3.2 Water System Research and Development
In FY 2011, management of the Water System program transferred from the Integrated Science Program (ISP) to RAL. Water System research is conducted by scientists at RAL, NESL, and EOL and works to improve fundamental understanding of the full water cycle, including ground and surface water processes, water resource and snowpack changes, and climate change impacts. A core element of this project, “Colorado Headwaters,” is designed to understand the impact of climate change on snowpack and runoff in the headwaters region within Colorado. A variety of sub-projects are addressing the impact of climate change on Colorado River runoff, snowpack, and water users such as water utilities. The effort utilizes high-resolution WRF model simulations of snowfall and snowpack linked to a hydrological model. System output is linked to the Water Evaluation and Planning (WEAP) tool to examine the impact of climate change on water resources. A number of applied research efforts funded by external sources complement
this base funding, particularly in the area of assisting decision makers in planning and managing water resources and the tradeoff of statistical versus dynamical downscaling in making such assessments. RAL scientists also contribute to the NSF-funded BEACHON program headed by NESL/ACD, principally through examining interaction of the water cycle with carbon, nitrogen, and aerosol cycles. (NSF: $1.2M; Non-NSF: $700K)

**Milestones:**
- Assess climate change impact on U.S. West snowfall, snowpack, and water supplies.
- Conduct future drought studies based on the IPCC AR4 climate model simulations.
- Develop and test improved convective parameterizations in climate models that take into account propagating convection in the lee of mountain ranges.
- Evaluate how to improve coupling of land surface, boundary layer, and convective schemes in climate models.
- Deploy the new X-band dual polarization radar purchased with ARRA funds from NSF (delivery scheduled for late summer 2011).
- Build collaborations with university investigators interested in water cycle research.
- Collaborate with social scientists in exploring relationships between and among climate, water, and human society; develop new proposals presenting integrated approaches to dealing with water sustainability issues.

**Expected Outcomes/Impacts:** Improved ability to observe and model water cycle processes, to better forecast impacts of climate change on water systems, and integrate this knowledge with that offered by the social science community. Making progress in this area will be of real importance to decision makers tasked with planning and managing water resource use under uncertain environmental conditions.

**8.1.4 New and Emerging Applications: Renewable Energy**

NCAR is uniquely qualified to help support the nation's transition to renewable energy due to our breadth of atmospheric science knowledge, experience with technology transfer, and access to university researchers. These capabilities led NCAR to include a new research Frontier in the 2009 NCAR Strategic Plan. RAL, in partnership with university collaborators, has been performing research on wind energy prediction and development of methods and techniques to improve assessment of global wind resources. This research includes boundary layer meteorology, turbulence and land surface characterization and prediction, as well as better modeling and data assimilation tools.

In pursuit of this understanding, one-time NSF funds were provided in 2009 for purchase of a vertically pointing Doppler lidar (termed a “WindCube”) that was deployed at a Colorado wind energy farm in 2010 to study boundary layer structure. The system has been in the field since June 2009 and is being used to understand boundary layer shear in different weather conditions (pre- and post-frontal, gust fronts, nocturnal inversions, etc.). Base funding to support the proposed 2010 expansion of the basic research effort focused on boundary layer meteorology did not materialize and analysis of these data has been undertaken with non-NSF funds. We are uncertain if outside funding will be available in FY 2012 to field the lidar or continue the analysis effort. (Initial NSF investment in FY 2010: $250K; Non-NSF funds: $1.8M)
Milestones:

• Evaluate results from the lidar-based system to determine effectiveness of more routine use of this instrument in wind studies.

• Continue to engage the renewable energy industry and federal laboratories, forming partnerships in the research and business communities, serving on committees focused on utilization of climate and weather information in alternative energy operations, present relevant papers at alternative energy conferences, and exhibit at trade shows.

• Continue to seek funding to support basic scientific research on weather and climate issues that are critical to effective, long-term use of renewable energy sources. Key topics include improved resolution of forecast information and diagnostic data in time and space, improved weather forecast accuracy, and better understanding of the uncertainty that is inherent in forecasts.

Expected Outcomes/Impacts: Bring sound scientific research to public-private partnerships working to harness renewable energy sources to meet the nation’s needs for power.

8.1.5 Climate, Weather, and Society

Addressing NSF and NCAR’s goal of science serving society, among the RAL research aims is improving societal welfare in the context of changing weather and climate. Toward this end, RAL scientists conduct interdisciplinary research on social, economic, and political activities related to climate and weather at local, regional and global scales.

8.1.5.1 Societal Impacts Program: Investigating Weather and Climate Information Needs and Decision Making

Established in 2004 as a collaborative NOAA-NSF endeavor, the Societal Impacts Program (SIP) helps society benefit from current and emerging weather forecasting capabilities by integrating social sciences knowledge and methods within the weather research and policy-making communities. Specifically, the program conducts research, develops infrastructure and outreach programs, and leads workshops aimed at developing and synthesizing knowledge on the use and value of current and improved weather information; building a community of researchers and practitioners engaged in developing knowledge on societal aspects of weather information; and applying the knowledge developed to enhance weather policy-making, weather research, weather information development, and weather information use. One of the more visible efforts within SIP is the Weather and Society * Integrated Studies (WAS*IS) program, which is building an interdisciplinary community of practitioners, researchers, and stakeholders who integrate social science into meteorological research and practice. The graph below shows the number of participants in WAS*IS workshops since 2005. (NSF: $0.25M; Non-NSF: $2.8M)
Milestones:

- Develop an integrated understanding of warning systems and processes, looking at flash floods in Boulder, Colorado, and hurricanes in Miami, Florida, to address the role of uncertainty throughout the warning process, including information dissemination and decision making to more completely identify factors influencing organizational and public decision making and action during extreme weather events, and characterize public preferences for different attributes of forecast and warning information.

- Improve communication of hurricane forecast advisories and warnings by examining processes through which advisories and warnings are developed, the resulting content and communication channels used by various actors in this process, and how at-risk coastal residents, including more vulnerable populations, comprehend and react to specific components of advisories and warnings.

- Explore and assess public awareness and understanding of storm surge and storm surge information to assess whether new approaches are needed to improve communication and decision-making with respect to extra-tropical and tropical cyclone storm surge risk.

Expected Outcomes/Impacts: Through publications, reports, web materials, and WAS*IS graduates, the SIP serves as a focal point for integrating social science and meteorological research in the community.

8.1.5.2 Climate Sciences and Applications

In FY 2010, RAL established a Climate Science and Applications Program (CSAP) to help society better understand, anticipate, and respond to the implications and impacts of climate change and climate variability. This work is largely aimed at stakeholders in the areas of water resources, environmental quality, surface transportation, air transportation, manufacturing, public health, disaster preparedness and relief, and national security that would benefit from information about seasonal weather anomalies and longer-range climate trends. Work is underway in climate science studies and climate applications. (NSF: $1.7M; Non-NSF: $1.2M)
8.1.5.2.1 Climate Science Studies
Demand for regional-scale information about observed and projected changes and impacts is growing. The ability to create and provide this information depends on improvements in climate models, frameworks, and tools to assess adaptive capacity, as well as on integrated interdisciplinary research efforts that draw upon and join climate science, ecology, sociology, economics, and other social and environmental sciences, along with fields such as statistics.

RAL scientists are working to build research frameworks and spatial methods for integrating diverse, multidisciplinary, quantitative and qualitative datasets that exist at different spatial and temporal scales. Current projects explore this integration in the areas of extreme heat and human health, and drought and water management. An on-going program called Adaptation to the Health Impacts of Air Pollution and Climate Extremes in Latin American Cities (ADAPTE), funded by the Inter-American Institute, explores human mortality/morbidity and vulnerability, as well as human and natural factors accounting for the differential distribution within cities. In addition to using GIS as a tool in climate studies, research is conducted at RAL to improve GIS systems’ ability to integrate quantitative and qualitative data and to improve compatibility of NCAR data and models with GIS data and analysis tools.

Milestones:
- Develop a conceptual framework and methodology for comparative analysis of water resource governance.
- Create a multidisciplinary integrative science framework for marine system governance.
- Study alternatives for avoiding destructive strategic behavior as part of effort to develop principles to design effective natural resources management climate adaptation policies.
- Investigate spatial and statistical linkages between survey-based household-level and census-based neighborhood-level data to improve spatial assessments of societal vulnerability to extreme heat. Complete a GIS-based analysis of global simulations from CESM with focus on spatial and temporal trends of future heat waves across the globe, and the effect of the urban heat island and temperature extremes on urban populations.
- Develop method and a set of geo-processing tools for modeling water demand at spatial scales needed to support decision-making in the Upper Colorado River Basin.
- Complete ADAPTE program to understand human and ecological factors related to the health impacts of air pollution and weather in four Latin American cities.
- Begin work on Chemistry and Climate over Asia, in collaboration with ACD.
- Use a model-centered meta-analysis approach to investigate dynamic determinants of common and differentiated vulnerabilities and capacities to respond to hazards within and across urban centers (Data Conservancy project in collaboration with the National Science Digital Library).
- Submit full collaborative research proposals with university partners to NSF on “Low Carbon Cities: New Innovations at a New Spatial Scale”, “Urban Infrastructures and Sustainability: Focus on Energy, Carbon and the Water-Energy-Climate Nexus” and “The Environmental MegaRegions Research, Laboratory and Design Center.”

Expected Outcomes/Impacts: Collaborative development, implementation and publication in refereed journals of new frameworks (e.g., ADAPTE) that cross traditional NCAR physical/social science boundaries, incorporating compatible and comparable data sources
such as surveys, time series, socioeconomic indicators, satellite images and inventories. Assessments of linkages between urban development and global environmental change (IPCC). Improved methods and models for characterizing current and future vulnerability to extreme heat events and drought; improved understanding of local-level vulnerability and adaptive capacity to weather extremes and climate change.

8.1.5.2.2 Climate Applications
Climate applications work focuses on development of knowledge, tools, and techniques to address needs of a wide range of stakeholders. Current RAL efforts, in coordination with the ISP, focus on impacts and implications of changing climate and weather on natural resource management and human health. RAL scientists are developing coupled atmospheric-health modeling systems to address impact of weather and climate on human health. NSF, Centers for Disease Control and Prevention (CDC), and the Google Foundation support a medical anthropologist and her staff in studying spread of infectious diseases such as meningitis in Africa and dengue fever along an altitudinal gradient in Mexico. In FY 2010, a new ASP/ISP post-doc program funded by NSF/NCAR and CDC launched to prepare researchers to work effectively in the atmospheric sciences/human health nexus. FY 2012 funding is anticipated to bring in two new post-docs. CDC funding also supports modeling of plague spread in Uganda. Investigators are also working to improve understanding of natural resource decision-making in the context of changing climate, with models being developed to better represent the numerous socio-economic and political dimensions of decision-making processes and the role uncertainty plays in those processes. Much of this work focuses on water resource management, with RAL researchers contributing to efforts to monitor the spread of drought, as well as mitigate its impacts, and improving the quality of climate change information available to the water resource management community.

Milestones:
- Initiation of new NSF-funded program to study spread of the mosquito vector for dengue fever along an altitudinal gradient in Mexico.
- Successful completion of the first year of the NCAR-CDC postdoc program.
- Exploration of collaboration areas through proposal submissions to NSF and the National Institutes of Health (NIH), e.g., the relationship between introducing clean cook stoves in northern Ghana and improved air quality/reduced incidence of meningitis; and improved understanding of barriers to bed-net use in Kenya and increased malaria incidence.
- Begin work with CSU on a U.S. Agency for International Development (USAID) program to model weather and climate impacts on spread of infectious disease among livestock.
- Increased collaborative activities with physical and social scientists across NCAR and in the university community.

Expected Outcomes/Impacts: Improved understanding of the relationship of climate change on human health, establishment of a new effective partnership with the CDC, and growing credibility as a research organization in the weather, climate, and health arena.
8.1.6 Education, Outreach and Training

Education, training, and learning are important aspects of a national center, and RAL devotes significant resources to these activities. Some of these are traditional, academically oriented activities, and others move beyond the confines of schools and universities to the research and operational communities. As in other NCAR Laboratories, RAL scientists hold teaching appointments, advise graduate students and serve on thesis committees. RAL has consistently supported a significant number of undergraduate and graduate student assistants; over the past five years 12-15 students have been employed each year. They are supervised and mentored by RAL staff members who help them contribute in a meaningful way to our programs while also enriching their educational experience. As noted below, RAL staff members actively participate as mentors in UCAR’s Significant Opportunities in Atmospheric Research and Science (SOARS) program, in NCAR’s High School Internship and Research Opportunities (HIRO) program, and in NCAR’s Advanced Studies Program.

<table>
<thead>
<tr>
<th></th>
<th>FY09</th>
<th>FY10</th>
<th>FY11</th>
<th>FY12 EST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teaching Appointments</td>
<td>7</td>
<td>6</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Graduate Students Advised</td>
<td>11</td>
<td>19</td>
<td>21</td>
<td>15</td>
</tr>
<tr>
<td>Thesis Committees</td>
<td>13</td>
<td>20</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>Students Supervised/Mentored</td>
<td>16</td>
<td>15</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>Post-docs Supervised/Mentored</td>
<td>6</td>
<td>6</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>SOARS/HIRO Students Mentored</td>
<td>6</td>
<td>17</td>
<td>20</td>
<td>18</td>
</tr>
</tbody>
</table>

8.1.6.1 Workshops/Tutorials

RAL staff host a variety of workshops and tutorials (see metrics below). Many of these are organized and funded by RAL’s Joint Numerical Testbed, frequently in collaboration with NESL/MMM, focusing on the WRF model, verification tools, data assimilation, and hurricane modeling and forecasting. These events are attended by hundreds of researchers from the U.S. and abroad, providing important education and training opportunities, as well as a means for discussing unmet user needs and planning future research agendas. The Societal Impacts Program’s Weather and Society *Integrated Studies (WAS*IS) program is also a significant means of outreach to the community; nearly 250 people have attended WAS*IS workshops since the program’s inception.

<table>
<thead>
<tr>
<th></th>
<th>FY09</th>
<th>FY10</th>
<th>FY11</th>
<th>FY12 EST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workshops</td>
<td>17</td>
<td>31</td>
<td>20</td>
<td>18</td>
</tr>
<tr>
<td>Tutorials</td>
<td>7</td>
<td>17</td>
<td>9</td>
<td>8</td>
</tr>
</tbody>
</table>

8.1.6.2 Visitor Program

Growth in base funding to RAL over the past decade has made it possible for the Lab to establish a formal Visitor Program that provides travel and other support for a variety of atmospheric and other scientists, including students and post-docs. This enables us to work with a number of atmospheric-scientists-in-training. Allocating program funding, even in bad budget years, is a top priority for the RAL Director.
8.2 Non-NSF Funding Supporting RAL
RAL receives the majority of funding from non-NSF sources. Below are brief descriptions of key RAL program elements primarily funded by non-NSF sources. Each of these has clearly defined objectives and metrics by which the sponsor determines effort success. This work supports, complements, and significantly leverages NCAR’s base-funded research, and clearly supports NSF’s mission to apply the results of scientific research for the benefit of society.

8.2.1 Aviation Applications
Work remains focused on improving the safety, capacity and efficiency of aviation. RAL plays a significant role in weather research for the Next Generation Air Transportation System, a multi-agency program coordinated by the Joint Planning and Development Office to safely triple the nation’s airspace capacity by 2025. The FAA sponsors this work aimed at creating more accurate forecasting and detection of aviation weather hazards (e.g., turbulence, icing, thunderstorms),
improved integration of weather into air traffic management, support of advanced data and information dissemination to a broad user base, and providing education and outreach services to the operational community so decision makers can more effectively use weather information and tools. A major new program aimed at improving forecasts of wake vortices began late FY 2011 and runs through FY 2013. FAA, NASA, and ITT primarily fund this work. (Non-NSF: $12.5M)

**8.2.2 National Security and Public Safety Applications**

Primarily funded by Department of Defense (DoD) agencies, work in this arena aims to advance understanding of mesoscale and urban-scale weather and climate processes in order to provide operational forecasts of atmospheric conditions for decision makers and emergency managers tasked with saving lives and property. Work in FY 2012 will continue to focus on development of customized NWP solutions on short-range to seasonal time scales. Work includes using the RAL-developed Real-Time Four-Dimensional Data Assimilation (RTFDDA) system to downscale present-day climate from archived global analyses (Climate-FDDA). This allows interpretation of climate statistics by sponsors who can use this tool to address their unique concerns. Other efforts involve developing an operational multi-scale forecasting system for urban environments that can be used to make cities safer, more energy efficient and livable, extending work on modeling plume transport of hazardous materials in stable boundary layers, simulating transport of dense gases, and coupling indoor and outdoor dispersion models, as well as discovering optimal methods for defining ensemble members for fine-scale features in urban environments and calibrating those members for operational forecasting by stakeholders. Developing and testing a 4-Dimensional Relaxation Ensemble Kalman Filter (4D-REKF) system is a priority. (Non-NSF: $7.5M)

**8.2.3 Hydro-Meteorological Applications**

In addition to emphasis on short-term storm forecasting and climate change impacts on the water cycle described above, significant effort will be expended on a broad variety of programs aimed at improving understanding of hydrometeorological processes, enhancing microphysical parameterizations in community models, and developing better decision-making systems for end users. These efforts range from flash flood forecasting research and development projects, to helping water resource managers incorporate climate change in planning scenarios, to cloud-aerosol interaction studies around the globe. This work is funded by a variety of private sector firms, state and local governmental entities, NOAA and NASA. A new program aimed at understanding impact of climate change on water supply and water use in the western U.S. has been funded by the Bureau of Reclamation and U.S. Army Corps of Engineers; new Cooperative Agreements between the agencies and UCAR are being established to facilitate this research effort. (Non-NSF: $3.7M)

**8.2.4 Weather Systems and Assessments**

Work in this area targets specific economic sectors such as surface transportation, energy, and agriculture to discover unmet needs for weather and climate information and to develop targeted, user-focused tools and systems to meet those needs. In FY 2012, primary emphasis will be on development of new methods to more accurately predict wind and solar radiation in support of renewable energy, including use of the WindCube system, refinement of decision-support systems for improved road weather management, and continued development of core forecasting technologies that are the foundation of these decision support systems. A number of new
proposals were submitted in FY 2011 to DOE, as well as to foreign government agencies to advance wind energy capabilities. Work is funded primarily by federal agencies (Federal Highway Administration (FHWA) and NOAA) and private sector firms. (Non-NSF: $5.7M)

8.2.5 Testing, Validating, and Verifying Advanced Numerical Forecasting Techniques
While NSF funding supports several activities in this area, much of the work performed within RAL’s JNT is supported by external funding. Data assimilation efforts are funded primarily by AFWA to test and evaluate data assimilation systems such as NCAR’s WRF-VAR and the NCEP Gridded Statistical Interpolation (GSI) systems. The JNT’s Tropical Cyclone Modeling Team is funded by NOAA’s Hurricane Forecast Improvement Project to evaluate changes in skill associated with improvements in new and operational hurricane models. Increased focus on evaluating NWP and ensemble forecasts will be undertaken with NOAA support. (Non-NSF: $5.8M)

8.2.6 Climate Sciences, Applications, and Services
Much of the work accomplished within CSAP is base-funded through ISP. This work is highly leveraged by external funding to assess impacts of heat on human health in Houston, Texas (NASA), study weather and climate impacts on human and animal health (Google.org, CDC, USAID), and assess impacts of climate change on water resource planning and management (NOAA, state and local governments, American Water Research Foundation, and others). A multi-year program to establish a Climate Modeling Program for Latin America and the Caribbean is funded by the Inter-American Development Bank. This project focuses on building individual and institutional capacity in the region to generate, analyze, visualize and integrate climate, climate variability and climate change data.

NCAR staff also work closely with public and private partners at the regional, national and international levels to determine how best to produce and deliver useful climate data, information, and knowledge to decision makers. In a new effort, RAL will provide scientific input and guidance to NOAA’s Climate Projection Pilot (NCPP) project in the areas of community modeling, multi-model ensembles, regional modeling and data portal development/operation. (Non-NSF: $1.2M)

8.3 Key Funding Decisions for RAL in FY 2012
In prioritizing Lab needs for base funding, RAL has followed traditional planning practices, re-examining the goals and priorities set forth in the RAL and NCAR Strategic Plans and reflected in previous ABRs. For the 2012 ABR exercise, RAL management had to evaluate and prioritize its base budget given a 10% reduction in funding. Each element of the base budget was scrutinized to determine the impact of cuts, with project managers working with colleagues in collaborative programs across NCAR (i.e., STEP, Water System, BEACHON, and NCAR Vulnerability, Impacts and Adaptation Program) to understand the full impact of reductions.

RAL chose to preserve the current DTC funding level at $250K. This is a highly-leveraged joint program with NOAA, making it imperative that NCAR/NSF maintain its current financial commitment. An NCAR funding reduction would likely prompt a cut in NOAA funding, creating collaborative repercussions as well as impacting DTC work. Every other element of the base budget was, to varying degrees, reduced. Should there be a 10% base funding reduction, a
number of staff will be moved to outside-funded projects, resulting in significant reduction in research conducted within the Lab, as well as within the cross-laboratory programs. Support for the GIS community and Lab visitor program will be reduced, several worthwhile education and outreach activities will be eliminated, and significant erosion of the RAL Director’s reserve will occur, thus affecting the flexibility in addressing needs for funding in FY 2012. RAL sees no “downstream” liabilities or commitments as the result of the proposed reductions.

**8.4 Challenges and Opportunities for RAL in FY 2012**

Clearly the biggest challenge over the next five years will be to maintain program and funding at reasonable levels in the face of federal budget pressures. RAL works hard to mitigate this risk by paying special attention to “program maintenance” and by devoting significant resources to developing new programs and diversifying the sponsor base. The recommendations of the Site Visit Team for the recent NSF Review of RAL confirm the importance of diversified funding. Current budget stringencies may indeed present opportunities for an applications-oriented group like RAL to find sponsors looking for new ways to implement improvements in efficiency, productivity, and safety. Many of RAL’s programs are well positioned to highlight such capabilities for international, transportation, water, renewable energy, health, and homeland security applications. There is also a clear need to build integrated physical and social science programs to help policy makers more fully understand relationships between the natural world and human activities as they grapple with complex issues such as climate change. The report highlighted several additional challenges/opportunities:

- Insufficient core funding exists for RAL; funding is needed to affirm the Lab’s central role in fulfilling NCAR’s mission and providing scientists with support to publish their work and engage in creative activities essential to professional development and job satisfaction. The report also recognized that finding the funds to make this happen will be difficult.
- Lack of diversity within the scientific staff. This is a significant challenge for the science community as a whole. Additional creative approaches to using Lab diversity funds to reach out to institutions serving African-American and Hispanic students are under discussion.

**8.5 Long-Term Plans (FY 2013–2016)**

Long-term plans, objectives, anticipated actions, and measures for success are described for each element of the program in the RAL Strategic Plan, which may be found on the web at [http://www.rap.ucar.edu/general/pubs/](http://www.rap.ucar.edu/general/pubs/).

**Program Operating Plans for NCAR-wide Programs**

**9.0 Advanced Study Program (ASP)**

The mission of the Advanced Study Program (ASP) is to help NCAR, and the university community it serves, prepare for the future. ASP’s activities cover the NCAR Imperative to attract a diverse group of university students and early career scientists and engineers to the atmospheric sciences and provide them with exciting opportunities for educational and professional development.
In pursuit of this mission, ASP activities focus on:

- Stimulating the intellect of the research community,
- Fostering the professional development of early career scientists,
- Promoting advanced scientific educational opportunities at NCAR,
- Focusing attention on emerging areas of science, and
- Facilitating interactions between NCAR, universities, and the broader community.

The primary ASP objective is to realize the full potential of its three major program elements: the Postdoctoral Fellowship Program (PDF), the Graduate Visitor Program (GVP), and the Faculty Fellowship Program (FFP). In doing so, the ASP supports the community by providing research and training opportunities in multiple atmospheric science and related sub-disciplines that span all NCAR programs, thereby directly supporting multiple Imperatives and Frontiers called out in the 2009-2014 NCAR Strategic Plan. The other major ASP intent is to continue to seed educational and research opportunities for scientists in the early stages of their careers by hosting colloquia and workshops at NCAR and by making awards for travel and visitor support. This explicitly addresses the NCAR Imperative to “attract a diverse group of university students and early career scientists and engineers to the atmospheric sciences and provide them with exciting opportunities for educational and professional development.”

ASP will continue all of its core programs in FY 2012 in addition to promoting a fairly new program that establishes a partnership between the PDF and some of NCAR’s Historically Black Colleges and Universities (HBCU) partners.

9.1 Engaging a Broader and more Diverse Community in the Atmospheric and Geosciences
All of the laboratories within NCAR play a role in cultivating a world-class, broadly inclusive science and engineering workforce, including dissemination of scientific information to the public, K-12 students, decision makers, undergraduates, and young researchers. The ASP leads multiple efforts in support and development of scientists at all stages of their careers. The ASP also plays a key role in integrating scientific research with the external community and across NCAR divisions and laboratories and in promoting cutting-edge research.

Milestones:
- As part of NSF and NCAR’s mission to encourage development of early career scientists in the atmospheric and related sciences, ASP will make 11 new postdoctoral appointments for FY 2012 and will maintain support for all continuing fellows in the program. (NSF Base: $1.8M)
- ASP will develop and host a summer colloquium in a new or rapidly developing area of research (NSF Base: $175K). In 2011, the ASP changed the format of the colloquium from two weeks to three weeks and included a Researcher/Faculty Colloquium during the middle week. This new format was well received and the ASP plans to continue this format in FY 2012.
- The Early Career Scientists Assembly will host a special Junior Faculty Forum before the WCRP’s Open Science Conference in Denver. The workshop theme will focus on examining the diversity of regional climate issues with an emphasis on developing countries. Topics will include droughts, floods, heat waves, severe storms, sea level rise,
water supplies, agricultural yields, and the survival of native species, pollution and human health. (NSF Base: $32K)

- ASP plans to support up to 20 Graduate Visitor Program participants (depending on visit duration) in FY 2012. The program gives NCAR staff the opportunity to host graduate students for 3- to 12-month collaborative visits; these visits enhance NCAR partnerships with public and private institutions. (NSF Base: $300K)
- ASP will make about three to seven new FFP appointments to allow university faculty to visit NCAR, and NCAR scientists to visit universities. (NSF Base: $190K)
- Lastly, ASP will continue efforts to better serve diverse communities through newly established recruiting efforts in the GVP, FFP, and PDF programs. A Frontier goal is to provide an opportunity for up to four ASP postdoctoral fellows to teach and/or conduct research and engage students in some aspect of their work while in residence at an HBCU partner institution for three to four months annually. Building on the success of our first postdoctoral fellow’s semester in residence at Howard University in 2010, ASP will sponsor two postdoctoral fellows at two HBCUs during the fall semester 2011. One postdoc plans to teach at Howard and the other will go to Hampton University. These partnerships will help NCAR to more effectively recruit HBCU graduate students and postdocs and provide NCAR postdocs with an opportunity to gain valuable teaching experience.

### Expected Outcomes/Impacts:
ASP leads NCAR’s efforts to develop the next generation of leaders in diverse areas of scientific research. ASP programs provide a bridge between NCAR and the university community, helping to foster and cultivate collaborations across all levels. These collaborations and partnerships have the potential to create life-long associations between early career scientists at other institutions and those at NCAR. Graduate students and faculty researchers tend to inject both enthusiasm and new ideas into NCAR researchers, which in turn naturally enhances the science and research of NCAR.

### 9.1.1 Education and Outreach
Virtually all ASP activities contribute to education and outreach in some way. Postdoctoral fellowships and visitor programs offer opportunities to conduct research at a national center to...
graduate students, recent graduates, and faculty members (see table above for recent statistics). The colloquium gives a select number of students hands-on training in important topics in the atmospheric and related sciences. These topics are cutting edge and generally provide instruction in areas for which course materials have not yet been developed (see table below for a list of recent colloquium topics). In this way, the ASP serves as a bridge between NCAR and the university community it serves.

### Recent ASP Summer Colloquia

<table>
<thead>
<tr>
<th>Year</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>Statistical Assessment of Extreme Weather Phenomena under Climate Change</td>
</tr>
<tr>
<td>2010</td>
<td>Asia in the 21st Century</td>
</tr>
<tr>
<td>2010</td>
<td>Forecast Verification in the Atmospheric Sciences and Beyond</td>
</tr>
<tr>
<td>2009</td>
<td>Exploring the Atmosphere: Observational Instruments and Techniques</td>
</tr>
<tr>
<td>2009</td>
<td>Marine Ecosystems and Climate: Modeling and Analysis of Observed Variability</td>
</tr>
<tr>
<td>2008</td>
<td>Numerical Techniques for Global Atmospheric Models</td>
</tr>
<tr>
<td>2007</td>
<td>Regional Biogeochemistry: Needs and Methodologies</td>
</tr>
<tr>
<td>2006</td>
<td>The Art of Climate Modeling</td>
</tr>
<tr>
<td>2006</td>
<td>The Challenge of Convective Forecasting</td>
</tr>
</tbody>
</table>

### 9.2 Key Funding Decisions for ASP in FY 2012

The PDF program has grown out of balance during the past two years due to uneven funding expectations and realities; ASP made 15 new appointments in FY 2010, but only seven for FY 2011. In FY 2012, balance will be restored to the PDF program. Essentially, the ASP will make fewer PDF appointments than funds available in the PDF program. The breakage will provide additional funding for the other visitor programs and the new Researcher Colloquium.

### 9.3 Challenges and Opportunities for ASP in FY 2012

A major and important challenge for the ASP is entrainment of a diverse workforce for both NCAR and our university partners. Toward that objective, the ASP will explicitly target some ASP PDF, GVP, and FFP opportunities at under-represented minority populations. The program will continue recruiting applicants from these groups, and seeking new and innovative ways to build upon existing programs. This philosophy is evidenced by the proposed Frontier activity aimed at building capacity at HBCUs, while providing ASP postdocs with opportunities to garner teaching experiences during a semester in residence at these schools.

### 9.4 Long-Term Plans (FY 2013–2016)

The three major ASP program elements – PDF, GVP, and FFP – along with the summer colloquium series, are established and successful activities that engage NCAR’s university partners and provide unique career development opportunities to program participants. Due to new funding guidelines established by the Executive Committee (i.e., nine PDF FTE appointments per year), the ASP will be able to maintain a consistent PDF program. In the coming years, we hope to provide more graduate students with exposure to the unique experiences that NCAR can provide, including our human capital, through the GVP, and provide additional opportunities for university faculty members to spend time in residence at NCAR pursuing topics of interest to both NCAR and the university community. However, once the PDF is fully funded in FY 2013, there only will be sufficient funds to award 10-12 GVP participants and two to four FFP participants. There may not be sufficient funding to continue a 3-week colloquium, and the Researcher Colloquium is out of the question. The ASP proposes
eliminating the ECSA Junior Faculty Forum as a separate meeting and rolling it into the researcher portion of the colloquium to help fund the new 3-week format. That still does not leave enough funds for the Researcher Colloquium; it would require an augmentation to the program in order to fund the colloquium on an ongoing basis. This, along with the GVP, will be the ASP’s highest priority for any funds that are freed up through early departures or late declines in the PDF program, or funds that can be identified through partnerships with other NCAR programs such as the Integrated Science Program (ISP).

Another major and important challenge for the ASP is the entrainment of a diverse workforce for both NCAR and our university partners. We are already recruiting postdocs for an HBCU exchange in FY 2013. What was once a Frontier Goal in ASP’s Strategic Plan is becoming a regular and integrated activity in the program through funding from the NCAR Diversity Committee and ASP Diversity Funds. ASP will try to fund these HBCU exchanges in the future through the ASP Diversity Fund, but those funds would need an augmentation from the NCAR Diversity Fund, university partners or somewhere else to ensure the continuation of this important activity.

10.0 Integrated Science Program (ISP)
The overarching goal of the Integrated Science Program (ISP) is developing the understanding needed to manage and adapt to climate change, weather, and chemical-weather through research that integrates the atmospheric sciences with other scientific disciplines. ISP is:

- developing new connections among the atmospheric sciences, social sciences, ecology, hydrology, and health sciences;
- fostering collaborations across NCAR laboratories, divisions, institutes, and programs;
- building new relationships with university programs and other research institutions whose expertise complements NCAR expertise; and
- promoting innovation in NCAR research and development.

ISP supports long- and short-term research projects, postdoctoral researchers and scientific visitors in targeted areas, and seminars, workshops and colloquia. (NSF Base: $3.2M)

10.1 Program Activities
All ISP activities are undertaken in cooperation with other NCAR organizations, university community collaborators, and other research institutions. ISP has a small central administrative staff but is a “virtual” organization to some extent; it provides funding and some logistical support for projects that are managed and carried out by staff from NCAR labs rather than maintaining its own scientific staff. In FY 2012, ISP will support four major projects:

- The Integrated Assessment Model (IAM) project, led by NESL/CGD (Section 7.1.6.1)
- The NCAR Vulnerability, Impacts, and Adaptation (NVIA) project, led by RAL/CSAP (Sections 8.1 and 8.2)
- The Weather Communication and Warning (WCW) project, led by NESL/MMM (Section 7.1.8.4)
- The Climate Change and Marine Ecosystems (CCME) project, led by NESL/CGD (Section 7.1.6.2)
Two (IAM and NVIA) have been ISP projects since FY 2009 program inception, the other two (WCW, CCME) gained FY 2011 support as exploratory efforts. While these latter efforts remain small in FY 2012, they have become more established and are considered ISP projects for future planning purposes.

ISP funds scientific and support staff, travel, visitors, students, and workshop expenses for each project, and actively introduces new researchers in relevant project areas, helping fund postdoctoral fellows (with ASP) in IAM, NVIA, and marine ecosystems, and funding postgraduate scientists in CCME and WCW. ISP is also supporting development of a new research effort focused on Carbon Cycle Observations and Modeling in FY 2012 that is led by EOL with participation by NESL/CGD. An ISP exploratory effort, research projects, goals, and duration will be defined in collaboration with the project lead and Lab leadership in FY 2012.

In Fall 2011, ISP’s IAM project will host an IPCC Workshop on New Socio-Economic Pathways and their Use in Climate Change Research and Assessment, to be held at NCAR. A process is under way in the climate change research community to develop a new set of long-term, global socio-economic scenarios for use in integrated research and to help facilitate assessments such as the IPCC reports. These scenarios will be used in conjunction with climate model simulations carried out at NCAR and in the rest of the climate modeling community to evaluate options for emissions mitigation, adaptation, and impacts, and will likely underpin research for the next decade. The NCAR workshop will be the fourth in a series that began in 2010 aimed at developing such scenarios, and will bring together researchers from integrated assessment modeling, impacts, adaptation, and vulnerability analysis, and climate modeling. The meeting will contribute to reaching decisions on scenario contents and defining key additional scenario elements to be developed over the next one to two years.

10.1.1 Education, Outreach and Training
ISP places a high priority on maintaining a strong portfolio of exploratory, planning, and community-building efforts, including workshops, colloquia, and visitor and postdoctoral research opportunities. Many of these are described above as ISP Program Activities, as well as in the corresponding Lab sections describing ISP projects. ISP provides significant and ongoing support of postdoctoral fellows, postgraduate research scientists, and interdisciplinary visitors, as well as support of planning workshops and colloquia.

In FY 2010, ISP co-sponsored an ASP colloquium on Asia in the 21st Century. Tentative plans exist for ISP to collaborate with ASP on an FY 2012 summer colloquium, with topic areas and timing under discussion. The FY 2012 POP Progress Report will provide further details. In FY 2011, ISP sponsored a Colloquium on African Weather and Climate: Unique Challenges and Application of New Knowledge, with support from NESL, NESL/MMM, the World Climate Research Programme, and the Network Startup Resource Center. This colloquium brought together 23 graduate students with lecturers and presenters from NCAR and U.S. and African universities.

Visitors play an important role in the ISP mission, and growth in both visit numbers and duration is anticipated in FY 2012 and beyond, as funds allow. ISP visit numbers and duration are detailed below.
In FY 2010, ISP received $750K in NSF special funds to address Climate Impact Research; $250K was used in FY 2010 and 2011 for graduate student researchers and equipment purchases for ISP projects, and $500K was used in FY 2011 and will be used FY 2012 to support joint postdoctoral appointments with other institutions. In the area of climate and human health, the Centers for Disease Control has provided funds for two postdoctoral researchers and ISP is providing funding for one. In the area ecological impacts of climate change, ISP is supporting one post doc and the National Ecological Observatory Network (NEON) is supporting another. ISP is also providing support for postdoctoral research on the use of regional climate models and land-surface models to understand impacts of climate change on hydrological processes in the western U.S. in collaboration with RAL and the Bureau of Reclamation. In each case, the post docs will work in and with each of the sponsoring institutions. At NCAR, ISP is collaborating with CGD to fund a new postdoctoral fellow in research ecology and climate.

**Milestones:**
- Completion of the term of the two initial postdoctoral fellows focused on human health impacts of climate change, in collaboration with the CDC, RAL, and ASP.
- Appointment of a postdoctoral researcher focused on ecological impacts of climate change, in collaboration with NEON.
- Appointment of a postdoctoral researcher in collaboration with RAL and the Bureau of Reclamation.
- Appointment of a postdoctoral researcher in collaboration with CGD.

**Expected Outcomes/Impacts:**
- Innovative interdisciplinary research on the impacts of climate change.
- New links between the atmospheric sciences and the health, ecological science, and hydrological science communities.
10.3 Key Funding Decisions for ISP in FY 2012
ISP made major changes to its suite of projects in FY 2011, including the transfer of three mature projects to the labs (BEACHON, UTLS, and Water Cycle) for continued implementation as part of NCAR’s core activities and the termination of a fourth project (BGS). Continuing ISP projects (IAM, NVIA, WCW, CCME) were augmented in FY 2011 with a strong emphasis on the low-cost, high-impact, short-term appointment of students and postdoctoral researchers. In FY 2012, ISP will maintain existing projects at current levels, in the short term creating a smaller, more focused ISP program. At the same time, ISP intends to increase its pool of flexible funds to support visitors, postdocs, and short-term projects in order to continue building new capacity in lieu of funding increments. Strengthening this component of ISP is important for building partnerships with the ecology, human health, social science, and hydrology communities that are essential for progress on the highest priority Frontiers in the NCAR Strategic Plan.

10.4 Long-Term Plans (FY 2013–2016)
ISP will continue support of long- and short-term projects in FY 2013. The number of large, long-term projects is expected to remain small, potentially allowing for their augmentation and eventual transfer to the Labs as ongoing NCAR projects. All small projects will be continued, and evaluated for potential future growth and impact. ISP may also invest in short-term projects that promise scientific progress on specific issues but do not create long-term funding commitments.

ISP will continue supporting postdoctoral and postgraduate appointments in targeted areas, including weather communication and warnings (with NESL/MMM) and integrated assessment modeling and climate scenario analysis (with ASP and NESL/CGD). Finally, ISP plans to enhance its visitor program in the long term by providing new opportunities for regular summer visits over a multi-year period, i.e., regular summer visits that continue for three years and are tied to collaborative projects. This will contribute to new NCAR-university partnerships and the development and implementation of new integrated research projects.

11.0 NSF Property Improvements
UCAR, the managing organization that operates NCAR, has the responsibility to manage and maintain the buildings and physical facilities used in the conduct of NCAR’s research, some of which are owned by the NSF. In addition to ensuring that these facilities are adequately maintained to meet NCAR’s operational needs, UCAR has a stewardship responsibility to protect the Government’s and the public’s investment in these unique research facilities. The Government-titled buildings managed by UCAR under this cooperative agreement are the Mesa Laboratory (ML), including the Fleischmann Building (FB), the Research Aviation Facility at Rocky Mountain Metropolitan Airport (RAF-RMMA), and the Marshall Field Site. (NSF Infrastructure Funding is scheduled at $1.5M annually.)

The original priority list, presented in 2007 and projecting needs through 2018, is revised and updated annually to reflect changing priorities based on the urgency of maintenance needs and programmatic requirements. UCAR is continuing to work its way through that list. A summary of current projects and their status, and future year projects is shown below.
FY 2011 Projects

Following the preliminary study effort and subsequent limited forensic demolition efforts in 2011, design development documents will be completed for the Mesa Lab 2B Refurbishment project. It should be noted that the primary project is titled “Mesa Lab 2B Refurbishment,” however, other above-grade areas of the Mesa Lab may be included in the programming and design effort in order to create a construction plan for the most efficient allocation of space for conference facilities, offices, library facilities, and storage. After the design development stage is complete, this project will pause until the Mesa Lab Facility Energy and Equipment Study is completed in FY 2012. See FY 2012 Projects Section below for a description of this project.

Though scheduled for 2012, design and minor construction projects for the ML Computer Room Infrastructure Refurbishment will begin in 2011. The work will be planned, designed and constructed in small packages so as to complete work in an “active” computer room.

The ML Wildfire Mitigation Project will begin in late August 2011. This project will address long-deferred tree thinning and grassland burns to protect the health of the forest and grasslands surrounding the Mesa Lab buildings, parking lot and the Walter Orr Roberts Weather Research Trail. Colorado is experiencing a very active wildfire season and this work is of primary importance. The first half of the forestry project and tree maintenance will be accomplished in FY 2011 at an estimated cost of $0.146M. The second half of the project will be accomplished in the spring of 2012 (FY 2012) to take advantage of optimum grassland humidity in April for the grassland burning component. This work is being accomplished in close partnership with the City of Boulder Open Space and Mountain Parks Division.

The Hazard Materials Storage Building at RAF-RMMA will be constructed prior to the end of FY 2011 at an estimated cost of $0.125M. The Marshall Field Site Upgrade project for Electrical Power and Networking will occur prior to the end of FY 2011 at an estimated cost of $0.55M this year. This project is intended to clean up safety issues and install proper data and power ports for scientific field site experimentation at Marshall. As a bonus, the power and network upgrades performed could easily accommodate the needs of the National Ecological Observatory Network (NEON) project.

An Americans with Disabilities Act (ADA) Compliance Study was accomplished in FY 2011. A list of issues was identified regarding the ML campus and RAF-RMMA site. UCAR Facilities Management & Sustainability (FM&S) is currently reviewing the barrier removal list from ADA, Inc., the outside consultant hired to research NSF facilities compliance. Estimates will be generated for the work required by the barrier removal list and assigned to upcoming fiscal year budget projections. An initial estimated amount of $0.1M is being assigned to FY 2012 to accomplish work required at ML and the Fleischmann Building.

The ML Energy and Equipment Replacement Study will be issued as an RFP at the end of FY 2011 in conjunction with the site’s utility provider, Xcel Energy. This study calls for an approach to the replacement of ML and FB end-of-life or past end-of-life mechanical, electrical and lighting systems. Most of these systems are original equipment, i.e.1965 era boilers and AC units. UCAR is asking for a response from a multi-disciplinary team that includes an energy service company (ESCO) to provide a design and implementation approach using an energy
performance contracting (EPC) model to fund the improvements. Due to the limited $1.5M annual budget for improvements across all NSF facilities, UCAR feels that this is the most cost effective approach to replace core mechanical, electrical, plumbing and lighting systems at ML due to their end-of-life criticality and associated price tag that will exceed the accumulated one or two year annual NSF facility maintenance budget. UCAR will provide a full proposal to NSF regarding this design approach, along with a cost model agreement and implementation schedule. An estimated amount of $0.05M is allocated to begin this study in FY 2011.

Other associated miscellaneous projects in FY 2011 include replacement of the obsolete fire detection computer and annunciation devices at ML, the installation of sprinklers in existing non-sprinklered areas in 2B, and the replacement of existing stairwell sprinklers.

**FY 2012 Projects**

Funding allocated for the ML 2B renovation will be moved forward to FY 2012 to help fund the recommendations made by the ML Energy and Equipment Replacement Study. The total estimated cost for the ML 2B Refurbishment ($2.1M) plus the Computer Room Infrastructure Refurbishment ($2.2M) is $4.3M. The phased work in both areas will expend the 2010 carry-over ($0.95M) + 2011 NSF allocations ($1.5M) + the 2012 NSF allocations ($1.5M). The balance of the estimated cost ($0.35M) will expend a portion of the 2013 allocation. During each yearly allocation, value engineering will be employed and cost savings will be applied as carry-overs to the next annual cycle. Prioritization of needs for the combined projects will be revisited, with higher ranking items completed first as allowed by the allocated funding.

In 2012, the second part of the ML Wildfire Mitigation and Tree Maintenance Project will be accomplished. This will include tree thinning in the remaining forest units located on the NSF property and grassland burns during the month of April to increase the diversity and protect the health of the surrounding grassland areas to the north, south and west of the ML and FB complex. The estimated cost for this work is $0.146M. An estimated amount of $0.1M is being set aside to begin the ADA barrier removal process at ML and FB. An additional $0.15M is allocated to complete the ML Energy and Equipment Replacement Study in early FY 2012. Subsequent to this study, NSF approval will be sought to engage in an energy performance contract to implement the recommendations for mechanical, electrical, plumbing and lighting equipment and systems replacement. An estimated budget amount of $2.1M is allocated for this effort. The second phase of site infrastructure work will be completed at the Marshall Field Site during spring 2012. The remaining $0.2M allocated for the improvements will be used to complete work.

**Milestones:**
- 100% completion of the ML Wildfire Mitigation and Tree Maintenance project.
- 100% completion of the ML Energy and Equipment Replacement Study.
- Proceed with implementation of the ML Energy and Equipment Replacement Study.
- Proceed with implementation of the ADA barrier removal compliance effort at ML and FB.
- Complete Marshall Field Site upgrades.
• Begin ML computer room to replace obsolete equipment and systems triggered by move to NWSC facility.

11.1 Key Funding Decisions for NSF Property Improvements in FY 2012
• Approximately $950,000 Carry Over funds to be used for design/construction.
• $1.5M NSF Infrastructure allocation used for design/construction.

11.2 Long-Term Plans (FY 2013 – 2018)
In 2012, the NCAR Supercomputing Group is scheduled to relocate to the new NCAR-Wyoming Supercomputing Center (NWSC) facility. The Mesa Lab computer room will require significant, multi-year infrastructure improvements, which are currently being planned. The rough order of magnitude cost of these upgrades is estimated to be $2.2M and work is anticipated to be completed in 2015.

Other work forecasted for FY 2013 through 2018 includes:
• Complete all recommended actions from the ML Energy & Equipment Replacement Study ($2.1M).
• Replace at least two large substations ($800K - $1M).
• Re-roof a significant portion of the Mesa Lab ($800K - $900K).
• Make structural repairs to the Mesa Lab HAO tunnel ($1M).
• Complete replacement of obsolete electrical systems ($1.4M).

2011 and 2012 will be intensive construction years for the Mesa Lab. It is possible some work may extend into 2014 due to the annual $1.5M cash-flow allocation limitation.

Priorities will need to be re-visited after 2011, but it may be feasible to re-prioritize the RMMA Refurbishment after the above work is completed.