Accomplishments and Plans
of the
Scientific Computing Division
of the
National Center for Atmospheric Research

FY1993 - FY1998

Prepared for the
National Science Foundation
Peer Review

submitted
October 1, 1995

56 pages
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I. Executive Summary

The Scientific Computing Division (SCD) is one of nine research and facility divisions at the National Center for Atmospheric Research (NCAR). The Introduction (Section II) of this document overviews NCAR -- its mission and role in the atmospheric and related sciences. The mission of SCD is also included in the Introduction.

To carry out its mission, SCD has assembled a supercomputing facility that contains four major components: high-performance computers, a mass storage system, networks, and distributed servers. In addition, SCD also provides collateral services to assist scientists in using these facilities. Thus Section III (Research: Accomplishments and Future Plans) is organized into five categories:

1. High-performance computing and data processing systems;
2. Mass storage system (MSS);
3. Networking and data communication systems for local and remote access;
4. Distributed servers dedicated to specific functions such as use of the World Wide Web (WWW) and production of scientific visualizations; and
5. User support services.

Section IV reviews our linkages to other supercomputer centers, suppliers of computing equipment, and so forth.

Section V summarizes SCD's educational activities including classroom use of supercomputers and other training activities.

Section VI documents some of the benefits of being part of NCAR -- such as the ability to carry out projects such as the MECCA numerical laboratory.

Section VII summarizes financial information for the review period for both income and expenses.

Section VIII contains appendices of supplementary material from Section I - V, including results of the User Survey that was conducted as a part of this review.

Finally, Section IX reviews SCD's Management Plan, including our metrics for success.
II. Introduction
   A. Overview of NCAR

NCAR is managed by the University Corporation for Atmospheric Research (UCAR) and its 61 member universities through the UCAR Board of Trustees. NCAR's principal mission is two-fold: to conduct research in the atmospheric and related sciences, and to support the university community by providing large computing, observational and instrument facilities, and community models. NCAR participates in educational programs ranging from elementary to postgraduate levels and in technology transfer, whereby NCAR-developed technologies and intellectual property are transferred to the private and public sectors.

NCAR and UCAR work closely with the National Science Foundation to establish priorities and plans consistent with those of the community, complementary to the NSF's university grants program, and responsive to national and international initiatives and scientific opportunities. These are set in the broader context of the strategic goals of the NSF to: enable the United States to uphold a position of world leadership in all aspects of science, mathematics and engineering; promote the discovery, integration, dissemination, and employment of new knowledge in service to society; and, achieve excellence in U.S. science, mathematics, engineering and technology education at all levels.

NCAR's research encompasses the disciplines integral to the earth system, including solar processes and their interactions with the earth; the chemistry and biology of the atmosphere, land surface and oceans; meteorological processes from the global to the microscale; the dynamics of the atmosphere and oceans; the earth's climate; and impacts of weather and climate on human activities.

Observing facilities include a diverse and highly capable aircraft fleet and ground-based facilities such as polarimetric radar, sounding and profiling systems, and surface flux systems. Supercomputing resources are provided for development and execution of large numerical simulations, archiving and manipulation of large data sets, and networking and data communications facilities.

While organized along disciplinary lines, there are strong interdivisional interactions at NCAR, consonant with the multidisciplinary nature of the research being conducted and supported. Science and facility divisions work closely together in design and deployment of new instrumentation; experimentalists and theorists combine expertise during the formulation of enhancements to numerical models, as well as in the planning of filed programs.

University interactions are integral to NCAR's program and span a wide spectrum of collaborative scientific research and facility development, education, training, and technology transfer. NCAR's multidisciplinary research benefits greatly from university participation, and university collaborators contribute directly through
long-term scientific visits. Bilateral affiliate appointments encourage such exchanges and provide opportunities for educational service by NCAR scientists.

NCAR's programs benefit from the broadest possible community reviews of scientific initiatives, facility allocations, and field programs, conducted in both formal and informal fora. University use of community facilities and models leads to improvements and new developments while furthering both NCAR and university research.

The Scientific Computing Division (SCD) is one of nine research and facility divisions at the National Center for Atmospheric Research (NCAR). The specific activities, accomplishments, and plans of the Scientific Computing Division are described in the following section.

B. Overview of the Scientific Computing Division (SCD)

The NCAR Scientific Computing Division (SCD) provides supercomputing resources and related services to support research in the atmospheric, oceanic, and related sciences. Much of the research in these disciplines requires large computer models and generates large amounts of data. Thus, SCD's mission is to provide:

- Supercomputing resources needed for the development and execution of large, long-running numerical simulations and the archiving, manipulation, and analysis of large datasets;

- Network and data communications capabilities required for a national and international user community to access NCAR computational and data resources; and

- A computing environment that emphasizes reliability, high performance, cost-effectiveness, and user productivity.

To carry out its mission, SCD has a staff of about 100 full-time equivalent employees (see Appendix A for an organizational chart and a complete listing of current SCD staff members). In addition, overview information about SCD may be found on the World Wide Web (WWW) at: http://www.ucar.edu/ scd.html.

SCD budget information is presented in Section VII.
III. Research
SCD Programmatic Overview

By definition, supercomputers are the most powerful computing systems available, and they are used primarily to solve problems that cannot be solved on any other class of equipment. Figure 1 shows the current configuration of computing resources available at NCAR and Figure 2 illustrates the growth in computing capacity at NCAR in recent years.

Figure 1
Current Configuration of SCD Computing Resources

The equipment delineated as "community computing" in Figure 1 is used by university scientists and NCAR scientists in support of the following areas:

- Climate - 34%
- Mesoscale and microscale meteorology - 26%
- Oceanography - 14%
- Chemistry and upper atmosphere - 11%
- Basic fluid dynamics and miscellaneous - 8%
- Cloud physics - 4%
- Astrophysics - 3%
Figure 2
Growth in Computing Capacity

<table>
<thead>
<tr>
<th>Date</th>
<th>Computers</th>
<th>YMP Equivalents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970</td>
<td>CDC 6600</td>
<td>0.016</td>
</tr>
<tr>
<td>1975</td>
<td>CDC 7600</td>
<td>0.080</td>
</tr>
<tr>
<td>1980</td>
<td>CDC 1-A</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>CDC 7600</td>
<td>0.08</td>
</tr>
<tr>
<td>1985</td>
<td>CRAY 1-A (2)</td>
<td>0.44</td>
</tr>
<tr>
<td>1990</td>
<td>CRAY XMP48</td>
<td>2.86</td>
</tr>
<tr>
<td></td>
<td>CRAY YMP8/864</td>
<td>0.00</td>
</tr>
<tr>
<td>1995</td>
<td>CRAY YMP8/864 (2)</td>
<td>10.66</td>
</tr>
<tr>
<td></td>
<td>CRAY J916</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>CRAY ELS (3)</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>CRAY T3D</td>
<td>1.1</td>
</tr>
<tr>
<td></td>
<td>IBM cluster</td>
<td>1.1</td>
</tr>
<tr>
<td></td>
<td>CM-5</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>IBM SP21</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>31.6</td>
</tr>
</tbody>
</table>

To use community computing resources, a scientist must obtain an allocation of General Accounting Units (GAUs). By the end of fiscal 1995, 78K GAUs were available for allocation. By agreement with the NSF, GAUs are distributed as follows:

- Universities .................. 33.0K (45% of Pool)
- NCAR .......................... 33.0K (45% of Pool)
- Director's Reserve and Joint Univ/NCAR Projects .................. 10.0K (13% of Pool)
- Other .......................... 2.0K (2% of Pool)
- Total 78.0K .................. (105% of GAU Pool)

Allocation to university scientists is by a peer review process. Twice each year, NSF grantees are invited to submit a proposal for an allocation of GAUs. Proposals for more than 100 GAUs are sent out for peer review. The SCD Advisory Panel uses these reviews to recommend a specific allocation. Members of the SCD Advisory Panel are listed in Appendix B. Allocation to NCAR scientists is by the NCAR Allocations Committee that reports to the Director of NCAR.

University scientists are using NCAR community resources for large computational projects. The following table gives (by fiscal year) the total amount of GAUs requested by university scientists, the number of requests that involved 350 or more GAUs, the total GAUs involved in these requests, and the total GAUs allocated to them.
Table 1
Requests for 350 or More GAUs by University Scientists

<table>
<thead>
<tr>
<th>FY</th>
<th>Total GAU requested</th>
<th>No. Req. &gt;350 GAU</th>
<th>Total GAU &gt;350 GAU</th>
<th>Allocated GAU &gt;350 GAU</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>36.5 K</td>
<td>28</td>
<td>28.5 K</td>
<td>19.3 K</td>
</tr>
<tr>
<td>1994</td>
<td>70.4 K</td>
<td>28</td>
<td>61.3 K</td>
<td>25.4 K</td>
</tr>
<tr>
<td>1995</td>
<td>38.7 K</td>
<td>31</td>
<td>31.5 K</td>
<td>24.3 K</td>
</tr>
</tbody>
</table>

SCD's charging system for community resources is priority based. Most university scientists use the lowest-priority queue, in which case they typically get about 1.8 equivalent Y-MP CPU hours per GAU. Thus an allocation of 350 GAUs often results in at least 600 CPU hours of computing.

The following table encompasses both university and NCAR usage of the community Y-MP8 and shows that the Y-MP8 is primarily used to execute long-running simulations. (Columns headed "% Wallclock" give the percent of wall-clock time that the community Y-MP8 spent executing jobs that require one hour of CPU time and four hours of CPU time.)

Table 2
NCAR and University Use of Y-MP8

<table>
<thead>
<tr>
<th>FY</th>
<th>Total Users</th>
<th>#NCAR Users</th>
<th>#Univ. Users</th>
<th>% Wallclock &gt; 1 CPU Hr.</th>
<th>% Wallclock &gt; 4 CPU Hrs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>93</td>
<td>1,525</td>
<td>522</td>
<td>739</td>
<td>75%</td>
<td>53%</td>
</tr>
<tr>
<td>94</td>
<td>1,582</td>
<td>583</td>
<td>768</td>
<td>80%</td>
<td>50%</td>
</tr>
<tr>
<td>95</td>
<td>1,437</td>
<td>566</td>
<td>755</td>
<td>80%</td>
<td>60%</td>
</tr>
</tbody>
</table>

Thus, overall usage of the community Y-MP8 is consistent with SCD's mission.

The equipment delineated as "accelerated computing environment" (ACE) is dedicated to a small number of activities that involve large simulations, e.g., coupled climate system models. In particular, ACE supports the new U.S. Global Change Research Program (USGCRP) multi-agency Climate Simulation Laboratory (CSL). It provides over 10,000 equivalent Y-MP CPU hours per month to eleven GCRP proposals. The CSL involves separate funding and allocation processes, both of which are discussed later in this report.

Figure 3 is a schematic of the NCAR mass storage system (MSS), and Figure 4 illustrates the growth in the amount of data stored in the MSS in recent years. About 10% of the holdings are meteorological, satellite, climate, and geophysical data organized into over 400 datasets, many of which are network accessible. The remaining 90% are model output.
Modern networking technology, national and international, provides users with convenient access to SCD and other Internet facilities. For many years, NCAR was a backbone node on the NSFnet, and NCAR is currently a node on the new NSF very High Speed Backbone Network Service (vBNS). Via indirect funding, SCD is also responsible for communication links between and within all UCAR/NCAR organizational units in the Boulder Metro area. The associated network is called UCARnet.
SCD routinely makes available a suite of tools and support services that are geared toward maximizing the productivity of the scientist when using SCD equipment. The tools range from continuously updated mathematical, graphical, and statistical software libraries to highly optimized job execution queues and scientific visualization of data. Support services, e.g., programming consultants, software engineers, network technicians, data specialists, scientific visualization and digital media experts, and computational theoreticians, are provided to assist scientists and researchers with the many aspects of computational science. SCD also provides meteorological and oceanic datasets and related data services to scientific investigators around the world. These datasets are provided from an SCD-maintained archive of computer-accessible research data. The archive is an irreplaceable store of observed data and analyses that are used for major national and international atmospheric and oceanographic research projects.

Advisory Groups, Committees, and Panels

SCD strives to provide a high level of service to its users and seeks their input and guidance through a number of advisory committees. They are:

- The SCD Advisory Panel
- The SCD Users Group
- The Mass Storage System Advisory Committee
- The Visualization Users Group
- The NCAR/UCAR Network Coordination and Advisory Board
- The NCAR Graphics e-mail Newsgroup
- The CSL Allocation Panel

Information about these advisory groups along with membership names may be found in Appendix B.

A. Achievements

Computing and communication technology change at a very rapid pace and the greatest challenge to SCD is to properly assess trends, then quickly fund and integrate new and suitable technologies. Many of our accomplishments during the review period reflect this challenge.

Highlights from the Review Period

- *Growth in computing capacity.* As illustrated in Figure 2, the total computing capacity grew rapidly during the review period with numerous systems being installed. In particular, six systems were installed in FY 94 as part of the Climate Simulation Laboratory (CSL), a new facility dedicated to large-scale climate simulations. Each new system has to be integrated into the network, connected to the MSS, and supported with documentation, consulting, and so on. The ability to
quickly assimilate new systems, whether they are traditional, parallel, or some other architecture, is one of SCD's greatest strengths.

- **Industry collaboration.** During the review period, SCD staff worked with Cray Computer Corporation (CCC) to test and harden the Cray-3 supercomputer. The Cray-3 was installed at NCAR in FY 93, integrated into our network, and used by many scientists. These tests uncovered some major problems that the company subsequently corrected. Eventually, the machine was made to be very reliable and became a popular system among NCAR users until CCC went out of business in early 1995.

- **MECCA Numerical Laboratory.** From July, 1991 through December, 1993, SCD provided the Model Evaluation Consortium for Climate Assessment (MECCA) with a numerical laboratory that included a dedicated Y-MP2. Over 42,000 Y-MP CPU hours were made available to MECCA projects. These projects generated and archived about 5.5 terabytes of model output, accessed over 40,000 files from SCD's MSS, and generated over 100 animations via the SCD Visualization Laboratory.

- **Accelerated Computing Environment (ACE).** NCAR and UCAR, with help from NSF and its High-Performance Computing and Communications (HPCC) program, established the ACE at the NCAR Mesa Laboratory. The mission of the ACE is to provide supercomputing resources to a small number of computationally intensive activities such as the US GCRP's Climate Simulation Laboratory (CSL).

- **MPP Technology Assessment.** Throughout the review period, the computing community was in ferment due to the availability of massively parallel processors (MPPs) and their potential to offer much greater performance and cost-effectiveness. The emergence of MPP technology posed the question of if (and when) should major investments be made in it. Thanks to HPCC funding from NSF and the Advanced Research Projects Agency (ARPA), SCD acquired three small MPP systems - a 32-processor CM-5, an 8-processor IBM SP-1, and a Cray Research 64-processor T3D. Having this equipment on site greatly facilitated its evaluation with respect to atmosphere, ocean, chemistry, and mesoscale models.

- **Growth in storage capacity.** NCAR has one of the most capacious and efficient mass storage systems in the world; in fact, the amount of data stored and accessible at NCAR is an order of magnitude greater than that found at typical supercomputer centers. Further, storage capacity grows at a rate proportional to computing capacity as shown in Figure 4. The NCAR MSS and the people who support it are one of NCAR's unique assets.

- **Interactive, multimedia network technology.** SCD established NCAR's first WWW server and has aggressively applied this technology to virtually eliminate the use of hardcopy for providing user documentation, research proposals, periodic reports, etc. In addition, SCD has been instrumental in providing other
divisions and programs within NCAR access to this new Internet-based, information distribution and discovery technology.

- **Special projects**. SCD routinely provides special efforts on behalf of field projects, university users, etc. For example, during the review period, real-time forecasting was provided to the Stormscale Operational and Research Meteorology - Fronts Experimental Systems Test (STORM-FEST), the Winter Icing and Storms Project (WISP), and the First ISCCP (International Satellite Cloud Climatology Project) Regional Experiment II (FIRE II) via dedicated, prime-time multiprocessing on the Y-MP8; a CD-ROM of data was developed in collaboration with the University of Washington and distributed widely; and the NCAR Graphics package was upgraded and made available to universities at favorable costs.

- **Enhancements to research data.** The SCD Data Support Section (DSS) maintains and makes available a rich collection of research data. During the review period, major enhancements were made to the TIROS Operational Vertical Sounder (TOVS), Global Area Coverage (GAC), and geostationary satellite datasets. Version 1a of the Comprehensive Ocean-Atmosphere Data Set (COADS) dataset was released, and major progress was made in collaboration with NMC on reanalysis of global observations for 1957 to 1994 using modern data assimilation methods and forecast models. DSS has established and continuously updates a WWW server and File Transfer Protocol (FTP) site to provide information about the DSS data base and other research activities.

- **DOE CHAMMP Initiative.** SCD was a major participant in the Department of Energy (DOE) Computer Hardware, Applied Mathematics, and Model Physics (CHAMMP) initiative by porting and evaluating the performance of the NCAR community climate model (CCM2) on several MPP architectures.

A detailed discussion of these and other accomplishments follows and is organized into the following five categories:

- **A1. High-performance computing and data processing systems**
- **A2. Mass storage system (MSS)**
- **A3. Networking and data communication systems for local and remote access**
- **A4. Distributed servers dedicated to specific functions such as use of the World Wide Web (WWW) and production of scientific visualizations**
- **A5. User support services**

**A.1 High-Performance Computing Equipment**

**A.1.a Enhancements to Community Resources**

The community Y-MP8 was installed in 1990 and continues to serve as the flagship system for community use. During the review period, the UNIX Cray Operating System (UNICOS) was periodically upgraded as new capabilities were added by
Cray Research, Inc. Disk capacity was increased by nearly 50% (current capacity is 97 Gbytes); this substantially improved the throughput of the machine due to its diverse job stream and large number of users.

SCD maximizes the Y-MP8's production time by using a Cray EL92 for system software development and checkout. This reduces the amount of time that the Y-MP must be taken out of service for software maintenance. Thus during the first nine months of FY 95, the Y-MP was available to users an average of 98% of wall-clock time.

Several researchers run simulations that can effectively use all of the Y-MP8's computational capability via parallel processing (multi-tasked) mode. Further, when all eight processors of a Y-MP8 are used in parallel, the machine can sustain well over 1 Gflops. Thus, for several years SCD has provided special services (e.g., performance analysis and code optimization assistance) and discounted charging to encourage scientists to incorporate parallel processing into their models. Today, parallel processing is available on the community Y-MP8 from 12:30 pm to 06:30 am, Monday through Friday and from 01:00 am Sunday to 06:30 am Monday.

Due to rapid progress in microprocessor technology, top-of-the-line Reduced Instruction-Set Computer (RISC) workstations offer computation performance that is within an order of magnitude of a single processor on a state-of-the-art supercomputer. Thus, for execution of "small" jobs, these work-stations offer a potentially cost-effective alternative to supercomputers. For the past two years, SCD has conducted an experiment wherein a cluster of four IBM RS/6000 workstations were made available for single-processor jobs. Although the cluster includes a high-speed communication link to the Mass Storage System it has not been heavily utilized.

Our most successful effort to enhance community computing resources came through a collaboration with Cray Computing Corporation (CCC). During the review period, SCD worked closely with CCC to test and demonstrate both software and hardware capabilities of the Cray-3. Since the Cray-3 operating system was first installed on a Cray-2 in Colorado Springs, NCAR provided a test load for the system and averaged about 1,000 hours of usage per month during 1992-93. A Cray-3 was installed at NCAR in 1993, and NCAR usage immediately uncovered various problems that CCC quickly fixed. By the fall of 1994, the Cray-3 had become a very reliable system, and its large memory made it popular. Unfortunately, CCC went out of business in the spring of 1995; thus the machine was decommissioned.

At the end of FY 94, SCD further increased computing capacity available to the general user community - by approximately 40% - through the availability of the two Cray EL98s and one EL92. Most of this additional capacity is a byproduct of the CSL. This additional computing capacity made it feasible to increase the amount of
time on the community Cray Y-MP8 that is dedicated to long-running, parallel-processing simulations.

A1.b. Accelerated Computing Environment (ACE) Background

In 1990, UCAR and the Electric Power Research Institute (EPRI) established the MECCA Project. EPRI, UCAR, and NSF were joined by other organizations in the United States, as well as organizations from France, Italy, Japan, and the Netherlands in this consortium.

The primary objective of MECCA was to quantify the probable range of future climate change and to assess the uncertainties in computer simulations of climate. Accomplishment of this objective required substantial amounts of supercomputer resources including associated infrastructure support for data archiving, data analysis, and user assistance. Since NCAR has had a leading-edge supercomputing facility for a long time, this led MECCA, NSF, and NCAR to establish the MECCA Numerical Laboratory at NCAR.

A cornerstone of the Numerical Laboratory's creation was that it would be embedded in the NCAR supercomputing facility, and that MECCA would pay only the incremental cost of the associated equipment and support for it. This led to the lease and installation of a two-processor Cray Y-MP at NCAR in the summer of 1991. The machine was dedicated to MECCA projects, and users were given access to the full range of NCAR supercomputing resources, e.g. the Mass Storage System, Visualization Lab, user assistance, code optimization, etc. From July, 1991 through December, 1993, SCD made 43,248 Y-MP CPU hours available to MECCA (98.7% of system availability). These projects generated and archived about 5.5 terabytes of model output, accessed over 40,000 files from SCD's MSS, and generated over 100 animations via the SCD Visualization Laboratory.

Since the MECCA Y-MP2 resources were spent on a small number of large simulations with strong support from SCD, MECCA investigators were able to complete projects in typically one-sixth of the time (on a calendar basis) that would have been required had they been using the NCAR community Y-MP8 that serves over 1,000 scientists. Thus the use of dedicated equipment greatly accelerated the completion of large simulations.

GCRP Computing Requirements
Over the past several years, it had become clear that the USGCRP was going to need substantial amounts of computing. For example, NCAR scientists are working to develop a comprehensive, fully coupled climate system model (CSM); one with a hierarchy of modular components within a unified model framework, flexible enough for implementation on several computing systems, and accessible to the climate modeling community. (For details, see NCAR Climate System Model Plan, Climate System Model Investigators Group, Byron A. Boville and William R. Holland, Co-Chairs, November 1994.)
For a modest-resolution simulation (T42L18 in the atmosphere, 2.8 degrees horizontal resolution with 45 vertical layers in the ocean) NCAR CSM version 1 will require about eight wallclock hours per simulated year on a computer that can sustain 1 Gflops (e.g., the Y-MP8). Put another way, at 1 Gflops, about one month of continuous computation is required to complete a 100-year simulation.

Clearly, these are extraordinary computational requirements despite the fact that various compromises were made in the NCAR CSM to balance computational requirements against the need for scientific understanding. Thus, the NCAR CSM and other GCRP coupled models will tax the capabilities of currently available supercomputers.

Establishment of the ACE
MECCA discontinued funding for the Numerical Laboratory effective January 1, 1994. In view of MECCA's success in using dedicated equipment to accelerate completion of large climate simulations and in view of the computing requirements of the USGCRP as exemplified by the NCAR CSM, NSF and NCAR decided to create an Accelerated Computing Environment. The purpose of the ACE is to provide high-performance computing and storage systems to support large, long-running simulations -- including HPCC grand challenge problems such as climate, weather, and turbulence - that need to be completed in a short calendar period. In the context of the ACE, a large simulation is one that requires hundreds, even thousands of processor hours for its completion. Incorporation of parallel processing is virtually mandatory in order for a model to make appropriate use of the ACE. It was agreed to invest substantial HPCC funds in ACE since climate modeling is an HPCC grand challenge application. Also, it was agreed that the ACE should provide support to international projects such as MECCA. The predominant component of the ACE is the USGCRP multi-agency Climate Simulation Laboratory (CSL) illustrated in Figure 5.

Figure 5
NCAR ACE/CSL
Since the Y-MP2 leased by MECCA was already installed at NCAR, there were various advantages, e.g., favorable lease costs, to using it as the initial equipment in ACE. Thus in FY 94, NCAR and NSF committed $1.1 million of HPCC funds, plus $0.75 million of Climate Modeling, Analysis, and Prediction (CMAP) Program funds and a one-time carryover of $0.6 million and established the ACE effective 1 January 1994. Further, NCAR negotiated agreements with Cray Research, Inc., to upgrade the Y-MP2 in the ACE during FY 94 contingent on availability of funding in FY 95 and beyond.

A.1.c Establishment of the USGCRP, multi-agency CSL

The initial funding for ACE would only sustain it through mid-FY 95. Given the extraordinary computational requirements of the USGCRP, Jay Fein at NSF began working with the Interdisciplinary Modeling, Analysis, and Prediction (IMAP) Program to establish a CSL within the ACE as a multi-agency USGCRP facility. This effort was successful and in FY 95 $7.5 million of CMAP funds were committed for the CSL. The establishment of the CSL required concurrence of the National Science Board, which was given in mid-FY 95. Immediately thereafter, criteria for use of the CSL were developed, an allocation panel was appointed, and plans were laid to bring the CSL into operation. Criteria for use of the CSL may be found in Appendix C of this report.

Allocation Process
An allocation panel of experts was established (CSDLAP). Its members are listed in Appendix B. The panel recommends allocation of CSL resources based on its review of the proposals (in the context of all the above criteria and factors), USGCRP priorities, and available CSL resources.

Initial Operation of the CSL as a USGCRP Facility.
An announcement of opportunity to use the CSL was made for the spring of 1995 to climate modelers in various government agencies and to all atmospheric science departments of UCAR member universities. By early June, 18 proposals had been received requesting 15,000 equivalent Y-MP CPU hours per month. These requests totaled about 150% of the CSL's monthly capacity. The CSDLAP met in July and allocated about 10,400 equivalent Y-MP CPU hours per month to 11 proposals. Eight of the 11 proposals received the full amount of their request.

Current ACE Status
By the end of FY 95, equipment described in Figure 6 was in service in the ACE. The Y-MP8I, T3D, and J916 are used for large simulations. The EL98 is used for software development, problem setup, and analysis of model output. In addition, users of the CSL have access to the NCAR MSS and the NCAR Visualization Laboratory. They also are given the full range of the NCAR SCD user support services.
A.1.d Migration to Highly Parallel Computing

Various applications in the geosciences can benefit substantially from computer performance that is at least 100 times faster than anything available today. Such levels of performance can only be obtained through highly parallel computing, and during the review period, SCD and the users we support made significant progress in the use and evaluation of highly parallel computers.

Thanks to funding from ARPA through the National Consortium for High-Performance Computing, SCD installed a 32-node CM-5 with 128 Mwords of memory in the late spring of 1993. The machine quickly attracted a small community of dedicated users, and by the end of FY 93, overall utilization was averaging about 75 percent. In FY 94-95, the machine was used for major simulations and was heavily used in development of a Data Parallel Implementation of the NCAR CCM2 (see A.5.b). It was also used in university classes by professors from the environmental sciences community. (See Section V.)

Under HPCC funding via NSF, in late FY 1993 SCD installed an eight-node IBM SP-1 system for experimentation and evaluation as a parallel processor. This machine was vital to the development of a message-passing (PVM) parallel version of the CCM2 (see A.5.b).

Throughout the review period, SCD's Computational Support Section (CSS) carried out a number of performance measurements of microprocessor-based systems and their incorporation into parallel architectures (see section IX.B. for associated staff). For example, sustained performance of the Data Parallel CCM2 on the CM-5 is about 10 Mflops per node. Sustained performance of the message passing version of CCM2 on the Cray T3D is also about 10 Mflops per node. Thus, a 1000 processor MPP might deliver 10-30 Gflops which is comparable to the projected performance of the next generation of supercomputers. By FY 96, however, distributed memory parallel systems may surpass traditional supercomputers.
in both performance and cost-performance. We expect to be well positioned with a variety of models to exploit that development if it occurs.

A.2 Growth in Storage Capacity - the Mass Storage System

NCAR's MSS is a central, large-scale data archive that allows users to store and access massive amounts of data both from main-frames and work-stations. Access from the MSS is at the file level. The MSS is a hierarchical system that currently has two levels of storage. The first level is an online cache that provides quick access to frequently referenced files. The second storage level provides offline for archival storage of files.

During the review period, the basic mass storage medium was upgraded to tape cartridges that each hold about 0.8 GB of data. This increased the capacity of the online cache to about 5 TB and the second storage level capacity to about 100 TB. This upgrade required replacement of all MSS tape drives. Fortunately, 100,000 MSS cartridges did not have to be replaced. However, they had to be rewritten at the new density, and this process took almost two years to complete. The robotic arm in the StorageTek online cartridge system was also upgraded from 160 cartridge mounts/dismounts per hour to 350 cartridge mounts/dismounts per hour. Also, during the review period, the MSS High-Performance Data Fabric was upgraded to High-Performance Parallel Interface (HIPPI). Staff members associated with this work are listed in section IX.B., under the High Performance Systems Section.

A.3 Networking and Data Communications Systems

For most scientists, desktop computers and/or departmental computers are the primary tools for software development and analysis of model results. We collectively refer to these systems as "user nodes," and they must communicate with other computing systems via networks in a distributed computing environment. Through the technologies of local area networks (LANs) and wide area networks (WANs), SCD has assimilated the user nodes into an integrated environment with the Cray Y-MPs and network servers of SCD.

A.3.a Local Area Networks

SCD is responsible for communication links throughout UCAR/NCAR's organizational units in the Boulder Metro area that support voice, data, and slow-scan video services (see Figure 7). Through a combination of Fiber Distributed Data Interface (FDDI), Ethernet, the Transmission Control Protocol/Internet Protocol (TCP/IP), other protocols, and network gateways, all NCAR/UCAR scientific and facility divisions enjoy full interconnectivity, including access to NCAR supercomputing facilities. This combination of FDDI backbones, Ethernets, and WAN links is known as UCARnet. SCD support for UCARnet is provided from UCAR indirect funds.
During the review period, an NCAR/UCAR Network Coordination and Advisory Board (NCAB) was formed in the spring of 1993. The NCAB reports to the director of SCD and is chartered to assist SCD with planning and management of UCARnet. The scope of the committee encompasses the performance and function of the network cabling plant and all associated network hardware. The NCAB has become a valuable part of the process to plan, install, and support state-of-the-art networking in UCARnet. Appendix B gives NCAB membership during the review period.

Figure 7
Sites Interconnected by UCARnet

During the review period, SCD refurbished the networking physical plant in the Fleischmann Building, most of UCAR North, and in most of Tower B at Mesa Laboratory. Twisted-pair wiring, coaxial cable, and fiber connectivity were provided to more than 300 data termination points. SCD also installed an extensive fiber plant on the FL site.

A3.3b Wide Area Networks

NSFnet and the NSF vBNS
For many years, NCAR was a backbone node on the NSFnet. During the review period, NSFnet was decommissioned and NCAR acquired commodity Internet service. NCAR also became a node on the new vBNS that interconnects all five NSF supercomputer centers (Figure 8).
**ATM Testbed**
During the past three years, SCD participated in two externally funded networking projects. The first was via U.S. West funding for a high-speed networking trial in the Boulder, Colorado, metropolitan area. This trial tested and evaluated a new distributed "access node" architecture employing asynchronous transfer mode (ATM) switching fabric running over OC3 fiber-optic links at 155 Mbps. ATM is designed to support voice, data, video, and multi-media communications with a wide range of bandwidths. This testbed gave SCD hands-on experience with ATM. This experience will be valuable since the NSF vBNS uses ATM and we will make extensive use of the vBNS (see B.1.c and B.3.d).

**CO-OP 3D Project**
Second, SCD and MMM were involved in the CO-OP 3D project, a distributed computing research project funded by ARPA. This project used the Advanced Communications Technology Satellite (ACTS) to set up high-speed data communication links between NCAR, the Ohio Supercomputer Center (OSC), and the Great Lakes Environmental Research Lab.

The goal of CO-OP 3D was to run a nested-grid, nonhydrostatic version of the Pennsylvania State/NCAR mesoscale model -- MM5 -- on NCAR’s CRAY YMP8/64 to model the atmosphere above Lake Erie with a grid spacing of 6-km/18-km/54-km (triple nests), while the OSC ran a 2-km MM5 model coupled with a 2-km lake model on OSC’s CRAY YMP8/64 in a two-way interactive mode. The 2-km MM5 model was nested within the 6-km MM5 model, and the coupling of information between them was exchanged in realtime via the ACTS using the Parallel Virtual Machines (PVM) message passing library. Interactive
visualization sessions were conducted at each site as the coupled models ran, and these visualization activities were shared between sites. CO-OP 3D was successfully demonstrated at the NCAR on the morning of September 13, 1995.

CO-OP 3D provided SCD and MMM with additional experience with PVM. Also, the project pointed out some serious flaws in the ability of PVM to interconnect geographically distributed systems. In fact, PVM had to be abandoned in some CO-OP 3D applications. This experience will be valuable to the plans for vBNS (see B.1.c). Finally, CO-OP 3D funded the purchase of project workstations and networking equipment that will be used long after the CO-OP 3D project is completed.

A.4 Distributed Servers

The use of distributed servers makes possible substantial economies in support and expansion of SCD facilities. By isolating functions to special network nodes, we can optimize each node for the function it provides, and can make changes with minimal disruption to other functions. These servers include a file server, the Text and Graphics System (TAGS), gateway and Internet servers, an electronic mail and news service, an information server, the domain name system, and a weather data server. Figure 9 illustrates SCD's current mix of servers and services.

**Figure 9**

**Distributed Servers and Services**

A.4.1 File Server

As the distributed environment evolves, options for storing files in various places across the network become more important. Distributed file spaces meet several needs for both university and NCAR users:
• Home directories provide permanent, long-term storage for a user.
• Project directories provide shared, long-term storage for groups of users.
• Temporary space provides short-term storage of files (which can be very large) that cannot be kept in home or project directories.
• Workstation software directories provide vendor and local software for use on workstations.

SCD’s main file server is an Auspex NS5000 Network Server that provides Ethernet-based Network File System (NFS) service to approximately 100 SCD diskless workstations and servers, the Cray computers, the IBM RS/6000 cluster, the SP-1, the Thinking Machines CM-5, the Sun front-end computer (named meeker), and many divisional systems. During the review period, we upgraded the Auspex host processors and added 10 Gbytes of disk storage.

A.4.b Text and Graphics Server (TAGS)

TAGS provides hardcopy output on film and videotape. During the review period, the TAGS batch video system was completed and made available to users for production output, as a complement to the interactive Visualization Labs at the Mesa Laboratory and the Foothills Laboratory. The video system allows users to produce animation sequences without requiring continuous user interaction. It supports VHS, SVHS, and Umatic-SP tape formats. University users often develop an animation on their workstation, then use TAGS to record it on videotape.

A.4.c Gateway and Internet Servers

The gateway servers provide batch-spooled access to SCD’s resources. Currently, there are two gateway access methods: the Internet Remote Job Entry (IRJE) system and the Mainframe and Server Network (MASnet) Internet Gateway Server (MIGS). These provide a buffer between the NCAR computing center and the rest of the world. They allow for unexpected disruptions in communications systems by monitoring network transfers and re-trying, if necessary, to prevent loss of information. IRJE provides a simple user interface based on FTP, and is primarily used by university users. MIGS provides a command-line interface with great flexibility and independence and is primarily used by NCAR users. MIGS and IRJE are used by over 600 SCD users. In a typical month, the MIGS/IRJE system services almost 66,000 user requests and moves more than 230 Gbytes of data. This amounts to over 90 requests per hour, and the data movement is equivalent to a sustained rate of six megabytes per minute, every minute of every day. Actual traffic to and from MIGS/IRJE is, of course, "bursty" depending on the time of day, the season, and other factors. During the review period, IRJE and MIGS were completely rewritten to improve robustness and efficiency.
A.4.d Electronic Mail and News Service

Electronic mail is supported by primary and secondary "central post office" systems. These systems understand the specifics of routing mail to the outside world, as well as delivering mail addressed to NCAR users using their full name or their SCD logon name aliases. This means that mail addressed to "user@ucar.edu" will be delivered regardless of the actual system on which the user reads his/her mail. Mail and news services are continually evolving and, thus, were continually enhanced during the review period. Also, a larger and more capable machine was installed to support this service.

A.4.e Information Server

SCD is now making most of its information available electronically over the Internet (see A.5.d., "Digital Information Design and Production"). The majority of this information is available via the WWW and is viewed with hypermedia-based, network information tools such as the Mosaic and Netscape browsers. SCD’s WWW address is: http://www.ucar.edu/scd.html.

During the review period, a single machine was dedicated to the support of WWW functions. In addition, Gopher, WAIS, Archie and other information browsers are available on this machine.

A.4.f Domain Name System

The Domain Name System (DNS) provides a lookup service that maps system names to network addresses. The primary DNS server resides on an SCD computer, and several secondary servers are defined in NCAR divisions. Delegation of the DNS authority to each NCAR division allows administrators to assign names and addresses for divisional systems. A global NCAR-wide list of hosts is constructed automatically from the DNS databases and is made available via anonymous FTP. During the review period, routine maintenance was performed on the DNS.

A.4.g Weather Data Server

SCD maintains and administers a Sun SPARCstation that runs Unidata software to ingest real-time weather products. FOS (Family of Services), HRS (High-Resolution Data Service), and satellite products from the University of Wisconsin are the primary data streams currently being received. Data includes station observations, gridded model products, and satellite images. The database is generally available to NCAR users who can access the data directly from SCD systems or have data forwarded to their own systems where a variety of products can be generated with Unidata software. Input data for this system is obtained via satellite transmission. The satellite link was switched from C-Band to Ku-Band in December 1994, and will likely switch to Internet in the near future.
A.5 User Support Services

User support services are provided by several SCD sections (see organizational chart in section IX.B.) and the following discussion is organized by SCD sections.

A.5.a Data Support Services (DSS)

DSS maintains a large, organized archive of computer-accessible research data that is made available to scientists around the world. There are now over 440 distinct datasets in the archive, ranging in size from less than 1 MB to over 1 TB. Growth of the archive during the review period is shown in Table 4:

<table>
<thead>
<tr>
<th>Date</th>
<th>Bit Files</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aug 1993</td>
<td>103,314</td>
<td>4.072 TB</td>
</tr>
<tr>
<td>Sep 1994</td>
<td>119,703</td>
<td>4.751 TB</td>
</tr>
<tr>
<td>Aug 1995</td>
<td>133,739</td>
<td>5.644 TB</td>
</tr>
</tbody>
</table>

The DSS staff provide assistance and expertise in using the archive and help researchers locate data appropriate to their needs. Many scientists use the data at their home institution; others access the archives directly via computers at NCAR. For example, during the period September 1993 through August 1994, the staff handled 441 requests for data to be sent off-site. The requests required reading 354 GB of information from the MSS (on 7,116 files) to select the 258 GB that was sent to users. Data were distributed on 262 1/2-inch tapes, 280 IBM 3480 cartridges, 260 Exabyte 8-mm tapes, 85 PC floppy diskettes, 35 CD-ROMs, and 82 FTP network transfers. DSS staff also assist scientists by providing data access programs (to read and unpack data), other software for data manipulation, and dataset documentation.

Users may also obtain copies of data by network access. The DSS online information system was developed during the review period and continues to grow and improve. Over 2,066 different sites accessed the system during June 1995. The system contains information on all datasets in the archive, catalogs for DSS and other archives, and general documentation and software. It may be accessed at its WWW address:  http://www.ucar.edu/dss/index.html.

DSS highlights during the review period include:

- **NMC/NCAR Reanalysis Project.** This huge project will result in 40 years of new analyses of old data. The production at the National Meteorological Center (NMC) started in June 1994, and 12 years of analyses will be completed by September 1995. NCAR is providing all types of surface and upper-air input data. NCAR will
archive and redistribute the NMC reanalyzed data as it becomes available. DSS staff members are collaborating with NCAR's Climate and Global Dynamics (CGD) division on this project. (section IX.B. gives the names of staff members within the Data Support Section).

- **Satellite Data.** Major archive additions included TOVS and GAC data from NOAA Polar Orbiters and data from GOES and METEOSAT geostationary satellites. Much of this work is supported by the NOAA/NASA Pathfinder program.

- **Climate Change Impact Studies.** DSS continues to support the U.S. Country Studies Program (established by the President) and provided support for the IPCC Working Group II climate change studies. DSS has set up an archive of climate model products for these studies and for general use. In Country Studies, about 55 countries use these data to study the effect of climate change on crops, rivers, forests, lakes, etc.

- **CD-ROM project.** In collaboration with the University of Washington, DSS published a CD-ROM on the Northern Hemisphere NMC gridded analyses for the period 1986-89.

- **Ocean Data.** Work on COADS reached a major milestone. COADS Release 1a, which contains global ocean data for 1980-92 and is produced in cooperation with NOAA, was completed, and over 60 copies have been distributed worldwide.

A.5.b Computational Support Services (CSS)

The SCD Computational Support Section (CSS) provides state-of-the-art expertise in numerical algorithms, mathematical software, model translation and implementation for parallel architectures, and performance measurement of computers. This expertise is available via consulting, publications, software development, training, and collaborations. The section also handles the administration of SCD's allocation process.

**CHAMMP Interagency Organization for Numerical Simulations**

During the review period, CSS staff members Paul Swarztrauber, Richard Sato, Steve Hammond, and Rich Loft participated in the DOE CHAMMP Interagency Organization for Numerical Simulations (CHAMMPions) project, which is funded in part through the DOE CHAMMP initiative. CHAMMP is intended to provide the technological advances required to support the development of an atmospheric circulation-simulation system on parallel supercomputers. The CHAMMPions project, which was initiated in the spring of 1990, is one component of the CHAMMP effort to develop an advanced climate model with throughput capability significantly greater than that of current models.
Interdisciplinary teams at each of three national research institutions, Oak Ridge National Laboratory, Argonne National Laboratory, and NCAR jointly perform research in three related areas: advanced numerical methods, model development, and parallel software tools. Results of the project are reported to the research community via research papers, parallel algorithm libraries, software tools, and parallel implementations of atmospheric circulation models. CSS collaborated with NCAR's Climate and Global Dynamics (CGD) division on portions of this project. CSS publications related to CHAMMP may be found in Appendix A.

CSS highlights from the review period included:

- **Data Parallel Implementation of the NCAR CCM2.** The data parallel implementation of the NCAR CCM2 was completed on the CM-5. This is the first data parallel, comprehensive three-dimensional global atmospheric model to have been developed. (CSS worked closely with scientists in NCAR's Climate and Global Dynamics (CGD) division as work on the code progressed.) The parallel code is fully compliant with the most recently released production version of CCM2. The parallel model has completed a series of validation tests designed to assess its correctness.

- **FFTPACK 5.0.** FFTPACK is a Fortran 77 library of two- and three-dimensional fast fourier transforms (FFTs) developed by Paul Swarztrauber and Richard Valent. These new routines were written in response to user requests for a complete, uniform package of multiple-dimension FFTs.

- **PVM (Parallel Virtual Machine) 1D CCM2 Decomposition.** In addition to development of a data parallel version of CCM2, CSS personnel also assisted in the development of a "generic" one-dimensional decomposition version of CCM2 that runs effectively on distributed memory MPPs and that uses the PVM library for interprocessor communication.

- **ACE Benchmark Suite.** As part of procuring a new supercomputer to be used in the NCAR ACE, CSS developed the ACE benchmark suite. The benchmark suite consists of 13 kernels and three complete geophysical simulation codes. The kernels measure specific aspects of system operation, such as accuracy of intrinsics, memory-to-memory bandwidth, processor speed, memory-to-disk I/O rates, and HIPPI transfer rates. The three applications are run at multiple resolutions as specified. Together these codes give a comprehensive measure of the capabilities of a computer system with respect to NCAR's computing environment as well as a computer system's performance under the anticipated computational load in ACE.

### A.5.6 Operations and Information Support

The SCD Operations and Information Support Section is responsible for the continuous operation of the NCAR computer center and supporting the use of...
information technology for SCD and NCAR. Operations staff are present 24 hours a day, 365 days a year. In addition to operating and monitoring computer systems, the staff are also responsible for monitoring the many electrical and mechanical subsystems required to support the needs of the supercomputer center. When any type of failure occurs, they notify the proper personnel and contractors to remedy these situations and monitor repairs.

The Information Technology Support Group, formed in November 1994, applies information technologies to solve problems and increase efficiency for SCD, the NCAR director's office, and SCD computer users. Information technologies supported by the group include relational and distributed databases, 4th generation programming languages, rapid application development (RAD) tools, and personal computers and their associated networks. The group also manages UCAR/NCAR site-licenses for many products on a variety of platforms, user accounts for the SCD computing facility, and NCAR Graphics licensing and distribution.

Operations highlights during the review period included:

- **MECCA Data Analysis.** During the conclusion of the MECCA Numerical Laboratory, enormous amounts of data were processed, calling for the mounting of many thousands of tape cartridges. During November 1993, Operations staff mounted 59,692 cartridges, and during December 1993, they mounted 65,731 cartridges.

- **Computer Room Equipment Upgrades.** To accommodate future needs for increased cooling capacity in the computer room, SCD, in collaboration with Facilities Support Services (FSS), has extensively upgraded the SCD chilled water system. Enhancements include a new 500 ton cooling tower, a new 215 ton chiller, and new condenser water pumps. This increase in cooling capacity, along with piping configuration changes, gives us the ability to operate the computing center on either the SCD cooling system, or the Mesa building system. This capability also represents an appreciable reduction in the amount of downtime required for preventative maintenance each year, as many maintenance procedures can now be done without interruption of the computing facility's operation.

A.5.d Technical Support and Development

As the primary point of contact for the user community, the Technical Support and Development Section delivers an integrated program of digital, multimedia information services, expert consulting, and software tools designed to assist users in improving their computational productivity and in increasing the cost-effective use of computing resources. This is achieved through four functional groups within the section: Technical Consulting (including mathematical and statistical software support), Digital Information design and production, Visualization, and NCAR Graphics development.
Technical Consulting
The Technical Consulting Group provides a centralized point of reference for receiving and resolving technical user problems, advising users on optimal programming techniques, recommending documentation for SCD's computing facilities, and channeling needs expressed by users into SCD's planning process.

In FY 94, an average of 450 user contacts per month were processed. A "contact" is defined as a user contact with a Consulting Office staff member, whether by phone, by e-mail, or in person (walk-in). One contact may involve more than one question and may often require additional research and follow-up. On average, over 95% of contacts are resolved on the day they are received. This service is often applauded by SCD users (see User Survey, Appendix D).

The closeness of the consultants with user problems provides opportunity to help users optimize models. This involves the use of tools to analyze programs in order to pinpoint critical areas that would benefit from various optimization techniques. It is not uncommon to see performance increases of several hundred percent through this service. Also, consultants help SCD software developers evaluate user interfaces and test functions of new software before it is released for general usage.

Math and Software Libraries
The SCD-supported applications software contains over 8,000 subroutines and functions, spanning 24 mathematical libraries. Requests for new software are given priority according to overall usefulness, quality of software, cost, and effort required to support the product. SCD provides both an online database with documentation for most of the mathematical software and source code for the nonproprietary libraries (see http://www.ucar.edu/ SOFTLIB/ mathlib.html). During the review period, SCD upgraded these libraries and assisted users in the application of them.

Digital Information Design and Production
SCD established NCAR's first World Wide Web (WWW) server (http://www.ucar.edu/). During the review period, we moved toward supplying and distributing all of our user documentation and other information online via the World Wide Web. We created a hypertext version of the SCD Information Resources Catalog that permits users to directly access the document they seek and produced an online, multimedia version of our newsletter, SCD Computing News, as well as the SCD Technical Brochure and information on charges for SCD computing resources. In addition, SCD created a "New User Information" branch of our online information system (http://www.ucar.edu/ newuser.html). It contains documents organized by computing system to allow users to quickly find help on the system they are using. The Information Resources Catalog is at: http://www.ucar.edu/docs/SCD_Catalog/catalog.html and the Newsletter may be viewed at: http://www.ucar.edu/docs/SCD_Newsletter/directory.html.
We contributed to the institution-wide efforts to improve the exchange of electronic information within NCAR and between NCAR and NSF by more widely publicizing Internet tools such as anonymous FTP, e-mail, and the WWW.

SCD documentation staff have received peer recognition and various awards in the Technical Publications and Art Competition of the Rocky Mountain Chapter of the Society for Technical Communication.

Visualization
Animation is widely used in scientific research, and SCD provides both batch and interactive facilities for the production of high-quality animations. The TAGS system provides batch video printing. A user simply sends digital imagery to TAGS in any one of several formats, including Computer Graphics Metafile (CGM), and receives back the finished videotape. Users who require high-performance exploratory animation, or the ability to produce more elaborate scientific video presentations, can do so interactively using one of SCD's two Visualization Labs -- one at the Foothills Lab and one at the Mesa Lab.

The Foothills Lab facility is a production, self-service lab used directly by scientists and their support staff to master single-frame animations and live visualizations to LaserDisc and professional Betacam-SP tape. The Mesa Lab visualization lab is a state-of-the-art facility supporting R&D in the areas of visualization of very large datasets, volume visualization, distributed visualization, digital media development, High-Definition Television (HDTV), advanced visualization environments including virtual reality technologies, and the application of advanced networking technologies. Thus, the Mesa Lab visualization lab provides focused support for special projects such as MECCA, HPCC, CO-OP 3D, and CSL. More detailed information about the two visualization labs may be found at: http://cyclone:7777/vidg/VisLab.html.

One of the most notable accomplishments with the Mesa Lab visualization lab involved an HPCC-funded activity. Don Middleton and John Clyne worked closely with personnel at the University of Colorado School of Medicine to visualize a digitized radiologic and photographic three-dimensional dataset of a male human cadaver. Termed the Visible Human Project, this effort seeks to combine visualization with the dataset for use in teaching and research.

The associated imagery has drawn a lot of attention and has appeared in several national news media. In particular, SIGGRAPH (the premier graphics and visualization conference typically attended by 30,000 to 40,000 people) runs an electronic theater; material to be shown is chosen via a peer review process. A video of the Visible Human was one of 70 animations selected (out of a field of over 400) for showing at the SIGGRAPH-95 Electronic Theater in Los Angeles this August. Past electronic theaters have included clips from "Terminator 2," "Forrest Gump," and NCSA's "Numerically Modeled Thunderstorm."
NCAR Graphics
NCAR Graphics is a software package that offers continually evolving graphics capabilities tailored to the needs of the atmospheric research community. It has been widely used in science and engineering for 20 years. The popularity of the package is due to the care developers have taken to ensure real-world utility through routines that can handle irregular data such as nonlinear spacing and missing data; backward compatibility with the support and maintenance of over 500 low-level plotting routines for legacy code; and portability through adherence to recognized standards and source code availability.

NCAR Graphics accomplishes platform flexibility by producing output based on popular industry standards such as PostScript and CGM. This allows users to import NCAR Graphics plots into non-NCAR visualization tools that run on Macintoshes, personal computers, and UNIX systems.

Completion of Version 4.0 of NCAR Graphics was a major accomplishment during the review period. The package contains multiple interfaces to accommodate diverse user skill levels and application needs. Many tools come bundled with the distribution to perform such functions as viewing and editing metafiles, creating animations, converting between raster formats, resizing and compressing raster images, and zooming on images.

The NCAR Graphics package is now being used at over 1,500 sites worldwide. Version 3.2 was released in the summer of 1993, and Version 4.0 was released in September of 1995. NCAR Graphics is made available to universities on favorable terms and is widely used by them. For example, during the review period, Version 3.2 was installed at 124 U.S. universities and 107 foreign universities.

B. Future Plans

Following the outline of Section A, SCD’s plans are grouped with respect to high-speed computing, mass storage, networking, distributed services, and user support services. However, this discussion is limited to plans for major and/or new activities. Evolutionary advances are not discussed.

B.1. High-speed Computing

During FY 96-98, SCD will focus on enhancing community computing resources, enhancing the CSL, and developing a distributed CSL.

B.1.a Enhancing Community Resources

While the growth in computing capacity shown in Figure 2 is substantial, it is less than the capability of state-of-the-art equipment. For example, a fully configured Cray 90 is equivalent to 40 Y-MP processors. A fully configured Cray T90 will be equivalent to 160 Y-MP processors.
**Short-term Enhancement**

Due to a combination of underutilization and technological obsolescence, in early FY 96 SCD will decommission the RS6000 cluster and the IBM SP-1 (see Figure 9, below). We may also decommission the CM-5, subject to availability of non-NSF funding to support it. To compensate for this loss of capacity, in early FY 96 we will install a Cray Research J908 with eight processors and 0.5 gigawords of memory. The J908 provides a high degree of compatibility with the Y-MP8. It will also provide a large memory - an asset that was frequently requested in the FY 95 user survey. The combined capacity of the Y-MP8 and J908 will be about 7,000 equivalent Y-MP hours per month.

Four of the questions in the user survey which showed a dissatisfaction level above 10% involved concerns about turnaround time for batch jobs or interactive response time. SCD believes its plans to add the Cray J908 will ease most of these concerns.

**Figure 10**

Functional Diagram of SCD Computing Facility/FY 96

![Diagram of SCD Computing Facility/FY 96](image)

**Long-term Enhancement**

Development and use of complex mathematical models have become central to nearly every realm of geoscience research. Progress in weather prediction theory, climate studies, severe storms research, ocean circulation, solid earth dynamics, and the solar influences all require such models (see Appendix D for related comments from the User Survey). In addition, the amount of environmental data available for modeling and for new knowledge will grow over the next decade by several orders of magnitude. To sustain progress in the geosciences and to meet the data challenge, four key technology components are required. They are:
• Supercomputers
• Copious data storage archives
• Powerful, software-rich workstations
• Very high-speed networks connecting NCAR with academic researchers and other centers throughout the world.

Annual debt service and maintenance for the community Y-MP is $4.5 million, and the last payment on the debt will occur in FY 97. Approximately $4.5 million of CSL funding is committed to the lease of computing equipment, and this may increase to $8.5 million by FY 97 (see section B.1.b). Thus in FY 98, the $4.5 million of annual debt service for the community Y-MP can be combined with CSL funding to create a substantially more capable facility for support of both the CSL and the general community. Our Request for Proposal for CSL enhancement invites bidders to include a five-year offer in which the associated equipment would support both the CSL and the community beginning in FY 97 (or even earlier).

The combined funding discussed in the preceding paragraph will not be adequate to meet the major computational needs of the atmospheric sciences over the next decade. Consequently, the ATM Division of Geosciences has formulated an Atmospheric Sciences Multi-user Facilities Proposal to the NSF Major Research Equipment Initiative. That proposal requests the following additional funding to support the long-range computing requirements of the atmospheric sciences:

<table>
<thead>
<tr>
<th></th>
<th>FY 97</th>
<th>FY 98</th>
<th>FY 99</th>
<th>FY 2000</th>
</tr>
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<td>$25.0M</td>
<td>$10.0M</td>
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If funding is not available from the NSF Major Research Equipment Initiative, then we will have a total of approximately $9-13 million per year for lease of equipment with which to support both the CSL and the broader atmospheric sciences community. Based on our projections and current trends in high performance computing technology, we estimate that $9-13 million per year will lease equipment that can sustain 20 to 30 Gflops by FY 98. If the NSF Major Research Equipment proposal is funded, then we should be able to lease equipment that will sustain about 40 to 60 Gflops by FY 98.

**B.1.b ACE Enhancement**

Beginning in FY 95, approximately $7.5 million of CMAP funds have been allocated for the CSL. NCAR will commit $1.1 million of its HPCC base funding to the ACE throughout FY 95-97. NCAR has also committed $1.0 million of one-time funding to the acquisition of new ACE equipment. The combination of these
funds makes possible a substantial upgrade to the ACE in FY 96 (approximately $4.5 million/year will be spent on new equipment). This additional computing capability is being acquired via an open, competitive procurement. Upon completion of this acquisition, we expect that ACE computational capability will be two to three times the 2.5 Gflops available in FY 95.

Once new equipment has been selected, a second announcement of opportunity to use the CSL will be issued, proposals evaluated, and new allocations made. Of course, installation and integration of the new equipment in ACE will require a great deal of work by SCD personnel.

The equipment being obtained by this procurement will have at least 0.5 gigawords of memory and up to 32 processors. Installation will probably occur in the second half of FY 96. To help CSL users develop models that can exploit these capabilities, in early FY 96 SCD will upgrade the ACE Cray J9 to 0.5 gigawords of memory.

B.1.c Distributed CSL (DCSL) Project

In FY 95, NSF established an "Opportunity Fund" that provides one-time funding of activities that might develop into new NSF strategic initiatives. NSF Directorates and Divisions compete for awards from the Opportunity Fund in a very fast track proposal process. Since the GCRP and HPCC research programs are two high-priority endeavors of the NSF, the Geosciences (GEO) and the Computer, Information, Science and Engineering (CISE) Directorates submitted a proposal to carry out a Distributed CSL (DCSL) project. The proposal was funded at $2 million split equally between GEO and CISE.

The NSF Opportunity Fund Award enables GEO and CISE to pursue the vision of enabling, for the first time, explicit collaborations between the GCRP and the HPCC in the area of distributed, high-performance computing. Specifically, the DCSL project will explore a potentially powerful climate modeling capability by utilizing the following emerging GCRP and HPCC assets within NSF:

- The NCAR CSL which is funded by the USGCRP and the HPCC;
- The NCAR Climate System Model (CSM) which is funded by the USGCRP and NCAR's base program, and uses message-passing technology to communicate fluxes among major model components that are running concurrently either on the same computer or on several computers linked by high speed communications;
- The NSF experimental (vBNS) which is funded by HPCC;
- One or more of the CISE supercomputer centers, which are funded by the HPCC;
- Other GEO/CISE assets such as mass storage and visualization systems.

The DCSL project will consist of two components: DCSM and LDT.
Distributed CSM Project
We plan to distribute the NCAR Climate System Model (CSM) between the NCAR CSL and the San Diego Supercomputing Center. We will refer to this as the Distributed Climate System Model (DCSM Project). All model output will be transmitted to NCAR and stored on a high-performance shared file system. Our primary objective will be to evaluate the potential of using all or most of the NSF metacenter high-performance systems to provide the amount of computing power required to undertake climate simulations that are simply impossible on any single computing system. We plan to assess this potential by carrying out a four-phase project (spanning FY 96-97) that builds on the aforementioned assets and culminates with "real science" climate simulations. These experiments will require the storage and distributed visualization of the associated model output data. The DCSM objectives are:

- To assess vBNS performance for model component intercommunications;
- To assess vBNS stability for production runs;
- To assess vBNS performance in support of transmission of model output data to NCAR;
- To assess the performance of a high-speed shared file system relative to the task of storing large model output datasets and making them available for postprocessing, visualization, and remote access;
- To develop and demonstrate high-performance distributed visualization of model results;
- To develop job management software to temporarily create a meta-computer which can run reliably and predictably in a production environment.

Large Dataset Transport (LDT) Project
Also under the Opportunity Fund Award, SCD will collaborate with the Pittsburgh Supercomputing Center (PSC) in exploring the potential of the vBNS to transport and visualize very large datasets (e.g., 25-100 Gbytes). We refer to this as the Large Dataset Transport (LDT) Project. Specifically, we plan extensive use and assessment of the vBNS in support of an HPCC Grand Challenge Turbulence Project.

The HPCC Grand Challenge Turbulence Project, led by J. Toomre (University of Colorado), J. McWilliams (University of California at Los Angeles /NCAR), J. Herring (NCAR), and P. Woodward (University of Minnesota), is similar to the DCSL Project in that large volumes of data are computed at various sites (notably PSC), and must be transported afterwards to the researcher's home site for analysis and visualization. Typical dataset sizes for a single integration currently range from 25 GB to 100 GB, and the researchers employ volume visualization processes both interactively and in batch mode to study the formation of coherent structures in the simulated fluid flow. SCD, PSC, NSF Atmospheric Sciences Division, and CISE are planning to develop a prototype large-dataset transport capability between
PSC and NCAR using the vBNS. If sufficient success is achieved, the knowledge gained can be used to develop a generic capability. In addition, SCD hopes to explore using the vBNS for remote, interactive visualization of the simulation data as well.

**Overall Benefits from DCSL**

Our plan for long-term enhancement of community resources (Sect B.1.a) includes high-speed networking between SCD and university atmospheric science departments. DCSL will help define and scope the associated functionality. A secondary benefit of DCSL will be ATM connectivity between the Mesa and Foothills Laboratories.

**B.2 Mass Storage System Plans**

While some of the data (about 10%) stored on the MSS originate from field experiments and observations, the bulk of the data are generated by global climate-simulation models, and SCD faces an increasing demand to archive data from ever-faster supercomputers. As evidenced in Figure 4, the more computing capacity we have, the more data there are to be archived.

Thus, in FY 96, FY 97, and FY 98 we plan to use $1.5 - 2 million per year of CSL funds to upgrade the MSS. In FY 96-97, we will:

- Upgrade the MSS controller (currently an IBM 3090) to a more powerful system;
- Replace the disks used in the MSS file directory;
- Increase high-speed connectivity to the MSS;
- Install new robotic technology tape.

These devices and media will provide about a factor of ten increase in storage density and a factor of three increase in data transfer rate. Combined with a new robotic library, an on-line tape library with a capacity of ten terabytes will be deployed. This library will be expandable to 30 terabytes. Total shelf capacity of the MSS will increase from 100 terabytes to 1000 terabytes (one petabyte).

In FY 96, we will start the process of migrating over 60 terabytes of data in the SCD open shelves from the current media to the new media. This migration will take up to five years to complete. Also, in FY 96-98, we will develop MSS Version IV, which will use the UNIX operating system. MSS IV will have a much improved user interface, greater security, and independence from the IBM MVS operating system.

**B.3 Network and Communications Plans**

SCD is underway with four major projects:
B.3.a Local Networks

The Mesa Lab Network Access Completion project encompasses all work necessary to upgrade the network access infrastructure at the Mesa Lab. The MLNAC project addresses network access for the north tower (Tower A), the first basement (1B), the library, and the public meeting rooms and public hallways. The south tower (Tower B), the second basement, and the Fleischmann Building have already been upgraded. The project includes all work required to complete the mechanical, wiring, termination, and equipment installation. The phases of the project will involve physical installation, testing, configuration, and activation of the network.

B.3.b Security Proxy Server

Several divisions, including SCD, have been attacked by hackers who have obtained root access to our systems. While hackers have yet to do any significant damage, SCD will take the lead in exploring options to provide a higher level of security for NCAR computing resources, starting by increasing security to SCD's resources.

One option is to prohibit any direct Internet access to critical systems. All access from the outside would have to go through one of the gateway hosts first and use either the IRJE system (for batch jobs or file transfers), or a proxy server (for interactive or FTP sessions). A proxy server is invoked by connecting to the gateway host, not the destination host. The user is then authenticated to the proxy server, and only then is a connection passed through to the destination host. Once the user has been authenticated by the proxy server, the user may then freely use SCD's resources from "inside the firewall."

Raising the level of security as proposed could adversely affect all external users and some UCAR/NCAR organizational components. So implementation will only be undertaken after discussion/coordination of the plan by appropriate groups.

B.3.c External Networks - vBNS

As discussed in section B.1, we plan extensive use and assessment of the vBNS in the DCSL. We will also upgrade the Commodity Internet Service to full T3 and then to OC3 speeds.

B.3.d National Laboratory for Applied Network Research

As the infrastructure of high-speed networks evolves, the NSF has funded its supercomputing centers to collaboratively undertake network research activities, apply them to leading-edge networks, and help drive the evolution. For this
collaboration NSF created the National Laboratory for Applied Network Research (or NLANR). The initial set of participating organizations are:

- Cornell Theory Center (CTC)
- National Center for Atmospheric Research (NCAR)
- National Center for Supercomputing Applications (NCSA)
- Pittsburgh Supercomputing Center (PSC)
- San Diego Supercomputing Center (SDSC)

This collaboration is aided by the availability of NSF's vBNS, a national network research vehicle that the centers connect to, and that is to be used by NSF-approved high-end applications.

NLANR expects to undertake a mission and work scope encompassing a range of activities in support of the network evolution: facility resources, information acquisition, collaboration environments, Internet traffic flow characterization, and operational network statistics prototype systems.

### B.4 Distributed Computing Services (DCS) Project

The DCS Project is an effort aimed at facilitating the use of SCD-provided computing resources (e.g., computational platforms, mass storage, special-purpose printing, etc.) by developing and deploying intuitive, platform-independent, standards-based user interfaces. Like many supercomputing centers and laboratories, SCD's computing resources are often made available to the user through a variety of locally developed, legacy (historical) software systems, many of which unfortunately have little in common with the interfaces found on today's industry-standard open systems. By providing uniform, standards-based User interfaces to SCD core resources, the DCS project will enable new, as well as seasoned, users to leverage their existing experiences and greatly facilitate computing at NCAR, while reducing the staff effort needed to maintain the present environment. Redundant and nonstandard interfaces are one problem. Another is the lack of functionality on all SCD computing systems, as well as the lack of key interface features which are expected by the user. Examples of the latter include robust error reporting and the ability to obtain job status. These deficiencies are generally attributable to the legacy, machine-and-vendor-dependent, network infrastructure upon which SCD's interfaces were originally developed. Thus, a secondary goal of the DCS project is to create an infrastructure that will be independent of underlying networks, mass storage environments, and computing platforms, and that will provide a cost-saving, network-secure, easily managed, state-of-the-art distributed computing foundation upon which these and future services may be layered.
B.5 User Support Services During FY 96-98

B.5.a Data Support

DSS plans for FY 96-98 include five major projects. Each is described briefly below.

The Reanalysis Project
The goal of the Reanalysis Project is to produce the best possible set of global observed data and a complete set of analyzed fields from the analysis/forecast system. Many of the input datasets come directly from the DSS archive and others are being obtained specifically for this project. They consist of the NMC operational data archive augmented by other sources, including satellite sounders from NOAA, station observations from the original collecting countries, ship observations from the COADS project, sets collected by other special projects, and older historical sets extracted from archives and processed into usable forms. The Reanalysis Project uses these data as input into a current state-of-the-art data assimilation system to produce a consistent set of analyzed fields.

The products of this project will be put to many uses. The observed data can be used for input into a total rerun of the analyses when progress in techniques justifies rerunning the data assimilation. They will also be used for initializing other modeling projects and should be a more complete set for various other research projects which currently use the operational collection. The analysis output products will be invaluable for model verification, initialization of other models, climate studies, case studies, surface forcing of ocean models, and studies in many fields which require atmospheric conditions for input.

The reanalysis project is scheduled for completion by mid-FY 97. The 40 years of reanalyzed output (about 2.2 terabytes) will be archived at NCAR. DSS will develop a number of archive products to help make this set more accessible. They will be inventoried, documented, and distributed via the Internet, CD-ROMs, and Exabyte tapes.

The Country Studies Program
DSS will continue to support the efforts of 55 countries to study the effects of climate change on their countries (crops, forests, etc.). DSS will prepare more climate model data from worldwide modeling groups, prepare guidance texts, and produce a CD-ROM of model products.

Mesoscale Data Bank for GCIP
Because of DSS experience in handling model data, DSS has been asked to archive high volume output from three mesoscale models (NMC, Forecast Systems Laboratory, and Canada). DSS currently archives about 20 years of 190 km-resolution regional grid data.
CD-ROMs for University Use
The universities have asked DSS to prepare several CD-ROMs with selected gridded and station data. CD-ROMs have been very popular with users.

Enhancing the UCAR and NCAR Data Services Infrastructure
Beginning in FY 96 and via funding from NSF's Information Infrastructure Technology Applications (IITA) initiative, SCD will work with ATD and Unidata in a 33-month effort to increase the coherence of data services and related efforts across all of UCAR as viewed by users, and to do so with methods that can be applied outside the organization, especially at universities engaged in producing and managing data. This project will produce:

- A user-oriented, UCAR-wide view of available data services by exploiting World Wide Web and related technologies, such as search engines;
- Capabilities for systematic access to real-time data needed in many UCAR/NCAR organizations. These capabilities also will help disseminate to the university community real-time data collected by certain groups in UCAR/NCAR;
- Enhancements to the netCDF software --- a data access library that potentially can improve the usefulness of data stored in one context, such as a supercomputer model, and retrieved in another, such as a visualization system;
- A series of workshops on future methodologies that will help UCAR/NCAR data services evolve to exploit advancing technologies and to maximize service to users.

The effort is designed to strike an appropriate balance between the desire to create a coherent, institution-wide view of data services and the need to maintain divisional and programmatic independence, as manifest in distributed responsibilities and data holdings. Lessons learned and methods developed in the UCAR/NCAR context will benefit a larger community of scientists whose work can be enhanced by the national information infrastructure, properly applied.

B.5.b Computational Support Services

A New General Circulation Model
Personnel from SCD, the NCAR Atmospheric Chemistry Division, and Los Alamos National Laboratory have formulated a proposal to construct a comprehensive General Circulation Model (GCM) coupled with an equally impressive chemistry package. Principal objectives in this proposal are:

1. To use a numerical technique and an icosahedral grid technique for the model dynamics that are scalable and particularly well suited to spherical geometry;
2. To use a state-of-the-art chemical module, including chemistry currently thought to be important for representing the ozone photochemistry of the middle atmosphere;

3. To use the physics modules from the Climate System Model version of the NCAR community climate model;

4. To benchmark and evaluate state-of-the-art, highly parallel systems using a comprehensive set of kernels developed at NCAR for the evaluation of supercomputer platforms.

We believe that these ingredients will enable, for the first time, truly scalable high performance atmospheric chemistry simulations capable of achieving high efficiency on the most advanced parallel computers available.

**Climate System Model**

CSS is taking a leadership role in the planning and implementation of software and machine resource strategies in the climate system model. Our particular responsibilities include the development and support of intermodel communication strategies which support the climate system model project. CSS, in conjunction with other SCD sections, is trying to develop strategies and software implementing those strategies which will schedule and manage computing resources of CSM jobs running across several machines.

**CSS and CHAMMP**

CSS will primarily focus on coupling the data parallel versions of CCM2 and a parallel version of an ocean model (termed POP). To accomplish this, software engineers in CSS will update the data parallel version of CCM2 to be consistent with the new atmospheric model adopted by the NCAR CSM. Then, CSS will evaluate conversion of existing Fortran 77 code to Fortran 90 to enhance future portability of the CCM and the flux coupler. In particular, we will take advantage of user-defined types, dynamic memory allocation, standardized pointer, array syntax, and the rich set of intrinsic functions available. This will significantly reduce the differences between the data parallel version of CCM2 and the parallel multi-tasked Cray version of CCM2.

As part of the DOE CHAMMP program, a workshop on "Numerical Methods for Computing Fluid Flow in Spherical Geometry" will be held in Breckenridge, CO, June 11-14, 1996. This is the fifth in the series of meetings which have been hosted on a rotating basis by Argonne National Laboratory, the National Center for Atmospheric Research, and Oak Ridge National Laboratory. From NCAR the program committee has representatives from both SCD and the Climate and Global Dynamics (CGD) Division.

Finally, a new numerical approximation system will be explored for application to global geometry. In this system, the equations are reformulated in the Cartesian
coordinate system where the pole problem and restriction of time step due to the clustering of grid points near the pole do not exist. This research will be conducted by Paul Swartztrauber and other members of the CSS technical staff.

B.5.c Technical Support and Development

NCAR/SCD Visualization Labs
As noted in Section B.1.c, the ML Visualization Lab will play a critical role in both components of the DCSL project. The CSM project will continue to use it and proposals are planned to fund continued use by the Visible Human Project.

Current plans call for an upgrade of the lab's SGI Onyx in the FY 96 time-frame. This will include an expansion of the disk array to 100 Gbytes, an increase in main memory to 512 Mbytes, an upgrade to a Reality-Engine-3 graphics subsystem, and additional scientific visualization/analysis software. Funding permitting, a high-resolution (possibly HDTV) digital video peripheral will be integrated into the lab's video plant.

NCAR Interactive Graphics
The SCD User Survey (see Appendix D) shows that many users want substantial improvements made to NCAR Graphics. While we believe that Version 4.0 (see Section A.5.b) will satisfy many of those needs, additional enhancements will have to be made during FY 96-98, e.g., the graphical user interface (GUI). We plan to continue providing NCAR Graphics at favorable cost.

Expansion of uses of WWW Technologies
The Digital Information Group will continue to monitor and make use of the evolving server/client technologies that are driving the expansion of multimedia information distribution over the WWW and the Internet. In particular, the group will enhance current capabilities by using the next generation of interactive, online documentation authoring tools and provide an expanded list of other information services to the university community, NCAR, and UCAR.

Technical Consulting will make expanded use of WWW technologies - particularly in the areas of Frequently Asked Questions (FAQs) via "ConsultWeb" - a new online feature being developed by the group.

C. Equipment

Because equipment is such an integral part of the nature of SCD's mission, all plans for equipment have been incorporated into the detailed plans described above.
IV. Linkages to Other Groups

SCD collaborations with other groups include:

- the Climate Systems Model Project in CGD (see B.5.b, page III-35)
- working with UNIDATA and ATD to enhance the UCAR and NCAR data services infrastructure (see B.5.a, page III-33)
- the CO-OP3d Project with MMM and Ohio Supercomputer Center (see A.3.b, page III-15)
- the DOE CHAMMPions Group (see A.5.b, page III-20)
- the San Diego Supercomputer Center (see B.1.c, page III-28)
- the Grand Challenge Turbulence Project and the Pittsburg Supercomputer Center (see B.1.c, page III-29)
- National Laboratory for Advanced Networking Research (NLANR) which includes all NSF supercomputer centers and is funded by NSF (see B.3.d, page III-31)
- the University of Colorado Medical School Visible Human Project (see A.5.d, page III-24)
- the SCD Advisory Panel which represents university users (see Appendix B)
- the CSL Allocation Panel (see Appendix B)
- the IMAP (see A.1.c, page III-11)
- various internal advisory groups (see Appendix B.)
- the IEEE/ACM annual Supercomputer Conferences
- the IEEE Mass Storage Working Group
- our primary suppliers of equipment, e.g. Cray Research, IBM, StorageTeK, etc.
V. Education, Training, and Knowledge Transfer

V.1 Educational Activities

SCD’s educational activities emphasize computing and information technologies. Our educational activities during the period include:

- Hosting the Colorado High School Computational Science Fair;
- University classroom use of the CM-5 and Y-MP8;
- Participation in the UCAR Summer Employment Program;
- Training activities and conferences

Colorado Computational Science Fair

SCD cosponsored and coordinated the Colorado Computational Science Fair (CCSF) in April 1994, as well as May 1995. The NCAR Mesa Lab served as the host site for both of these high-school competitions. For the 1994 CCSF, 87 students from the state of Colorado entered 26 projects into the contest; in 1995 these numbers increased to 99 students entering 45 projects.

The CCSF is intended to serve as a supercomputing/information technology competition for the entire state of Colorado. Projects were submitted in four categories: (1) computational science, group projects, (2) computational science, individual projects, (3) visualization, and (4) information technology. In 1995 so many projects were submitted in category (1) that it was split into two groups: (1a) chemistry and biological sciences and (1b) physics and mathematical sciences.

For the 1995 fair, strong emphasis was placed on networking, modern visualization techniques, and the WWW capabilities. Students were encouraged to generate and display computer visualizations in addition to their posters. Abstracts were accepted and displayed on the WWW at NCAR. Network connections were made available to the students and most of the projects made use of these facilities.

With the success and growth of these two years of sponsorship, SCD plans to host the CCSF in 1996, where more direction toward electronic, leading-edge media will be offered and encouraged.

University Classroom Use of the CM-5 and Y-MP8

During the review period, modest amounts of time on the CM-5 and the community Y-MP8 were used for classroom projects. During FY 94 and FY 95, three professors used the CM-5 in classroom projects:
PI Name | University | Total CPU Hrs Used
--------|------------|---------------------
Oliver McBryan | CU at Boulder | 24
Dale Grit | CSU | 44
Manavendra Misra | Colorado School of Mines | 38

During FY 93-95, 12 professors used the community Y-MP8 in classroom projects, as summarized in Table 8:

**Classroom Projects and Use**

FY93 + FY94 + FY95

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<tr>
<td>Vakalis, Dr. Ignatios</td>
<td>0.1</td>
<td>Capital University</td>
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<tr>
<td>Zachmann, David</td>
<td>26.7</td>
<td>Colorado State University</td>
</tr>
</tbody>
</table>

183.5 Total CPU Hours

**Participation in Summer Employment Program (SEP)**

During each summer of FY 93, FY 94 and FY 95 SCD sponsored a Summer Employment Program (SEP) minority student.
V.2 Training Activities

Training is provided to increase users' skills and knowledge about SCD's computing resources. This increases their productivity and their ability to extract additional computing power from the NCAR computing environment. Training is also provided for certain areas in which there is an institution-wide need for computer- and network-related skills.

To facilitate the increased use of the World Wide Web and support goals to make the WWW a major, institution-wide vehicle for disseminating information, Documentation staff designed a class in the hypertext markup language (HTML). Over 125 university users, NCAR staff, and User Conference attendees have taken advantage of this class. Another training first was a two-day Fortran 90 Seminar (80 attendees), which targeted major areas of change in the language from the 1977 standard. We also sponsored a machine-independent message-passing class with PVM examples (40 attendees), and a five-day applications programming class on the Cray T3D (30 attendees).

SCD User Conference

The SCD User Conference is held at NCAR approximately every 18 months depending upon the needs of the user community and the latest Division plans and software/hardware changes; all users are invited and encouraged to attend. Feedback from attendees is strongly solicited for planning purposes as well as current operations. The conference themes vary to cover the current topics of interest to the users. As an example, the most recent conference - the Tenth SCD User Conference (held August 1994) - focused on programming languages for parallel processing and information technology. Highlights included SCD's parallel machines, NCAR's CSL, Fortran 90 and High-Performance Fortran, general programming on parallel machines, parallel implementation of the Community Climate Model (CCM2), SCD's research data archives, information technology for access to online information, and SCD's role in the NSF metacenter and the national HPCC program. Suggestions and concerns were requested of the 80 attendees who were from sites including Colorado State University, University of Colorado, Texas A&M University, University of Miami, Massachusetts Institute of Technology, University of Wisconsin, University of Michigan, Florida State University, Princeton University, as well as NCAR. The next User Conference is scheduled to occur in 18 - 24 months.

NCAR Graphics User Conference

To keep the user community up to date with developments and enhance- ments for the NCAR Graphics package, we hold an NCAR Graphics User Conference. The opinions of the attendees help prioritize various development efforts. The last conference was held in 1992 and involved 120 participants, 14 of whom were
from outside the United States. The meeting included a tutorial class and attracted graphics users from government agencies, universities, and commercial sites. As an outgrowth of user suggestions and discussions from this conference, an e-mail group was established by SCD staff to service the graphics community regarding their problems, concerns, and suggestions (see Appendix B). A teaching conference was held in September of 1995 with a focus on the new features and functionality of the NCAR Graphics Version 4.0 scheduled for release that same month.

V.3 Knowledge Transfer

Please see "Technology Advancement" in Section IX.
VI. Impact of Center Funding

By being part of NCAR, SCD centralizes the acquisition, operation, and continual upgrading of high-performance computing, data storage, and networking capabilities to provide university researchers with access to facilities that their home institutions usually cannot afford. These facilities are administered in collaboration with the university community to ensure fair access based on quality of science.

SCD is chartered to be a discipline-specific high-performance computing resource; namely, to serve the computational needs of the atmospheric and oceanic sciences. Being a part of NCAR facilitates a rich scientific and technical interaction with a large and diverse set of researchers and projects (e.g., CSM, CCM2, MM5, etc.) as well as students and visitors to the center. As a result, most SCD capabilities are specialized to the computational requirements of the atmospheric sciences; for example the mass storage system, computational support, advanced visualization, graphics, research data, and so forth.

NCAR’s prominence within the national scientific infrastructure assures continued, strong interactions between SCD, other national laboratories, and supercomputing centers. For example, SCD’s recent receipt of an NSF Opportunity Fund Award (see Section B.1.c) was made possible largely because SCD is a part of NCAR and has close ties to NSF/CISE centers. Similarly, SCD’s participation in the MECCA and CO-OP 3D projects reflect NCAR’s national visibility.

Finally, being part of NCAR helps SCD respond to specific needs of the community. With our budget flexibility and reputation as a development site for leading-edge equipment, SCD can quickly acquire and support specialized capabilities. Both the MECCA project and the Accelerated Computing Environment (ACE) are outstanding examples of how specialized computing resources were made available to meet specific computational needs during the review period. MECCA and the ACE/Climate Simulation Laboratory (CSL) complement and support atmospheric science research at universities, while the Distributed CSL project will explore technologies that offer significant potential to enable greater service and linkages between NCAR and universities.
VII. Financial Information

The following table shows funds expended during the review period.

Financial Summary

<table>
<thead>
<tr>
<th></th>
<th>FY 1993</th>
<th>FY 1994</th>
<th>FY 1995</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
<td></td>
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<tr>
<td>Program Targets</td>
<td>$15,818,300</td>
<td>$17,297,600</td>
<td>$23,619,900</td>
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<td>Special Allocations from NCAR Director for Augmentation of Supercomputing</td>
<td>$135,900</td>
<td>$452,300</td>
<td>(See note below.)</td>
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<tr>
<td></td>
<td>$15,954,200</td>
<td>$17,749,900</td>
<td>$23,645,600</td>
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<tr>
<td>NSF SPECIAL FUND EXPENDITURES**</td>
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<td>$11,600</td>
<td>$851,000</td>
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<td></td>
<td>(See note below.)</td>
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<tr>
<td>NON-NSF FUND EXPENDITURES**</td>
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<td>$1,858,800</td>
<td>$2,038,000</td>
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<tr>
<td></td>
<td>(See note below.)</td>
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<td></td>
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<tr>
<td>TOTAL</td>
<td>$20,652,300</td>
<td>$19,620,300</td>
<td>$26,534,600</td>
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</table>

All figures include indirect costs at a rate of 51% to 55%, varying by year.

Notes:

1. The large increase in NSF Regular in FY 1995 reflects additional CMAP funds for the Climate Simulation Laboratory.
2. The unusually large amount of Non-NSF funding in FY 1993 was derived from ARPA grants for experimental use of massively parallel processing technology, including equipment acquisition.
3. The increase in NSF Special Fund spending for FY 1995 is for the Distributive Climate Simulation Laboratory, for which NSF Opportunity Funds were received.

* Program targets are allocations for the NSF Base Program and Focused Programs.
Allocations from NCAR Director are one-time funds from the NCAR Reserve and Equipment & Instrumentation Fund.

** The figures for expenditures are actual spending for FY 1993 and FY 1994, and estimated spending for FY 1995.
The following tables give additional details about NSF special funds and non-NSF funds received by the division. Much of SCD's budget involves the purchase or lease of equipment. While most funding is committed in the year received, actual expenditures may occur in the subsequent year. Thus, the totals given below may not agree with those on the previous page.

### NSF Special Funds Received

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<thead>
<tr>
<th></th>
<th>FY93</th>
<th>FY94</th>
<th>FY95</th>
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<td>1,000,000</td>
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<td>NLANR</td>
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<td>171,900</td>
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<tr>
<td>NCSC</td>
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<td></td>
<td>55,000</td>
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<tr>
<td>ITA funds to be determined</td>
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<tr>
<td><strong>Total NSF Special Funds Received</strong></td>
<td></td>
<td></td>
<td>$1,226,900</td>
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### Non-NSF Funds Received

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<thead>
<tr>
<th></th>
<th>FY93</th>
<th>FY94</th>
<th>FY95</th>
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<tbody>
<tr>
<td>MECCA</td>
<td>2,333,500</td>
<td>747,920</td>
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<td>EPRI</td>
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<td>ARPA</td>
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<td>CM-5</td>
<td>1,454,500</td>
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<tr>
<td>ACTS</td>
<td>0</td>
<td>234,543</td>
<td>132,560</td>
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<td>35-Year Reanalysis</td>
<td>194,800</td>
<td>152,640</td>
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<td>Country Studies</td>
<td>0</td>
<td>10,000</td>
<td>83,530</td>
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<td>CHAMMP</td>
<td>144,300</td>
<td>205,696</td>
<td>145,000</td>
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<tr>
<td><strong>Totals for Non-NSF Funding Received</strong></td>
<td>$4,127,100</td>
<td>$1,905,399</td>
<td>$521,090</td>
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</table>
### Scientific Computing Division - FY 1995 NSF Regular Funding

**SUMMARY PROPOSAL BUDGET**

<table>
<thead>
<tr>
<th>ORGANIZATION</th>
<th>University Corporation for Atmospheric Research, National Center for Atmospheric Research: Scientific Computing Division</th>
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</thead>
<tbody>
<tr>
<td>PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR</td>
<td>Richard A. Anthes, President</td>
</tr>
</tbody>
</table>

#### A. SENIOR PERSONNEL: PI/PD, Co-PIs, Faculty and other Senior Associates

1. Scientists, includes Division Management
2. Visitors
3. Associate Scientists
4. Section IX-B Contains Staff Information
5. Others (list individually on budget explanation page)
6. Total Senior Personnel (1-5)
7. **44** 228,300

#### B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)

1. **78** Other Professionals (Technician, Programmer, etc.)
2. **8** Graduate Students
3. **3** Undergraduate Students
4. **8** Administrative Support (Direct Costs, including Secretarial-Clerical and Student Assistants)
5. Other
6. Total Salaries and Wages (A+B)
7. **4,214,700**

#### C. FRINGE BENEFITS (Direct Costs) (At 41.5% of Work-time Salaries. Work-time excludes Holidays, Vacation, Sick Time, etc.)

1. **1,749,100**

#### D. PERMANENT EQUIPMENT (List Item and Dollar Amount for Each Item Exceeding $1,000.)

Items costing $5,000 or more each, for scientific, computing and other equipment

- **2,251,200**

#### E. TRAVEL

1. Domestic (Incl. Canada and U.S. Possessions)
2. Foreign
3. **120,200**
4. **47,600**

#### F. PARTICIPANT SUPPORT COSTS

1. Stipends
2. Travel
3. Subsistence
4. Other
5. Total Participant Costs

#### G. OTHER DIRECT COSTS

1. Materials and Supplies (Includes Purchased Services)
2. Publication Costs/Documentation/Dissemination
3. Consultant Services
4. Computer (ADPE) Services
5. Subcontracts
6. Other
7. Total Other Direct Costs
8. **11,232,100**

#### H. TOTAL DIRECT COSTS (A THROUGH G)

1. **19,614,900**

#### I. INDIRECT COSTS (SPECIFY RATE AND BASE)

1. At 54.9% on Modified Direct Costs of $7,341,900
2. **4,030,700**

#### J. TOTAL DIRECT AND INDIRECT COSTS (H+I)

1. **23,645,600**

#### K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPM 252 AND 253)

1. **23,645,600**

#### M. COST SHARING: PROPOSED LEVEL

1. **$**

#### AGREEED LEVEL IF DIFFERENT

1. **$**

---

**NSF Form 1030 (1/94) Supersedes All Previous Editions**

* Signatures required only for Revised Budget (GPM 233)

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Date: 26 Sep 95

Indirect Cost Rate Verification:

- Date Checked: Date of Rate Sheet: Initials-DOC
FORM 1030 ASSUMPTIONS

Section A General: Schedule 6 for each division was put in database form and filtered to pull out NSF Regular accounts, associated worktime salaries, and person years based on staffing categories 1 through 12. These categories are defined in the Program Plan Budget Guidelines under the Schedule 6 section. Director's Reserves and Senior Scientist Allocations are added to the Schedule 6 figures if needed. The attached spreadsheet details these allocations.

Note: For some divisions, Schedule 6 Salaries did not = Schedule 1. In these cases, the difference was prorated to each category below based on salary (worktime) totals in each category on Schedule 6 to = Schedule 1. Please let Geoff or Rena know as soon as possible if this is a problem.

Section A #1: Senior Personnel - From Schedule 6a - Staffing Budgets:
Category 1, PhD Scientists, i.e., Scientist I-IV & Sr, Section Heads and Sr Research Assoc.
Category 2, Other Scientists, i.e., Data Analyst, Research Assistant, Assoc. Scientist I-IV
Category 3 & 4: Salaried & Non-Salaried Visitors
(Does not include Division Director's or Senior Managers, these people are included in Secretarial-Clerical (Administrative Support)

Section A #2: Others - Not used

Section B #1: Post Doctoral Associates
Category 5, Post Docs

Section B #2: Other Professionals (Technicians, Programmer, etc.)
Category 7, Professional Support, i.e., R&D Engineers, Pilots, Research Engineers, Services Engineers, Programmers
Category 8, Technical Support, i.e., Computer Operator, Observer, Computer Graphics, Technician, Drafter, Technical Specialist
Category 9, Maintenance Facility Support, i.e., Crafts/Trade Group, Service Worker

Section B #3: Graduate Students
Category 6, Graduate Research Assistants

Section B #4: Undergraduate Students
Not used. Student Assistants and other non-GRAs or Post Docs are included in Section B #5.

Section B #5: Secretarial-Clerical (Includes Administrative Support)
Category 10, Administrative Support, i.e., NCAR Director, Division Director, Administrator, Associate Director, Program Director,
Category 11, Secretarial/Clerical Support, i.e., Clerk/Typist, Administrative Assistants, Accounting Clerk, Secretary, Facility Worker
Category 12, Others, i.e., Casuals, Student Assistants and other student categories not included above.

Section B #6: Other - Not Used

Section C through L General: Information from Schedule 1. Allocations from Director's Reserves, Equipment Fund and Senior Scientist Allocations are added to the Schedule 1 figures. The attached spreadsheet details these allocations.

Section C: Fringe Benefits
NSF Regular Benefits at 41.5%. From Schedule 1 and rounded to nearest hundred dollars.

Section D: Permanent Equipment
From Schedule 1 total Equipment for NSF Regular Funds rounded to nearest hundred dollars.

Section E: Travel
From Schedule 1 total travel for NSF Regular Funds rounded to nearest hundred dollars.
Prorated between Domestic and Foreign travel based on YTD actuals in division's NSF Regular programs as of 9/16/95 (Close #1).

Section F: Participant Support Costs
Not Used. Included in Section E.

Section G #1: Other Direct Costs - Materials & Supplies
Schedule 1 Material & Supplies (5200) and Purchase Services (5300) rounded to nearest hundred dollars
G2 through G6 is not used

Section I: Indirect Costs
From Schedule 1 and indirect cost portion of Director Reserves etc. allocations. MDC amount is a calculation which divides the indirect amount by 54.9%.

9/22/95
<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
<th>L</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SCD</strong></td>
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<tr>
<td><strong>Transfers from Director's Reserves, Equip Fd, Sr Sci Alloc &amp; 1-Time Relief:</strong></td>
<td></td>
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<td><strong>111</strong></td>
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<td>Salaries</td>
<td>Benefits</td>
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<td>Indirect</td>
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<tr>
<td><strong>115</strong></td>
<td>Additions to Target for 1030 Form</td>
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<td>0</td>
<td>25,700</td>
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<tr>
<td><strong>116</strong></td>
<td>1-Time Relief for Sen. Sci. Taxes</td>
<td>Excess OH</td>
<td>59,688</td>
<td>59,688</td>
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<tr>
<td><strong>117</strong></td>
<td>Total Transfers from Dir Off.</td>
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<td>0</td>
<td>0</td>
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<tr>
<td><strong>119</strong></td>
<td>FY 95 Target (General Target)</td>
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<td>1,510,545</td>
<td>6,112,125</td>
<td>164,500</td>
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<td>3,541,070</td>
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<td><strong>120</strong></td>
<td>FY 95 Target (CSL)</td>
<td>574,876</td>
<td>238,573</td>
<td>5,120,000</td>
<td>3,300</td>
<td>2,151,680</td>
<td>489,571</td>
<td>8,578,000</td>
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<td><strong>121</strong></td>
<td>FY 95 Total Target</td>
<td>4,214,742</td>
<td>1,749,118</td>
<td>11,232,125</td>
<td>167,800</td>
<td>2,225,473</td>
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<tr>
<td><strong>123</strong></td>
<td>Total for 1030 Form (Rounded to nearest hundred $)</td>
<td>4,214,700</td>
<td>1,749,100</td>
<td>11,232,100</td>
<td>167,800</td>
<td>2,251,200</td>
<td>4,030,700</td>
<td>23,645,600</td>
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*Note: The table represents financial data for various categories and targets for a fiscal year.*
**SCD Pivot**

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<thead>
<tr>
<th>Fund Source</th>
<th>Sum of Fnd by Acct</th>
<th>Staff Cat2</th>
<th>Staff Cat</th>
<th>Grand Total</th>
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<tr>
<td></td>
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<td>Sen Prs*</td>
<td>Oth Prof**</td>
<td>Sec Cler***</td>
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<tr>
<td>NSFRCORE</td>
<td>215,080</td>
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<td>NSFRHPCC</td>
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<td>161,841</td>
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<tr>
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<td>3,583,021</td>
<td>389,276</td>
<td>4,199,802</td>
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* Includes: Ph.d. Scientist, Other Scientist, Visitors (salaried) & Visitors (non-salaried).

** Includes: Professional Support & Technical Support.

*** Includes: Secretarial/Clerical Support, Administrative Support & Other.