Survey of NCAR User Needs for Visualization Tools

A research report of the Digital/NCAR Joint Research Project

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SURVEY OF NCAR USER NEEDS FOR VISUALIZATION TOOLS

Introduction

The visualization project within the Scientific Computing Division (SCD) was implemented to bring the latest visualization tools to the atmospheric and oceanographic research communities served by NCAR. The first step toward achieving this goal in the eyes of the Scientific Visualization Group (SVG) of SCD was to try to better understand the status and objectives of current research activities. Toward this end, a number of personal interviews were conducted in the winter of 1989 with selected scientific research groups. Interview topics included:

- A description of the research
- Types and extent of data collected and generated
- Descriptions of data formats and transformations
- Useful displays
- Workstation requirements and experience
- Evaluations of software currently in use
- Future needs and requirements in graphics and visualization
- Visualization support facilities needed
- User interfaces

Five research programs were interviewed which were judged to be representative of the display needs of a substantial portion of the total community. The discussions focused on the activities within these projects that depend on the generation, collection, visualization, and analysis of data in support of the research. A knowledgeable representative of each of the programs was interviewed. They described the scientific and operational needs for data management and display, the general characteristics of the data, the types of access, and the presentations that were necessary for the timely support of a research experiment. SCD then asked for their requirements in data access facilities, graphical tools, and ancillary support such as networking and user interfaces between different service nodes in a distributed computing environment.

This report is a recording of these interviews and a compilation of the general similarities and differences between the projects and their activities. The Summary Section at the end of this report gives SVG plans for addressing the needs which were reported as being most important and of the most universal value.

The Background of Atmospheric Research

Atmospheric research, oceanography, solar research and other related topics such as turbulence studies involve the investigation of comprehensive systems of great dynamic and structural complexity. To support this research, a wide variety of measurement systems and simulation models are used to assess the dynamics, interactions, and structures on a broad range of scales. These systems and models create vast quantities of data as they attempt to describe the actual atmosphere, ocean, or other physical system. These data must be consumed by the scientist and made comprehensible with visualization tools. It is typical of an experiment to produce a data base of five dimensions in space, time, and number of variables.

Simulation models can easily produce several million elements of information per time step. Each simulation is run over thousands of time steps. While every time step is not archived and used for visualizing the experiment, two billion data items for display from one experiment is not uncommon.
A scientific productivity goal associated with these models is to be able to control the simulation as it executes on the supercomputer. In order to interactively display the results of each sequential time step as it is computed, the supercomputer must be networked to a display node.

Field experiments in the above-mentioned sciences are equally demanding in their data requirements. Datasets from satellites, radar, aircraft, and ground station networks are very large and must be processed and analyzed at several levels. A series of data processing steps are performed on the data to take it from a raw set of instrumentation measurements to a final set of derived and transformed physical variables which can be used in future research. Some of the processing steps must be done in real-time or near-real-time to the operation of the instrument. Good display tools are critical to the direction of the field experiment as well as to the assimilation of the enormous amount of information gathered.

The Computing Environment

Historically atmospheric and oceanic sciences have needed supercomputing services to support both the simulation modeling and the major field experiments. NCAR has provided this service to the national research community for over 25 years. SCD facilities include supercomputers, a major storage and archival system (currently holding 14 trillion bytes), high-performance microfilm/microfiche systems, and high-speed networks for interconnectivity. The national and local area networks connect the central facility with many separately owned and operated minicomputer and workstation environments. These heterogeneous environments are both within NCAR and at university departments across the country.

In support of this distributed and heterogeneous environment, SCD must seek and recommend tools that are:

- portable to a variety of operating systems and hardware
- based upon standards like Postscript, the Computer Graphics Metafile (CGM), the Graphical Kernel System (GKS), the Programmer's Hierarchical Interactive Graphics System (PHIGS), the X Window System, and others
- priced at an economy rate
- easy to use
- integratable into a complete graphics service.
SCD must also plan and design data and image paths that will allow the distribution of work among the various workstations and centralized servers including the supercomputers, mass storage, microfilm, and video film systems. This design must include data management, data compression, and data conversion, as well as translation of images from one display system to another.

The Five Research Programs Selected

The programs selected for our interviews were representative of many of the research activities in the atmospheric sciences. They included major simulation modeling efforts to understand the dynamics and chemical composition of the fluids, the analysis of raw data from field experiments as the data are collected in real-time, and the analysis of derived data after they have been collected and archived for use by the whole community. The five programs can be briefly described as follows:

1. Climate and Global Dynamics Research
2. Oceanographic Research
3. Atmospheric Chemistry Research
4. Research Support for Application of Radar Analysis
5. Radar Systems and Display Development

While each program focuses on a different major area of the science, it nevertheless collaborates with the others in many ways and shares a common interest in the analysis and display of comparable research data. In particular, each has a vital interest in the management and visualization of very large databases.

Similarities

All these programs have many experiments that create extensive datasets for analysis. While some are generated by simulation models and others by satellite or radar collection systems, the data are commonly five dimensional in nature and very large in volume. Much of the time the same physical variables are computed or derived and need to be compared with results from other projects. The displays for these variables are often similar. The form and use of the tools may be different across the programs because of the operational needs of each research activity, but many graphics tools are common.

This is a dynamic, hands-on research environment that is constantly in development activity and is staffed by too few trying to do too much. The scientists, engineers, and programmers are tackling sizeable research problems which demand ancillary tools like visualization to aid their productivity. These tools will be applied to changing experimental and exploratory demands, and they must be easy to learn and use by a scientist. They will be shared with a larger community if the tool is valued and the non-expert can be shielded from its complexity.

Differences

The research activity in each of these programs requires different operational environments. If the activity is modeling, then the work is done in a controlled environment where computation is done on a supercomputer, a full archival of the experiment is recorded on a mass storage device, and selected portions of the archival information are distributed to visualization workstations and other servers along the network. Quality control of the data is good in this environment. The biggest challenge is in dealing with the large sizes of the datasets. Other challenges include management and delivery of subsets of the data to visualization workstations, maintaining data flows and conversions among heterogeneous servers, and overcoming incompatibilities among different display
facilities. These difficulties are compounded when the task is to compare several experiments from different sources and integrate these data into a compatible form for evaluation.

In a modeling environment, the scientist needs interactive and visual access to his model as it runs on a supercomputer so that s/he may direct the experiment as it proceeds.

This environment, while complex, must only deal with well-defined, computer generated, scientific variables. Visualization tools can be developed to highlight these variables, probe the results of various experiments and explore the history data for new or surprising events.

On the other hand, when the activity is a field experiment, or the analysis of data that originated from a field experiment, then additional facilities are needed before the scientific variables can be archived and delivered to the community. During a field experiment sample measurements are taken and recorded. These raw data must typically be digitized, calibrated, filtered, and transformed before the information is sufficiently accurate and in the proper units that other scientific variables can be calculated and derived. Each step in this data processing chain is a candidate for the use of visualization tools. Often the data processing is done in a real-time or near-real-time environment. These time constraints and the need for quality control monitoring place additional constraints on the interfaces to the tools. Nevertheless, many graphics tools are common among the different projects.

Program Interviews

Our interviews addressed program science, data requirements, existing graphics and visualization tools, and anticipated future needs.

Climate and Global Dynamics Research

• Research Activities

The earth's atmosphere carries with it life-giving moisture and ever changing patterns of weather and climate. Scientists within the Climate and Global Dynamics Division (CGD) focus on theoretical and observational studies of the dynamics and thermodynamics of the atmosphere, the oceans, land surfaces, and the biosphere. One of the programs within this division is the study of climate, representing the mean state of atmospheric circulation and the variability about that state. These studies require the use of very complex general circulation models that are designed to simulate as closely as possible atmospheric circulation. These simulations are run over several decades of model time and produce a large database of model history.

• Data Description

The primary data for visualization are generated from climate models running 10 to 30 years of general circulation simulations. These are computed on a supercomputer, and the history of the experiment is generated during the run. A typical climate model will have about 10 levels in the vertical and a grid of 1,920 points in the horizontal. It will contain about 20 variables represented in this space and use a 30 minute time step throughout the simulation. The history files do not contain every time step of the simulation but usually contain the data at 12-hour intervals. Statistical datasets like monthly means will also be generated and used for analysis and display.
**Current Computational Environment**

The simulation models are currently executed on a CRAY supercomputer and the history files are sent to a mass storage system for permanent storage. The history files are then analyzed by a 'post-processor' on the CRAY and graphical displays are sent to the SCD Text and Graphics System (TAGS) to be recorded on a DICOMED film recorder. Some or all of these displays are also sent to a mini-computer, via a local area network (LAN), where they can be interactively reviewed. When a film of the time sequence of an experiment is desired, the DICOMED and CRAY are used to generate the frames.

Portions of the history files are also sent to the mini-computer, via tape or LAN, for display with existing interactive visualization tools. However, better visualization tools and videotape facilities are clearly needed. SCD plans to provide videotape recording and editing facilities in the near future.

CGD recently submitted a major video project to the Scientific Visualization Program at the National Center for Supercomputing in Illinois. Output data from two climate model runs were compared. One run had normal levels of carbon dioxide in the atmosphere, while the other assumed that carbon dioxide had doubled, as might happen in the near future in a global warming scenario. The model results were visualized as surfaces of constant average warming over the globe and then animated over a 30-year time span using Wavefront software. In addition to extensive time put in by NCAR scientists, this effort required two person-months by a visualization expert at NCSA. Each frame of the video animation required 10 cpu minutes on an Alliant FX/8 superminicomputer.

**The Audience for Visualization Products**

This program has a broad audience for the presentation of its experimental results. There are presentations for the primary scientist(s) doing the experiment, for colleagues with similar research activities, for the general community of atmospheric researchers, for scientists in other disciplines such as the earth sciences who also participate in global change studies, and finally for the general public and political communities to inform them about the latest scientific discoveries. The content and emphasis may be quite different for each group, but the ability to re-use portions of presentations is important. While the general presentations will be on film, video, or slides, the primary scientist will need interactive tools to review an experiment as it runs on the CRAY, and similar tools for discussions with colleagues.

**Staffing of the Visualization Work**

The climate modeling program consists basically of three scientists, two full-time programmers, one student, and a draftsman. One scientist uses computers extensively for simulation model development; the other two scientists work through the support staff. None of the staff is devoted solely to visualization. While the scientist can expect this staff to import and manage the software tools, he will frequently need to use these tools himself as he develops a presentation. An easy-to-use set of tools will be necessary as well as a fully integrated environment for access to a variety of special data and graphics servers.

**Current Software Tools**

The NCAR Graphics Package is a mainstay for the graphics work in this program. These two-dimensional utilities are used in batch form on CRAYs and interactively on the minicomputers and workstations. These utilities were developed for the atmospheric community and contain a number of useful facilities like projections and maps. CGD has also acquired a number of two-dimensional tools from colleagues at universities but these tools are limited in scope and usefulness, and are not integrated into a uniform graphics environment.
• Desired Tools and Distribution

This program obviously needs strong two-dimensional and animation tools. The optimum set of tools is unclear. Without experience on a variety of existing tools, the best presentation of an event, relationship, or the variability of a climate parameter is still undefined. This group would like to see SCD bring in and evaluate a broad range of software packages. Then, with consulting support from SCD, the group would like to conduct a few experiments using the most promising packages to highlight their value to the science. Tools for three-dimensional (3-D) display are also of interest and the experience at Illinois with experts using Wavefront software is the beginning of this experimentation.

The increasingly distributed computing environment at NCAR represents both opportunities and challenges to CGD. This group will need to use its own workstations, minicomputers, and local video system as well as the core facilities in SCD for computing, storage, and film and video recording. The need to distribute the visualization work according to the power, size, and time constraints of the job will demand a compatibility among the servers and a powerful network to link these facilities. The ability to create images on one server, transmit them to another for editing and insertion in other text or pictures, and transmit the composite image to another server for hard copy recording will demand a global plan of standards and translation. CGD wants such a plan.

Oceanographic Research

• Research Activities

A physical view incorporating the ocean circulation is crucial for understanding and predicting how the weather and climate systems will behave. The annual and longer-scale climate fluctuations of the earth involve both the atmosphere and the ocean, each reacting to and sometimes reinforcing changes in the other system. The Oceanography Section of CGD studies the dynamics of these oceans with models that simulate regional to global-scale oceanic phenomena. The models may deal with processes occurring on scales varying from 10 km or less to the planetary scale. Because of the long time sequences needed in these simulations, these models are very computationally intensive and produce large datasets that are a record of the experiment.

• Data Description

Enormous history files can be generated by these experiments. A five-year archive (120 samples/year) from one experiment required 55 gigabytes of mass storage. The data structures used to maximize I/O efficiency on the CRAY during the model integration are generally not the most efficient for analysis or visualization tools. This orientation causes problems of access for visualization tools. The irregular boundaries of the ocean basins are specified by special values in a rectangular array, and these also are a nuisance to the tools. Data management is a major concern in gaining access to these experiments.

• Current Computational Environment

The simulation models are executed on the CRAY and the history files sent to the mass storage system for archiving. A postanalysis code is run on the CRAY and graphics sent to the DICOMED film recorder or a laser printer. Portions of the history file are shipped to a minicomputer owned by the program. The program acquired an Ardent Corporation Titan workstation to use as a primary system for interactive visualization.

The Titan will also be used as a computational engine for some model runs and postanalysis computing. The program also owns a Sun computer and hopes to acquire additional low-end and
high-end workstations. With such a diversity of machines in the program and the central computing facility, it will be important to have a well-designed plan for integrating all the services.

- The Audience for Visualization Products

The state of the art in ocean modeling lags behind that of atmospheric modeling. This NCAR program is one of a few research groups that have begun an intense effort to develop the simulation models. The oceanography community is very interested in the work of this core group. The atmospheric research community is also awaiting the development of these models, as it needs oceanographic models to link with atmospheric models for climate and forecast studies. It can also be anticipated that the general public will want a view of new discoveries about the flows and dynamics of the ocean and how these can bring about substantial changes in the climate and environment. Animations produced by this group have already been used by the public television program "Nova", for example.

It is clear that this program needs visualization facilities for several audiences and to meet several needs. They must have interactive tools for monitoring their experiments and analyzing the results. They will need video and film facilities as well as good editing tools for a smooth presentation, and they will need a good way to integrate an environment of diverse systems.

- Staffing of the Visualization Work

This program consists of five computational scientists with a support staff of three programmers. Three part-time computer science students are also employed. The scientists pursue many collaborative efforts with scientists from other institutions and must manage the simulation experiments that this joint work demands. With this work environment, the scientists need to be able to use the visualization tools directly and perhaps show their collaborators how to use portions of them. With the planned diversity of the visualization systems that the program would like to acquire and the use of the core facilities of SCD, the program will need to emphasize a simplified and well-integrated interface between the scientists and the visualization tools offered. It may well want a joint implementation strategy between itself, other programs in its division, and SCD.

- Current Software Tools

The program makes heavy use of the NCAR Graphics Package for its production runs of the models and uses SCD's film facilities. It also interactively uses this package on its own systems along with other tools that were developed within the division. NCSA Imagetool, from the University of Illinois, and Show, from the University of Colorado, are used for raster image oriented visualization.

- Desired Tools and Distribution

This program would like to make a major investment in visualization systems and tools in the next few years. It has already acquired an Ardent Titan and is interested in other 3-D graphics workstations. It would also like some level of video recording facilities. With this selection of systems, it will have an opportunity for testing and evaluating a goodly number of visualization options.

With the acquisition of the Titan, the program is now testing the Dore' software environment for the support of their work. They would like this software, if it proves valuable, to be supported on SCD facilities. They will further experiment with volume rendering software (e.g., Pixar) and will generally pursue visualization options as aggressively as their resources and staffing will allow.

The issues of diversification and distribution will be a major design problem for the program. To make these tools readily available and useful to the scientists, the program will need to integrate its own systems into a uniform environment and get the cooperation of SCD and other sections of
NCAR to form a complete visualization service. It will be a major and important expansion of the support tools that this program needs.

Research Support for Application of Radar Analysis

- Research Activities

One of the fundamental goals of atmospheric science is to reconstruct and understand mesoscale phenomena such as severe thunderstorms by gathering high-resolution data collected by various instrumentation systems. Observational meteorologists from around the world periodically plan and conduct field experiments designed to probe the physical environment in and around summer storms using the latest tools available to them. The primary data collection systems include: multiple Doppler radars, instrumented aircraft, surface weather stations, and balloon borne sensors.

The process of reducing these raw measurements to a common 3-D grid at comparable spatial and temporal scales typically requires the computational power and data storage facilities of the CRAY. However, once a set of these storm "snapshots" has been created across a period of interest, it can be manipulated and examined more easily in an interactive environment.

- Data Description

The original radar dataset from a large field experiment can be close to a terabit (10**12 bits) in size. Although only portions of these data, recording particular events, are of prime interest to the scientist, all the data are reviewed and archived for ready accessibility for the researcher. The initial processing of the data is performed in batch mode. The data are then added to a central archive for general access. A large set of tools for manipulating and analyzing the archived datasets are available in a package developed at NCAR called CEDRIC.

- Current Computational Environment

The largest share of the processing and analysis of the data are carried out using a version of CEDRIC in batch mode on the CRAY. The measurements are archived and film is produced to record the experiment and present the results of any analysis. VAX minicomputers are then used to interactively support the scientific evaluation of the data as well as the interpretation and correction of the data as they are reviewed. Scientists not located at NCAR who also have VAX/VMS systems can acquire an interactive version of CEDRIC which is designed for their independent use. Interactive analysis of a single data set takes 2-3 minutes on the VAX 8530. This is not considered to be a bottleneck.

- The Audience for Visualization Products

The scientists who use CEDRIC are familiar with field experiments and will use these tools to interpret, refine, and incorporate the data into a composite picture of the experiment. These manipulative tools must have dynamic presentations to illustrate the impact of any changes in the data and the results of many analyses. The scientists will want to take these presentations to their peers and to a much larger community of scientists for review and publication. Video and film facilities will also be necessary to record events in an experiment for viewing by the community and perhaps the public at large.

About six to eight scientists at NCAR are regular CEDRIC users. Mostly they use it as is and do not make modifications; thus, the users do not have to be programmers. Users choose the CRAY version or the VAX/VMS version depending upon how much data must be analyzed. CEDRIC is also installed at about two dozen sites outside of NCAR (mostly universities).
Staffing of the Visualization Work

The support of this complex environment of data management, integration, analysis, and display is staffed by specialists who are familiar with both the characteristics of field experiment data and the analysis requirements of the scientists. The number of staff is very limited; thus, they must strive to serve a large community with the most generalized tools possible. At the time of this interview the CEDRIC project was being staffed with less than one half-time programmer and one part-time student. A proposal is being considered to have three full-time programmers work on an expanded version which would be supported on the UNIX operating system using the latest version of NCAR Graphics and an X Window System interface.

The visualization will require simple display facilities and complex composite structures. The staff will need to incorporate these tools into the packages and worry about the portability of this software.

Current Software Tools

This software system currently uses the original NCAR Graphics package to generate its displays. The interactive versions of the CEDRIC analysis package and the supporting NCAR Graphics facility were designed to function on DEC equipment under VMS. Modifications were made to the graphics metacode translator so that it could be invoked within a running program. This enabled researchers to specify and examine their displays without having to exit CEDRIC. Whenever the interactive software was exported to other institutions, DEC equipment had to be utilized in order to avoid portability problems.

Desired Tools and Distribution

This program requires a general, well-documented, Fortran-callable facility for visualizing information in 3-D Cartesian data structures. Although a standalone visualization facility would certainly be attractive, providing callable interfaces to it would make visualization features easy to incorporate into the existing analysis package, significantly enhancing its usefulness. The visualization needs of thunderstorm observationalists and modelers are actually quite similar. They are both trying to recreate and comprehend the same phenomenon. There is a crucial interest in the delivery of common facilities that provide color, standard user interfaces, merger of text and graphics, and combined vector and raster images.

The unified version of CEDRIC described above would only be supported on UNIX systems. Eventually, VMS will be phased out, and the VAX nodes will be converted to Ultrix.

Radar Systems Display Development

Research Activities

The Research Applications Project (RAP) at NCAR was part of the Atmospheric Technology Division at the time of this interview. A reorganization which promoted this project to the status of an independent facility has since occurred. A primary mission of RAP is to transfer atmospheric technology into aviation operations. The project we interviewed is focused on advanced radar data analysis for "nowcasting" (analysis of the current weather situation) and short-term forecasting. The purpose of this effort, under sponsorship of the FAA, is to develop an integrated terminal weather information system. This system would provide warnings on weather hazardous to aviation such as microbursts, tornadoes, high winds, hail, etc. This moves the traditional research environment into a more operational role.

RAP has a commitment to develop a system which will provide a hazardous weather warning to aircraft in "real time"; i.e., fast enough to analyze a complete Doppler radar volume scan and
issue a warning before aircraft are endangered. An additional constraint is that only one Doppler radar can be used in the airport system, compared with the two or more typically used in research field programs.

- **Data Description**

Doppler radars produce data on the intensity and radial velocity (velocity toward or away from the radar) of precipitation. The data are collected in a series of cones, as the radar sweeps through an arc of azimuth while maintaining a constant elevation angle. Thus, each sweep of data has information from different elevations above the ground, depending on the range from the radar. To visualize these data, they must first be interpolated onto a series of horizontal planes. Typically, raster color techniques are then used to display data from a horizontal plane (plan view) or a vertical cross section (range height). With Doppler data, the radial velocities are also displayed. Various parameters derived from the velocities, such as vorticity and divergence, can also be shown. Each interpolated or derived parameter set is 256X256 (horizontal) by 32 planes in the vertical for a total of 2 million data values per volume per variable.

- **Computational Environment**

The RAP program has assembled a complete set of custom hardware and software (and people) for the purposes of:

1. providing high-performance visualization tools for the forecaster in close to real time, and
2. developing artificial intelligence as an aid to the forecaster in data analysis.

The current system uses an Alliant FX/4 computer which directly accesses Doppler radar data. The Alliant is used to convert standard conical range-gate data as Plan-Position Indicator (PPI) displays into a series of 256X256 horizontal data planes called Constant Altitude Planes (CAPs). The grid spacing is variable depending on the scan pattern, however 120 meters is a typical grid spacing. Currently the measured parameters (reflectivity and radial velocity) and one derived parameter (radial divergence) are saved. The radar volume scan can take up to one and a half minutes to complete. The Alliant can calculate a complete CAP dataset within 30 seconds after the volume scan is complete. The data are then transferred to a Symbolics computer for display on an attached Pixar Image Computer. This data transfer is the slowest part of the process.

Once on the Symbolics, the data are loaded into the Pixar memory. Currently eight CAP volumes from eight different time periods are available at any one time. Volume rendering techniques are used to display some of the data on the Pixar. Horizontal plan views and vertical cross sections are shown at the same time on the Pixar screen. The time steps are used to create a film loop animation. A set of four transparent volume displays for each time step is also available.

Symbolics was chosen as the display workstation for two reasons. One is that the ultimate goal is to develop an automated forecasting system, an application that is well suited to a rule-based approach. The other reason is that this group believes that the Symbolics/LISP environment is far superior to conventional workstations for developing new applications code, especially window interfaces. Among the Symbolics advantages are the ability to link new pieces of the application while it is running and the ability to reuse most of the code developed for previous applications. RAP is also able to write new microcode for the Pixar using LISP.

- **The Audience for Visualization Products**

The applications are developed by highly trained graphics and software specialists, who must also use the displays as part of the development process. Data are analyzed and the prediction rules are created by atmospheric scientists, who are currently totally dependent on the graphics specialists for any development and modifications. In the next year, the scientists will be able to modify the rules themselves through a window interface. The eventual goal is to create a system
that automatically provides a nowcast that is usable by air traffic controllers who are focused more on the management of the air space than on atmospheric science. In summer 1989, a combined human/computer system will provide convection initiation forecasts to the control tower at Denver's Stapleton International Airport as the first step in the development of automatic forecasting.

The nowcaster workstation has been used to help educate National Weather Service personnel and research scientists about emerging forecasting techniques at NCAR.

While the system was developed for the single Doppler nowcasting application, the technology is also interesting to research meteorologists who use multiple Doppler radars in thunderstorm and other field experiments. There is also demand for the system as a post-processing analysis tool. This is a much larger group of potential users and applications developers.

- **Staffing of the Visualization Work**
  
The program is a small one with a few engineers, software specialists, and meteorologists. There is sufficient graphics and workstation expertise on the team to meet all their needs. Engineers, programmers, and meteorologists work together as a team to develop the concepts and implement them in an advanced workstation environment.

- **Current Software Tools**
  
The visualization software consists of custom-built user interfaces using the LISP language and development environment, in conjunction with the volume rendering and image manipulation software in the Pixar Image Computer. The initial analysis, which includes converting from PPI to CAP is done in Fortran on the Alliant.

- **Desired Tools and Distribution**
  
RAP requirements for an enhanced system are basically to add several more variables (derived parameters such as vorticity) and more time steps to the basic capabilities they now have. They are looking at putting the Pixar directly onto the Alliant VME bus for more speed; however, they will need to write the driver themselves (based on a Sun-4 VME driver). They will also be working on the rules for prediction of hazardous weather.

For more advanced systems, they are looking at creating polygon meshes and transferring them to the rendering machine, a more efficient use of network bandwidth. They will be obtaining five Ardent Titan superworkstations and developing software using Dore' to render the polygons. Also, they will develop a LISP front end to Dore' for Ardent.

They are also being asked to support research programs which use two or more Doppler radars. Their users, the radar meteorologists, need to have custom, high-performance visualization tools to support various research projects. The Ardents will be used to support some of these applications.

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### Atmospheric Chemistry Division Research

- **Research Activities**
  
The Atmospheric Chemistry Division (ACD) at NCAR has the mission of conducting research into the distribution, transport, and reactions of various chemicals in the atmosphere. This includes assessing the effects of man-made air pollution on the environment, as well as researching natural sources and sinks of atmospheric chemical constituents. NCAR is heavily involved in examining the stratospheric "ozone hole" and the occurrence of various "greenhouse effect" gases such as carbon dioxide and methane.
The ACD is divided into five major groups. The Global Remote Observations Group is involved with data analysis from satellites and other remote sensing platforms. They perform large amounts of observational work and data analysis, as well as utilizing existing 3-D models created in other divisions such as Climate and Global Dynamics. They often work under contract to NASA or other agencies to analyze all the data from a certain satellite. They also are investigating the "ozone hole." Because of the large size of the datasets and the computationally intensive nature of data analysis, the SCD CRAY facilities, including mass store and graphics post-processing, are heavily used. The interview is focused on the needs of this group.

The Chemical Modeling Group uses numerical models developed for climate or other modeling and modifies them to compute chemistry also. They are also heavy CRAY and graphics users. The Chemical Kinetics Group performs laboratory spectrographic measurements, and would like more graphics capability for data analysis. The Biosphere/Atmosphere Interactions Group are not heavy computer users today, but may soon be involved in satellite data analysis, which would create graphics requirements similar to those in the Global Remote Sensing Group. The Chemical Measurements Group creates and operates sensors which detect chemicals in the atmosphere. They use a relatively small amount of computing for reduction of field data.

- Data Description

Two of the groups, the Chemical Modeling Group and the Global Remote Observations Group, perform heavy data processing. The Chemical Modeling Group mostly produces data of the grid-ded 3-D model output type as described in the description of Climate and Global Dynamics data. Graphics are used in post-analysis.

Datasets of the Global Remote Observations Group are observational, beginning with raw satellite data which go through extensive preprocessing, calibration, quality control, etc. The data may also have to be interpolated from the original satellite-centered form to regular 3-D grids. On some projects, some of this processing is performed at NASA before the data are delivered to NCAR. Graphics are extensively used to display the data.

The data which are displayed often represent the concentrations of various chemicals over large areas of the globe. They also may represent different levels of the atmosphere. Map overlays and projection of data and graphics into spherical coordinates are thus very important. In a video of the ozone hole created from Atmospheric Chemistry Division data by SCD, different ozone concentrations were represented as different tinges to a transparent atmosphere over a spherical Earth. Data are often displayed in raster form. The data are usually part of a time series; therefore, animation is also desired.

The Global Remote Observations Group is interested in several major NASA data analysis contracts. Among these is a project to use data fed into models to feed back information to point the satellite sensors to get the next data set. This would obviously involve rapid data reduction, visualization of both data and model output, and high-performance computation and graphics. The NASA contracts for this type of advanced application development are bid competitively among various universities and research institutions.

- Computational Environment

Most of the ACD researchers make use of SCD facilities such as the CRAY computers and the DICOMED microfilm device. They have one VAX 8300 running VMS and a Pyramid minicomputer running UNIX, plus some PCs and a lot of the more preferred Apple Macintoshes. The VMS VAX is used largely for compatibility with NASA which uses VMS heavily in areas such as data analysis, Space Physics Analysis Network (SPAN) DECnet networking, etc.

- The Audience for Visualization Products
Like the other projects interviewed, ACD expressed a need for both "personal" research tools and "peer and presentation" graphics tools. The audiences will be the scientists themselves, their peers, both informally and at conferences, and the general public.

- **Staffing of the Visualization Work**

  The staff in Global Remote Observations consists of six scientists, three support scientists, three programmers, and two students. The support scientists have backgrounds in atmospheric science, and develop applications using NCAR Graphics and other utility packages. The programmers have backgrounds in math or computer science, and develop new utilities for use by the scientists.

  Many of the scientists are Macintosh users and would like to do their data analysis without doing any more programming. Others have Fortran programming experience and would like some easy-to-use software tools (preferably supported by SCD). ACD looks to SCD to provide base-level tools and standardization.

- **Current Software Tools**

  The currently used software tools include NCAR Graphics, Interactive Data Language (IDL), supported on VAX/VMS, and interactive graphics tools which run on the Macintosh. They use NCAR Graphics to produce DICOMED output from the CRAY. Another tool they use is called Graphics Formatter (GF), a language for quick preparation of graphics. GF is supported by the Climate and Global Dynamics Division at NCAR.

- **Desired Tools and Distribution**

  ACD desires, as a first step, better presentation tools. These include Postscript output on the DICOMED, better interactive slide preparation tools, and support for tools across UNIX, Macintosh, and IBM PC platforms. They are also interested in videotape animation of graphical output.

  ACD believes that workstations will not be popular with scientists until SCD makes them available for the average scientist to use, with easy to use software tools included. ACD also is looking for standard data-handling utilities such as netCDF.

  Beyond these tools, they are most interested in the Wavefront software package with its ability to render data in 3-D, transparently, in a spherical projection.
Summary - Survey of Visualization Needs at NCAR

Another visualization needs survey was conducted at NCAR at about the same time as the above set of in-depth interviews. Bob Lackman of the SVG distributed a questionnaire containing a list of about 40 visualization related projects to the members of the NCAR Visualization User Group (VUG). A copy of the questionnaire is included as Appendix A. VUG contains representatives from all NCAR divisions and the Unidata Project of UCAR. This group was formed to coordinate visualization activities among the various research groups, disseminate related information, and to serve in an advisory capacity to SCD in its efforts to provide graphics and visualization support to the broader community of users. VUG members were asked to circulate the questionnaire among their graphics knowledgeable colleagues. The top 12 items from the questionnaire (Table 1) were taken as an action list to be addressed by the SVG. The specific questionnaire requests were combined with support requests from the interviews and distilled into the following five major categories:

1. The capability to process and archive many large datasets.
2. A highly integrated, yet heterogeneous, distributed computing environment.
3. A wide range of integrated visualization tools, including both locally developed and acquired tools.
4. Improved presentation graphics, including color print, slides, film, and video animation.
5. Nonprogrammatic intuitive interfaces to visualization tools, including NCAR Graphics.

The first two items relate to the general NCAR computing environment and will be addressed in the context of current capabilities and future plans of SCD. The last three items will be discussed from the point of view of the SVG.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Relative Weight</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>186</td>
<td>Support CGM output on the NCAR B &amp; W film recorders</td>
</tr>
<tr>
<td>2</td>
<td>136</td>
<td>Implement an NCAR raster file standard</td>
</tr>
<tr>
<td>3</td>
<td>131</td>
<td>Install a color print and transparency output server for CGM and PostScript</td>
</tr>
<tr>
<td>4</td>
<td>126</td>
<td>Acquire an SCD video animation system</td>
</tr>
<tr>
<td>5</td>
<td>122</td>
<td>Implement an interactive interface to NCAR Graphics</td>
</tr>
<tr>
<td>6</td>
<td>122</td>
<td>Develop a CGM to NCAR raster filter</td>
</tr>
<tr>
<td>7</td>
<td>117</td>
<td>Implement this filter (item 6) on the NCAR film recorders</td>
</tr>
<tr>
<td>8</td>
<td>114</td>
<td>Develop a subroutine interface for the NCAR raster format</td>
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<tr>
<td>9</td>
<td>113</td>
<td>Develop compositing tools for CGMs and NCAR raster files</td>
</tr>
<tr>
<td>10</td>
<td>106</td>
<td>Create a better color table editor</td>
</tr>
<tr>
<td>11</td>
<td>105</td>
<td>Support low resolution animation</td>
</tr>
<tr>
<td>12</td>
<td>101</td>
<td>Support easy output of VERY LARGE image files on the NCAR film recorders</td>
</tr>
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</table>

Large Data Sets

At NCAR, analysis of VERY LARGE datasets is a primary focus. The SCD supercomputing facilities include a CRAY Y-MP8/864 supercomputer, various other high-performance systems, huge amounts of mass storage on both disk and tape, an IBM 4381 front end system, and networks to support access to the supercomputer facilities by users on UNIX and VMS systems. Output from the supercomputers onto printed and graphical media is also a major requirement. These facilities are
used by thousands of researchers both within NCAR and at universities and agencies. SCD is committed to advancing the state of the art in data-intensive supercomputing, while at the same time providing a high level of support for all the users.

At the current time, SCD has about 14 terabytes of data in the mass storage archives. The locally developed MSS (Mass Storage System) file system software supports hierarchical migration of the datasets between storage media types based upon dataset usage and size. Active datasets automatically migrate toward quick access media while unused datasets migrate toward low-cost off-line storage. The actual storage medium is transparent to the software interface. Thus, as media evolve with higher data storage densities, these media can be installed in a manner which is transparent to the user. SCD currently supports "fast-path" transfers of data between the MSS media and the supercomputer. It also supports the transfer of large files over the local Network Systems Corporation (NSC) HYPERchannel, and is currently testing Large Packet TCP/IP transfers over the HYPERchannel. SCD is also a leader in high bandwidth networking using satellite, microwave, and leased-line communication media. SCD is actively participating in mass storage and networking research activities and special interest groups. Plans call for SCD to remain at the forefront of both of these areas. For more detail the reader is referred to SCD FY90-91 Development Plan. Copies are available from the Scientific Computing Division at NCAR, P. O. Box 3000, Boulder, CO 80307-3000.

Users in all of the NCAR divisions, as well as researchers around the country, are wrestling with the problems of visualizing massive datasets and providing higher productivity for their scientists and programmers. This involves the adaptation of new visualization techniques such as 3-D presentations, animation, volume rendering, and image compositing. It also highlights the need for efficient data compression and decompression of network files.

Distributed Computing

Several of those interviewed mentioned the need to distribute the computational work between SCD central facilities and user facilities where a heterogeneous mix of computers is common. One person mentioned the need to support Macintoshes, IBM PCs, UNIX workstations, and the central computers. An evolving standard which figures prominently in SCD plans for a common distributed computing environment is the X Window System. X11 products which support all of the above systems are already available.

Scientists at NCAR are using X11 to generate graphics on the supercomputer and display it on their local workstation in the supercomputer client window. The support of X11 on IBM PCs, Macintoshes, and UNIX workstations is an integral part of the plans of the SCD Distributed Computing Environment Group.

Integrated Visualization Tools

Most of the staff interviewed expressed the importance to their work of the NCAR Graphics software. However, most also mentioned other tools which they found useful. Some of those mentioned were the NCSA Tools (X-Image and X-DataSlice), IDL (the Interactive Data Language), SHOW from the University of Colorado, GF (a command language NCAR Graphics interface) from the Climate and Global Dynamics Division at NCAR, Macintosh tools, and several 3-D rendering packages, including Dore' by Stardent Corporation, Wavefront, and PolyPaint from the Mesoscale and Microscale Meteorology Division at NCAR.

The key word here is integrated. Are the packages portable across machines? What format do they expect for input data? What is the format of the output data? Can output from one package be
input to another? Can the graphics be output on all available graphics servers? Does the software and hardware support indexed and/or true color? These are some of the compatibility problems one encounters in attempting to integrate tools from a variety of sources. Some of the data formats commonly involved include:

- The Computer Graphics Metafile (CGM)
- PostScript and Color PostScript
- Raster formats including NRIF (NCAR film recorders), GIF, TIFF, three raster formats from X11 for B&W, indexed color, and true color, IDL, Sun, Iris, Abekas, any other vendor, ...
- netCDF of UCAR Unidata for data of multiple types and dimensions
- HDF of NCSA for data of multiple types and dimensions

The SVG has made a major investment in developing a suite of filters for converting data between the various formats. Virtually all of the raster formats listed above have been addressed. A filter from CGM to PostScript exists. Filters from CGM to raster and CGM to HDF are being developed. The SVG has also developed filters for converting pre-CGM NCAR Graphics metafiles to CGMs, and for adding or removing the NCAR wrapper that turns an external CGM into the private NCAR encoding. There are three encodings of the CGM allowed in the ANSI/ISO standard, binary (NCAR Graphics output), clear text (useful in reading a CGM for debugging a problem), and character. It is conceivable that translator/filters could be written to convert between any of the three allowed CGM encodings.

SCD has developed a tool called makrastg which allows the contents in a window on a Sun, Macintosh, Iris, or a workstation running X11 to be dumped to a film recorder for the creation of a 35-mm slide. For each system a different raster filter is needed. In the Macintosh case any one of a number of different filters may be needed depending upon the software being used. In the case of X11, one of three filters is needed based upon whether the contents of the window are B & W, indexed color, or true color.

At this point it should be clear as to why, whenever possible, data formats should be standardized. Many graphics packages have standardized on the CGM as a two-dimensional vector graphics standard. A similar raster standard is needed. Raster files tend to be very large, up to 3 MB per frame. Thus, running such files through multiple filters in order to take advantage of another software tool, or to output the file to another device is very costly in time and storage. At this point, virtually every hardware and software vendor has its own raster format. Although they are all very similar, the slight differences are enough to create an integration nightmare.

**Presentation Graphics**

Both questionnaire respondees and those interviewed cited a need for better tools to allow the users to more easily prepare presentations using existing data files (CGM and raster files) and hard-copy graphics devices (such as DICOMED and Postscript devices). In other words, a way of easily converting existing "personal" graphics into "peer" and "presentation" graphics.

They also asked for new tools such as workstation animation loops of images held in memory, and video and optical recording of multiple graphics images for playback animation. Editing capabilities are needed for both image sequencing and individual images.

The SVG is responding to these needs in a number of ways. We have recently added new font capabilities to the NCAR Graphics translators. We have created the massive set of filters which allow the contents of screens and windows on many workstations to be output on the film recorders. We
have acquired and integrated a video animation system that allows recording, editing, and playback. We make this equipment available to scientific research groups at NCAR and work with them as time allows to help create their videos. We are working on a CGM rasterizer, CGM and raster compositing tools, and a color CGM to color PostScript filter. We have created a new NCAR Graphics utility PLOTCHAR which generates better quality stroked characters with a more convenient user interface. We have developed a prototype interactive X Window System based tool called "idt" which allows editing of CGMs on a frame level. We are developing a powerful color editor for use with CGM and raster files.

The missing item is a hierarchical editor for CGMs. Users need to move lines and legends, change fonts, line widths, character sizes, and colors of image components, etc. Within the SVG we have discussed the creation of a hierarchical, object-oriented CGM to be output by NCAR Graphics. However, such a large undertaking would require major funding of new staff.

User Interfaces

Most of the survey and interview participants want easier to use, nonprogrammatic interfaces to their software tools, including NCAR Graphics. They want to use the tools in an interactive manner when possible, with intuitive menus and selections of items on the menus. They would like a consistent "look and feel" across the range of available tools.

The SVG believes that the X Window System software for creating application interfaces holds the most promise for achieving this goal across many software tools installed on diverse hardware. The SVG has created the prototype X11-based tool "idt" for displaying and editing CGMs. NCSA has created X-Image and X-DataSlice. The SVG color editor is being created with an X11 interface. At this point, some application developers are building their interfaces on top of the MIT Project Athena widgets. Some are using the Open Software Foundation (OSF) Motif widgets. Most of the application builders we have discussed the toolkit selection problem with have stated that they would convert their application to use whichever toolkit becomes the defacto standard. Most felt the conversion would not be too difficult. This is also the SVG position.

Recurring Themes

Additionally, the following general statements about the demand for scientific visualization at NCAR were recurring themes in the interviews.

- Besides graphical software, visualization also requires the ability to ingest data. There is considerable interest in netCDF, a self-describing data format and associated software distributed by the UCAR Unidata Project.

- Most scientists still use terminals or PCs; only a few have access to bitmapped workstations. However, as easy-to-use visualization software is made available to the scientists, the demand for workstations will increase dramatically.

- For the most part, researchers are not keenly aware of available visualization products, and are looking to a support group such as SCD to advise them. A couple of the groups we interviewed were exceptions to this rule. They mentioned that they wanted to use, or had already used 3-D rendering software, such as the Wavefront rendering software, Pixar volume-rendering software, Dore' the 3-D visualization toolkit from Stardent Corporation, and PolyPaint, the NCAR 3-D polygon creation and rendering system.

Most scientists understand in principle how visualization will be critically useful to advance their science and ability to compete in the future; however, they need help in taking the first steps toward this goal.
- Scientists who deal with raw field data feel that the initial stages of data analysis, such as sensor calibration, data reduction, and quality control, are too specialized to benefit much from use of general interactive visualization tools. In contrast, both "data-intensive" and "model-intensive" researchers feel that the display of fully reduced data, which is usually in regular three-dimensional grids, is common across a wide range of research applications. Hence, better use can be made of common graphics tools.

- The first tool most scientists ask for is a way to easily prepare presentations, usually on slides, which incorporate existing graphical images.

The Scientific Visualization Group Support Model

There are two basic models for organizing the development of new software and methodologies for scientific visualization. In the "graphics expert" model, highly skilled specialists in graphics and software development work directly with the scientist, who does not need to know how to program. In the "graphics toolkit" model, the graphics experts create or support software which is well documented and has easy to use interfaces, both interactive graphical user interfaces and programming interfaces. The scientists and their applications programmers are then able to create their own visualization applications on the basis of their own needs.

The NCAR Scientific Visualization Group is currently organized to support the "graphics toolkit" model with NCAR Graphics and associated utilities. However, as SVG moves away from a batch and two-dimensional graphics orientation toward much more complex 3-D and X Window System interactive applications, the "graphics expert" model will also be adopted, at least during the learning phases.

Several joint visualization projects between SVG staff and research groups are under way in the areas of ozone depletion, global warming, and ocean modeling. The expressed objectives of these projects will be to gain knowledge of what software tools, technologies, and methodologies will work best in the user environment. Software under consideration for these collaborative efforts includes Wavefront 3-D rendering software, PolyPaint 3-D rendering software, and two-dimensional color contouring by the NCAR Graphics CONPACK utility. All of the projects involve the creation of a presentation video. The knowledge gained in these joint visualization projects will be used by the SVG in ongoing efforts to acquire, build, integrate, and interface visualization tools which will best serve the broader NCAR/UCAR scientific community.

The long-term direction and near-term plans of the SVG are given in Appendix B.
Appendix A: NCAR Visualization Needs Survey

Items included in this survey are specific to the NCAR environment. The questions contain many local and technical terms and acronyms which are expanded upon in a glossary appended to the questionnaire.
Questionnaire on Graphical Needs

Enclosed is the wish list for graphical services, tools, and facilities which was put forth at the February 22 meeting of the NCAR Graphics Users Group. Your feedback on associated priorities is requested.

Please mark an H, M, or L in the left margin to indicate whether you feel this item is of high, medium, or low importance to you and your colleagues. No mark means no opinion.

Please return the form to Bob Lackman, SCD, NCAR. I will tabulate the results and forward them to all who respond. If many new items are proposed I will repeat the process for the new items. I would also appreciate any general feedback such as items that need more clarification, etc.

Blank lines are included for adding items which were not proposed in this first pass.

SCD Environment

CGM output on the black and white DICOMEDs
QUAL = BEST on SUDOOS
Software on SUDOOS for processing massive MSS files such as color movies. Data flow is by frames rather than by file. A SUDOOS camera is locked up by this job until completion.
PostScript output on SUDOOS
A video tape recorder on SUDOOS. Mailing of tapes to remote sites.
A high capacity PostScript laser printer
A color printer for CGM and PostScript prints and transparencies
A color reproduction machine for NCAR

User Workstation Environment

A PostScript to Mac PICT filter
Logging of workstation command sessions for subsequent replay
Data handling tools under a common menued user interface
Quick low resolution animation
Presentation quality high resolution animation
Color table editor(s)
NCAR Graphics Enhancements

- An interactive front end for the utilities
- Better and more character fonts
- CGM metafile editors
  - Clear text and binary encodings of the CGM.
  - (Clear text editing with binary translation.)
  - Interactive editing of CGM objects.

NCAR Raster Files

- A standard raster file format for NCAR
- A subroutine interface for generating raster files in NCAR format
- Tools to manipulate raster images such as rotating, sizing, etc.
- Tools to composite (combine/overlay) raster images
- A CGM to NCAR raster format rasterizer.
- A PostScript to NCAR raster filter
- A SunView window to NCAR raster filter
- An X11 window to NCAR raster filter

Visualization

- 3D solid image rendering software
  - PHIGS
  - Dore'
  - PolyPaint
  - WAVEFRONT
  - Other
- Video animation system (at a department level)
- Video animation system (an SCD central service)
- Common menued interface to visualization software packages

Name ___________________________ NCAR site _______________________
e-mail address ___________________
Glossary of Jargon

CGM clear text and binary encodings

There are three possible output formats for a CGM: binary, clear text, and character. The NCAR CGM output from the NCAR GKS01A package is binary. Thus there is no reasonable way to print the information in a manner that can be human readable. The binary format was selected for CGM output because it is the most efficient form for computer processing.

The clear text format, on the other hand, inserts text descriptions of the CGM elements such as the polyline, or polytext. It is much more human legible. Thus, people use the clear text form for reviewing the contents of a CGM. It is also possible to build filters to go from one type of encoding to the other. Thus, it is conceivable that one could edit a clear text file with a standard screen editor, then convert it to a binary encoding for output.

CGM: Computer Graphics Metafile

This is an ANSI/ISO approved graphics standard. It is a device-independent graphics file produced by the GKS version of the NCAR Graphics package which runs on the Crays and other computers. It is a different format than the "old" NCAR plot package. Currently, only "old" NCAR metafiles can be plotted on the black-and-white microfiche cameras, and only CGM can be plotted on the color Dicomed 35-mm camera.

Color table

A table of indices that are associated with particular Red-Green-Blue mixtures. A color table editor would allow a person to interactively "tune-up" a color display.

Common menu-based user interface

A Macintosh-like way of running your applications. Options are selected from menus using mouse clicks, etc. The X Window System toolkit seems to be evolving as the best choice for the creation of a same look and feel application environment across heterogeneous workstations and X supporting terminals.

Doré: A 3D visualization package developed by Ardent Corporation

Interactive editing of CGM objects

It is conceivable that one could use the CGM escape element to encode descriptions of CGM objects such as: which polylines are grid lines, which are tick marks, which are contour lines, etc. Based upon these object descriptions, one might then build an
interactive editor that would allow changing the color or line width of all tick marks, grid lines, specific contour lines, etc.

MSS: Mass Storage System

PHIGS: Programmers Hierarchical Interactive Graphics System

It is an evolving ANSI/ISO graphics standard. The GKS packages running at NCAR are oriented toward 2D graphics. PHIGS is oriented toward 3D graphics. Much of GKS is a subset of PHIGS. PHIGS is very adept at rotating, sizing, translating, and replicating 3D objects.

PICT: A graphics format on the Macintosh

It is used for applications such as MacDraw. A CGM-to-PostScript format converter already exists. This filter would allow a CGM frame to be edited in an object oriented way on a Macintosh so as to convert it to publication quality. The result could then be output on a LaserWriter.

PolyPaint: A 3D visualization package distributed by NCAR

This package is being developed by Joe Klemp and Bill Boyd of the NCAR Mesoscale and Microscale Meteorology Division.

PostScript: An object oriented page description language

PostScript is used by most desktop systems to specify what will be printed on a page. A PostScript translator on TAGS would allow PC and Macintosh users to produce color presentations on their desktop systems and then output them to color 35-mm slides with less than 24 hour turnaround.

QUAL: A keyword in the TAGS command language

It indicates the quality level desired for the output plots. QUAL=BEST will result in no color mixing. That means that the last color plotted on a pixel will be the color to appear on the Dicomed frame.

Raster file

A display format in which an image is portrayed by rows and columns of individual pixels rather than objects such as lines and characters. Traditionally, these formats have been very device and vendor dependent. Satellite imagery is a common example. Screen dumps from a workstation is another. Compositing is the ability to lay a series of rasters on top of each other. This allows continental outlines to be put on top of a satellite image for example.
SunView

In the context of this survey it refers to a window dump of a file in a Sun dependent raster format.

TAGS: Text and Graphics System

At present TAGS only supports output on the color Dicomeds. It will only process CGM metafiles from the GKS-based version of NCAR Graphics. One question deals with the priority of moving the black-and-white film and fiche units to this system. This move would be coupled with a filter being made available to convert an old NCAR metafile to a CGM.

WAVEFRONT: A very expensive, but very functional, 3D visualization package

It is used by the Visualization Group at the National Center for Supercomputer Applications (NCSA) to create scientific video animations.

Workstation window dumps

When a plot is displayed in a window (subset of the screen) on a workstation it is in the form of a raster file in some workstation dependent format. To output that image on the color Dicomed it must first be converted from the workstation dependent raster format to the raster format accepted by TAGS. The TAGS format is called the NCAR raster format.

X11: Version 11 of the X Window System developed at MIT

The X Window System is being adopted by most major workstation vendors as the windowing standard. It is a network-based system that consists of two distinct parts: a display server (PC or workstation) that manages user input and provides displays, and the client (same or another computer) running application tasks. Thus, X11 will eventually allow graphics to be generated on the UNICOS Cray and displayed on the user's workstation. (Some terminals now support X11 also.)

Included with the system is a toolkit for building menus to support user applications that give the interface an appearance similar to that of a Macintosh. Many people believe that X will be the common user interface of the future. X11 is public domain free software.

HP, Digital, IBM and others are working on another collaborative effort called the Open Software Foundation (OSF). Digital has a windowing system built on top of X called DECwindows. The Scientific Visualization Group X11 driver in the C language translator ported to DECwindows without a problem.
Appendix B: Scientific Visualization FY90-91 Plan

This appendix contains Chapter 4 of the second issue of Supercomputing: The View from NCAR, a published review of FY89 activities of the NCAR Scientific Computing Division (SCD), and the FY90-91 plans for SCD.

4. SCIENTIFIC VISUALIZATION
4. SCIENTIFIC VISUALIZATION

In FY89, the Graphics Group name was changed to the Scientific Visualization Group to reflect the widespread trend in the evolution of visual tools for scientific analysis.

The term "scientific visualization" refers to the process by which scientists gain insight into problems using visual techniques. It implies a shift in emphasis away from computer graphics and towards the overall process of analysis. Scientific visualization tools leverage this process by unifying several technologies including, but not limited to, computer graphics, user interfaces, data management, artificial intelligence, and signal processing. The SVG extended plan is to provide a comprehensive set of state-of-the-art visualization capabilities to the UCAR/NCAR scientific community.

At present, the SVG provides NCAR Graphics, which is a set of predominantly two-dimensional graphical tools well-suited for applications in the atmospheric and other geosciences. NCAR Graphics is primarily a subroutine library and, as such, has only minimal provisions for the user interface and data ingest. NCAR Graphics does, however, include tools for viewing graphical output that address the user interface; these are evolving rapidly. The current release of NCAR Graphics extends the realm of two-dimensional (2-D) graphics to a reasonable functional plateau. Future emphasis will continue to focus on the user interface, data interface, and a seamless fit into the modern desktop computing environment.

The next generation of visualization tools for NCAR will rely heavily on three-dimensional techniques coupled with animation in a distributed computing/supercomputing environment. The tools will, in most cases, not be used programmatically. The user interface will be window-based and easily as important as the visuals it allows one to create. The explosive growth in the area of scientific visualization will give rise to a diverse and rich set of tools available from many institutions. Commonality and interoperability will be key issues and probably the focus of much development work. Nonetheless, it is still likely that certain capabilities that are somewhat unique to the geosciences will need to be developed. There are three-dimensional analogs to much of the functionality in NCAR Graphics; thus, techniques such as velocity vectors, streamlines, contouring, and mapping are all likely candidates for a migration to the world of temporal three-dimensional visualization.

The SVG will assume a leadership role in technology evaluation for NCAR. This will lead to the development, acquisition, and installation of visualization tools and services that satisfy a complex set of requirements bal-

ancing function, cost, standards conformance, portability, supportability, and interoperability.

Charting a course in an area that is changing so rapidly is an exceedingly difficult task. In an attempt to unravel some of the complexity, the next section offers a "visualization architecture" that serves as a foundation for examining existing tools, how they are related, and possible evolutionary paths.

4.1 An Architecture for Visualization

Figure 22 shows a simplified visualization architecture that represents the SVG view of our anticipated future direction.

The user sits at a terminal or workstation that is an X Window System server and selects the NCAR interactive application. A top-level window appears and provides the user access to a number of tools including NCAR Graphics, NCSA tools, PolyPaint (graphics mapping/rendering software developed by staff in NCAR's Mesoscale and Microscale Meteorology Division (MMM)), and others. The top-level interface will be easily extensible to allow the addition of new tools. All tools available through the top-level window have their own X-based interactive interfaces.

Three minimization efforts are needed to constrain the complexity of this workstation environment: software selection, software standards, and archive formats.

4.1.1 Software Selection

The visualization and data processing tools should be functionally complete, but not redundant. The SVG is currently reviewing visualization software based upon previously mentioned selection criteria.

4.1.2 Software Standards

The number of underlying graphics standards should be as few as possible. To simplify the creation of a full visualization service based upon the integration of a variety of tools from a variety of sources, the SVG remains committed to use standards whenever possible in all stages of the visualization cycle. Visualization tools that are written or acquired will adhere to programming language standards. Currently, FORTRAN 77 and ANSI-proposed C are the popular choices in visualization software.

The X Window System has evolved as a very strong defacto standard for networked client/server applications. Applications can be executed on a client and the results can be displayed at the server. X Window System platforms can include supercomputers, workstations, and X
Figure 22. A visualization workstation.

Window terminals. Moreover, X Window System toolkits have become the de facto standard for interactive "point-and-click" window-based user interfaces. Current graphics standards include the 2-D GKS standard and the 3-D Programmer’s Hierarchical Interactive Graphics System (PHIGS) standard that enables the rendering of images from 3-D structures. Thus, multiple views of a 3-D structure are more efficient to generate since creation of a next view need not return to a geometry-rendering stage. PHIGS functionality is being added to the X Window System through the development of PEX (PHIGS Extensions to X). The first public release of PEX is expected in late 1990.

Since the functionality of GKS is a subset of the functionality of PHIGS, one possible approach to reducing the number of underlying standards would be to convert any tools, such as the NCAR Graphics utilities, from dependency on GKS to dependency on PHIGS. The SVG will investigate this possibility in FY90.

4.1.3 Archive Formats

Scientists will be encouraged to format their model output and observational data in netCDF format to facilitate input of that data to data processing and visualization tools. The netCDF format was developed by the UCAR Unidata Project for use in a networked environment. It is a generalization of the NASA Common Data Format (CDF).

Archive files generated by the visualization software will include raster images, encoded metafiles of 2-D vector images, and 3-D structures of graphical objects. For raster images, the SVG will adopt the NCAR Raster Interchange Format (NRIF) developed in support of SUDOOS. The 2-D vector images will be in CGM format, which is a very strong, widely adopted standard. The standard format for 3-D structures is still too new to list here. However, PHIGS, which is a possible candidate, has an archive format for data structures. Also, the Pittsburgh Supercomputing Center has proposed an extended structure, called P3D, to the Sandia National Laboratories, Los Alamos National Laboratory, and the Air Force Weapons Laboratory Technical Exchange Committee (SLATEC) Plotting Library Group. To avoid an excessive number of format filters, it is important for the visualization community to adopt as few archive formats as possible. The SVG has already developed numerous raster format filters because a strong standard has yet to emerge.

4.2 The Visualization Pipeline

Figure 23 shows a generic pipeline through which data might flow in an attempt to create visuals from data in a
The available options include reformatting data, resampling and sequencing data, and creating a direct image of the data by assigning red/green/blue (RGB) values for the data values (image rendering). A final option is performing geometry mapping into a new structure followed by structure rendering to obtain an image, combining and editing the images, and finally generating output of the images to soft- or hardcopy.

Figure 24 shows a typical NCAR Graphics application that follows this pipeline.

First, a model history file written in a local user format is converted to a netCDF format. This filter would probably be written by the user. The next step would be to use the netCDF interface library to extract a series of 2-D data slabs from the archive. For each 2-D data slab, the CONPACK color fill contouring utility of NCAR Graphics would be called to map the data into the desired geometry and render the contour images. This CGM file would be read into NCAR View, an interactive package to display, combine, and output CGMs and NCAR NRIF files, where it could be viewed on an X-based workstation or terminal and output to any of the listed devices.

Tools needed to support the visualization pipeline include:

- Format Filters
  Possible examples are to alternate between NCSA's Hierarchical Data Format (HDF) and netCDF, between proprietary vendor raster formats and NRIF, between CGM and PostScript, between CGM and NRIF, between pre-CGM NCAR metafiles and CGM, between PHIGS archive and P3D, etc.

- Resampling and Sequencing
  A possible example may be to extract a subset of data from a larger set that could exist in up to five dimensions: three in space, one in time, and one in parameter. One might also combine subsets into a larger set, or reorder the data. These are traditional database management functions. Sequencing in two-dimensional images could be altered. Fill frames could be interpolated from key frames. Raster images could be resized to a larger or smaller number of pixels.

- Compression and Decompression Filters
  These tools would be useful for reducing file sizes for network transmission and media storage. They would be desirable for all of the common formats.

- Mappers
  Mappers are utilities that generally convert between the input scientific data and a visualization geometry. Many of the NCAR Graphics utilities (CONPACK, EZMAP, HISTGR, AUTOGRAPH, VELVCT, STRMLN, SRFACE, etc.) are mappers. The "Poly" in PolyPaint is a mapper that creates polygonal vertices of a 3-D isosurface from parameter values on an (X, Y, Z) grid.
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- **Renderers**
  
  Renderers create images from geometries. PHIGS renders PHIGS structures. The “Paint” in PolyPaint is a renderer. It renders the geometric structure created by Poly. Rendering functions include altering the eye position, altering the number and position of light sources, surface coloring, Gouraud or Phong shading, etc., in the creation of a final image.

- **Image Processing**
  
  Images might be edited, resized, combined in various ways, enhanced, compressed, etc.

- **Output and Storage**
  
  Data of any of the previously discussed varieties might be stored on magnetic or optical media. Images in NRIF, CGM, or PostScript format might be output to laser printers, SUDOOS, and other devices. Images might be displayed in windows on X-based workstations using NCAR View. RGB output from the workstation might be recorded on optical disk or videotape.

To create a full functionality working environment, these visualization-related tools would also have to be augmented by tools for signal processing, spectral analysis, statistics, etc. The desired goal relative to the X Window System interface would be a menu-building and application integration facility that is simple enough so that the user could add and remove utilities to create a personalized application environment.

The following sections detail the visualization activities conducted in FY89 and the planned enhancements for FY90 and FY91.

### 4.3 FY89 Review

The primary focus of the SVG in FY89 was to complete Version 3.00 of NCAR Graphics/2-D, based upon the Graphical Kernel System (GKS). Thus, most of our effort was devoted to completing a project that began in FY88. Nevertheless, we still initiated a small visualization research effort.

First, we conducted a number of interviews with NCAR scientists on their visualization needs. Next, we acquired, installed, and integrated graphics workstations, a number of visualization software packages and video animation equipment, and began to help users visualize their scientific datasets. We tried rendering the data in several ways using various 3-D software packages. Finally, we assisted many scientific groups in creating short video animations of their data. Other FY89 projects included:

- **NCAR Graphics Distribution**
  
  Approximately 200 sets of the NCAR Graphics package were distributed by SCD with the assistance of User Services and Operations staff.

- **Version 3.00 of NCAR Graphics/2-D**
  
  At the end of FY89, Version 3.00 was essentially complete. It contains a number of enhancements including:
  - Autoinstallation on more UNIX systems;
  - Seven new utilities (CONPACK, PLOT-CHAR, SOFTFILL, COLCONV, GFLASH, STITLE, and LABELBAR);
  - All Hershey fonts and improved character handling;
  - Improved translators;
  - More device drivers (LaserJet, DEC VT330, Talaris 1590);
  - Documentation of the new utilities; and
  - Color example plots and a color chart.

- **Version 3.00 of NCAR View**
  
  The components of the package include:
  - A new CGM translator, “ctrans,” which supports the X Window System, SunView, as well as the standard library of “graphcaps” (a translation table for turning CGM elements to output device draw instructions);
  - A library of routines for manipulating CGM files called “cgmtools;”
  - CGM and raster filters for converting from the NCAR private CGM encoding to/from external CGMs, for converting from NRIF format to a CGM cell array, etc.;
  - Graphcap-based device drivers to support many of the popular printer/plotter and terminals; and
The Interactive Display Tool (idt), a "point-and-click" style interactive facility based on the X Window System for previewing and combining CGMs. Since idt is a pilot project based on user interface capabilities that are neither widespread nor stable, it will be made available "as is" in Version 3.00 of NCAR View, but not as a supported product.

Figure 25 shows the components and dependencies of NCAR View.

Figure 26 shows a contour image from the NCAR Graphics utility CONPACK, using the X Window System driver in NCAR View.

- Support of SCD Services

Support of NCAR Graphics in SCD spreads across many sections including User Services, Systems, and Operations as well as Distributed Computing.

SVG staff, in conjunction with SCD's Systems Section staff, have supported the SUDOOS/Didiomed effort by providing software, reviewing documentation, and participating in design reviews. Contributed software includes a collection of raster filters that allow Macintosh, Sun, X Window System, and NRIF images to be processed by SUDOOS, translator enhancements, software fill, color charts, and various CGM filters.

- User Services

- Training

SVG staff provided a detailed CONPACK seminar and wrote functional descriptions of the new utilities and new graphics products including NCAR View.

- Site Liaison, User Conference, SCD Computing News

SVG staff contributed approximately two-dozen presentations and demonstrations, both inside and outside NCAR, in the areas of NCAR Graphics and visualization.

- COS Implementation of NCAR Graphics

- UNICOS Implementation of NCAR Graphics

SVG staff added an autoinstallation capability for UNICOS 5.x. They provided training support to the User Services Software Libraries Group in the installation and support of the package on shavano.

- Technical Consulting Support

SVG staff continued to support the User Services Consulting Group in technical consulting on NCAR Graphics.

- System Installation, Integration, and Maintenance

SVG staff added a substantial amount of visualization hardware and software to the existing collection including Sun and Digital workstations; WaveFront, Dorf and Plot-3D software; and a video animation mastering system.

- CU Student Project

The SVG sponsored the Windowed Interface to NCAR Graphics (WING) pilot project, wherein four University of Colorado computer science students developed a prototype interactive interface to CONPACK as a year-long credited class.

- NSF Proposal for an NCAR Interactive Interface

- Visualization Research and Development (R&D)

Most of the effort in visualization involved planning, acquiring, and integrating related hardware and software, initiating the DEC/NCAR Joint
Research Project, surveying user needs, making visualization presentations, and hosting visitors interested in visualization. The following R&D projects were performed:

- Created an ozone depletion video in collaboration with DEC/WaveFront and NCAR's Atmospheric Chemistry Division (ACD);

- Generated a set of terrain data visuals for the UCAR President that demonstrate the results of using different size grid meshes in models;

- Supported scientific groups in the use of SVG video animation equipment;

- Used 3-D techniques to visualize oceanographic stream function data produced by Bob Chervin's [NCAR's Climate and Global Dynamics Division (CGD)] ocean model; and

- Assisted NCAR's High Altitude Observatory (HAO) staff in interfacing animation equipment to their systems and producing a presentation-quality video.

- Support of NCAR Graphics at NCAR

SVG staff installed the Version 2.xx translator on SVG systems including the Imagen laser printers, the Apple LaserWriters, the IBM 4381s, and supported its installation on SUDOOS. Support for SunView and the X Window System was added to NCAR View.

- Collaborations

- DEC/NCAR Joint Research Project

The formal agreement between Digital Equipment Corporation and NCAR was signed by NCAR in December 1988. NCAR Graphics was ported to the VAXstation ULTRIX and Reduced Instruction-set Computer (RISC) DECstation ULTRIX systems. Formal support for all DEC RISC-based systems was announced in August 1989. Collaborative work to install NCAR Graphics on DEC systems was very successful. Figure 27 shows SVG's John Clyne and MMM's Bill Boyd involved in that effort.
The NGUG and the SVG staff initiated a number of cooperative visualization efforts. First, to facilitate information sharing, a new group was formed called visual@ncar. Next, a community effort to share visualization software and its associated documentation was initiated. An SCD user login called VISTOOLS was created to establish a root directory on the SCD Mass Storage System. The SVG then added files under this directory, including netCDF from Unidata and the compression/decompression software (scry.tar) for raster images from the Lawrence Berkeley Laboratories. Other members of the NCAR visualization community are encouraged to add their favorite public domain software.

4.4 FY90 - FY91 Plan

The SVG staff will continue to track, acquire, and evaluate new visualization hardware and software to determine how it might fit into or alter long-term visualization plans. We will consult with scientific projects to help them configure and use hardware and software systems to meet their visualization needs. In FY90, the SVG will increase emphasis on working with the scientific groups to help create optical disk and videotape animations using SVG equipment. We will pursue standardization of input and output datasets and interactive application interfaces via the X Window System.

We will explore whether the DEC/NCAR Joint Research Project should be continued beyond the original FY90 period; and if so, determine new project goals.

We will continue to provide support for SVG software, including NCAR Graphics, NCAR View, and format filters, as follows:

- **Version 3.00 of NCAR Graphics/2-D**

  We will distribute Version 3.00 in the first quarter of FY90. We will complete new pricing, discounts for Version 1.xx and 2.xx holders, and new advertisement brochures and order forms before the first package is shipped. SCD will provide both UNIX and generic versions. MMM will continue to provide the VMS version.

- **Version 3.00 of NCAR View**

  NCAR View will be bundled with NCAR Graphics/2-D orders; however, NCAR View will
also be offered as a stand-alone product. It could
be used remotely to display CGMs created on
SCD mainframes or to display CGMs created by
packages other than NCAR Graphics.

- Version 4.00 of NCAR Graphics/2-D

This version will essentially complete the 2-D
utilities to be offered in NCAR Graphics. More
of the development effort will then be channeled
into 3-D graphics and interactive interfaces.
Some features to be reviewed for Version 4.00
include:

- Options for contouring irregularly gridded
data to replace the CONRAN suite of util-
ities;
- Filled fonts in support of publishable quality
output;
- Support for more CGM elements in ctrans;
- More device drivers;
- Coherent setting of color and other attributes
in the utilities through option setting rou-
tines;
- Documentation of the old utilities as per the
Version 3.00 new utilities; and
- Abstraction of GKS calls from the utilities
into the System Plot Package Simulator
(SPPS) level.

- New Releases of NCAR View

Some of the new features planned for NCAR
View include:

- Support for more CGM elements in ctrans;
- More device drivers; and
- Development of idt to include more work on
the look and feel of the user interface. For-
mal support for idt will be considered based
on the stability of X toolkits. Functionality
will be enhanced to include support for NRIF
file input and image compositing.

- NCAR Graphics/3-D

During FY90, we will evaluate the need for and
availability to our users of 3-D tools and visuali-
ization software. We will determine whether ther
are 3-D tools that bridge the gap between what is
available and what is needed. We will also instal
and review one or more implementations of the
PHIGS standard.

- NCAR Interactive

In general, any new product created by SVG
staff, such as NCAR View or NCAR Graphics/3-
D utilities, will have an interactive “point-and-
click” style of interface based upon the X Win-
dow System.

- Support of SCD Services

SVG staff will continue to work with other SCD
sections and NCAR divisions to deliver a full
visualization service. We will continue to sup-
port the SCD Systems Section in providing
diverse graphics output on SUDOOS and other
output servers. In FY90, the SVG staff will write
a CGM-to-NRIF rasterizer for SUDOOS support
of the QUAL = BEST option. We will continue
to provide technical graphics support to the User
Services Consulting Group. We will investigate
using videotapes as a training mechanism for
GKS and NCAR Graphics. SVG and User Ser-
vices staff will provide support to NCAR Graph-
ics users to convert codes from dependence on the
NCAR System Plot Package (NSPP) to the GKS/
CGM-based Version 3.00 package.

A new initiative in FY90 will be to work with the
User Services Section to acquire and make avail-
able to the user community high-quality graphics
software such as the NCSA Tools and PolyPaint
from NCAR/MMM.

- Support of NCAR Graphics at NCAR

- System Installation, Integration, and Maintenance

Planned systems upgrades and additions include a
Sun-4 SPARCstation, Digital video animation
equipment, a DEC workstation (yet unannounced
but probably RISC-based with 3-D capability),
and a review of RPCTRAN. [RPCTRAN is a
template software package developed at the
Sandia National Laboratories at Albuquerque
(SNLA) for generating distributed graphics codes
containing Remote Procedure Calls (RPCs).]

- CU Student Project

The SVG is sponsoring a two-semester class in
The FY90 C.U. project will develop a set of graphical objects (widgets) for the X Window System that simplifies building abstracted user interfaces in NCAR Interactive. These widgets would provide intuitive ways of setting colors, line widths and styles, hatch styles, character sizes, and character orientations.

**Distributed Scientific Visualization and Animation**

The geosciences community is collecting and generating vast amounts of data that span the four dimensions of space and time and include more than one variable. Thus, the ability to generate animation sequences of this data is essential to gaining insight into the contents of the data in a time frame that is in keeping with the rates at which the data are being collected. The computer and video technology necessary to create good quality animation sequences of these data in a convenient manner is an expensive but sharable resource.

In FY89, SVG staff acquired video animation equipment that they intend to make available to the SCD scientific community in FY90. The systems and services include:

- An optical disk-based video mastering system that may be used with most color workstations including Sun, Digital, Ardent, and Silicon Graphics;
- A professional quality, video postproduction system that allows the video editor to assemble production output from a variety of sources including computers, video cameras, and other videotapes;
- A facility to generate high-quality text and titles; and
- Consulting expertise and assistance.

In addition, SVG plans include acquiring a digital frame store that may be accessed using TCP/IP network protocols for file transfer (FTP, rcp) and a color workstation for user control and image editing of colors, titles, etc. The workstation would also provide in-memory animation loops, video mastering, and video playback.

These systems will be available in FY90 on an appointment basis for use by the scientific community. If the frame buffer and workstation are added, remote users could also transfer imagery via the Internet. However, these systems are still intended for use as a test bed for video-based animation, not as a production facility. Based on the experience we gain in FY90, we will make recommendations for the integration of production video into the SUDOOS environment. SUDOOS users will then be able to select either film or video for animation output. SUDOOS components would include a workstation with video, animation controller, videotape recorders, a high-capacity frame store, and associated system integration software.

Long-range plans call for the exploration of High Definition Television Video (HDTV) technology. This will likely provide the resolution of 35-mm color film, much enhanced color capabilities, and a digital format. This technology will be expensive to implement, and will place increased loads on computer resources and network bandwidths. However, compared to current 35-mm film technology, it should be more convenient to use and easier to maintain quality control at a similar price.

**Collaborations**

The SVG will continue to participate with all appropriate user communities, standards groups, and vendors to examine new developments in visualization that will best benefit our user community. Collaborations will include:

- DEC/NCAR Joint Research Project

DEC’s priorities for this collaboration are:

1. Seek information to help design a scientific visualization architecture that could be useful up to five years into the future. This would include relevant integration standards for graphics, networking, user interface design, etc.

2. Evaluate evolving visualization software packages from both the public and private sectors, including specifying how the software package fits into the visualization architecture, and the quality and usefulness of each package. This
information will be used to advise DEC customers which packages might be most useful to them, and to advise DEC on which packages should be supported on their systems.

3. Create a high level of project visibility within and outside of DEC through reports, demonstrations, presentations, and published articles.

To DEC, the term "Scientific Visualization" has a global meaning that spans all phases of interacting with data, from the data generation stage through journal publication of resulting analyses. Thus, their highest priority of the three listed above is similar in scope to the workstation environment described in Figure 22. It would include capabilities for data storage, data management, signal processing, computer graphics, image processing, and electronic publishing, with the capability of rapidly integrating these functions into a single application or a series of related applications. Eventually, all these capabilities might be fully integrated using a common interactive user interface. The SVG shares the belief that such an integrated environment is the desired goal. Thus, even if we can only contribute toward some part of the overall functionality, we intend to keep in mind the integration of those components into the grand design.

SVG staff have compiled much information on existing visualization software packages that will be updated and made available to DEC and others in FY90. This information is equally valuable to SCD and the SCD user community in planning and implementing visualization capabilities.

Finally, SVG staff will continue to provide feedback and public relations support for DEC. Milestones for FY90 and the first quarter of FY91 are:

- December 1989. Give technical review presentation to DEC.
- January 1990. Release to the NCAR community a document that describes the current state of our knowledge in visualization architecture and software integration standards. This document will also include the evaluation of as many visualization software packages as possible.
- November 1990. Publish an evaluation of scientific visualization tools for use with weather models.
- December 1990. Give two-year technical review presentation to DEC. Present the results of this collaboration at conferences and in SCD Computing News.

The original DEC/NCAR contract called for a two-year collaboration that will culminate in December 1990. During FY90, we will investigate whether the project should be extended, the length of time, and the contributions from both parties.

- WaveFront National Academic Advisory Program

WaveFront is a leading supplier of software for scientific visualization and creation of dynamic 3-D imagery. NCAR has been selected to participate in their academic advisory program along with other major players in the visualization arena such as NCSA and Cornell University. WaveFront will provide us with their software and training at no cost, and NCAR will give them feedback to assist them in their future development strategies.

- SLATEC Plotting Library

We will finalize the SPL cross licensing agreement; provide NCAR Graphics to contributing members; track the Standard Graphics Interface (SGI) package being developed by Lawrence Livermore National Laboratory (LLNL) of the SLATEC Group; determine if it can be adapted to provide alternate graphics roots for the NCAR Graphics utilities including PHIGS and CGM; and promote additional emphasis on higher-level visualization contributions.

- UCARF

The SVG will continue to work with the UCARF in support of NCAR Graphics.
- NGUG

The SVG will continue active participation in the NGUG and will report pertinent events to SCD staff; make design review presentations to the NGUG on all proposed SVG software products; review proposals for SVG student projects before the group; use the group as a sounding board for SVG ideas; and continue to poll the group on most needed SCD services and products.