UCAR

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Office of the President

27 April 1987

MEMORANDUM

TO: James G. Anderson
Francis P. Bretherton
William E. Gordon
James F. Kimpel
Harold D. Orville
Juan G. Roederer
Aksel Wiin-Nielsen

FROM: John A. Dutton

SUBJECT: Committee Report

I enclose for your consideration and (I hope) endorsement, a draft version of the NSF-UCAR Long-range Planning Committee report that has suffered through the vicissitudes of what appears to be a major change in NSF funding possibilities. In response to the potential for doubling the NSF budget in five years, the ATM folks are preparing long-range plans with budget scenarios considerably more generous than those with which we worked last June. They have urged us to revise our recommendations to be consistent with what appear to be the new realities. The changes in the budgets that appear in the draft were made by Francis, Dick Greenfield, and me to reflect the following considerations. They are all consistent, we believe, with the program and research priorities enunciated by the Committee.

1. All initiatives are now funded at the optimum level presented by the proposers;

2. The Large Earth Solar Telescope (LEST) has been specifically included, as has an NCAR participation in TOGA that dropped through the cracks before;

3. Additional funds have been added to the NCAR Facilities and Instrumentation initiative, which includes the supercomputer replacement at NCAR;

4. The Climate Monitoring initiative has been considerably augmented in the out-years to reflect more accurately the true magnitude of this task;

5. We have increased the CEDAR and NSTP initiatives above the original optimum levels to maintain the balance of the budget and because we believe that the "optimum" interpretation used in the proposals in this area was more stringent than that used by other proposers;

6. We have added an item for Base Program opportunities which is intended to cover growth in the base program not necessarily related to the stated initiatives. This item, in effect, takes the place of the "planning wedge" that occurred in later years of the plan; and,

7. An item to replace and enhance university research equipment has also been added. This is a high priority NSF need.

Our current intention is to make the documentation examined by the Committee available on request, but not to include it as an Appendix primarily because of its uneven nature and length. Thus, it is important that my summaries of the initiatives be accurate. We are asking you to examine carefully those about which you are knowledgable. Text for some of the new items is not included, but the budgets, we hope, are in final form. Text for LEST is included, but will have to be shortened to fit with other descriptions.

We are rushing to get the report finished and printed by 1 July so it can be mailed to National Science Board members for consideration at their August meeting. The text is being edited by UCAR in Boulder. Please send your comments or recommendations to Harriet Crowe (UCAR, P.O. Box 3000, Boulder, CO 80307; 303-497-1657; or H.CROWE on telemail), and indicate whether you are willing to endorse the report. In case you have serious problems with the substance of the draft, please phone me as soon as possible (814-865-6546). If we are to meet our deadlines, we must have your response no later than 15 May, and must necessarily interpret silence as concurrence.

- End of Memorandum -

cc: H. Crowe
S. Dickson
J. Fletcher
R. Greenfield
E. Harrison
V. Mohnen
C. Murino
S. Tilford
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CMT/PlanCom4

THE ATMOSPHERIC SCIENCES: A VISION FOR 1989-94

Report of the NSF - UCAR Long-range Planning Committee

(date)

Introductory Letter to be Obtained

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THE ATMOSPHERIC SCIENCES: A VISION FOR 1989-94

Report of the NSF - UCAR Long-range Planning Committee

(date)

EXECUTIVE SUMMARY

OVERVIEW

Man's spirited coexistence with Nature has accommodated ice ages, volcanic eruptions, droughts, and severe weather. Our instincts about the historical record have assured us that the Earth returns, despite the severity of any single event, to a time-honored mean. Human society is built upon generations of experience about our climate and natural environment, on expectations about limits of natural variability in day-to-day weather and the cycle of seasons, about the richness of life in the forests and oceans, about the fertility of the soil and the abundance of natural resources.

But now observations over the last few years have revealed a striking change in key indicators of the state of the planet: the atmospheric concentrations of carbon dioxide, methane, fluorocarbons, and ozone are all changing dramatically, indicating that the dynamic balances that control the planetary environment are being altered. We see an emerging image of profound change on the scale of decades to centuries.

In contemplating the immediacy and threat of change on the global scale, science has discovered anew that processes on vastly different spatial and temporal scales are all interrelated in the components of the Earth System -- the atmosphere, ocean, land surface, and the terrestrial and marine biospheres. All respond to variations in the solar energy that drives the system, and all are part of the complex process of controlling the Earth's energy budget and the planetary environment.

The challenges of understanding and predicting global change are forcing re-examination of the traditional roles and structures of the earth sciences, of the aims of individual scientists, of the organization of university departments. The scientific community, Federal agencies, and governments throughout the world are responding with initiatives such as the World Climate Research Program, the recently-approved International Geosphere Biosphere Program: A Study of Global Change, the National Aeronautics and Space Administration (NASA) Earth Systems Science Program, and the National Science Foundation (NSF) Global Geosciences program.

The atmospheric sciences community thus faces its own challenge of contributing to the study of global change while continuing to advance in its traditional efforts to understand and predict phenomena appearing in the realm extending from the surface of the Earth to the sun. Great opportunities lie before us for improvements in weather prediction, over both short and longer ranges, in understanding climate change, in portraying complex atmospheric phenomenology and analyzing the physical interactions that govern their evolution, and in understanding the intricate couplings between the sun and the various layers of the atmosphere.

This document is the report of a committee formed jointly by NSF and the University Corporation for Atmospheric Research (UCAR) to combine the major community initiatives and the available scientific opportunities into a coherent and balanced program of research in the atmospheric sciences. It recommends a six-year plan through which the Atmospheric Sciences Division (ATM) of the National Science Foundation (NSF) Geosciences Directorate can provide signal contributions to the effort to understand and predict global change while continuing to expand and strengthen the basic research that is the precursor to all scientific progress.

FINDINGS

In examining the current state of the atmospheric sciences and related disciplines and in projecting present trends into a vision of the next decade or more, the Committee reached a number of conclusions:

- The potential and reality of global change present intellectual and practical challenges to which the atmospheric sciences must respond with vigor and determination. The collective experience in observation, modeling, simulation, and prediction of the global atmosphere compels the atmospheric sciences to seek and to accept a position of leadership in addressing global change.

- The complexity of the atmospheric phenomena now being studied mandates new technological and organizational approaches to atmospheric science. Systems designed to observe phenomena such as severe storms or oscillations in tropical climates must involve multiple sensors operating from multiple platforms in a variety of modes. Data from such systems must be assimilated into simulation models to be fully analyzed and understood. The tasks involved are so complex that they can only be undertaken by groups of scientists committed to long-term collaboration.

- Community-wide facilities and university facilities will be increasingly important over the next decade as the emphasis on global geosciences and on the observation and modeling of complex phenomenology brings new technology to the fore and drives the science in directions that require renewal of the empirical knowledge base. The investments in advanced instruments and observational systems, research aircraft, and supercomputers will return astounding intellectual and practical dividends.

- The management of data increasingly will become the critical issue in scientific progress. Scientists and students must be provided with interactive, flexible, and transparent channels to utilize the data from new surface and satellite observational systems and from model simulations on supercomputers. New structures for active data bases must be developed, with consideration given to approaches utilizing self-organizing algorithms and the procedures of artificial intelligence. The key to progress is the ability of the scientist to explore fully the vast resources of observed data and model results that are becoming available at an accelerating rate.

- The partnership between the university scientific community and the National Center for Atmospheric Research (NCAR), forged through the University Corporation for Atmospheric Research (UCAR) consortium with NSF support, has been a signal accomplishment and a stimulus to progress in the atmospheric and related sciences. NCAR fosters a research program that attracts university collaboration and it provides outstanding community-wide facilities--a combination that will be even more important as the science turns to global issues and to the detailed examination of complex atmospheric processes and phenomena.

- Advances in global geosciences will be achieved through diverse efforts in the university and federal research communities. Collaborative structures reaching across disciplines and across institutions will be required and will take various forms. The creation and support of a variety of university centers for the study of global change may be expected to focus efforts and enhance progress.

- The atmospheric sciences, along with the other earth sciences, must create new educational approaches in order to develop scientists with the breadth and creativity that will be required in the next half-century. The multidisciplinary approach necessary to address global change will require individuals who are able to collaborate with specialists in oceanography, geology, geography, global biology, dynamical systems, chemical kinetics, remote sensing, and computer science. Practical problems in the atmospheric sciences will require a greater mastery of both fundamentals and technology.

- Maintaining the intellectual foundation of the atmospheric sciences is of paramount importance. It is essential that the vitality of individual initiative and insight be stimulated and supported and that the NSF/ATM program maintain a broad program.

of basic research unconstrained by immediate or collaborative initiatives. Future generations of scientists must be attracted, motivated, and educated to address creatively the key problems of the atmospheric and related sciences. Only by investing now in the development of fundamental knowledge and the education of talented individuals can we provide the foundation for the progress of future generations.

FORMULATION OF RECOMMENDATIONS

The Committee recognized at the beginning of its deliberations that it faced a challenging task of integrating exciting community-wide initiatives and critical enhancements of the NSF base program, both in the grants program and at NCAR, with the continuing effort in basic research in the atmospheric sciences.

In collaboration with senior staff members from NSF, NASA, and the National Oceanic and Atmospheric Administration (NOAA), the Committee critically reviewed the present activities and the initiatives proposed for the period FY1988-93. First, it evaluated the community-wide initiatives proposed by National Academy of Sciences committees and by formal scientific planning and steering groups. Then it examined the base enhancements for specific scientific initiatives proposed by NSF and NCAR staff. Finally, it reviewed the ongoing NSF and NCAR programs, paying special attention to the expected contributions to the initiatives and to the vitality of the program elements.

The Committee then assigned priorities to the community initiatives and program enhancements. On the basis of these assignments, it selected seven of eighteen proposed base enhancements and constructed what it believes to be an exciting and coherent program of new and continuing activities in global geosciences and in atmospheric science.

The Committee is recommending reprogramming of base funds and a responsible increase in total ATM resources in order to support the recommended program. With full recognition of the fact that the recommendations will require some investigators to redirect their work, the Committee believes that the new programs and the strengthening of some ongoing programs will offer all atmospheric scientists exciting opportunities to continue their contributions and will encourage the development of new generations of investigators.

RECOMMENDATIONS

The Committee foresees the International Geosphere Biosphere Program: A Study of Global Change, as the major new endeavor of the world scientific community for the next few decades. The NSF Global Geosciences Program must be poised to support and stimulate this initiative. We propose a redirected and augmented program for the Atmospheric Sciences Division that is both bold and balanced, but designed to contribute to this global initiative at an optimum rate while maintaining strength in the traditional areas of interest.

The Recommended NSF Atmospheric Sciences Division Program

The recommended program includes:

- Four major community science initiatives aimed at problems of global change (listed in priority order)

  Global Tropospheric Chemistry Program

  Mesoscale Meteorology

  Tropical Oceans - Global Atmosphere

  Coupled Energetics - Dynamics of Atmospheric Regions

- Five facility and organizational/infrastructure enhancements (each of equal priority)

  NCAR facility and equipment enhancements

  ATM program in Computer Science and Engineering

  Development of four university centers in global geosciences research

  Large Earth-based Solar Telescope

  University Research Equipment

o Eight new scientific initiatives in the grants program (GPS) and the NCAR scientific program (listed in priority order)

Coupled Climate Systems (NCAR)
Abrupt Climate Change (GPS)
Climate System Monitoring (GPS)
National Solar Terrestrial Program (GPS)
Cloud and Precipitation Physics (GPS)
Dynamic Extended Range Forecasting (GPS)
Solar Physics (NCAR)
Base Program Opportunities (NCAR and GPS)

The four community science initiatives have all been widely studied and endorsed by National Academy of Sciences committees and are now being guided by formal science steering committees. The enhancements of data management and computational equipment recommended as NCAR facilities enhancements and for the universities through the CSEI initiative are of crucial importance to all of the scientific initiatives. The Committee has thus provided explicitly for the enhancements of the community's scientific program and facilities that will be required to successfully address the global geosciences initiative and the foci of basic research. The CSEI initiative will extend and augment the ATM-sponsored efforts of the UNIDATA project to provide researchers and students with interactive weather analysis and prediction capabilities and communication with supercomputers.

As indicated in the Findings, the Committee believes that the multi-disciplinary efforts required to understand and predict global change will be stimulated by providing continuing support for university global geosciences centers. Envisioning perhaps eight such centers being supported by the Geosciences Directorate, the Committee recommends funds for ATM to support four university centers.

The Large Earth-based Solar Telescope (LEST) is an international cooperative venture to construct the world's most advanced solar telescope--a high-resolution, large-aperature system utilizing adaptive mirrors and a design minimizing residual telescope polarization. Its construction will permit observations of the highly structured solar atmosphere on spatial scales crucial to the understanding of the transport of energy and momentum.

(UNIVERSITY RESEARCH EQUIPMENT text to be added)

The Committee notes that the three initiatives related to climate (Coupled Climate Systems, Abrupt Climate Change, and Climate System Monitoring), in collaboration with the plans of other agencies, could constitute another initiative of community-wide significance, although they are not yet coordinated by a formal planning mechanism.

Budget Recommendations and Projections

To indicate the support necessary for this program to proceed at an optimal rate, the Committee has prepared recommended budget projections that blend significant transfers of base funds with incremental additions to the ATM budget. The recommended transfers average 15 per cent per year and the increments are equivalent to 14 per cent annual growth over the six-year period. Recognizing the desirability of new initiatives within the period, the committee has provided a modest planning wedge of available funds in the last year. A summary of the budget recommendations is given in Table 1.

Finally, the Committee examined the impact of its recommendations on the subdisciplines supported within ATM. The fractions of total support to universities through the grants program and to NCAR remain essentially the same, increasing marginally in favor of the universities. The fractions of total support to various subdisciplines within ATM are altered significantly by our recommendations, but compensated in part by the plans of other agencies. Nevertheless, the three major groups of dynamical and physical meteorology, atmospheric chemistry, and aeronomy and solar and terrestrial physics are all strengthened significantly by our recommendations. Table 2 gives more detailed information on the implications of our budget recommendations.

We stress the integrated nature of the recommended program. It is designed to provide progress in all areas in which atmospheric sciences must contribute to global geosciences, to strengthen those areas of greatest practical and immediate concern, and to maintain strength in the traditional pursuits of the discipline. Overall, the total program constitutes a redirection of the atmospheric sciences that we believe will produce strength, vigor, scientific excitement and progress, and considerable benefit to society. Although priorities within the program could be altered, implementing only part of it will distort the overall design, create uncertainty and confusion, and delay the accomplishment of essential scientific objectives.

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TABLE I - SUMMARY OF BUDGET RECOMMENDATIONS AVERAGE FY 1989-94

($ in Millions)

	ATM New Effort	Continuing Effort	Total NSF/ATM	NASA/NOAA
Community Initiatives	35.9	23.6	59.5	55.0
Facilities & Organizational/ Infrastructure Enhancements	24.5			
Base Enhancements	30.1			
Total New Effort	90.5			
FY 89 - 94 Average Base	100.0			
Base Reassignments	-14.7			
ATM Program	175.8			

TABLE 2

IMPLICATIONS OF BUDGET RECOMMENDATIONS

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TABLE II - IMPLICATIONS OF BUDGET RECOMMENDATIONS

($ in Millions)

Discipline	FY87 Base Total	FY 89 - 94 Average: Base Reassign-ments	Community Initia-tives	Facilities & Organ./ Inf. Enhan.	Base Enhance-ments	Total	Per-cent
Dynamics & Physical Meteorology	58.8	-8.7	14.3	17.7	22.6	104.7	60
Atmospheric Chemistry	18.2	-2.6	16.6	3.5	1.6	37.3	21
Aeronomy & Solar	23.0	-3.4	5.0	3.3	5.9	33.8	19
	100.0	-14.7	35.9	24.5	30.1	175.8	100

Division of Funding Between the NSF Grants Program and Upper Atmosphere Facilities, and NCAR

	GPS & UAF	NCAR
FY 1987 Base	55.3%	44.7%
Recommended Program FY 1989 - 94 Average	58.4%	41.6%

CHAPTER 1

OPPORTUNITIES AND CHALLENGES

These are exciting times in the atmospheric sciences. Opportunities for dramatic scientific progress and significant new contributions to society abound, ranging from short-term weather prediction to understanding and predicting global change. But these are also challenging and stressful times. The combination of current efforts and new opportunities presents funding requirements that exceed available resources, forcing careful consideration of choices and possible redirections of effort.

The scientific imperatives and the potential for service mandate that the necessary choices be made, that the efforts within and across disciplines be integrated for maximum effectiveness, that new international and interagency collaboration be implemented, and that the partnership between the atmospheric sciences and government be made more productive for all.

This report presents the findings and recommendations of a committee convened jointly by the National Science Foundation (NSF) and the University Corporation for Atmospheric Research (UCAR) to reconcile the opportunities and challenges with funding realities and thereby to propose a plan for NSF funding of the atmospheric sciences for the period fiscal years 1989-94. We believe that our vision of the future of the atmospheric sciences is indeed exciting; we anticipate scientific success and accomplishment though a program that addresses significant scientific opportunity, provides urgently needed facilities, and maintains attractive opportunities for meaningful contribution by individual scientists and students.

1.1 The Opportunities

The excitement that pervades the atmospheric sciences today is stimulated both by intellectual and technological progress and by potential accomplishment.

We are developing a more integrated view of the atmosphere, its complexity, and its interactions with the oceans, the land surface, and the biological systems of the planet. As we recognize the extent to which atmospheric evolution is governed by its role as but one of the subsystems of the planet, the boundaries between traditional subdisciplines are blurring and becoming less distinct. We are learning that atmospheric interactions with various chemical components have profound implications and that we must design coherent investigations of atmospheric and chemical processes to unravel them. The importance of mesoscale structures and phenomena in producing weather impacts on society has become clear at the same time that we have discerned the true complexity of the interactions of dynamics and thermodynamics involved in moist convection. Studies of the El Nino and Southern Oscillation have revealed the global effects of what at first appeared to be local phenomena, and pointed out the complexities of understanding the interactions between the atmosphere and the tropical oceans. The interactions between the various layers of the atmosphere are also becoming clearer and we can foresee a better understanding of atmospheric response to the flows of energy from the sun.

Phenomena with time scales considerably longer and shorter than the traditional synoptic time scale have been attracting increasing interest. Understanding the reasons for the concentrations of energy present in severe storms and identifying the instability mechanisms that produce them is needed to enhance prediction. The prospects for improved prediction of severe weather is accompanied by possibilities for extended range forecasts of larger-scale systems and short-term climatic perturbations. The causes and limits of climatic variability are under active study, and a better understanding of them will require cooperation with other geosciences disciplines.

Atmospheric science must also respond to the evidence that human activities are inducing change on the global scale. The exponentially increasing concentrations of carbon dioxide and methane and the disappearance of the wintertime Antarctic ozone layer portend change with possibly serious implications in the next few decades or centuries. Understanding and possibly predicting global change will require comprehensive knowledge of the interactions among the atmospheric, oceanic, terrestrial, and biological components of the Earth System. Extensive global observations from space and detailed, in-situ studies of processes and interactions will be necessary precursors to the development of models of planetary evolution that can simulate global change and be used to study its implications.

The attack on these many scientific issues will be enhanced by the technological opportunities available today. We are on the threshold of a revolution in observational capability, with remote sensing techniques from both space and the surface providing the potential for major advances. Operational Doppler radar and profiler systems ready for operational deployment will greatly increase our knowledge of the detailed structure and evolution of smaller-scale systems. Research remote sensing systems, operating from the surface and from space, will provide observations at multiple wavelengths and from a variety of viewpoints. The utility of such observations in resolving and understanding atmospheric processes will be greatly enhanced by concomitant development and deployment of new generations of observational systems on research aircraft.

The increased capabilities in observing atmospheric phenomena will be reflected in the increased capabilities for simulation made possible by both scientific and technological advance. Increased emphasis on interactions between the atmosphere and other Earth System components and on interactions between processes within the atmosphere will provide the information to construct more realistic models of atmospheric phenomena and evolution. New developments in computer hardware will enlarge the range of simulations that are practical; new computer architectures may provide greatly increased capabilities for atmospheric modeling and may stimulate revolutionary approaches.

1.2 The Challenges

The excitement about opportunities for scientific progress in the atmospheric sciences must be, unfortunately, tempered with the realities of the times. Federal funding restrictions are an obvious challenge; others will be encountered in the attempt to develop an infrastructure and the modes of collaboration required to promote progress at an optimum rate.

Federal deficits are looming larger in public policy and causing restrictions on spending throughout the federal government. Still, federal funding of basic research through NSF has increased, as demonstrated in Table 1.1. Nevertheless, NSF support of atmospheric sciences has not increased at the same rate, presumably because higher priorities were placed on other programs and initiatives by the Foundation.

The challenge to the atmospheric sciences, then, is to develop a program that promises exceptional long-range return on the investment of increased federal funds. The Strategic Planning Environment context within which this must be accomplished is made clear by the following excerpt from a memo to the NSF staff sent by NSF Director Erich Bloch on 24 March 1986:

TABLE 1.1

NSF, GEO AND ATM BUDGET SUMMARIES IN CONSTANT DOLLARS

TABLE 1.1 NSF, GEO, AND ATM BUDGET SUMMARIES IN CONSTANT DOLLARS

(Constant FY 1987 dollars in millions)

	FY 82	FY 83	FY 84	FY 85	FY 86 Estimate	FY 87 Request	Percent 82-87
NSF	$1249.5	$1264.7	$1470.6	$1615.0	$1586.2	$1685.7	35
GEO	313.6	325.1	366.0	379.6	360.8	383.2	22
ATM	84.9	87.4	98.4	102.2	95.9	100.6	18
ATM/ NSF (%)	6.79	6.91	6.69	6.33	6.05	5.97	
GNP Budget Deflators	0.8284	0.8638	0.8978	0.9299	0.9607	1.000	

Source: Table C-4

"... specific guidance for preparation for strategic plans for FY1988 and beyond:

o reductions to base of the order of 10 percent per year will be required both to cope with possible sequestration and to provide a margin for new initiatives under other budget conditions;

o initiatives will be limited to specific, well-defined programs which respond to scientific opportunities, research competition from abroad, and national needs;

o support for facilities and instrumentation, as well as for human resources, is essential and must be accommodated even in level budgets;

o expanding the support base by international or interagency cooperation, by interaction with industry, and by cost-sharing of all types is desirable; and

o interdisciplinary research in the academic community should be mirrored by true, inter-Directorate collaboration within NSF to develop and justify cross-cutting initiatives."

The scope of the major scientific initiatives of atmospheric science provides organizational and management challenges. Programs for developing an understanding of global change have been recommended by several bodies and call for wide interagency and international cooperation. The plans for the International Global Geosphere-Biosphere Program: A Study of Global Change have been adopted by the International Council of Scientific Unions (ICSU). The recommendations of the Earth System Science Committee (formed by the National Aeronautics and Space Administration (NASA)) call for extensive collaboration among NASA, NSF, and the National Oceanic and Atmospheric Administration (NOAA) as well as international collaboration. Within NSF, the Global Geosciences program is aimed at many of the same objectives and has enjoyed a high priority. Other major initiatives in atmospheric chemistry, mesoscale phenomena, interactions between tropical oceans and atmospheres, and the dynamics of the layers of the upper atmosphere similarly will require collaboration between the academic community and various components of the federal and international science establishment.

It is not evident that the necessary modes of collaboration can be easily developed or maintained for the requisite lengths of time. A balance must be maintained between achieving the goals of the initiative and encouraging the participation and contributions of individual investigators. In any case, a wide spectrum of talents will be required and the initiatives will not be successful without long-term commitments by both individuals and organizations.

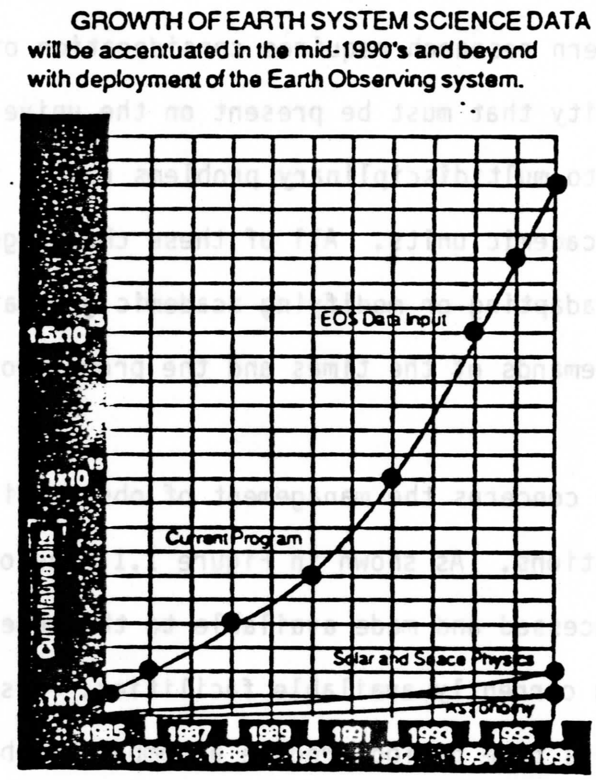
Another set of challenges concerns the way the scientific effort is to be organized and nurtured. The unique partnership between the academic community, UCAR, the National Center for Atmospheric Research (NCAR), and NSF has flourished for more than a quarter-century. It must now adapt to new requirements for multidisciplinary research, for community observational and computational facilities, for stimulus and management of complex scientific endeavors. The increasing sophistication of modern research requires consideration of the level of technological capability that must be present on the university campuses. The trend to multidisciplinary problems raises issues about the organization of academic units. All of these challenges raise the further challenge of adapting or modifying academic graduate education and research to the demands of the times and the promise of the future.

A final challenge concerns the management of observational data and the results of simulations. As shown in Figure 1.1, the observational data that must be processed and made available to the research community will easily overwhelm currently available facilities. Results of simulations may in this time period produce a comparable body of information that will in many cases be too valuable to be utilized by only a single research group. If these observations and simulations are to achieve the objective of stimulating the development of understanding, theories, and models, then they must be readily available to the research community. Thus it is urgently required that the atmospheric and related earth sciences develop flexible, interactive

FIGURE 1.1

ESTIMATES OF ACCUMULATED OBSERVATIONAL DATA IN THE

EARTH AND ATMOSPHERIC SCIENCES



data management and supercomputer access networks and provide the software environments that will make them friendly and transparent. Because of the complexity of the task, the urgency of the requirement, and the implications for the progress of the science, this may well be the most important challenge of all.

1.3 The Committee's Task and Procedures

NB: This section to be revised by Crowe to describe Committee process; this present version is combination of material from Dutton draft, without revision or editing.

The NSF - UCAR Long Range Planning Committee was charged with the task of developing recommendations for an innovative and coherent NSF program in atmospheric sciences for the period FY1988-93. (Appendix A gives the full charge.) To do so, the Committee analyzed the initiatives proposed for support by the NSF Atmospheric Sciences Division (ATM) along with the main elements of the current program in the universities and at NCAR. The initiatives were divided into three classes: major endeavors widely endorsed by the community, proposals for new or improved facilities, and proposed enhancements in the grants program and the NCAR scientific program.

It was clear from the beginning that not all of the scientifically worthwhile initiatives and elements of the current program could be supported at optimum levels. The initiatives and program enhancements proposed to the Committee amounted to a total of $700M over the six-year period compared to a total of $600M in base funds projected at the current level for the six-year period.

modify to fit "upscale" budget

Thus the committee faced the necessity of determining the significant trends and developments in atmospheric science and recommending a redirected program that would be responsive to the most important scientific opportunities and imperatives. Clearly, support for some current efforts would have to be reduced in order to accommodate new initiatives within realistic proposed funding levels.

For the community initiatives and program enhancements, the Committee sought to judge relative scientific merit, programmatic considerations, and societal benefits in order to develop a priority ranking and eventually a recommended program.

Evidently, the formulation of such a program must take into consideration a number of objectives and constraints, including the balance between university and NCAR research, the provision of adequate facilities, and most of all, the encouragement and stimulation of individual creativity and initiative that is the foundation of basic research and future scientific accomplishment.

The opportunities in science, it seems, always exceed the available resources. Thus the provision of resources to science and to scientific initiatives inevitably involves evaluating the relative worth of competing proposals and assigning priorities to them.

An essential task is to determine the basis on which such evaluations should be made. Unless it is clear what goals we hope to accomplish and what values we hope to foster, it is impossible to evaluate proposals in a reasoned way. A specific set of criteria designed to illuminate the contributions of proposals to our basic goals in supporting science are thus essential to allow us to develop useful comparisons.

Scientific merit is clearly the most important aspect of a proposal to assess. It must be judged relative to the essential questions of a discipline and to the progress of science from a more general viewpoint. Programmatic considerations are important in determining whether a proposed effort is timely. Societal benefits must be carefully considered in the competition for public funds.

The NSF-UCAR Joint Planning Committee adopted as part of its process the formal use of a set of criteria (formulated as questions) developed by the NASA Space and Earth Sciences Advisory Committee (SESAC) to aid in the evaluation of proposals for major space science missions. The rationale for the criteria is documented in the SESAC report << Title >> now in press. The entire set of criteria is presented in the Appendix B.

The formal steering committees, NSF program officers, and NCAR scientific managers responsible for the initiatives put before the Committee were each asked to describe their proposal by responding explicitly to each question in the set of criteria. The members of the

Committee independently ranked the four major community initiatives separately by scientific merit, programmatic considerations, and societal benefits. The results were accumulated and turned out to independent of the weights assigned to the three categories, thus establishing the priorities shown in Table 3.2. The same process was followed for the proposed program and facilities enhancements, but only scientific merit was considered. As a further experiment, the Committee asked the observers from NSF, NOAA, and NASA to separately and independently perform the same evaluation; the results were essentially identical to those of the Committee.

After determining the relative priorities within the major groupings, the Committee developed recommended resource allocations responsive to the rankings, and then finally made adjustments as necessary based on issues related to balance and timeliness.

CHAPTER 2

CONCLUSIONS: A VISION OF THE FUTURE

The rapid evolution and the exciting prospects for the atmospheric sciences mandate that any recommended program for a six-year period be set in the context of a clear vision of how present trends will combine to shape events in the next decade or more. Thus the Committee reviewed the current state of the atmospheric sciences, identified trends, issues, and opportunities, and organized its conclusions into a list of eight imperatives that must be addressed by the proposed program.

2.1 Responding to Global Change

FINDING: The potential and reality of global change presents intellectual and practical challenges to which the atmospheric sciences must respond with vigor and determination. The collective experience in dealing with the observation, modeling, simulation, and prediction of the global atmosphere compels the atmospheric sciences to seek and to accept a position of leadership in addressing global change.

The reality of global change has moved from paleoclimatology and geology into the present and the future. Key indicators, including trace gas concentrations and global mean surface temperature, demonstrate that change is occurring now, and at an increasing rate.

Understanding global change is a tremendous challenge for the earth sciences because it requires resolution of the interactions and feedbacks between diverse processes and phenomena in the atmosphere, oceans, land surface, cryosphere, and the terrestrial and marine biological systems. The disciplines of the earth sciences can no longer proceed entirely in the traditional independent modes but must combine efforts to develop a comprehensive understanding of the fluxes of energy and matter between and within the components of the Earth System and the associated nonlinear interactions that control the evolution of the planet.

Understanding global change is no longer solely an intellectual endeavor; it has become an urgent task because of the implications for human society of a world that may be significantly different than the present in surface temperature, precipitation patterns, and the distribution of vegetation. It is even more urgent since there is a strong correlation between present rates of change and human activity, suggesting that scientific understanding of the implications of our activities may indicate beneficial or essential modifications.

It is generally agreed that the scientific study of global change requires, in addition to available operational and research data, an entirely new suite of global, long-term observations from space of key indicators and processes and a focused set of in situ studies of interactions, especially those involving the biosphere. Analysis and interpretation of these observations will provide the information necessary to construct models of components of the Earth System itself. These models, in turn, can be used to test the accuracy of our understanding through verification studies using present and past conditions, to predict conditions in the next few decades or centuries, and to study the consequences of modifications in human activities.

The atmospheric sciences, as the discipline most sophisticated in managing global data bases and in modeling and simulating the evolution of complex phenomena involving multiple time scales, have a crucial responsibility to foster the study of global change. We must seek to cooperate with the other earth sciences and provide the leadership necessary to unite disciplines in a bold scientific study of all aspects of global change.

2.2 The Observational Revolution

> **FINDING: The complexity of the atmospheric phenomena now being studied mandates new technological and sociological approaches to atmospheric science. Systems designed to observe phenomena such as severe storms or oscillations in tropical climates must involve multiple sensors operating from multiple platforms in a variety of modes. Data from such systems must be assimilated into simulation models to be fully analyzed and understood. The tasks involved are so complex that they can only be undertaken by groups of scientists committed to long-term collaboration.**

The intellectual achievements of the atmospheric sciences, as in other sciences, have their roots in observations. We observe, analyze, theorize, and verify in an endless chain in which new observations are both catalyst and consequence of progress. Technological advances in remote sensing, both from space and from the surface, are producing an observational revolution that will drive the atmospheric sciences into new realms of complexity, subdisciplinary integration, and service to society.

The scientific challenges of severe storms, oscillations of tropical climates, the interaction of atmospheric and chemical processes, the interactions of the upper layers of the atmosphere with events in geospace and on the sun, and global change all require high resolution simultaneous observations of a collection of variables, some new, some old. The evolution of the critical aspects of these diverse processes and phenomena can only be resolved through the deployment of multiple sensors operating on multiple platforms in a variety of modes.

Modern observational technology will provide the necessary capability with sophisticated radars, high-resolution spectrometers, vertical wind, temperature, and humidity profilers, laser profilers, and sophisticated new observational systems for research aircraft. The deployment of operational Doppler radars and vertical profilers on the surface and improved observational systems on spacecraft in polar and geosynchronous orbit promise great benefits.

The current challenge to the atmospheric sciences is not to develop or manage the observational systems; rather, it is to use the new flows of data effectively. We shall encounter unprecedented data rates and as always, must convert images or sensor response information into physical variables or statistical quantities. Even having achieved the necessary conversions, the task of analyzing, comprehending, and using the resulting data sets will be a monumental task.

Since the data rates will preclude the possibility of human analysis, objective methods of computer analysis must be developed. Since we expect to find new phenomena and structure, we shall need methods based on pattern recognition or artificial intelligence to detect departures from the norm. Since we hope to understand the implications of what we observe, we shall have to assimilate the flood of data into simulation models that will produce comprehensive analyses of its implications.

This observational revolution will have strong impacts on atmospheric science. Clearly the techniques of observation will have to be integrated with the concepts and processes of computer analysis and modeling; observational campaigns must be carefully planned to provide for analysis and model simulation in nearly concurrent modes or the data will, effectively, be lost. There is a tremendous task ahead in the development of a suitable scientific infrastructure to take advantage of the observational effort. The tasks are largely new and exceedingly complex, and success will be achieved only through new modes of collaboration between the scientific community, the operators of the observational systems, and federal sponsors. Long-term commitments will be essential to take advantage of the observational revolution and to create from the rising stream of data a parallel revolution in scientific understanding and achievement.

2.3 Community and University Facilities

> **FINDING: Community-wide facilities and university facilities will be increasingly important over the next decade as the emphasis on global geosciences and on the observation and modeling of complex phenomenology brings new technology to the fore and drives the science in directions that require renewal of the empirical knowledge base. The investments in advanced instruments and observational systems, research aircraft, and supercomputers will return astounding intellectual and practical dividends.**

The atmospheric sciences have long required and utilized a diverse spectrum of facilities for observation and simulation of atmospheric phenomena, ranging from boundary layer fluxes to the evolution of global circulation patterns. The continuing interplay in atmospheric science between public service and research has produced interactions between operational and research facilities that have stimulated progress in both activities. This collaboration can be expected to intensify.

Optimum progress over the next decade or two in observation of atmospheric processes will continue to require a carefully balanced spectrum of national, community, and university facilities. Clearly, space-based observational systems will be primarily national in scope as will the new surface-based operational observing systems. Detailed studies of specific phenomena or closely connected processes through field experiments will require the provision of community facilities such as fleets of research aircraft, portable observing systems, and sophisticated radars and profilers. The development of new techniques, local studies, and the education of students in observational concepts and philosophies will require that sophisticated observational systems be operated by some university groups.

A similar spectrum of facilities and scientific opportunities must be maintained to promote the simulation of atmospheric phenomena. The success of numerical weather prediction and large-scale modeling along with increasing computational capability has stimulated the use of numerical simulation across an increasingly wide range of atmospheric and oceanic phenomena. Models now exist of severe storms, boundary layer processes, ocean circulations, mesospheric chemistry and dynamics, middle atmosphere evolution, plasma processes in geospace, and the dynamics of the circulation on the sun itself. Most of these models have been developed and operated on supercomputers, usually those of the NCAR Scientific Computing Division (SCD).

University computational facilities of increasing power and sophistication are made possible by technological advance and are required by both scientific advances and new modes of managing model and data analysis computations on supercomputers. Effective local computational flexibility will be the key to take full advantage of the benefits of the observational revolution and the increasing capabilities of simulation models operated on supercomputers.

2.4 Management of Data

FINDING: The management of data increasingly will become the critical issue in scientific progress. Scientists and students must be provided with interactive, flexible, and transparent channels to utilize the data from new surface and satellite observational systems and from model simulations on supercomputers. New structures for active data bases must be developed, with consideration given to approaches utilizing self-organizing algorithms and the procedures of artificial intelligence. The key to progress is the ability of the scientist to explore fully the vast resources of observed data and model results that are becoming available at an accelerating rate.

The observational revolution has begun. Whether the data management revolution that is required to turn the new observations to the purposes of science will also occur is still an open question. Observations are the key to scientific progress, as argued above, only if scientists have access to them. Current data management schemes and facilities are archaic and overwhelmed. Unless swift, prompt, and decisive action is taken, the atmospheric sciences will drown in the new observations that are expected in the next decade or two.

Access is the essential concept; students and scientists must be provided with interactive, flexible, transparent channels to use the observations. Data should not only be archived--they must be made readily available in active data bases. The requisite information system will involve a collection of active data bases, a network, and a management infrastructure to maintain the data bases and to ensure the effectiveness of the software environment that provides access. The workstation, in the university, NCAR, or federal laboratory must be, through the information system, a window through which to view the entire world as revealed in the observations.

With the advent of increasingly sophisticated and expensive models on supercomputers, the results of simulations will become a community information resource that also must be shared. Baseline calculations, the results of major computational initiatives, and the results of assimilation of observed data in models will all have to be managed in active data bases.

Current concepts and procedures of data base management are likely to be inadequate for the tasks ahead. New structures for active data bases must be conceived, tested, and improved. Undoubtedly, the data management revolution will require the development of self-organizing data bases and access through the procedures of artificial intelligence.

The flood of new data will thus force the atmospheric and associated sciences to face formidable issues related to data processing and transmission equipment, effective management of interactive data bases, governance of information systems, and the degree to which local processing in a distributed computing configuration will foster the necessary flexibility and efficiency.

Scientists have not generally done well with data management, for they usually skip that step to get to scientific rewards of working with the data. Now the issue can no longer be ignored if we are to be ready to reap the harvest promised by the observational revolution. The creation of new scientific and governmental structures to manage data is essential; we shall threaten our scientific future if we do not act now.

2.5 The NSF-UCAR-NCAR-Community Partnership

FINDING: The partnership between the university scientific community and the National Center for Atmospheric Research (NCAR) forged through the University Corporation for Atmospheric Research (UCAR) consortium with NSF support has been a signal accomplishment and a stimulus to progress in the atmospheric and related sciences. The combination of a research program that attracts university collaboration and the provision of outstanding community-wide facilities by NCAR will be even more important as the science turns to global issues and to the detailed examination of complex atmospheric processes and phenomena.

More than a quarter-century ago, the atmospheric sciences embarked upon a grand and exciting experiment to create a national center with a mandate to stimulate significant progress in the most important scientific issues of the discipline. The Center was to be supported by the National Science Foundation and managed by a consortium of universities granting doctorates in the atmospheric sciences. The concept of the center was bold: it would range across the entire discipline, it would support a strong scientific program in collaboration with the universities, and it would provide observational, experimental, and computational facilities designed to stimulate significant scientific advances.

From that concept emerged the University Corporation for Atmospheric Research (UCAR) and the National Center for Atmospheric Research (NCAR). The Center has indeed been a prime force in progress in the atmospheric sciences; examples of achievements by NCAR and its university collaborators are given in Figure 2.1. UCAR has, in the last five years, expanded its activities beyond management of the Center to the management of collaborative projects among the universities. A notable example is the Unidata project to create and maintain a community-wide capability for interactive weather analysis and prediction, to create and implement new approaches to computer-to-computer communication, and to develop interactive observational and field research capabilities.

FIGURE 2.1

EXAMPLES OF PROGRESS IN THE ATMOSPHERIC SCIENCES ACHIEVED BY NCAR

- First measurements of fluorocarbons in the stratosphere, confirming that these chemicals are capable of depleting the earth's protective ozone shield.

- Development of Doppler radar techniques that can detect severe windshear in the vicinity of airports and provide timely warnings to aircraft attempting to take off or land.

- Discovery of the 40-50 day oscillation, a large-scale, slowly-propagating wave in the Equatorial Pacific that strongly modulates precipitation systems in this region.

- Development of theories of the limits to atmospheric predictability.

- The continuing development of techniques of radiative transfer in the solar and stellar atmospheres, permitting an understanding of their fundamental structure.

- Development of an understanding of severe thunderstorms, including how the variations in the environmental flow surrounding the storms determine their characteristics.

- First systematic measurements of atmospheric hydrogen peroxide, the compound believed to modulate the amount of acidic rain that will fall from clouds.

- Research indicating that there are true connections between the so-called El Nino and subsequent unusual climate events elsewhere around the globe.

- The development of a sophisticated and realistic model of climate, the Community Climate Model, that is now being used by more than 40 climate research groups around the country.

- The discovery that mass ejections of gases and particles from the sun are a frequent form of solar activity, involving large-scale motion of coronal material and magnetic fields.

- Development, through observational, theoretical and modeling studies, of an understanding of severe downslope windstorms that occur to the lee of mountain ranges.

- Establishment that an array of trace gases, including fluorocarbons, methane, ozone, and nitrous oxide, produce as much of a greenhouse effect as carbon dioxide, and thus the likelihood that a significant increase in the temperature of the earth's atmosphere will occur in the next half century.

The recently-formed UCAR Foundation represents an attempt to turn intellectual properties developed at NCAR or by the Foundation into successful commercial products with the proceeds being returned to the support of scientific activities.

The successes of the partnership are due in part to its uniqueness--no other science manages a national center that serves as research partner and facilities resource for university science--and in part to the recognition that the problems of atmospheric science, significant in intellectual challenge and global in scope, can only be attacked successfully by collaboration based upon a determination to succeed.

2.6 Collaboration in Global Geosciences

> **FINDING: Advances in global geosciences will be achieved through diverse efforts in the university and federal research communities. Collaborative structures reaching across disciplines and across institutions will be required and will take various forms. Focusing efforts through the creation and support of a variety of university centers for the study of global change may be expected to enhance progress.**

The challenges of global change and of the global geosciences initiatives mandate new academic, national, and international approaches to science. New forms of collaboration and cooperation must be designed, implemented, and maintained by both governmental and academic institutions. The challenge of obtaining and managing the requisite observations is matched by the challenge of developing and maintaining the necessary intellectual breadth in concert with penetration to the truly significant scientific issues.

The evidently multidisciplinary nature of the scientific issues surrounding global change require new attitudes and effective modes of communication and collaboration between previously isolated or disparate disciplines. We believe that this will require the establishment of formal structures, and observe that some universities have already begun to create them. The scientific plans of NCAR include new components aimed at the study of global change; the Center will presumably accept important responsibilities in this endeavor, but will find it necessary to broaden its range of disciplinary expertise with consequent implications for both NSF and UCAR.

University groups must also be created with specific mandates to attack global change issues from a broad perspective. We believe that the NSF must actively support the formation and operation of multidisciplinary university centers to foster the necessary re-orientation and commitment of university efforts to the study of global change.

2.7 Educational Imperatives

FINDING: The atmospheric sciences, along with the other earth sciences, must create new educational approaches in order to develop scientists with the breadth and creativity that will be

required in the next half-century. The multidisciplinary approach necessary to address global change will require individuals who are able to collaborate with specialists in oceanography, geology, geography, global biology, dynamical systems, chemical kinetics, remote sensing, and computer science. Practical problems in the atmospheric sciences will require a greater mastery of both fundamentals and technology.

Global change, as it does with research, mandates the development of new approaches to education in the atmospheric and other earth sciences. Careful attention must be given to a suite of concerns related to breadth, depth, abstraction and hierarchies, and technology.

A basic strategy of the Earth Sciences has been to develop theories and models of the various components as though they were independent of the others. While this approach has been successful for phenomena on a variety of temporal and spatial scales, it surely must be abandoned to proceed to the critical issues of global change. Thus the education we provide to both undergraduate and graduate students must develop an awareness of the major issues in related disciplines and put new emphasis on a rigorous examination of the role of the interfaces between components of the earth system in controlling the evolution of both the components and the system. The action is at the interfaces, and we can no longer enjoy the luxury of temporally invariant boundary conditions.

The greater breadth mandated by global change cannot be attained by simply roaming superficially through the earth sciences. The subleties and complexities of system response, the demands for effective approximations in modeling, and the effective use of diverse types of data will all require that scientists have a deep understanding of the structure, thermodynamics, dynamics, and chemistry of the system and its components.

The complexities of modeling the earth system and of assimilating the anticipated observational material imply that greater emphasis will be required on the development and use of appropriate abstractions and hierarchial structures. Mathematical approaches will provide insight into the topology of solution spaces, the methods of artificial intelligence will be used to organize and manage data bases and information systems, and computer program-writing programs will move us further from machine language and closer to conceptual structures.

The explosions of technological capabilities, in observation, communications, and computational power, must all be managed creatively and integrated with intellectual and conceptual developments if they are to be used to optimum advantage. It has been widely recognized that the university facilities available for students to experience the realities of using and controlling technology -- the stimulation and the frustration -- are sadly obsolescent.

The conclusions above, although stated relative to the demands of earth system science, apply equally well to the traditional concerns of atmospheric science. The same basic issues must be considered, and it is clear to us that the critical scientific and practical problems of atmospheric science will require a greater mastery of fundamentals, a broader competence in related fields, and creativity in the application of technology.

2.8 Maintaining the Intellectual Foundation

FINDING: Maintaining the intellectual foundation of the atmospheric sciences is of paramount importance. It is essential that the vitality of individual initiative and insight be stimulated and supported, and that the NSF/ATM program maintain a broad program of basic research unconstrained by immediate or collaborative initiatives. Future generations of scientists must be attracted, motivated, and educated to address creatively the key problems of the atmospheric and related sciences. Only by investing now in the development of fundamental knowledge and the education of talented individuals can we provide the foundation for the progress of future generations.

We see great challenge, opportunity, and reward in earth system science and in several other community-wide endeavors now ready for implementation, but we hasten to observe that none would be possible without the intellectual and empirical foundation patiently created by basic research. The excitement of collaborative projects with grand objectives or significant practical benefits must not be allowed to obscure the fact that individual initiative and creativity are the key to the creation of knowledge and the wellspring of a vigorous science.

The atmospheric sciences have grown, as have the other sciences, in scope, power, and maturity through the emphasis of the NSF on basic research. A consequence of success in science is that critical questions often concern increasingly complex issues that often can only be resolved through approaches that require greater commitment to infrastructure and collaborative efforts, that obscure the basic knowledge on which the investigation is based, and that do not explicitly anticipate the final step of creation of new basic knowledge through conversion of the results into theoretical abstractions.

Basic knowledge is the nation's most important possession and the key to the future; it is the foundation for scientific and economic progress. We can do no better than to invest in the talented individuals, be they students or experienced scientists whose creativity will strengthen that foundation.

CHAPTER 3

THE RECOMMENDED PROGRAM

The possibilities for new initiatives in the atmospheric sciences, for exciting research addressing a variety of significant scientific opportunities, exceed the resources that might realistically be expected to be available. Thus the responsibility of the NSF-UCAR Joint Planning Committee was to develop recommendations for the Atmospheric Sciences Division that blended the highest priority initiatives and maintenance of a continuing fundamental research effort into a vigorous and balanced program for the next six years.

The recommended program presented in this Chapter accomplishes that objective. It is an integrated and coherent plan through which the community supported by the Atmospheric Sciences Directorate can contribute to understanding and predicting global change, while expanding and strengthening the basic atmospheric research that is the precursor to scientific progress and practical benefits for society.

The committee considered proposals for research initiatives or program enhancements from a variety of sources, including diverse committees of the National Academy of Sciences and the National Research Council, formal scientific steering groups for major programs, program officers in ATM, and the formal NCAR long-range plan approved by the UCAR trustees.

The ATM program (President's budget request) for fiscal year 1987 totaled \$100M. Level funding of the program at this level for the six-year period FY89-94 would thus total \$600M. The proposed initiatives and enhancements for the same period were estimated to have a total cost of \$700M, thus mandating that the committee develop a set of priorities that selected some of the initiatives for funding and redirected some of the base effort in order to recommend a program that was both responsible and realistic.

The process employed by the committee, described in Chapter 1, relied on responses by proponents of initiatives or enhancements to questions elucidating a structured set of criteria emphasizing scientific merit, programmatic considerations, and societal benefits of the proposed research. With the aid of this extensive documentation, the Committee developed an explicit set of priorities for structuring the recommended ATM program.

Once the priorities of a proposed program have been set, it is possible to develop a wide range of budget scenarios, all of which are responsive to the priorities. The committee first developed a budget proposal, based on a perception of continued stringency in NSF funding, that allowed for optimal progress in a few highest priority initiatives and only minimal progress in the rest. In view of recent NSF and Administration requests to Congress for sharply increased funding to revitalize the nation's research endeavor and to restore economic competitiveness and in view of the growing perception of the urgency of addressing the problems of global change, the committee now presents a budget that responds to its priorities by providing for optimal progress in all of the initiatives but still requires substantial reprogramming of base funds. In summary, the program involves, over the six-year period, a total of $543M in initiatives and enhancements, a redirection of $88 in the base program, and requires $455M in new funding, as summarized in Table 3.1. The recommended ATM budget thus obtained represents annual growth at a rate of approximately 14 per cent.

3.1 Description of the Recommended Program

The Committee divided the proposals for an augmented program in atmospheric sciences into three categories:

* Community Initiatives--Major scientific endeavors developed and recommended through formal processes by NAS/NRC or international scientific bodies

* Facilities and Organizational/Infrastructure Enhancements--Development of observational or computational facilities or creation of new organizational structures to support research

* Base Enhancements--New endeavors with specific scientific goals to be supported by the ATM base program and implemented in the university community or by NCAR.

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Table 3.1 SUMMARY OF RECOMMENDATIONS -- FY 1989 - 94

($ in Millions)

	Total for Six Years	Average per Year
PROPOSALS		
Initiatives and Enhancements	700	117
Level Base Program	600	100
Total	1300	217
RECOMMENDATIONS		
Initiatives and Enhancements	542.8	90.5
Base Redirections	-88.0	-14.7
Required New Funding	454.8	75.8
TOTAL PROGRAM		
New Efforts and Continuing Base Efforts	1054.8	175.8

The recommended program is shown in Table 3.2. The community initiatives are listed in priority order, as are the base enhancements. The facilities and organizational enhancements are considered to be of equal priority. The three major categories are also considered to be of equal priority, for emphasis on one at the expense of another would lead to a seriously unbalanced program that would not be responsive to long-term national needs or the scientific imperatives now extant.

3.1.1 Community-wide Initiatives

In this section we provide a brief explanation of the objectives and approach of each of the four major community-wide initiatives. Detailed descriptions may be found in Appendix B.

GLOBAL TROPOSPHERIC CHEMISTRY PROGRAM

OBJECTIVES: The primary goal of the GTCP during its first decade is to measure, understand, and predict changes over the next century in the chemistry of the global atmosphere, with particular emphasis on changes affecting oxidizing capacity and radiative properties of the atmosphere and the atmospheric component of the biogeochemical cycles. Scientific issues in four distinct but interrelated areas to be addressed are:

- Global distribution and trends
- Biological and surface exchange processes
- Gas phase photochemistry
- Multiphase processes

TABLE 3.2

THE RECOMMENDED PROGRAM IN ATM--FY1988-93

Four major community-wide science initiatives (in priority order):

* Global Tropospheric Chemistry Program (GTCP)
* Mesoscale Meteorology Initiative
* Tropical Oceans - Global Atmosphere Program (TOGA)
* Coupled Energetics - Dynamics of Atmospheric Regions (CEDAR)

Five facilities and organizational/infrastructure enhancements (equal priority):

* NCAR facilities and instrumentation enhancements
* Computer Science and Engineering Initiative within ATM
* University Global Geosciences Centers
* Large Earth-Based Solar Telescope (LEST)
* University Research Equipment

Eight initiatives in the ATM grants and NCAR programs (in priority order):

* Coupled Climate Systems (NCAR)
* Abrupt Climate Change (Grants)
* Climate System Monitoring (Grants)
* National Solar Terrestrial Program (Grants)
* Cloud and Precipitation Physics (Grants)
* Dynamic Extended Range Forecasting (Grants)
* Solar Physics (NCAR)
* Base Program Opportunities (Grants and NCAR)

APPROACH: The GTCP will develop a broad program of local and global observations from the land surface, ships, aircraft, and satellites; studies of chemical mechanisms and kinetics; studies of biological trace gas emissions; theoretical studies; and development of three-dimensional models integrating atmospheric chemistry, thermodynamics and radiation, and dynamics with surface chemical fluxes.

PARTICIPANTS: University scientists, NCAR, NOAA, NASA, and other agencies

SPONSORS: NSF, NASA, NOAA

ADVOCACY AND MANAGEMENT: Global Tropospheric Chemistry Program Steering Committee, NAS; inter-agency coordination mechanisms being developed; transition to an international program envisioned.

MESOSCALE METEOROLOGY INITIATIVE

OBJECTIVES: The Mesoscale Meteorology Initiative is an integrated program with the broad goal of achieving the enhanced scientific understanding necessary to establish the predictability of mesoscale phenomena. Key scientific issues to be addressed emphasize scale interactions and production of precipitation, including:

- o Development of cumulus convection and mesoscale convective systems and their interactions with the large-scale environment

- Effects of mesoscale fluxes of energy, moisture, and momentum on synoptic systems and climatic variability

- Interactions of mesoscale systems with topography, land-surface characteristics, planetary boundary processes, radiative fluxes, condensation and evaporation

- Mesoscale effects in regional and global atmospheric chemistry and in determination of local climates

APPROACH: The MMI will utilize the powerful observational capabilities now available from new radars, wind and thermodynamic profilers, lightning detectors, aircraft and satellites to obtain high-resolution data sets, both on operational time scales and as part of the field studies of the National Stormscale Operational and Research Meteorology (STORM) program, and apply these data in theoretical studies and in development of improved three-dimensional mesoscale simulation and prediction models.

PARTICIPANTS: University scientists, NCAR, NOAA (especially the Environmental Research Laboratories and the National Weather Service), NASA, and other agencies; Canadian scientists and agencies.

SPONSORS: NSF, NOAA, and NASA, for U.S. components.

ADVOCACY AND MANAGEMENT: NAS committees, especially the Board on Atmospheric Science and Climate (BASC), the National STORM Planning Committee (UCAR); the STORM program office (NOAA) is established and will coordinate STORM research and operational interfaces.

TROPICAL OCEANS -- GLOBAL ATMOSPHERE PROGRAM

OBJECTIVES: The scientific objectives of the TOGA program are:

i) To determine the extent to which the time-dependent behavior of the tropical oceans and related planetary-scale circulation patterns are predictable on time scales ranging from weeks to a few years and to understand the mechanisms that give rise to this predictability;

ii) To explore the potential of coupled atmosphere-ocean models for predicting climate variability on these time scales and, within the context of that predictability, to develop an operational and data management system to support operational climate prediction.

APPROACH: TOGA will augment available observations with new measurements of time-varying subsurface thermal structure and currents in tropical oceans through buoys, XBT lines, and tide gauges; develop and utilize satellite techniques for determining oceanic surface wind stress, sea-level, and precipitation; collect special observations from Pacific islands. The program will develop models of unique features of the tropical atmosphere and oceans, and thus attempt to create an improved capability to model dynamical and thermodynamic processes in the atmosphere-ocean boundary layer and the fluxes at the surface.

PARTICIPANTS: University scientists, NOAA, and NASA along with scientists and agencies from many other countries.

SPONSORS: NSF, NOAA for U.S. components

ADVOCACY AND MANAGEMENT: TOGA is an international program contributing to the World Climate Research Programme; an international steering committee and program are established and active; the U.S. TOGA program office resides in NOAA.

COUPLED ENERGETICS AND DYNAMICS OF ATMOSPHERIC REGIONS

OBJECTIVES: The goal of the CEDAR program is to develop an improved understanding of the coupling, energetics, and dynamics of the neutral and ionized upper atmosphere from the mesosphere to the exobase (50 - 500 km). The aim is to develop the knowledge necessary to accurately tie together extant models of the troposphere, stratosphere, mesosphere, thermosphere, and ionosphere by resolving the physical processes that couple these atmospheric regions together. CEDAR will examine the upper atmosphere as part of the solar-terrestrial system, complementing the NASA

International Solar-Terrestrial Physics Program (ISTP) to study the interactions of the sun and the interplanetary medium with the magnetosphere and the auroral ionosphere and the NASA Upper Atmosphere Research Satellite (UARS) program to study the physics and chemistry of the middle atmosphere by bridging the gap between these regions.

APPROACH: CEDAR intends to take advantage of new electro-optical technologies to enhance the capabilities of surface-based radar, optical, and laser remote observation systems to resolve physical processes in sufficient temporal and spatial resolution to provide significant improvements in models of structure and evolution of the upper atmosphere and the coupling between atmospheric regions.

PARTICIPANTS: University scientists in U.S.; scientists from other nations, especially Canada.

SPONSOR: NSF, for U.S. component.

ADVOCACY AND MANAGEMENT: As a component of the National Solar and Terrestrial Program (NSTP), CEDAR has a functioning Science Steering Committee.

3.1.2 Facilities and Organizational/Infrastructure Enhancements

The Committee recommends the support of four facilities enhancement programs and the creation of University Global Geosciences Centers in order to strengthen the infrastructure of the atmospheric and related sciences. Details of these initiatives are provided in Appendix B.

NCAR FACILITIES AND INSTRUMENTATION

Progress in the atmospheric sciences depends in part on the development and maintenance of sufficiently sophisticated and powerful computational and observational facilities to meet the challenges posed by advancing scientific imperatives, including the initiatives recommended in this report. The facilities enhancements proposed here include:

- Improvement in computational facilities, including communications networks, a data storage system, improved color graphics capabilities, and a replacement advanced vector computer late in the six-year period;

- Replacements for aircraft in the research aviation fleet through instrumentation of a medium twin turbo prop aircraft already acquired through government property transfer and through acquisition of a high altitude medium twin-engine jet aircraft.

- Improvements in the field observing system through development of airborne Doppler radar and improvements in surface radar systems, and development of a micrometeorological facility, airborne lidar wind-motion sensing system, and other systems to support initiatives in mesoscale meteorology and atmospheric chemistry.

o Repair and maintenance of NCAR buildings and physical facilities is mandated by deterioration of major mechanical systems.

COMPUTATIONAL SCIENCE AND ENGINEERING INITIATIVE

The Committee endorses the vigorous participation by ATM in the NSF Computational Science and Engineering initiative; the goal for atmospheric sciences component is to provide a work environment that will maximize scientific productivity. The initiative will support development of enhanced capabilities for interactive weather analysis and prediction, interactive communication with remote data bases and other scientists, and interactive and friendly access to remote super computers by supporting improvement of university facilities, technique development, and continued emphasis on the UNIDATA project as a collaboration university effort.

UNIVERSITY GLOBAL GEOSCIENCES CENTERS

The demands of the NSF Global Geosciences initiative and the scientific imperatives of global change mandate the development of vigorous multidisciplinary efforts. The Committee recommends that the initiatives in this direction at NCAR be complemented by the support of University Global Geosciences Centers in each of the disciplines of the Geosciences Directorate. The support envisioned would cover basic administrative and facilities costs in such centers and thus provide encouragement to universities to accept the challenge of stimulating multidisciplinary efforts. The bulk of the work of such Centers would be financed through competitive research proposal to the relevant agencies.

LARGE EARTH-BASED SOLAR TELESCOPE

(See pages 65a and 65b for text; this will be shortened at a later time for consistency with other sections)

UNIVERSITY RESEARCH EQUIPMENT

(See pages 65c and 65d for text; this will be shortened at a later time for consistency with with other sections)

3.1.3 Enhancements in the Base Program

Eight initiatives or enhancements of the NSF/ATM base program are recommended by the Committee in addition to the community-wide and facilities initiatives.

COUPLED CLIMATE SYSTEMS (NCAR)

OBJECTIVE: The emphasis of the CCS program will on the study of the interactions and feedbacks, or coupling between systems, of the most important physical, dynamical, chemical, and biological processes that determine climate and its past and future variations. High-priority initial projects include consideration of atmosphere-

LARGE EARTH-BASED SOLAR TELESCOPE (LEST)

The growing awareness that physics of the directly observable layers of the sun is governed to a large extent by plasma-magnetic field interactions occurring in localized regions has focused attention on the need to observe the sun at spatial scales much smaller than those achieved in the past. This presents a difficult challenge, and solar physicists throughout the world are searching for ways to meet it-- via both orbital and ground-based facilities.

The urgent need for a high-resolution ground-based facility is recognized worldwide, and is currently receiving much attention. However, the challenges presented by the observational requirements are so complex and costly that individual national efforts are of questionable merit. The telescope and ancillary equipment require the most advanced technology and must be located at a truly superior observing site. A large-aperature system is required to provide the necessary light-gathering power to permit appropriate measure of spectroscopy and polarization to be carried out on small-scale domains which dominate the energy and momentum transport in the lower solar atmosphere.

In order to assure availability to and selection of the best possible site and to provide adequate opportunities for use by the world-wide community of solar physicists, and international effort is required. Thus, the motivation for the program entitled Large Earth-based Solar Telescope (LEST), the effort of an international consortium. UCAR, through NCAR's High Altitude Observatory, serves as the U.S. coordinator and liaison for this effort. The LEST consortium involves nine institutes in as many countries (U.S., Sweden, Australia, Peoples Republic of China, Federal Republic of Germany, Switzerland, Norway, Israel, and Spain); The U.S. share of the construction cost, based on a formula involving gross national products, is one-third of the total (about $8M). The LEST program offers a cost-effective approach, involving most of the world's experts in the area.

At present, surveys are being carried out at three sites (La Palma and Tenerife, Canary Islands, and Mauna Kea, Hawaii) believed to be representative of the best available in the world. The telescope design is being completed, and technical studies of system concepts are in progress within each of the participating institutes. Detailed design and site construction could begin immediately upon site selection.

While the LEST construction is being presented as an NCAR initiative, it should be noted that none of the funds will actually flow to the NCAR program. All of the construction funding would be paid directly to the consortium on behalf of the U.S. It is also not clear at this time exactly where the funding should come from within the NSF. The Astronomy program and the office of International Programs at NSF, as well as the Geosciences Directorate will want input into these decisions.

NATIONAL SCIENCE FOUNDATION

ATMOSPHERIC SCIENCES

UNIVERSITY RESEARCH EQUIPMENT

It is apparent to those who have examined the needs of universities to conduct leading edge research that equipment and instrumentation requirements are not being satisfied. That message is clearly stated in reports issued by such bodies as the National Academy of Sciences and the National Science Board. Although support for those requirements has been rising recently, the demand continues to outstrip the available funds. In view of accelerating research requirements for sophisticated and expensive equipment and instrumentation, it is likely that this demand excess will continue for the forseeable future.

The atmospheric sciences have special requirements for equipment and instrumentation by virtue of the field observational nature of the research and the large, complex data sets that must be processed, analyzed, and synthesized. As a consequence of these research characteristics and the fact that atmospheric science budgets have not grown at the same rate as the Foundation's budget, the demand excess is more intense in atmospheric sciences.

In the course of the period covered by this long range plan, several, large, coordinated observational programs will be undertaken. These, of course, will involve substantial support for equipment and instrumentation. The majority of atmospheric scientists, however, will not be involved in these programs and, therefore, their activities will not directly benefit from those resources. It is vital that the equipment and instrument needs of those scientists not be ignored during this period.

The atmospheric grant programs recognize the importance of state-of-the-art equipment and instrumentation for many of the research and educational activities that they support. There are, however, no special funds for these items. In FY 1987 it is estimated that approximately $10 Million will be provided directly to universities through the grant programs for equipment and instrumentation. It is proposed that, over the period of the long range plan, this amount be increased by 60%. Therefore, for the six years, a $36 Million initiative for university equipment and instrumentation should be considered. The distribution of annual funding should allow for a significant initial increase coupled with a steady growth, i.e.:

YEAR	1	2	3	4	5	6	TOTAL
INCREMENT	4	5	6	7	7	7	36
BASE	10	10	10	10	10	10	60
TOTAL	14	15	16	17	17	17	96

Since it is Division policy to have proposals solely for equipment or instrumentation compete with research proposals, special evaluation criteria have been developed for the former. Those criteria are:

(1) the quality and importance of the scientific and/or educational activities for which the equipment/instrumentation is to be used,

(2) the suitability of and need for the equipment/instrumentation, its expected lifetime and its expected contribution to research and/or educational activities.

(3) the institutional commitment to share acquisition costs and to support the operation and maintenance of the equipment/instrumentation (expected to be between 25 and 50%),

(4) the qualifications and past record of the principal investigator(s) and associated staff,

(5) the potential benefits to be realized by other scientists and students from using the equipment/instrumentation, and

(6) whether reasonable access to the requested equipment/instrumentation (or its equivalent) already exists in the principal investigator's department or at other institutions.

All proposals for instrumentation or equipment in the atmospheric sciences are peer reviewed using these criteria.

The funds proposed under this initiative will be provided to the grant programs under the condition that they will be used for a combination of purely eqauipment or instrumentation grants or for those components of research grants.

biosphere interactions, coupled atmosphere-ocean interactions, regional climate studies, cryosphere-climate interactions, societal interactions with droughts, and the global hydrologica cycle.

APPROACH: Observations of paleoclimatic data and operational weather data and the results obtained from new observational systems in field studies will be combined with theoretical studies and a sequence of modeling studies to develop three-dimensional coupled numerical models of the components of the earth system.

ABRUPT CLIMATE CHANGE (GRANTS PROGRAM)

OBJECTIVE: This focused research effort will attempt to develop understanding of the episodes of rapid climatic change, lasting several centuries or a few millenia, suggested by the geological and paleoclimatic record. These episodes may be oscillatory or abrupt transitions between apparently stable climate states and may contribute a significant fraction of the total climatic variance. Since variations in external forcing presumably occur on much longer time scales, there is a presumption that these events are dominated by internal feedback mechanisms.

APPROACH: The program involves observational, analytical, theoretical, and model components designed to systematically compile evidence, determine physical causes and consequences, and enable modeling and perhaps prediction of episodes of abrupt climate change.

CLIMATE SYSTEM MONITORING (GRANTS PROGRAM)

OBJECTIVE: The task proposed by this initiative is to collect, process, and analyze all available and relevant data from the atmosphere, ocean, and land to produce a global data for a 20-year period, 1979 - 1999, beginning with the four-dimensional Global Atmospheric Research Project (GARP) Global Weather Data sets. It is intended to assemble data from surface and satellite sources and, with the aid of appropriate coupled climate system models, produce a four-dimensional internally consistent record of the evolution of the climate system.

APPROACH: In addition to collecting and archiving the relevant climate data in an appropriate interactive data base, this initiative will support or encourage the parallel development of analysis, assimilation, and modeling and simulation techniques.

NATIONAL SOLAR AND TERRESTRIAL PROGRAM (GRANTS PROGRAM)

OBJECTIVE: This augmentation of the continuing program in solar-terrestrial research will focus on key components of the National Solar and Terrestrial Program. The major emphasis will be on observational studies of solar variability and on data analysis to support modeling, simulation, and theoretical studies of magnetospheric interactions and couplings with the sun and other components of the atmosphere.

APPROACH: The observational efforts will take advantage of technological advances to improve the precision, resolution, and dynamic range of observations of the sun in key spectral bands. The modeling efforts will emphasize the transfer of energy across the interface of colliding plasmas, as occurs at the boundary between the solar wind and the magnetosphere, and the subsequent effects on other parts of the atmosphere.

CLOUD AND PRECIPITATION PHYSICS (GRANTS PROGRAM)

OBJECTIVE: This initiative expands efforts to take advantage of enhanced computational power and rapidly improving observational technology to produce an increased understanding of cloud and precipitation processes. Detailed observations from radars and aircraft and the results of improved tracer experiments, coupled with strongly focused precipitation modification experiments, will lead to models that can provide comparative simulations of the evolution of natural and modified versions of the same cloud.

APPROACH: The initiative will support the development of enhanced observational and experimental technology to be applied in focused field studies designed to address the key issues that must be resolved to improve the numerical simulation of cloud systems and moist convection.

DYNAMICAL EXTENDED RANGE FORECASTING (GRANTS PROGRAM)

OBJECTIVE: The goal of this initiative is to determine whether the predictability of suitable temporally or spatially-average quantities may be significantly greater than that of transient weather systems. Increased computer power has led to recent experiments at major centers of issues associated with this initiative; key research topics include sources of climate drift in models, role of initial conditions in extended forecasting, discrimination between predictable and unpredictable regimes, and the development of appropriate parameterization schemes for boundary and cumulus effects.

APPROACH: University scientists will be encouraged through this initiative to attack problems related to dynamical extended range forecasting and to collaborate with the efforts in progress at major forecast centers.

SOLAR PHYSICS (NCAR)

OBJECTIVE: This enhancement of the NCAR program in solar physics will concentrate on the structure of solar magnetic fields, definition of appropriate physical variables within the solar interior, and development of improved understanding of terrestrial system response to solar variations; later efforts will emphasize development of new observational capabilities, diagnostic techniques, and models.

APPROACH: Observational efforts will concentrate on the solar interior and on determination of fine-scale structure; modeling efforts will be focused on numerical simulations of the earth's thermosphere and on the role magnetic fields in solar structure and evolution.

BASE PROGRAM OPPORTUNITIES (NCAR-NSF/ATM GRANTS)

(See page 70a for text)

3.2 Budget Recommendations and Implications

The task of developing a comprehensive scientific program for a discipline involves a number of steps that must be performed in sequence, and perhaps iteratively. First, priorities must be determined among the competing opportunities. Next, budget scenarios must be developed to determine the costs of supporting the highest-priority initiatives. Third, these must be combined with an assessment of the base program and the degree to which high priority initiatives can be supported by reassignment of base funds. Fourth, the implications on disciplines, institutions, individuals, and the political realities of the total recommendation must be carefully examined. This four-step process must usually be iterated in order to reach an optimum recommendation.

Base Program Opportunities

The purpose of this enhancement is to provide both the NSF Grant Managers and the NCAR management some flexibility to fund research targets of opportunity as they may arise, without specific regard for consistency with formally identified initiatives. While the committee feels it has accurately sensed the priorities of the community at this time, it cannot presume to have set the absolute boundaries for research programs for the atmospheric sciences for the entire period of the plan. The ability to fund particularly outstanding proposals which may be outside the "mainstream" of the planned program is seen as essential to the continued health and relevance of the science. This year's opportunity proposal could well lead to a future community initiative. In fact each of the initiatives and enhancements in this plan no doubt developed from the seed of individual research that may well have been out of the mainstream of atmospheric science plans in years past.

Recognizing the reality and desirability of new initiatives within the period, the committee has provided a modest planning wedge of available funds within this enhancement in the later years.

Chapter 2 presents the Committee's recommendations concerning the relative priority of the initiatives or enhancements in each of the three groups. In this chapter, we turn to budget recommendations and implications.

3.2.1 Budget Recommendations

Needs modifying to match "upscale" budget (nothing now at minimum l(...l).

As the second step in the process outlined above, the Committee developed a proposed budget for the ATM program. The highest priority opportunities in each category were recommended for funding at a level that would permit optimum progress to made. Lower priority items were recommended for funding at the minimum level that would permit adequate progress on the main issues and ensure success. The recommendations are summarized in Table 3.3.

The detailed budget scenario developed by the Committee for the ATM program is shown in Table 3.4. The purpose of this table is not to recommend a detailed funding plan for the six-year period, but to estimate the portion of new initiatives to continuing base efforts and to ascertain the total funding level required to support both new initiatives and the fundamental research contained in the base program.

The table makes it evident that it would be impossible to develop a comprehensive recommendation for the ATM program without considering the base program and without considering the reassignment of a portion of the base funds. The Committee did not examine the present base in detail, but reached a judgment concerning the vigor and vitality of the d3320a87

TABLE 3.3 - SUMMARY OF BUDGET RECOMMENDATIONS AVERAGE FY 1989-94

Average FY 1989 - 94
($ in Millions)

	ATM New Effort	Continuing Effort	Total NSF/ATM	NASA/NOAA
Community Initiatives	35.9	23.6	59.5	55.0
Facilities & Organizational/ Infrastructure Enhancements	24.5			
Base Enhancements	30.1			
Total New Effort	90.5			
FY 89 - 94 Average Base	100.0			
Base Reassignments	-14.7			
ATM Program	175.8			

TABLE 3.4

BUDGET SCENARIO FOR ATM PROGRAM FY 1989-94

BUDGET SCENARIO FOR ATM PROGRAM FY 1989-94 — d3420a87 20-Apr

Table 3.4

($ In Millions)

	FY-89	FY-90	FY-91	FY-92	FY-93	FY-94	Total
INITIATIVES & ENHANCEMENTS:							
COMMUNITY INITIATIVES							
Global Tropospheric Chemistry	9.0	15.0	18.0	20.1	18.2	19.5	99.8
Mesoscale Meteorology	8.5	11.1	12.0	12.6	7.1	7.6	58.9
TOGA	3.3	3.4	4.5	4.7	5.4	5.4	26.7
CEDAR	3.4	4.3	7.4	8.3	3.9	2.6	29.9
Subtotal, Community Initiatives	24.2	33.8	41.9	45.7	34.6	35.1	215.3
FACILITIES & ORGANIZATIONAL/ INFRASTRUCTURE ENHANCEMENTS							
Computational Science & Engr.	4.9	5.0	4.0	3.5	3.5	2.5	23.4
Facilities & Instrument.(NCAR)	2.8	11.3	11.0	22.1	22.7	14.0	83.9
Univer. Global Geosciences Ctrs.	1.0	1.5	2.0	2.0	2.0	2.0	10.5
Large Earth-Based Solar Tel.	2.5	2.5	3.0	0.0	0.0	0.0	8.0
University Research Equipment	2.0	3.0	4.0	4.0	4.0	4.0	21.0
Sub., Facilities & Organizational/ Infrastructure Enhancements	13.2	23.3	24.0	31.6	32.2	22.5	146.8
BASE ENHANCEMENTS							
Coupled Climate Systems(NCAR)	1.4	2.7	2.3	2.6	2.7	2.7	14.4
Abrupt Climate Change(GPS)	0.9	1.4	2.6	3.0	2.5	1.7	12.1
Climate System Monitoring(GPS)	5.2	10.3	10.3	10.3	13.4	13.4	62.9
Nat. Solar Terrestrial Pro.(GPS)	0.9	2.4	3.4	4.0	4.0	3.7	18.4
Cloud & Precip. Physics(GPS)	2.2	2.4	1.6	1.6	2.5	1.6	11.9
Dynam. Ext. Range Forecast.(GPS)	0.4	0.4	0.4	0.4	0.4	0.4	2.4
Solar Physics(NCAR)	0.0	0.5	0.6	0.9	0.9	1.7	4.6
Base Program Opportunities	4.0	6.0	8.0	10.0	12.0	14.0	54.0
Subtotal, Base Enhancements	15.0	26.1	29.2	32.8	38.4	39.2	180.7
Sub., Initiatives/Enhancements	52.4	83.2	95.1	110.1	105.2	96.8	542.8
BASE	100.0	100.0	100.0	100.0	100.0	100.0	600.0
BASE REASSIGNMENTS	-6.0	-16.4	-16.4	-16.4	-16.4	-16.4	-88.0
RECOMMENDED ATM PROGRAM	146.4	166.8	178.7	193.7	188.8	180.4	1054.8
14% GROWTH	121.6	138.7	158.1	180.2	205.4	234.2	1038.2

effort there based on the initiatives proposed by the program officers and the NCAR long-range plan. We comment further on the required redirection of effort in the next section.

3.2.2 Implications of the Recommendations

The most important consequence of the recommended program is that it provides support for initiatives that meet the scientific challenge of both global change and the observational revolution, while maintaining a vigorous program in the fundamentals of atmospheric science. The recommendations thus respond to the urgent scientific and societal imperatives that mandate vigorous attention and yet provide for deliberate attention to the future of the science.

Nevertheless, reassignments of base funds will surely require that both institutions and individuals must, in sum across the community, redirect a portion of present activities to new efforts. At the level of reassignment of effort recommended here, the Committee considers this to be a natural consequence of progress in science. We also observe that the process is well underway: experienced and talented scientists are, in increasing numbers, attracted to the scientific challenges represented by the initiatives and reformulating their own research programs in new directions. The community-wide initiatives are the creations of the leaders of atmospheric science in this country and abroad, and represent collaborative responses to the most exciting, challenging, and urgent scientific opportunities of the discipline.

In part for this reason, the Committee did not attempt to specify what components of the base program should be given less emphasis as a consequence of the recommended redirection of funds. The movement of leaders to new areas, the quality of proposals, and the communal sense of significant science will combine to make the redirection more natural and less painful than might be anticipated at first consideration.

The community-wide initiatives, moreover, represent endeavors that have attracted support from other relevant agencies, most notably NOAA and NASA. As shown in Table 3.5, the total anticipated funding for the four major initiatives is divided approximately evenly between NSF and NOAA and NASA together. The estimates for NOAA and NASA do not include substantial contributions of continuing efforts that will support these endeavors.

TABLE 3.5

SUMMARY OF RECOMMENDED AND PROJECTED SUPPORT FOR THE COMMUNITY-WIDE INITIATIVES

SUMMARY OF RECOMMENDED AND PROJECTED SUPPORT FOR THE COMMUNITY-WIDE INITIATIVES

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Table 3.5

FY 1989-94 AVERAGE, COMMITTEE RECOMMENDATION

($ In Millions)

COMMUNITY INITIATIVES	ATM NEW $	CONTINUING EFFORT	TOTAL NSF /a	NASA /b	NOAA /b	Total
Global Tropospheric Chemistry	16.6	8.9	25.5	13.1	14.6	53.2
Mesoscale Meteorology	9.8	12.0	21.8	0.0	21.3	43.1
TOGA	4.5	2.0	6.5	0.0	6.0	12.5
CEDAR	5.0	0.7	5.7	0.0	0.0	5.7
Total, Community Initiatives	35.9	23.6	59.5	13.1	41.9	114.5

a/ Excludes OCE contribution which was proposed at $13.5M/year average at the optimum and $9.5M/year at the minimum level.

b/ NASA and NOAA figures are the amounts planned to be specifically designated for these initiatives. These amounts do not, at this time, include other support activities not specifically designated for these projects.

As already indicated, the national portion of these community-wide initiatives require substantial effort by both university and NCAR scientists, in addition to the efforts of government scientists. The projected levels of effort for each initiative in the grants program and at NCAR are shown in Table 3.6.

The impact of the recommendations on disciplines and on the division of ATM funds between university and NCAR efforts is shown in Table 3.7. The three discipline categories shown would all receive increased support under the recommendations, with a clear shift in emphasis toward atmospheric chemistry occurring as a result of the GTCP effort.

The recommendations maintain the division of the total ATM effort between the universities and NCAR essentially at the present level, although it is evident that in some of the initiatives and enhancements NCAR plays a dominant role and in others the effort will be centered in the universities.

TABLE 3.6

PROJECTED DIVISION OF EFFORT BETWEEN GRANTS PROGRAM AND NCAR IN THE COMMUNITY INITIATIVES

PROJECTED DIVISION OF EFFORT BETWEEN GRANTS PROGRAM AND NCAR IN THE COMMUNITY INITIATIVES — Table 3.6 — d3620a87

($ In Millions)		ATM NEW $	CONTINUING EFFORT	TOTAL NSF
COMMUNITY INITIATIVES				
Global Tropospheric Chemistry	GPS	11.8	6.5	18.3
	NCAR	4.8	2.4	7.2
Subtotal, GTC		16.6	8.9	25.5
Mesoscale Meteorology	GPS	2.9	4.0	6.9
	NCAR	6.9	8.0	14.9
Subtotal, Mesoscale		9.8	12.0	21.8
TOGA	GPS	3.9	2.0	5.9
	NCAR	0.6	0.0	0.6
Subtotal, TOGA		4.5	2.0	6.5 /a
CEDAR	GPS	4.7	0.7	5.4
	NCAR	0.3	0.0	0.3
Subtotal, CEDAR		5.0	0.7	5.7
Total, Community Initiatives		35.9	23.6	59.5 /a
FACILITIES & ORGANIZATIONAL/ INFRASTRUCTURE ENHANCEMENTS				
Computational Science & Engr.	GPS	3.9	0.0	3.9
	NCAR	0.0	0.0	0.0
Subtotal, Comp. Science & Engr.		3.9	0.0	3.9
Facilities & Instrument.(NCAR)	GPS	0.0	0.0	0.0
	NCAR	14.0	0.6	14.6
Subtotal, Fac. & Inst.		14.0	0.6	14.6
Univer. Global Geosciences Ctrs.	GPS	1.8	0.0	1.8
	NCAR	0.0	0.0	0.0
Subtotal, U. Global Geo. Ctrs.		1.8	0.0	1.8
Large Earth-Based Solar Telescope	GPS	0.0	0.0	0.0
	NCAR	1.3	0.0	1.3
Subtotal, LEST		1.3	0.0	1.3
University Research Equipment	GPS	3.5	0.0	3.5
	NCAR	0.0	0.0	0.0
Subtotal, URE		3.5	0.0	3.5
Sub., Fac. & Org./Inf. Enhan.		24.5	0.6	25.1

a/ Excludes OCE contribution which was proposed at $13.5M/year average at the optimum level and $9.5M/year at the minim[illegible]vel.

TABLE 3.7

IMPACT OF RECOMMENDATIONS ON DISCIPLINES
AND ON UNIVERSITY AND NCAR FRACTIONS OF EFFORT

IMPACT OF RECOMMENDATIONS ON DISCIPLINES AND ON UNIVERSITY AND NCAR FRACTIONS OF EFFORT
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Table 3.7

Millions of Dollars:

	FY 1987 Base				FY 1989-94 Average				
	GPS	NCAR	UAF	Total	Base Reas- signments	Community Initiatives	Facilities & Organ./ Inf. Enhan.	Base Enhance- ments	Total Base Plus 89-94 AVG
Dynamics, Climate & Physical Meteorology	28.0	30.8	0.0	58.8	-8.7	14.3	17.7	22.6	104.7
Atmospheric Chemistry	9.2	9.0	0.0	18.2	-2.6	16.6	3.5	1.6	37.3
Aeronomy & Solar	14.1	4.9	4.0	23.0	-3.4	5.0	3.3	5.9	33.8
	51.3	44.7	4.0	100.0	-14.7	35.9	24.5	30.1	175.8

FY 1987 Base vs. FY 1989-94 Recommended Average Total Program

	FY 1987 Base			FY 1989-94 Recommended Avg. Total		
	GPS & UAF	NCAR	FY 1987 Total	GPS & UAF	NCAR	Total
Dynamics, Climate & Physical Meteorology	50.6%	68.9%	58.8%	56.3%	67.6%	60.7%
Atmospheric Chemistry	16.6%	20.1%	18.2%	25.1%	21.9%	23.8%
Aeronomy & Solar	32.7%	11.0%	23.0%	18.6%	10.5%	15.5%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

GPS & UAF vs. NCAR

	GPS & UAF	NCAR	Total
Base	55.3%	44.7%	100.0%
Augmented Percent	58.4%	41.6%	100.0%

CHAPTER 4

TWO CAVEATS

The recommendations presented in this report have been carefully developed to respond to the scientific and societal imperatives we face in the atmospheric sciences as the 20th century comes to an end. We have sought to maintain the vigor of all of the subdisciplines and yet proceed at an optimum pace to pursue the most important opportunities before us. The program we recommend is designed to stimulate progress in all areas in which the atmospheric sciences must contribute to the challenge of global change, to strengthen those areas of greatest societal benefit and immediate concern, and to maintain an emphasis on fundamental research that will ensure the vitality of the atmospheric sciences in the years ahead.

The total program constitutes a redirection of the atmospheric sciences that we are confident will produce strength and vigor, scientific progress and excitement, and provide considerable benefit to society. Although priorities within the recommended program could be altered slightly, major changes in these priorities or implementing only part of the program will destroy the overall design, create uncertainty and confusion, and delay the accomplishment of essential scientific objectives.

The second caveat concerns community response to these recommendations. The atmospheric sciences have not fared well at NSF in the past decade for a variety of reasons. The most important are two-fold: the atmospheric sciences have not presented their case effectively to either the Executive or Legislative branches of government and the community has not had a compelling and comprehensive vision that it advocated with unity and dedication.

We cannot ensure that this program will be accepted and supported enthusiastically by NSF, the Administration, and Congress. But if longing for the past inhibits embracing the future, if discontent with details is turned into vocal criticism of the total program, and if elements of our community seek advantage at the expense of others, then it is certain that we shall be interpreted as divisive and diffident; our apparent uncertainty will then provide the opportunity for other disciplines to prevail and prosper.

- End of Text -

APPENDIX A: CHARGE TO THE COMMITTEE

APPENDIX B: CRITERIA FOR SETTING PRIORITIES

APPENDIX C: PATTERNS AND TRENDS IN FEDERAL FUNDING OF THE ATMOSPHERIC SCIENCES

The intellectual challenges and the societal implications of weather and atmospheric phenomena and events have diverse and varied consequences for nearly every segment of American activity. As a consequence, research and development in the atmospheric sciences is supported at the federal level by a variety of agencies and programs. The total funding of the nine agencies with the largest budgets for atmospheric research and development amounts to more than $500M annually. The patterns and trends in federal funding of atmospheric science are thus complex, not completely coordinated, and subject to a variety of economic and political pressures.

In this Appendix, we present first a statistical summary of these funding patterns derived from data collected by (ICAS ?) and then turn to trends in NSF funding of the atmospheric science over the past decade.

Table C-1 shows the funding for research and development in the atmospheric sciences for each of the nine agencies for FY1985-87. Detailed budgets for NASA, NSF, DoD, and NOAA are shown in Table C-2. Although the total for NASA is the largest of all the agencies, more than half is devoted to the development and construction of the Upper Atmosphere Research Satellite (UARS); the Research and Analysis budgets that support continuing research relevant to the NASA mission in the universities and NASA centers total about $60M.

TABLE C-1

R&D IN THE ATMOSPHERIC SCIENCES

R&D IN THE ATMOSPHERIC SCIENCES

(dollars in millions)
^ current

AGENCY	FY 1985 Actual	FY 1986 Estimate	FY 1987 ~~Cong.~~ Budget Request
NASA	$181.3	$238.5	$282.2
NSF	95.8	92.6	100.6
DOD	84.9	92.7	100.5
DOC (NOAA)	104.9	93.1	91.9
DOE	26.6	24.3	26.4
EPA	13.8	19.6	23.8
DOT (FAA)	11.6	8.9	12.8
DOA	6.8	6.8	6.8
DOI (BUREC)	6.8	6.4	4.8
TOTAL	$531.7	$582.9	$649.8

- All FY 1986 figures for NASA, NSF, and NOAA include the 4.3% reduction required by Gramm-Rudman-Hollings Act.

TABLE C-2
(PART 1)

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

(NASA)

Put all four parts together

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)
(dollars in millions)
current

	FY 1985	FY 1986	FY 1987
Upper Atmosphere R&A*	$31.8	$31.2	$33.4
Atmospheric Dynamics R&A	28.5	28.8	38.9
Space Physics R&A	16.7	16.9	18.8
Shuttle/Spacelab Instrument Development	7.8	5.3	12.8
Earth Radiation Budget Experiment	8.1	1.9	—
Extended Mission Operations	29.5	35.1	33.6
Interdisciplinary R&A	1.8	1.8	1.1
Tethered Satellite Payloads	3.8	4.3	1.8
Upper Atmosphere Research Satellite Mission	55.7	114.8	152.2
TOTAL	$181.3	$238.5	$282.2

*R&A denotes Research and Analysis

TABLE C-2
(Part 2)

NATIONAL SCIENCE FOUNDATION (NSF)

NATIONAL SCIENCE FOUNDATION (NSF)
(dollars in millions)

Grants Program ~~Atmospheric Project Support~~	FY 1985 ~~Actual~~	FY 1986 ~~Plan~~	~~% Change~~	FY 1987 Request	~~% Change~~
Aeronomy	$6.5	$6.2	-4.6%	6.6	6.5%
Atmospheric Chemistry	7.1	6.7	-5.6%	8.9	32.8%
Climate Dynamics	7.6	7.6	0.0%	8.7	14.5%
Experimental Meteorology	5.1	5.8	13.7%	5.6	-3.4%
Global Atmospheric Research	4.9	4.3	-12.2%	3.8	-11.6%
Meteorology	8.9	9.3	4.5%	10.1	8.6%
Solar Terrestrial Research	7.5	7.1	-5.3%	7.6	7.0%
Subtotal	47.6	47.0	-1.3%	51.3	9.1%
National Center for Atmospheric Research	43.5	41.1	-5.5%	45.2	10.0%
Upper Atmospheric Research Facilities	3.9	4.0	2.6%	4.1	2.5%
TOTAL	$95.0	$92.1	-3.1%	$100.6	9.2%

C-2 III

TABLE C-2
(Part 3)

DEPARTMENT OF DEFENSE (DOD)

DEPARTMENT OF DEFENSE (DOD)
(dollars in millions)
current

	FY 1985	FY 1986 *	FY 1987
Atmospheric Sciences			
Army	$12.7	$14.1	$15.6
Navy	19.3	21.0	22.2
Air Force	52.9	57.6	62.7
TOTAL	$84.9	$92.7	$100.5

Gramm-Rudman-Hollings

~~Figures for FY 86 & FY 87 are tentative and may change considerably~~

* GRH Act reduction is not reflected in these budget figures

TABLE C-2
(Part 4)

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA)

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA)
(dollars in millions)

	FY 1985	FY 1986	FY 1987
Atmospheric Programs	$87.8	$77.3	$74.9
Satellite and Environmental Data	10.0	8.9	9.6
Ocean and Coastal Programs	73.7	58.1	34.5
Marine Fisheries	61.1	72.3	48.2
Saltonstall-Kennedy Fund	9.1	7.7	0
Program Support	28.1	29.8	29.1
Total	$269.8	$254.1	$196.3
Atmospheric Sciences	$104.9	$93.1	$91.9

Funding data for NSF, for the Geoscience Directorate, and for the Atmospheric Sciences Division are shown in current dollars in Table C-3 and in constant FY1982 dollars in Table C-4. Some of the data in Table C-4 are displayed in Figure C-1. It is evident that federal funding for NSF, GEO, and ATM has been relatively constant over the decade, declining from FY1978 to FY1982 and then increasing slowly. The dashed curve in Figure C-1 showing the ATM percentage of the NSF budget reveals a persistent decrease from nearly seven per cent in FY1982 to less than six per cent in FY1987.

The percentage increases from FY1982 to FY1986 for NSF, GEO, and ATM were 27, 15, and 13. The NSF increase is equivalent to a 6.1 per cent increase compounded annually. This rate of increase was applied to estimate total NSF budgets in the period FY1988-93 for comparison with the recommendations made in this report. The results are shown in Table C-5.

TABLE C-3

TABLE C-3

(*Current*) **Dollars in Millions)**

	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984	FY 1985	~~CURRENT~~ ~~PLAN~~ FY 1986	BUDGET REQUEST FY 1987
NSF APPROPRIATION	863.3	911.6	996.3	1076.1	1035.1	1092.2	1320.3	1501.8	1523.9	1685.7
GEO	211.5	223.2	273.8	257.9	259.8	280.8	328.6	353.0	346.4	383.2
ATM	56.4	59.1	63.3	69.3	70.3	75.5	88.3	95.0	92.1	100.6
~~GPS~~ *Grants Program*	29.7	32.0	34.5	37.6	38.5	39.6	45.3	47.6	47.0	51.3
NCAR	24.9	25.3	26.6	29.2	30.3	32.4	39.3	43.5	41.1	45.2
~~UAF~~ *Upper Atmosphere Facilities*	0	0	0	0	0	3.5	3.7	3.9	4.0	4.1
NSBF	1.8	1.9	2.2	2.4	1.5	0	0	0	0	0
GNP BUDG. DEFLATORS	0.7172	0.7790	0.8474	0.9321	1.0000	1.0425	1.0838	1.1225	1.1597	1.2071

TABLE C-4

TABLE C-4

(Constant FY# 1982 Dollars in Millions)

	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984	FY 1985	~~ESTIMATE~~ FY 1986	REQUEST FY 1987
NSF APPROPRIATION	1203.7	1170.2	1175.7	1154.5	1035.1	1047.7	1218.2	1337.9	1314.0	1396.5
GEO	294.9	286.5	323.1	276.7	259.8	269.4	303.2	314.5	298.7	317.5
ATM	78.6	75.9	74.7	74.3	70.3	72.4	81.5	84.6	79.4	83.3
[illegible]S	41.4	41.1	40.7	40.3	38.5	38.0	41.8	42.4	40.5	42.5
NCAR	34.7	32.5	31.4	31.3	30.3	31.1	36.3	38.8	35.4	37.4
UAF	0.0	0.0	0.0	0.0	0.0	3.4	3.4	3.5	3.4	3.4
NSBF	2.5	2.4	2.6	2.6	1.5	0.0	0.0	0.0	0.0	0.0
GNP BUDG. DEFLATORS	0.7172	0.7790	0.8474	0.9321	1.0000	1.0425	1.0838	1.1225	1.1597	1.2071

Budget

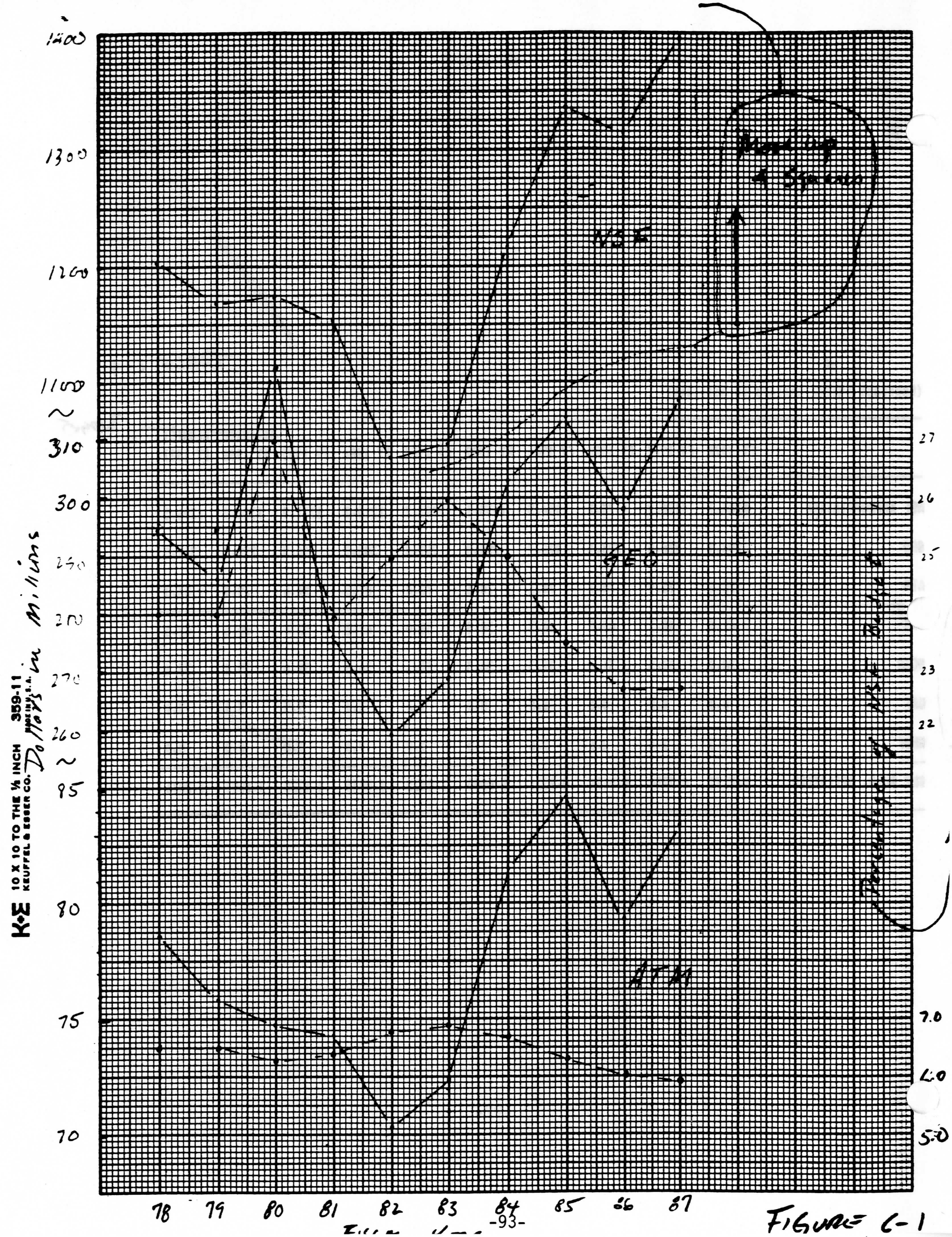
1400
1300
1200
1100
310
300
290
280
270
260
95
80
75
70
Dollars in Millions
27
26
25
23
22
7.0
6.0
5.0
Percentage of NSF Budget
NSF
GEO
ATM
Moving up 4 Spaces
78
79
80
81
82
83
84
85
86
87
K+E 10 X 10 TO THE ½ INCH 359-11
KEUFFEL & ESSER CO. MADE IN U.S.A.

FIGURE C-1

TABLE C-5: PROJECTED NSF AND ATM BUDGETS IN CONSTANT DOLLARS

(Dollars in millions)

FISCAL YEAR	NSF	ATM	ATM/NSF (per cent)	GNP BUDGET DEFLATOR
1982	$1249.5	$84.9	6.79	0.8284
1983	1264.7	87.4	6.91	0.8636
1984	1470.6	98.4	6.69	0.8978
1985	1615.0	102.2	6.33	0.9299
1986	1586.2	95.9	6.04	0.9607
1987	1685.7	100.6	5.97	1.0000
1988	1789	125.9	7.03	1.0000
1989	1899	135.7	7.15	1.0j
1990	2016	142.8	7.08	1.0000
1991	2140	151.6	7.08	1.0000
1992	2271	145.0	6.38	1.0000
1993	2411	137.0	5.68	1.0000

SOURCE: Derived from Tables C-4 and 3.2

APPENDIX D: BIBLIOGRAPHY OF PLANNING DOCUMENTS USED BY COMMITTEE

- End of Appendices -

27 April 1987

CMT/PlanCom5