NARSTO

Research Strategy and Charter

Final Version

November 1994

NARSTO

NORTH AMERICAN RESEARCH STRATEGY for TROPOSPHERIC OZONE

Printed by the United States Environmental Protection Agency

NARSTO
Research Strategy and Charter

Final Version
November 1994

TABLE OF CONTENTS

FOREWORD

This document presents the research strategy and the organization and management plan for the governance and implementation of the **North American Research Strategy for Tropospheric Ozone (NARSTO)** program. These ideas represent the efforts of working teams consisting of private and public sector scientists, air quality managers, and policy makers from Canada, Mexico and the United States who attended a NARSTO Planning Workshop in Boulder, Colorado during June 6-8, 1994. Every effort has been made to solicit the broadest possible involvement in this formative effort to build a joint private and public research program on tropospheric ozone.

This document is organized into separate presentations dealing with the four principal scientific and technical components of the NARSTO (Analysis and Assessment, Observations, Modeling, and Emissions), and dealing with Organization and Management and Liaison activities. It includes (a) a NARSTO research strategy and (b) a plan (Charter) for organizing and managing the NARSTO program.

This document presents the NARSTO research strategy, which includes the principal science and policy questions of interest, descriptions of strategic activities and goals, a prioritized listing of major research tasks needed to address these questions, and cost estimates for implementing the strategy over the next 10 years. Appendix C contains the Charter describing the structure and management of the NARSTO program.

The Charter describes how the NARSTO program will be organized and managed and suggests permanent membership guidelines. The primary planning group under the NARSTO organization is the Executive Steering Committee consisting of 7-11 private and public sponsoring organization representatives selected by an Executive Congress (i.e., one representative from each private and public sponsoring organization). A Cooperative Research and Development Agreement (CRADA) will serve as the framework for implementing the NARSTO program as a private/public partnership. Negotiations with potential NARSTO sponsors is underway. The research strategy will serve as the Statement of Work under the CRADA. A formal signing of the Charter and CRADA will be held to launch "the strategy" as an official continental research program.

ACKNOWLEDGEMENT OF WORKING TEAM PARTICIPANTS

Analysis and Assessment Team

Amar, Praveen, NESCAUM
Bailey, Brent, NREL
Dann, Tom, Env. Canada
Guzman, Francisco, Inst. Mexicano del Petroleo
Japar, Steven, Ford Motor Co.
Middleton, Paulette, SUNY
McFarland, Mack, DuPont Co.
McNider, Richard, U. of Alabama
Neff, William, NOAA
Rao, S. T., NY Dept. of Environ. Conservation
Roth, Phil, ENVAIR
Schere, Ken, EPA *
Smith, Richard, NISS

Emissions Team

Cadle, Steve, General Motors
Croes, Bart, California Air Resources Board *
Gertler, Alan, Desert Res.Inst.
Guenther, Alex, NCAR
Harley, Robert, U. of California
Fujita, Eric, Desert Research Institute
Jones, Larry, EPA
Lamb, Brian, Washington State Univ.
Lauer, George, Atlantic Richfield
Moucheron, Marie Colette, Mexico City Gov't.
Oliver, Bill, Radian
Price, Jim, Texas Natural Resource Conserv. Commission
Rodgers, Mike, Georgia Institute of Technology
Sarofim, Adel, MIT
Seebold, Jim, Chevron
Solman, Ron, Environment Canada
Somers, Joe, EPA
Wells, Dale, EPA, Region 8
Wendt, Jost O. L., Univ. of Arizona

Liaison Team

Allen, Tom, NY Dept. of Env.
Collom, Bob, GA Dept. of Natural Resources *
Cowling, Ellis, NC State Univ. *
Hall, Bob, EPA *
Heap, Michael, Reaction Eng.Int.
Hicks, Bruce, NOAA
Hofmann, John, Nalco Fuel Tech.
Hogsett, Bill, EPA *
Johnson, Steve, PSI Technology
Kelly, Michael, TVA
Svoboda, Larry, EPA, Region 8
Tremblay, Jean, Environment Canada
Wendoll, Robert, Dunn-Edwards Corp.

Modeling Team

Atkinson, Roger, U. of CA-Riverside
Chock, David, Ford Motor Co.
Carter, William, U. of CA-Riverside
Dennis, Robin, EPA *
Dodge, Marcia, EPA
Dunker, Alan, General Motors Research Lab
Georgopoulos, Panos G., EOHSI
Hansen, Alan, EPRI
Harley, Robert, U. of CA-Berkeley
Lee, Yin-Nan, Brookhaven Nat'l. Lab
Liu, Shaw, NOAA
McCarthy, James, Gas Research Institute
Milford, Jana, U. of Colorado
Olson, Marvin, Environment Canada
Peters, Len, Virginia Tech.
Richardson, Jennifer, NASA
Samson, Perry, U. of Michigan
Seaman, Nelson, Penn St. Univ.
Venturi, Ron, Public Service Electric & Gas Co.

Observations Team

Anlauf, Kurt, Environment Canada
Calvert, Jack, NCAR
Chameides, William, GA Tech.
Coffey, Peter, ESEERCO
Crow, Walter L. Radian
Curran, Tom, EPA
Demerjian, Ken, SUNY
Ennis, Chris, NOAA
Fehsenfeld, Fred, NOAA *
Feldman, Howard, API
Kolb, Chuck, Aerodyne
McNair, Stuart, AES/Canada
Meagher, James, TVA
Newman, Leonard, Brookhaven
Ray, John, NPS
Roberts, Paul, Sonoma Technology
Sacks, Jerry, NISS
Scheffe, Rich, EPA
Varns, Jerry, EPA
Wolff, George, GM
Ziman, Steve, Chevron

Organization & Management Team

Belian, Timothy, Coordinating Research Council
Blumenthal, Don, Sonoma Technology, Inc. *
Curtis, Bill, Univ. Corp. for Atmos. Research
Donleavy, John, Public Service Electric & Gas Co.
Farwell, Sherry, National Science Foundation
Fradkin, Larry, EPA
Frick, Bill, American Petroleum Institute
Hales, Jake, Envair
De La Luz, Guadalupe, INE/SEDESOL, Mexico
Lusis, Maris, Environment Canada
Messcher, Walter, DOT
Olivotto, Carmelita, AES/Environment Canada
Patterson, Ronald, EPA *
Pennell, Bill, Pacific Northwest Laboratory/DOE
Smith, Martin, Niagara Mohawk Power Corp.

Workshop Coordinators

Albritton, Dan, NOAA
Mueller, Peter, EPRI
Vickery, Jim, EPA

* = Work Group Chair or Co-chair

1. INTRODUCTION

The products of photochemical smog processes in the lower atmosphere, where they may harm humans, animals, vegetation, and materials have been the subject of repeated control attempts for nearly 30 years in portions of North America. These products include ozone (O_3), nitrogen dioxide (NO_2), peroxyacetyl nitrate (PAN), aerosols, acid pollutants, and other potentially damaging trace gas species. As growth and industrialization have migrated from urban areas to suburban and rural areas, these products have traveled as well. Their signatures have been measured in the lower troposphere over vast areas of the North American continent. Previous efforts at smog control often have not met expectations, in part, because of the incomplete scientific understanding of the complex physical, chemical, and biological processes affecting the accumulation of ozone and other smog products, as well as inadequate monitoring data to verify the effectiveness of past emissions control measures for the precursors of O_3, notably nitrogen oxides (NO_X) and volatile organic compounds (VOC). A part of this problem can be attributed to the fact that tropospheric ozone research has been sponsored by a variety of government and non-government organizations, with their individual efforts largely uncoordinated.

The National Academy of Sciences (NAS) and others have recently called for a rethinking of the ozone problem through a comprehensive program of tropospheric ozone research coordinated across organizations from government (federal, state/provincial, and local), industry, academia, and other private-sector interests within North America. This call is based on the apparently disappointing results of recent efforts to control high ozone concentrations and the lack of coordination of ongoing research efforts in tropospheric ozone science. The present effort, described here, is known as the North American Research Strategy for Tropospheric Ozone (NARSTO). Formal and informal discussions and workshops among the principal sponsors, performers, and customers of North American tropospheric ozone research have been taking place over the past two years. Participants have come from government agencies at the national level, as well as state, local, and provincial levels. Representatives from industry and the private sector, including the electric power, gas, automobile, petroleum, and forest products industries have participated. Members of the university and contractor research community have been involved, as well as non-profit environmental interest groups. A broad consensus toward coordinated collaborative research is emerging from these discussions.

Scope and Goals of the NARSTO Program

The overall scope and goals of the NARSTO are presented below.

Scientific Goals

- Develop and implement a research strategy reflecting both scientific and policy concerns.
- Conduct timely, productive, policy-relevant tropospheric ozone research with frequent and appropriate reporting of the research results to the scientific, policy, and air quality management communities.
- Develop and deliver timely, useful, and scientifically credible assessment tools and guidance to the policy/air quality management community.
- Provide periodic state-of-science assessments of the North American ozone problems and their control, and to revise the NARSTO research strategy based upon the identified assessment needs and remaining scientific gaps and uncertainties.
- Provide a clearinghouse of current scientific and technical information generated as part of NARSTO (i.e., data, publications, results).

Organizational Goals

- Provide for sustained coordination, collaboration, and leveraging of resources in tropospheric ozone research by the multiple organizations in North America (both public and private) sponsoring and participating in this research.
- Develop an organization and management structure that facilitates a high level of individual organizational ownership in the NARSTO program, and encourages and supports the critical short- and long-term research required within the research strategy.
- Provide a unified, cohesive, scientifically sound basis for planning and implementing tropospheric ozone research that will help sustain sponsors' commitments to a long-term NARSTO program.
- Include representation within the NARSTO organization from all stakeholders, including the policy and air quality management, health and ecological effects research, and emissions control technology research communities, in order to maintain critical communications links with key customers and other interested parties.

This document represents the thoughts and opinions of more than 100 research scientists, engineers, air quality managers, and policy makers, representing more than 80 public and private organizations currently engaged in tropospheric ozone-related activities. A brief background and overview of the NARSTO is presented, as are initial proposals for a prioritized near-term and long-term research strategy, and organizational and management options for the implementation of NARSTO. It is hoped that this "blueprint" for NARSTO will evolve into a ratified plan for its implementation.

Background

The perception and understanding of the ozone problem during the 1960s and early 1970s was that photochemical smog was a localized problem, confined to certain urban air sheds, mostly in California and in a few other large urban areas, where the required combination of conducive meteorological conditions and source emissions led to the chemical accumulation of ozone. Research begun during this time period elucidated the relevant chemical kinetics of the urban smog phenomenon through laboratory and controlled smog chamber experiments. Some of the first urban air quality simulation models developed in the early 1970s were based on this conceptual model of photochemical smog, and the models were useful for understanding the phenomenon and non-linear complexity of the Los Angeles smog situation. During the mid to late 1970s field measurements in the eastern United States began to show a picture of widespread regional areas of elevated ozone concentrations during the spring and summer months, not as severe as the measured concentrations in Los Angeles, but nonetheless significantly above tropospheric background levels. Wolff et al. (1977) analyzed some of these early ozone data from the eastern United States and aptly described the "rivers of ozone" flowing over 1000-km spatial scales. The perception of the ozone problem thus began to change from purely a local phenomenon to one of regional character, with embedded local/urban hot spots or plumes. As measurement networks improved and instrument capability increased, the scale and complexity of the regional ozone problem began to reveal itself. Previously unknown and unquantified sources of highly reactive biogenic and naturally occurring VOCs, such as isoprene, were discovered to be ubiquitous in forested areas of North America. The photochemistry of the rural atmosphere, of distinctly different regimes than chamber-studied urban atmospheres, began to be elucidated. Complex temporal and spatial, including vertical, structures, in ozone and precursor concentrations were observed. Some of these more recent findings have changed our perception and conceptual models of the ozone problems in North America.

Since the late 1980s significant new studies and compendiums of recent O_3 research and air quality management experience have been published (see, for example, AWMA, 1988, 1991, 1992, 1993; OTA, 1989; EPA, 1989). Perhaps the single most significant publication of late on the subject is the National Research Council/National Academy of Sciences report (NAS, 1991) on the state of science in tropospheric ozone research and applications. The report, commissioned and published in response to an explicit requirement in the Clean Air Act Amendments of 1990 (CAAA-90), provides an important milestone in summarizing and reflecting on current science in ozone research, as well as reflecting on the successes and failures of the last 20 years. There are a number of important findings and recommendations, as shown in Box 1. The last one, in particular, bears on the subject of a coordinated national research program on tropospheric ozone.

Since the publication of the NAS report, many new findings have begun to emerge as a result of research related to recent major field studies. These studies include the Southern Oxidants Study (SOS), the Lake Michigan Ozone Study (LMOS), the San Joaquin Valley Air Quality Study/Atmospheric Utilities Signatures: Predictions and Experiments (SJVAQS/AUSPEX), the Southern California Air Quality Study (SCAQS, in Los Angeles), and others. At a meeting coordinated by the Air & Waste Management Association in San Diego, CA, in November 1993, results from these studies were reported, and are in the process of being published. Many of the findings reaffirm the validity of the major conclusions of the NAS report, while others point to new areas that have not been given sufficient attention in the past, including among others, emission inventory verification and refinement for episodic modeling, development and use of innovative diagnostic observational approaches to studying ozone-to-precursor relationships, and the quantification of uncertainty and risk management in decision support.

At the same time that scientific research on the tropospheric ozone problem has been conducted, air quality managers and decision makers have been attempting to integrate the most current relevant scientific information into the process of making public policy decisions with regard to the best management of the O_3 problem. Public policy choices have been made with regard to the ozone problems in the United States at the federal level since 1970 with the passage of the Clean Air Act and a series of Amendments to the Act, most recently in 1990 (see Box 2). Thus, there are existing statutory mandates that specify these choices that have already been made

Box 1 National Academy of Sciences Findings

1. Despite the major regulatory and pollution-control programs of the past 20 years, efforts to attain federal standards for ozone largely have failed.
2. The principal measure currently used to assess ozone trends is highly sensitive to meteorological fluctuations and is not a reliable measure of progress in reducing ozone over several years for a given area.
3. The State Implementation Plan process is fundamentally sound in principle but is seriously flawed in practice because of the lack of adequate verification programs.
4. Current emission inventories significantly underestimate anthropogenic emissions of VOCs. As a result, past ozone control strategies have been misdirected.
5. The combination of biogenic VOCs and anthropogenic NO_X can have a significant effect on photochemical ozone formation in urban and rural regions of the United States.
6. Ambient air quality measurements now being performed are inadequate to elucidate the chemistry of atmospheric VOCs or to assess the contributions of different sources to individual concentrations of these compounds.
7. Although three-dimensional grid-based air quality models are currently the best available for representing the processes of ozone formation, they contain important uncertainties. Moreover, uncertainties in input data, such as emissions inventory data, must be considered when using such models to project the effects of future emissions controls.
8. State-of-the-art air quality model and improved knowledge of the ambient concentrations of VOCs and NO_X indicate that NO_X control is necessary for effective reduction of ozone in many areas of the U.S.
9. The use of alternative fuels has the potential to improve air quality, especially in urban areas. However, the extent of improvement will be variable with location and specific fuel used. Alternative fuel use, alone, will not solve ozone problems nationwide and will not alleviate increased auto emissions as in-use vehicles age.
10. Progress toward reducing ozone concentrations in the United States has been severely hampered by the lack of a coordinated national research program directed at elucidating the chemical, physical, and meteorological processes that control ozone formation and concentrations over North America.

in efforts to reduce the photochemical smog burden in the United States. These choices have been made without the benefits of a full understanding of the basic science of photochemical smog and therefore may not be the optimum choices. The CAAA-90 reflect a recognition of this incompleteness in the science in two areas. First, under Title I (Section 185B), the Act requires that EPA and the NAS conduct, within one year of enactment of the Act, a study of the roles of VOC and NO_X in O_3 formation and control; this is, in essence, the state-of-science document discussed above. Additionally, the U.S. Department of Energy, the American Petroleum Institute, and the Motor Vehicle Manufacturer's Association of the United States joined the EPA in supporting the NAS for this task. Second, under Title IX (Clean Air Research) the Act requires EPA to conduct longer term research, testing, and development of improved methods for monitoring and modeling to form a better understanding of the tropospheric O_3 problem.

It is explicitly understood that the research conducted within NARSTO by the participating organizations will be relevant to policy makers and analysts and to air quality managers. Figure 1 presents a potential policy timetable of significant milestones. There are clearly sensitive

Box 2 Clean Air Act and Amendments

In the United States, beginning with the Clean Air Act of 1970, and continuing with the most recent Clean Air Act Amendments of 1990 (CAAA-90, or the Act) the federal government has given the States and local governments responsibility for identifying and implementing additional emissions control measures, beyond those federally mandated (such as the Federal Motor Vehicle Control Program), if the latter do not result in sufficient progress toward reduction of ambient ozone in a particular area. Title I of the CAAA-90 further provides guidelines on the categorization of urban areas (from "marginal" to "extreme") based on their degree of measured exceedance of the National Ambient Air Quality Standards (NAAQS) for ozone. Depending upon the severity of the classification, the State or local government must submit a State Implementation Plan (SIP) demonstrating, by a mandated date, the effectiveness of proposed emission control measures at bringing the area into compliance with the NAAQS. This is generally performed with an air quality simulation model using estimates of projected future emissions along with proposed control strategies to reduce those emissions. Title II (Mobile Sources) of the CAAA-90 also bears on the ozone problem by establishing stricter emissions standards for automobiles and trucks that will phase in reductions of tailpipe emissions of NO_X, VOC, and CO beginning in model year 1994, as well as require cleaner, or reformulated, gasoline to be sold beginning in 1995 in the nine cities with the worst ozone problems. Additionally, there are limitations imposed by Title IV (Acid Rain Control) of the CAAA-90 on the amount of NO_X emitted by large industrial boilers.

1993	❑ Marginal areas attain
1994	❑ RACT Complete
1995	❑ 11/94 modeling based SIP attainment strategies, rules, 15% progress rules, Tier II/LEV decisions
1996	❑ Moderate areas attain or bump up
1997	❑ New ozone standard decision*
1998	❑ Mid-course correction modeling*
1999	❑ New standard (if applicable) attainment modeling
2000	❑ Serious areas attain or bump up*
2001-2003	❑ Severe (2005, 2007) mid-course correction modeling
2005 2007	❑ Severe attainment*
2009-2010	❑ Attain new standard

*If new NAAQS (8-hr, long-term) replace current, post 1997 activities may defer to new NAAQS schedule.

Figure 1. Potential ozone policy timetable for the United States

portions of this timetable in which new research products, discoveries, and other insights would be useful in the decision making process. Modeling demonstrations of attainment are required for particular areas currently in violation of the O_3 NAAQS. Future modeling of potential changes in emission control strategies ("mid-course corrections") will be needed for the most serious O_3 non-attainment areas. Also, assessments against potential new forms of the O_3 primary and secondary standard may be necessary. These various modeling and assessment needs by the policy community represent targets of opportunity for NARSTO to deliver research products that may be used in a timely manner to meet policy deadlines.

Overview

The NAS (1991) found that "Progress toward reducing ozone concentrations in the United States has been severely hampered by the lack of a coordinated national research program directed at elucidating the chemical, physical, and meteorological processes that control ozone formation and concentrations over North America." Their recommendations on this subject include the establishment of just such a program, that would elucidate the response of ambient ozone concentrations to possible regulatory actions or to possible changes in atmospheric composition or climate. Such a program, they recommend, should be managed independently from the government offices that develop regulations under the Clean Air Act so as to avoid conflict between the long-term planning essential for scientific research and the more immediate requirements of regulatory agencies. The NAS further suggests that the program be broad based, drawing on the best atmospheric scientists in the nation's academic, government, industrial, and contract research laboratories. The NAS recommends using the U.S. research program to address stratospheric ozone depletion as a model of multi-organization cooperation.

In large part as a response to the NAS recommendations, a series of workshops and research planning efforts was undertaken in late 1992 and early 1993 to outline a comprehensive research program and to discuss the potential of performing coordinated collaborative research among all North American organizations performing and sponsoring tropospheric ozone studies. Two workshops, jointly sponsored by the EPA Office of Research and Development (Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC) the National Oceanic and Atmospheric Administration Aeronomy Laboratory (Boulder, CO), and the Electric Power Research Institute (EPRI, Palo Alto, CA), were primarily for the major sponsors of ozone research, both government and non-government groups, to discuss their respective priorities and needs, and their ongoing projects in tropospheric ozone science. Separately, a large scale planning effort, preceded by numerous working group discussions and conference calls, brought together the principal scientists in North America working in all aspects of the science, to articulate the principal questions and potential projects for a long-term (10-year) effort to provide definitive answers and policy-relevant guidance to the outstanding issues of the tropospheric ozone problem. Foremost among the results of these discussions and workshops was a comprehensive proposed research strategy, "Coordinated North American Research Strategy for Tropospheric Ozone" (NARSTO), which identified major unresolved questions of tropospheric ozone science and the principal projects needed to adequately address these questions. The publication and dissemination of this report was coordinated by EPA/ORD, but the contents represented the thinking and writing of the dozens of scientists, engineers, and managers participating in the workshop discussions. Also among the results of this effort was a resolve among the major sponsors to put a research coordinating organization together to facilitate collaborative research in the implementation of future programs. There was a mutual recognition that many of the projects needed to answer the outstanding questions were of sufficient cost that they could be done only by leveraging resources across sponsors.

The Subcommittee on Air Quality Research of the Committee on Environment and Natural Resources (CENR) within the National Science and Technology Council will facilitate the coordination of NARSTO research activities with other ozone-related and air quality research. The scope of this committee includes the issues of ozone and other ambient air pollutants, acidic deposition, airborne toxic materials, visibility and particles, and indoor air quality. In recognization that many of the phenomena associated with these issues share the need to better understand common atmospheric processes, a major role of the Subcommittee will be to improve the coordination among these research areas. A specific NARSTO-related example of coordination that the Subcommittee will assist is improving the interaction among monitoring networks and between the atmospheric and effects research. An additional role of the Subcommittee is the setting of priorities across the spectrum of air quality research needs. An improved understanding of the formation and consequences of surface-level ozone in both urban and rural areas, the sources of ozone precursors, and the effectiveness of current and alternative control strategies is deemed the highest priority for additional emphasis in the near future.

The science and technology questions identified in the original NARSTO draft report were subdivided into six particular areas: Health and Ecological Effects of O_3, Ambient Monitoring and Tracking Research, Atmospheric Chemistry and Modeling, Emissions Inventory, Alternative Fuels, and Control Technologies. Among these areas 43 specific scientific and technical questions were raised to cover the needs of all potential future ozone research. As the result of comments received during an extensive review of the original strategy document regarding high implementation costs, a subset of the scientists and managers participating in the workshops and working groups leading up to the NARSTO report, helped set relative priorities among the 43 questions. Both the NARSTO draft report and the results of the priority-setting exercise have been widely distributed throughout the ozone science and policy community.

In recent planning meetings and discussions focusing on finalizing and implementing the strategy, several additional decisions were made. First, it was decided that the research areas of health and ecological effects and emissions control technologies were sufficiently different from the other types of research to be conducted within NARSTO that these areas would not be directly included in the strategy, but would be connected through Liaison Teams that would contain members of these research communities to ensure relevance and communication between NARSTO research and these other research areas. The liaison teams would also have members from the policy and air quality management communities to facilitate critical links with NARSTO research. (Appendix 1 presents the NARSTO Liaison Teams Report that provides more detailed thinking and recommendations regarding the possible expansion of liaison functions and responsibilities.)

Other teams being established within NARSTO would oversee and perform the component process-level research required by the strategy. These other teams include the following.

Analysis and Assessment Team	Scope: Data analysis and interpretation, integration and assessment
Observations Team	Scope: monitoring/networks, intensives, methods development, observations-based analysis
Modeling Team	Scope: air quality and meteorological modeling, development, research applications, and evaluation; laboratory, smog chamber, and mechanistic studies of atmospheric chemistry
Emissions Team	Scope: process and activity analysis, field studies, emissions modeling and projections, and control technology implications

The revised, prioritized NARSTO research strategy is presented in this document in the context of these working teams. Project priorities reflect deliberations within each team, but not between teams. Also, a proposal for an organizational structure for NARSTO and management options for implementing and overseeing the research are presented here as a result of the work of an ad hoc committee dealing with organization and management issues.

Interface of Science and Policy

Given this background of major events in North American ozone science and policy, we are now at a significant decision point on how to proceed as a community of scientists, engineers, policy analysts, and policy and decision makers to jointly make further progress toward managing the tropospheric ozone problem. It is clear that the NAS recommendation of a coordinated comprehensive program is sound, but the implementation of such a program will not necessarily be easy or straightforward. Many agencies and organizations have research and/or policy interests in ozone research, with varying perspectives and priorities, especially as regards short-term versus long-term research needs. It may be prudent to take lessons from past history of such major collaborative projects.

The NAS has suggested using the stratospheric ozone research program as one example of successful collaboration among organizations. In this case the National Aeronautics and Space Administration (NASA) was the lead federal agency. NASA developed a basic research program of laboratory and field measurements, satellite data analysis, and theoretical modeling. While

NASA was awarded the majority of federal research funding in this area, they actively formed joint partnerships with other Federal agencies and organizations in developing a common intellectual plan and in executing the plan. The particular strengths of the program have been its broad participation base, including academic, government, industrial, and contract research groups, its careful coordination with other federal and industrial programs and non-U.S. research efforts, and the trust and effective joint working relationships built among the participating groups. The results of this comprehensive and coordinated research effort have been reported to Congress, EPA, and the United Nations. Its scientific assessments have included modeling studies that meet the regulatory and policy needs of EPA and regulatory organizations in other nations. Clearly, these are valuable lessons that should be taken seriously as the NARSTO effort becomes organized.

Another large program, now in its mature stages, is the National Acid Precipitation and Assessment Program (NAPAP). The NAPAP 10-year, $600M effort was to assess what was known about the causes and consequences of acid precipitation and to develop understanding of what might be done about it. Several retrospective evaluations of the NAPAP program have been performed (and no doubt more will occur). Russell (1992) provides a number of compelling lessons. NAPAP's scientific research was expected to contribute to resolving a public-policy problem; this was not a program designed to advance knowledge per se, such as might be the case with NSF investigator-initiated research projects. Many of the conflicts within NAPAP arose because of differing expectations about its role and mission and what success entailed. Another lesson was that assessment questions should be clearly defined and carefully articulated because they must guide the research design from which all else follows. The proper role of science is to advise on what is practicably achievable, and with what expected level of certainty. It is not to seek to influence, based on inherent scientific merit, what the policy questions should be. Simply put, policy makers define what is important to inform the ultimate decision and then make the decision after getting the information they require. Policy analysts define and explicate the options for the policy makers, bringing to bear relevant scientific information, along with other considerations of relevance to the decision. Scientists provide estimates of causes and effects under alternative conditions based on their research, fully disclosing all uncertainties and areas of ignorance.

Finally, Russell indicates the proper relationships between these constituencies. For a program at the interface of science and policy to succeed, what is required is a series of highly selective semi-permeable barriers that allow or block influence of different types from one set of players to another. For example, scientists doing and reporting their research must be isolated from influence over what they find and report, but be subject to direction over the questions that are of importance to the decision. Policy makers must be protected from policy analysts or scientists telling them what they should decide, but open to information about what the consequences of alternative decisions are likely to be. Building and maintaining such barriers are inherently difficult and sometimes contentious, but are also essential for the ultimate success of a program such as NAPAP.

What then might we conclude from these lessons that might have relevance to the NARSTO? First, like the NAPAP and the stratospheric ozone program, the tropospheric ozone research program is also at the interface between science and policy. Unlike the others though, public policy decisions have been made by federal and state statute and implemented through interpretations of the law and the relevant science over the past 24 years. Thus, the constituencies that Russell refers to are perhaps more clearly defined and entrenched in their positions with regard to tropospheric ozone, than the comparable groups participating in NAPAP or the stratospheric ozone research program. Given its history, the stakeholders in the tropospheric ozone issue have much to gain or lose, depending upon the future decisions that are made. It seems then, that for NARSTO to be successful, much care must go into defining the constituencies and their respective roles at the outset, with agreement among all NARSTO participants on these roles. For the scientific research conducted as part of NARSTO to be relevant, the proper role of science within the tropospheric ozone issue should be established, and clear semi-permeable boundaries between science and policy must be specified. With this done, the NAS recommendation of the separation of research from regulation will be accomplished, and at the same time the relevance of the research to the policy issues will be maintained.

It is important to separate the issues of science from those of policy to help define the boundaries, discussed earlier, for the NARSTO. The research effort required to address the fundamental science questions needs a long-term focus and sustained support for both applied and basic research. The needs of the regulatory community (including both regulators and regulatees) are driven more by immediate policy concerns and usually have a shorter term focus. The key to a successful NARSTO will be the establishment of a program that is broad enough to take a long-term view of the needed research and assessments, providing support to laboratory and academic institutions, while at the same time supporting the production of interim research products for use by NARSTO customers and clients. For this to occur, certain groups within the NARSTO community must take ownership of the long-term science issues and work with other groups within and outside of NARSTO to infuse the results of the basic and applied research at regular and timely (short-term) intervals into products (methods/models for assessment purposes and guidance for their use) for the regulatory community. With this framework for collaboration within a NARSTO multi-organization community, there is room for both short-term and long-term interests, and an objective approach for meeting the needs of all constituents will have been constituted. As Russell (1992) noted, however, the establishment of the division of responsibility and authority among the constituents is an inherently difficult task, and it will take good communication and a willingness to negotiate on the part of all involved. This difficult task must be performed at the outset of NARSTO. Assisting with such coordination is one of the major functions of the CENR's Subcommittee on Air Quality Research. For example, major stakeholder communities were involved in the 1994 National Forum on Environment and Natural Resources R&D that was sponsored by CENR and the National Academy of Sciences as part of the national priority-setting process. Ultimate success will depend heavily on establishment of a working interdependence, trust, and true teamwork among all organizations involved.

Policy Concerns

Examples of the policy issues and questions that are of concern are given below.

(1) For a given area, how do we determine whether an ozone problem exists and how can we determine its severity?

(Is there a problem?)

(a) What is the best way to characterize the nature of the problem? Is the form of the existing ambient air quality standard (NAAQS) the appropriate metric to use?

(b) Under potential alternative forms of an ambient air quality standard for ozone (both acute episodic and chronic longer term type standards) will the perception of an ozone problem change, and in what ways?

(2) For an area considered to have an ozone problem, what portion of the problem is essentially irreducible (based on such factors as natural emissions of ozone precursors and stratospheric influx of ozone) and what portion of the ozone problem is potentially controllable (based on anthropogenic precursor emissions into the troposphere)?

(*What part of the problem is tractable?*)

(a) For the portion that is potentially controllable, what part of the problem is due to locally-generated ozone and precursors, and what part is due to sources outside of the area (regional transport)?

(b) What are the principal anthropogenic sources of precursors and what options are available for their control?

(3) Do we have evidence that existing control measures are having an impact?

(*Are my current efforts helping to alleviate the problem?*)

(a) Can we verify that existing source emissions control programs for precursors have influenced ambient ozone concentrations? What demonstration will be made to establish the effectiveness of these programs on ozone? How do the demonstrated changes in ozone compare to the anticipated changes?

(b) Can we verify that existing source emissions control programs have decreased ambient concentrations of ozone precursors (VOC, NO_X, and CO)? What demonstration will be made to establish the effectiveness of these control programs on precursors? How do the demonstrated changes in precursors compare to the anticipated changes?

(4) What are optimal approaches for reducing current and future high ozone concentrations for a given area considered to have an ozone problem?

(*What more should I be doing? How can I be sure that my current and future efforts will pay off?*)

(a) What are the current predictions, and their associated uncertainties, of existing policies on ozone and other related pollutants?

(b) Will adequate scientific understanding that links the causes and distribution of ozone pollution, particularly with regards to model predictions and emission inventories, be available on the timetable of the Clean Air Act Amendments?

(c) What are the risks and cost-benefit implications associated with these emissions control approaches? What is the technical, economic, social, and political feasibility of reducing tropospheric ozone?

(d) What periodic assessments leading to "mid-course" adjustments in control programs are indicated, and when should the assessments be performed?

(e) Will new potential forms of the ozone NAAQS require a change or redirection in emission control strategies? Should non-traditional air quality management approaches be considered?

(5) What is the magnitude and impact of trans-national-boundary transport of ozone and its precursors?

(What are the international implications?)

(6) How can the relevant science and scientific uncertainties be meaningfully communicated to the air quality management and policy communities?

(How can communications be improved between scientists and non-scientists on technical issues?)

(a) How can tropospheric ozone science be translated into actionable knowledge (changes in activity patterns) by the public?

Science Concerns

Examples of the research issues and questions to address the above policy concerns are the following.

(1) How can we determine the current trends in ozone concentrations and exposures on local and regional scales in North America?

(a) What measurements, monitoring networks, and analyses are needed to establish ozone trends and exposures?

(b) What measurements, monitoring networks, and analyses are needed to establish regional and local precursor (NO_X, VOC, CO) trends in North America?

(c) What refinements and developments are needed in instrumental methods to enable routine monitoring of key species (O_3, and O_3 precursors) and meteorological parameters?

(d) What are the uncertainties associated with these measurements, networks, and analyses?

(e) How can the monitoring data be archived so that they are easily accessed and incorporated into analytical tests of ozone distribution and trends?

(f) Can the effects of meteorological variability be separated from the effects of precursor emissions influence in the trends of ozone and/or its precursors?

(2) How can we better understand, further identify, isolate, and explain the fundamental physical, chemical, and meteorological processes responsible for ozone accumulation on local and regional scales in North America?

(a) What intensive field studies are needed, and in what locations, to further knowledge about these processes?

(b) What laboratory studies are required to increase understanding of the gas-phase and heterogeneous chemical processes?

(c) How can the data associated with these measurements be archived so that they are easily accessed and incorporated into analytical tests of our understanding and the processes that control ozone accumulation?

(d) What modeling and diagnostic data analyses are needed to further understanding about these processes?

(e) What refinements and developments are needed in instrumental methods to enable measurement of key chemical species (precursors, radical intermediates, oxidized products, etc.)?

(f) How can we enhance and further build upon the existing science infrastructure in North America for performing tropospheric ozone research?

(3) How can we incorporate and use the evolving scientific understanding of relevant processes in diagnostic and prognostic tools (methods/models) for explaining observed phenomena and estimating impacts of future perturbations of independent variables (emissions, meteorology, etc.)?

(a) Can we establish quantitative methods of uncertainty in the estimates from these methods and models?

(b) How do we use the estimates from our methods and models in conjunction with socio/economic analysis tools for impact assessments?

(4) How do we evaluate and periodically assess the relative contribution of VOCs and NO_X, and their control, to ozone accumulation on local and regional scales in North America?

(a) Is the production of ozone limited by the availability of VOCs or NO_X?

(b) Does this limitation change from day to day for a given area or region, or from area to area on a given day, based on changes in meteorology and emissions?

(c) What data are required, and with what precision and accuracy, to evaluate and apply diagnostic and predictive methods and models for ozone assessment and control strategies?

(d) What portion of ozone near the surface can be attributed to natural subsidence from the stratosphere? How does this change with meteorology and season?

(e) Can we quantify the contribution of urban areas to rural and regional ozone concentrations, and conversely, can we quantify the rural/regional photochemical impact on particular urban areas?

(f) Can we determine the flux of emissions of key ozone precursors through field studies or other measurement programs, and reconcile ambient measurements with emission inventory estimates of fluxes?

(g) What portion of the ozone precursors are from natural (biogenic) sources and how will these emissions change with natural (e.g., meteorological variability) and human-induced (e.g., land-use, climate change) perturbations? What are the biological factors controlling the emissions of natural VOC and NO_X emissions?

(5) What technologies and approaches are most cost-effective in achieving and maintaining ozone precursor reductions and reducing ozone concentrations and exposures?

References

AWMA, 1993: Tropospheric Ozone: Nonattainment and Design Value Issues, Transactions (J. Vostal, S.T. Rao, S. Capone, eds.), Air and Waste Management Association, Pittsburgh, PA, 690 pp.

AWMA, 1992: Tropospheric Ozone and the Environment II: Effects, Modeling, and Control, Transactions (R. Berglund, ed.), Air and Waste Management Association, Pittsburgh, PA, 955 pp.

AWMA, 1991: Tropospheric Ozone and the Environment, Transactions (R. Berglund, D. Lawson, D. McKee, eds.), Air and Waste Management Association, Pittsburgh, PA, 875 pp.

AWMA, 1988: The Scientific and Technical Issues Facing Post-1987 Ozone Control Strategies, Transactions (G. Wolff, J. Hanisch, K. Schere, eds.), Air and Waste Management Association, Pittsburgh, PA, 736 pp.

EPA, 1989: Atmospheric Ozone Research and its Policy Implications, Proceedings (T. Schneider, S.D. Lee, G.J.R. Wolters, L.D. Grant, eds.), Elsevier, New York, 1047 pp.

NAS, 1991: Rethinking the Ozone Problem in Urban and Regional Air Pollution, National Academy Press, Washington, DC, 489 pp.

OTA, 1989: Catching Our Breath: Next Steps for Reducing Urban Ozone, OTA-O-412, U.S. Congress Office of Technology Assessment, Washington, DC, 237 pp.

Russell, M., 1992: Lessons from NAPAP, *Ecological Applications*, 2:107-110.

Wolff, G., P. Lioy, G. Wight, R. Meyers, and R. Cederwall, 1977: An investigation of long-range transport of ozone across the midwestern and eastern United States, *Atmospheric Environment*, 11:797-802.

2. ANALYSIS AND ASSESSMENT RESEARCH STRATEGY

Introduction

The Analysis and Assessment Team within NARSTO performs an integrating function by coordinating the process-level research on observations, modeling, and emissions toward answering the policy-relevant science questions of importance to NARSTO. As such, the members of this team must fully understand the policy concerns, expressed earlier, as a basis to assess the relevance of specific portions of the research strategy. It is expected that the leadership of the team would bring knowledge and experience from the air quality management community as well as the scientific community to bear on the assessment questions. A close association with NARSTO's Liaison Teams must also be established to assure the relevance of the assessment research to the concerns of the effects and control technology research communities. Defining "assessment" within a NARSTO context must be one of the first orders of business of the team. Periodic assessments of the state of science and policy-relevance of tropospheric ozone research is an obviously needed activity. NARSTO assessment activities become a component of, but not the whole of, so-called "integrated" or "end-to-end" assessments which follow through to the health and welfare impacts on pollutant-sensitive populations and the control technologies through which ozone management will be achieved. For NARSTO, the key science questions from an assessment perspective have to do with the relative contributions of VOCs and NO_X to ozone concentration and exposure patterns. Analysis and assessment of regional and local patterns of ozone and its precursor chemicals will provide a focus for this fundamental issue.

The links between the research planning mechanisms for Analysis and Assessment and the key policy decision junctures for ozone air quality managers in North America are extremely important. The ongoing research should provide quantitative assessment of risks associated with using the NARSTO scientific results in decision making processes at points in time that are relevant to the processes. Such timely interaction with the policy community should help to galvanize its support for the continuing research that underpins sound policy decisions. The scientific process in this regard must also remain an open process of inquiry, without the "institutionalizing" of scientific judgements once they are stated in an assessment. Periodic questioning of long-held beliefs must be part of these scientific research and assessment processes.

A key function of the Analysis and Assessment Team is to coordinate the research activities among the other working teams toward joint analyses satisfying assessment objectives. The leaders of the observations, modeling, emissions, and liaison teams are also to be members of the Analysis and Assessment Work Team. There are many overlaps in the scopes of these individual teams that can be worked out jointly. Often the overlaps represent the types of research that bear most strongly on assessment issues. Examples of such overlaps are the understanding and reconciliation of observation-based diagnostic analyses and emissions-based modeling analyses of O_3 response, understanding the mechanisms and significance of transport on local, regional, and trans-boundary spatial and temporal scales, and the evaluation and refinement of emission-model estimates of source fluxes with ambient concentration data. The Analysis and Assessment Team will work closely with the NARSTO management team, the liaison teams, the data management group, and the other research groups to coordinate and implement the tasks necessary to meet the assessment objectives and to periodically evaluate progress toward these objectives and the overall NARSTO goals.

Objectives

The broad objectives of the Analysis and Assessment Team are to (1) provide scientific guidance to air quality managers and decision makers in a timely manner and (2) provide guidance for setting research priorities for the relevant science. The following set of principal objectives then follows from these broad objectives.

Assessment

- Define and periodically refine the concept of "assessment" within the context of the NARSTO.
- Perform periodic and timely assessments of the state-of-knowledge in policy-relevant tropospheric ozone science.

Integrated Analysis

- Identify and support cross-cutting data analysis between observations, modeling, and emissions research teams.
- Develop recommendations for systems of data management, archiving, and dissemination, that meet the needs of both the prime NARSTO research community clients as well as interested clients in related communities, including effects research, control technology research, and air quality management and policy.
- Facilitate the transfer of assessment tools, including measurement technologies, modeling methods, analysis techniques, and guidance for their use, to the NARSTO customer communities.

Communication

- Develop an effective dialogue process between the science and policy communities regarding air quality management concerns.
- Provide common reporting structures and formats for conveying to the NARSTO customer communities findings and interpretations of research studies in clear and unambiguous terms.
- Develop connections with other air quality and climate issues and provide recommendations as to how the total tropospheric air quality burden can be assessed.

  (Note that this may be especially critical for the linkage between NARSTO research and particles and air toxics research, as impending regulations and possible emission controls for each of these pollutant categories will affect the other areas in terms of their atmospheric synergism as well as the social and economic impacts of cumulative controls.)

Uncertainty/Risk Analysis

- Quantify and characterize scientific uncertainty toward assessing risks in air quality management decisions.
- Provide continuing and comprehensive research planning to maximize the chances of achieving scientific objectives toward addressing the relevant policy issues in a timely manner.

Approach [1]

The initial approach to meeting the objectives of NARSTO Analysis and Assessment is outlined below. The high (**) and highest (***) priority major tasks are generally assigned to near-term activities, although many of these will lay the groundwork for more intensive longer term activities to be initiated later.

Near-Term Activities (through 1998):

Strategic Activity 1: Defining and refining the assessment concept within the NARSTO.

Activity Goal: To periodically reinterpret and refine the principal policy and science issues relevant to the NARSTO, and to establish the broad scope of NARSTO assessments to address these issues. *(Contributes to answering all Science Questions and all Policy Questions)*

Major Tasks: ***Conduct early and continuing series of meetings, with representatives from the policy and air quality management, effects, and control technology communities, to define and refine the concept of assessment as it applies to NARSTO and these other communities. (This task is to be conducted jointly with the Liaison Teams.)

- Refine the policy questions and the policy timeline with milestones.
- Refine the major science questions and their priorities, with milestones.

Strategic Activity 2:

Planning for future assessments.

Activity Goal: To develop the guiding principles and protocols for conducting NARSTO assessments. *(Contributes to answering all Science Questions and all Policy Questions)*

Major Tasks: ***Develop a design for reducing scientific uncertainty and minimizing risk in the air quality management process. The design should help elucidate existing scientific uncertainties, in both observational and modeled data, and their risk impacts on the decision-making process in the management of ambient ozone. Methods for using results of the uncertainty/risk assessment analyses are suggested to decision makers.

---

[1] The priorities that were determined for the tasks during the Boulder Workshop (June 6-8, 1994) are shown before each major task. The priorities are: *** (first or highest); ** (second or next); * (third or lowest).

***Develop the elements of an assessment protocol for NARSTO, including, but not limited to, the elaboration of the principal questions and objectives to be addressed by an assessment, the methods and tools to be used to accomplish the assessment, the establishment of a baseline for the assessment, and the treatment of uncertainty in the assessment.

- Identify clients/audiences for assessments and the appropriate means of communicating results to these clients/audiences.
- How are stakeholders involved in the steering of the assessments?
- How is the science community to be organized to conduct the assessments?

Strategic Activity 3:

Assessment of existing knowledge.

Activity Goal: To determine our current knowledge base on the tropospheric O_3 problem in North America. *(Contributes to answering all Science Questions and all Policy Questions)*

Major Tasks: ***Review and summarize the current state-of-science, state-of-assessment tools, and adequacy of databases, identifying their strengths, limitations, and needs for improvement.

- Complete an integrated analysis of scientific findings, conclusions, and lessons learned from all major recent and on-going urban/regional photochemical oxidant field and modeling studies.

***Conduct an integrated scientific assessment of the tools and databases for use in "mid-course correction" State-Implementation-Plan (SIP) modeling to improve the scientific quality and credibility of the analyses.

***Conduct a scientific assessment of the adequacy of the PAMS monitoring network toward meeting assessment objectives.

**Study the feasibility of developing methods for determining reliable trends in O_3, NO_X, VOCs and separating the meteorological "signal" from the chemical signal in trend analysis.

Continuing and Long-Term Activities (through 1998 and beyond):

Strategic Activity 4:

Integration of NARSTO research activities toward assessment goals.

Activity Goal: To establish an integrated and coordinated program of policy-relevant tropospheric ozone research. *(Contributes to answering all Science Questions and all Policy Questions)*

Major Tasks: ***Provide ongoing guidance to observations, modeling, and emissions teams to facilitate integrated plans of data analysis.

***Reconcile emissions inventories with source-oriented field observations.

**Quantify the role of long-range transport using modeling, observations, emissions, and meteorological analyses.

*Develop confirmatory evidence between diagnostic analysis of observations and diagnostic analysis of air quality model results.

*Characterize and quantify the relevant scientific uncertainties, and provide information derived from these uncertainties appropriate for risk analyses for decision makers.

**Define reliable trends in O_3, NO_X, VOCs and separate meteorological "signal" from chemical signal in trend analysis.

**Develop recommendations for database management (QA, archival, dissemination) to facilitate integrated data analyses. Data types include, but are not limited to:

- observations from routine air quality and meteorology networks
- observations from intensive field studies
- key modeling results
- relevant emission inventory data

*Provide for the transfer of assessment tools, including measurement technologies, modeling methods, analysis techniques, and guidance for their use, to the wider NARSTO research and customer communities.

Strategic Activity 5:

Conduct periodic NARSTO assessments.

Activity Goal: To perform assessments as needed and communicate the scientific findings, conclusions, and lessons learned to the appropriate communities. *(Contributes to answering all Science Questions and all Policy Questions)*

Major Tasks: *Conduct periodic assessments, based on the developed protocols and principles, at timely intervals to provide guidance to the air quality management and policy communities.

Strategic Activity 6:

Establish effective communications.

Activity Goal: To establish and maintain a dialogue between the assessment community and decision makers, effects researchers, control technology researchers, and other groups representing social values related to air quality management. *(Contributes to answering Science Questions 3,4,5 and all Policy Questions)*

Major Tasks: ***Develop a dialogue and communications plan between the NARSTO assessment community and client/customer communities.

- Develop critical links to effects community and implement communications plan to assess impacts on human health and ecosystem exposure.
- *Develop critical links to emissions control community and implement communications plan to explore feasibility and timing of new emissions reduction technologies and approaches.

*Develop critical links to policy community (including national and local interests) and implement communications plan to assess risks and cost-benefit implications, including socio-economic and political aspects, of reducing ambient O_3.

*Develop and maintain a sustained linkage and effective communications with the assessment activities of the Subcommittee on Air Quality Research of the U.S. Committee on Environment and Natural Resources (CENR), who will be promoting broadly based state-of-understanding assessments involving all of the appropriate agencies and communities. Develop and maintain similar interactions with such groups in Canada and Mexico.

*Develop and maintain substantive relationships with the Mid-Latitude Ecosystems and Photochemical Oxidants (MILOX) research activity of the International Global Atmospheric Chemistry Project (IGAC), with the European Experiment on Transport and Transformation of Environmentally Relevant Trace Constituents in the Troposphere over Europe (EUROTRAC-2), and with the EMEP Program for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe.

*Develop useful reporting structures and formats for conveying scientific and policy findings and interpretations of NARSTO assessments and scientific research to various customer communities.

Strategic Activity 7:

Linkage between ozone and other air quality and climate issues.

Activity Goal: To coordinate atmospheric research pertaining to ozone and other related environmental and climate issues. *(Contributes to answering Science Questions 1,2,3 and Policy Questions 2,4,6)*

Major Tasks: **Develop linkages and connected research issues between the tropospheric ozone problem and other related environmental and climate issues (ex., PM-10/PM2.5, visibility, toxics, acids, global climate change, etc.). Utilize field measurement infrastructures, to the extent possible, to measure atmospheric constituents of interest to the various environmental and climate issues.

**Develop recommendations for dealing with multiple pollutant or "total air burden" assessments. Consider the impacts on tropospheric ozone air quality management of emission control strategies proposed for other environmental and climate issues; and conversely, the impacts on other issues of proposed ozone management strategies.

3. OBSERVATIONS RESEARCH STRATEGY

Introduction

Ozone levels are not simply a function of local emissions and chemistry but rather are dependent on the transport of O_3 and O_3-precursors from adjacent areas. Observing the flux of O_3 and its precursors between identifiable point-sources, urban complexes, and rural areas can determine the relative contribution of each of these types of sources to each other under a variety of climatological conditions. The Observations Section of the NARSTO organization is aimed at developing a comprehensive research strategy to accomplish policy relevant scientific research in the following areas.

- monitoring and monitoring networks (including PAMS upgrades)
- comprehensive field studies
  - methods development and evaluation
  - observational based analysis (OBA)

This document discusses the research required to deal with the key policy concerns and the associated science questions outlined in the introduction to the NARSTO Plan. The following sections describe: (1) the objectives that this research is aimed at accomplishing; and (2) the approach that is suggested to accomplish each of the objectives for which this section of the program has assumed responsibility.

This section is written with the cognizance that critical research, fundamental to managing the ozone problem, is underway. This research must continue and the support required to maintain this research must continue. However, this outline describes the future work in the "Observations" section of the NARSTO Program that is of sufficient importance that **additional** resources must be provided to protect the public interest in managing the ozone problem. The division between near-term and long-term research is based on the belief that data already on hand will likely provide the informational base most likely to provide a near-term pay-off. In addition, we feel that monitoring networks are of critical importance to future progress in managing air quality in North America. Hence, the definition and design of these networks demand near-term attention.

However, the designation of near-term and long-term does not necessarily imply priority. In this regard, several long-term activities may elicit higher priority than some near-term projects. It must be recognized that managing air quality requires long range commitments. The NARSTO Program must be structured with that in mind.

In addition, considerable attention has been directed toward developing and validating measurement techniques. Many critical measurements cannot yet be made; the accuracy and reliability of others are open to question. If critical data is to be obtained, measurement technology must improve. In addition, it will be necessary to greatly improve the reliability, increase the operational simplicity, and train technical personal in proper operation of research grade instruments before these instruments can be used for methodical monitoring. The development of techniques, platforms, monitoring sites, and the design of the studies that use them must be aimed at providing data products and data product formats that fulfill a specific need and can be readily and easily used.

For each strategic activity a priority was assigned to the tasks that comprise the activity. The elements of the observations component of the NARSTO program are described in more detail in Appendix 3 of this document. The appendix also contains an estimate of the resources required to undertake each strategic activity of the program. For programmatic guidance, the resources required to undertake the highest priority elements in each activity are list along with the total required. A resume of the estimates are contained in Table I.

Finally, there may appear to be areas of overlap between the activities and tasks that are called for and described in this section and those described and called for in the sections dealing with "Chemistry and Modeling" and "Emissions." This is a natural consequence of the crosscutting nature of the key problems in atmospheric sciences, particularly, as they relate to the ozone problem. As these apparent areas of the overlap indicate, the approach to understanding and managing ozone must be cooperative and interdisciplinary.

Objectives

The management of photochemical oxidants such as ozone and their harmful effects on human health and welfare is confounded by the fact that these oxidants are secondary pollutants; that is they are not emitted directly into the atmosphere but are instead produced in the atmosphere by photochemical reactions involving the precursor compounds: CO, VOCs, and NO_X. Management of photochemical oxidants is further confounded by the non-linearities inherent in the photochemical mechanism responsible for ozone production; because of these non-linearities the effectiveness of pollution control measures that focus on limiting VOC emissions and/or NO_X emissions can vary greatly depending upon the chemical, meteorological, and land-use characteristics of the area of interest. Thus a simple reduction of precursor emissions is not always the most effective method of ozone pollution abatement. Generally more sophisticated and targeted strategies are needed and the development of these targeted strategies requires a thorough understanding of the underlying chemical and meteorological processes leading to ozone pollution in a given locale or region.

Chemical and meteorological measurements are fundamental to our understanding of atmospheric chemical processes and thus are a prerequisite to the development of effective ozone abatement strategies. These measurements: (a) Identify the location and temporal periods where ozone pollution problems exist and the severity of these problems; (b) Provide information on precursor sources and distributions critically involved in the generation of the ozone pollution in various locales; (c) Provide data for driving and evaluating Observation-Based and Emissions-Based Models (and the modules contained within these models) used to determine and test possible abatement strategies for ozone pollution; and (d) Track ozone and relevant precursors to determine the effectiveness of the various abatement strategies that are adopted. Recognizing the essential role of atmospheric observations, the NARSTO research plan must incorporate an observations component that is scientifically comprehensive and fully integrated into the other components of the plan.

It must also be recognized that for NARSTO to be successful, the measurements carried out under its auspices must be technically and scientifically sound. NARSTO recognizes from the outset the imperative to collect data of the highest quality. To accomplish this goal, significant resources must be allocated in the program to "instrumentation science"; that is the development and testing of field instrumentation. As a general rule, NARSTO participants agree to use only fully evaluated and field-tested instrumentation and sampling protocols and to adhere to rigorous and well-founded quality control and quality assurance practices.

Out of the two general principles enunciated above (i.e., the need for scientifically comprehensive and technically sound field observations), two objectives for NARSTO's Observations Program have been formulated. These objectives are:

1. Develop monitoring and diagnostic analysis approaches and technology needed to measure and track O_3 and its precursors including that needed:

   (a) to capture representative spatial and temporal patterns of local and regional ozone and precursor distributions;

   (b) to identify and separate the component of ozone and precursor trends influenced by meteorological variability from that caused by variations in chemical parameters (e.g., emissions);

   (c) to establish regional and local trends of ozone precursors (CO, NO_X, VOCs) in North America;

   (d) characterize the contribution of North American emissions on the Northern Hemispheric tropospheric ozone budget;

   (e) to diagnose and evaluate emission inventories;

   (f) to identify and separate the influence of precursor emission distribution and trends from meteorological variability on local and regional O_3 distribution and trends;

   (g) to determine the roles of various ozone precursor species in the production of ozone on local and regional scales.

   (h) provide data needed to evaluate and assist development of observational based models (OBMs) and emission based models (EBMs).

2. Design and implement comprehensive field programs needed to understand the physical, chemical, biological and meteorological processes involved in the accumulation of ozone in the lower atmosphere by:

   (a) developing the needed measurement capabilities;

   (b) formulating scientifically well-poised measurement strategies;

   (c) carrying out comprehensive field studies of varying duration, seasonal and spatial coverage;

   (d) analyzing data from field programs to address appropriate scientific questions.

Approach [1]

Near-Term Activities

Strategic Activity 1:

Analysis and Evaluation of Existing Data. (Done in concert with the Analysis and Assessment Team.)

Activity Goal: Determine the current state of understanding concerning ozone and ozone precursor trends and distribution. *(Contributes to answering Science Questions 1d-f, 2c-e, 3a, and 5.)*

Major Tasks: ***Provide an inventory of quality assured (i.e., retrospective QA/QC) data sets (in standard units and a standard data base format) that are available and accessible for O_3 and O_3-precursors.

***Establish a virtual data center for surface ozone measurements made in Canada, Mexico, and the United States. The center would provide NARSTO scientists with an on-line service that would provide ozone distribution and trends for North America.

***As a follow-up to the National Academy of Science Report, "Rethinking the Ozone Problem in Urban and Regional Air Pollution," using measurements of O_3 and O_3-precursors obtained from various regional studies and monitoring networks, develop peer-reviewed articles indicating the present scientific understanding of the chemical processes that shape the ozone distribution in urban and rural areas of Mexico, Canada, and the United States.

***Develop an analysis strategy for use of data to determine processes and improve emission inventories.

- Undertake additional analysis to determine the influence of meteorological variables on urban and rural O_3 concentration. Use statistical regression models to identify meteorological conditions conducive to O_3 accumulation.
- Develop analysis strategies using air concentration data gathered by the regional studies as a cost-effective means to independently check emission inventories and understand photochemical pathways.

---

[1] The priorities that were determined for the tasks during the Boulder Workshop (June 6-8, 1994) are shown before each major task. The priorities are: *** (first or highest); ** (second or next); * (third or lowest).

Strategic Activity 2:

PAMS review and enhancement. *(Done in concert with the Modeling Team and the Analysis and Assessment Team.)*

Activity Goal: Develop measurement and analysis strategy to enhance and maximize information and utility of the network of Photochemical Assessment Monitoring Sites (PAMS). *(Contributes to answering Science Questions 1, 2c, and 4a-c, e, g.)*

Major Tasks: ***Provide advice for the design and implementation of a data archive for all PAMS data and derived products.

***Institute annual instrumentation-science course for training of local and state personnel responsible for implementation and maintenance of PAMS and encourage "monitoring partnerships" between local and state agencies and academic and private Centers of Excellence in air quality monitoring.

***Carry out blind PAMS-relevant intercomparisons of measurements of ozone, NO, NO_2, NO_y, and speciated VOC at selected sites.

***Obtain observational data for the purpose of determining relative sensitivities of urban ozone plume to VOCs and NO_X emissions.

***Develop and test a hierarchy of diagnostic procedures and analyses that could make use of data from a PAMS network and review PAMS sampling strategy to optimize the compatibility of the data-stream with the data input requirements of these diagnostic procedures and analyses.

- Identify analyses and diagnostic applications that will require PAMS data products and insure that the network will provide these data products.
- Utilize existing data where possible to aid in network assessment and enhancement.
- Carry out measurements of ozone, NO, NO_X, and speciated VOC measurements in selected urban locations using densely-spaced networks and a complement of airborne platforms (airplanes, helicopters, sondes, etc.) to determine horizontal and vertical variability of ozone and precursor species in typical urban settings.
- Based on these results, develop spatial and temporal sampling strategies for the PAMS network that will optimize the scientific output of the network.

***Develop diagnostic tools for the PAMS network based on insights gained from the above tasks.

***Develop improved data handling approaches.

***Establish similar measurement capabilities and sites in Canada and Mexico.

**Begin implementation of improved and enhanced PAMS network based on insights gained from above tasks.

Strategic Activity 3:

Network design for monitoring. *(Done in concert with the Modeling, and Analysis and Assessment Teams, and in coordination with the Effects program.)*

Activity Goal: Determine the implications for air quality monitoring of an improved air quality standard for ozone. *(Contributes to answering Science Questions 1, 2c, and 4a-c, e, g.)*

Major Tasks: **Develop an objective classification system needed to identify the various types of O_3 monitoring stations. Determine the similarities, differences, opportunities and trade-offs required to undertake adequate programs in exposure, regulatory/compliance, trans-boundary flow, and diagnostic monitoring of ozone and ozone-precursors.

**Provide support for the formulation of new ozone metrics that are statistically robust and account for other relevant factors such as the effects of meteorology.

**Determine if potential alternate statistical forms of reporting ozone air quality (both acute episodic and chronic long-term) will alter the characterization of ozone air quality compared to the current statistical form of the standards.

**Determine chemical measurements appropriate to the needs of each network.

**Network design.

- Design a meteorological monitoring component that captures the role that meteorology and dynamics play in the redistribution of airborne chemicals. In addition to the standard complement of measurements, attention should be given to determination of solar flux and the dynamical structure of the boundary layer and lower free troposphere.
- Develop a comprehensive plan for quality control and quality assurance of the data to be acquired from this network.
- Determine a criterion to judge how representative ground based measurements are on various vertical and horizontal scales.
- Develop a strategy for determining the optimum location for monitoring ozone and ozone precursors.
- Determine the spatial resolution needed to properly describe O_3 production, accumulation, and consumption on urban and regional scales.

Strategic Activity 4:

Northeastern Scoping Study. *(Done in concert with the Modeling Team and the Analysis and Assessment Team)*

Activity Goal: Provide information that would be of assistance to states in the Northeast in the state implementation planning (SIP) process on attainment of the National air quality standards for ozone, and to serve as a nucleus for more intensive studies in future years. *(Contributes to answering Science Questions 1, 2c, and 4a-c, e, g.)*

Major Tasks: ***Review existing data taken from state air quality and acid rain research programs. Develop a retrospective quality control and quality assurance plan by assessing the merit of given data.

***Initiate PAMS siting at strategic locations in the Northeast corridor.

***Design Northeastern Scoping Study.

**Implement short term studies.

- Measurements of upper air meteorology.
- Surface measurements of O3, NO, NO_y, VOCs, and meteorology.
- Aircraft measurements of O3, NO, NO_y, VOCs, and meteorology.

Strategic Activity 5:

Continue existing/ongoing regional field studies.

Activity Goal: Better understand, further identify, isolate, and explain the fundamental physical, chemical, and meteorological processes responsible for ozone accumulation on local and regional scales in North America. *(Contributes to answering Science Questions 2; 4)*

Major Tasks: ***Develop a quantitative estimate of the role of vertical mixing in the redistribution of compounds between the boundary layer and the free troposphere. **(underway)**

***Obtain a quantitative estimate of the exchange of ozone and ozone precursors between urban and rural areas. **(underway)**

***Determine the physical and chemical processes that determine the importance of point-source emissions to: (1) urban air quality; (2) rural air quality. **(underway)**

***Determine the relative contribution of biogenic and anthropogenic NO_X and VOCs to O_3 formation in urban and rural areas in various areas of North America. **(underway)**

***Determine the identities of the natural and anthropogenic sources of NO_X and VOCs and, where possible, estimate the emission of VOCs and NO_X from these sources. **(underway)**

***Promote development of observational based models (OBMs) and emission based models (EBMs). **(underway)**

***Provide a retrospective assessment of the problems and failures of existing regional studies to serve as additional guidance in formulating future field programs. **(underway)**

Long-Term Activities

Strategic Activity 1:

Development of techniques for routine measurements.

Activity Goal: Develop adequate "routine" sampling techniques for monitoring CO, VOCs, NO_X, NO_y, and meteorology from surface locations and, where needed, above the surface. *(Contributes to answering Science Questions 1c,d, 2e, and 4f. Done in concert with the Modeling Team and the Analysis and Assessment Team.)*

Major Tasks: **Determine capabilities of current technology for precise and accurate routine measurements for speciated VOC, H_2O_2, NO, NO_2, PAN, and NO_y in urban and rural environments.

**Develop and test methods for profiling O_3, NO_2, NO_y, CO, H_2O, VOCs, and aerosols.

**Develop and test methods for precise and accurate routine measurements of photolysis rates of NO_2, H_2CO, and O_3.

**Develop and test methods for precise and accurate routine measurements used for meteorological profiling.

**Develop methods to calibrate and audit these measurements and develop and maintain low-concentration calibration standards.

**Develop methods for short turnaround/real-time data handling and visualization of monitoring network data via telemetry or internet links.

Strategic Activity 2:

Development of techniques for process studies.

Activity Goal: Develop techniques that will provide comprehensive chemical and meteorological data to understand atmospheric processes and test models. *(Contributes to answering Science Questions 1c,d, 2c,e, and 4f)*

Major Tasks: ***Develop fast response measurement techniques for NO_X, NO_y, CO, and O_3 that are suitable for aircraft applications.

***Sponsor unbiased evaluation and intercomparison of critical instrumentation and techniques.

***Develop reliable measurement techniques for oxygenated VOCs.

***Develop new techniques or approaches to measure NO_3, HONO, and HNO_3.

***Develop and deploy techniques to measure odd-hydrogen radicals.

***Develop and validate LIDAR measurement techniques for O_3 and aerosols.

***Develop long-path measurements for O_3, NO_2, H_2CO, H_2O_2, SO_2, and O_3, and OH.

**Develop and validate instruments for meteorological profiling.

***Develop calibration and audit procedures to be used with these techniques.

***Develop techniques to measure the heterogeneous uptake, processing and revaporization of trace chemical species by clouds and background aerosol.

**Develop improved statistical methods to evaluate the performance of existing chemical measurements.

Strategic Activity 3:

Observation-based emission inventory evaluation. *(Done in parallel and in concert with "Emissions")*

Activity Goal: Perform air concentration measurements to improve emissions inventories for ozone-related chemicals. *(Contributes to answering Science Questions 1b, f, 4a, and 4a,b,e,f,g.)*

Major Tasks: ***Estimate the relative contribution of natural/biogenic and anthropogenic NO_X and VOCs to O_3 formation in urban and rural areas in various areas of North America.

***Identify the natural/biogenic and anthropogenic sources of NO_X and VOCs and, where possible, provide estimates of the emission from these sources through ^{14}C measurements, chemical mass balance, principal component analysis, and receptor models, diagnostics, and analyses.

***Identify and develop tracers to indicate origin of air-mass (i.e., upper atmospheric, stratospheric, marine, continental, etc.)

**Provide database and analysis methods suitable for use in the development of observational based models (OBMs) and emission based models (EBMs).

Strategic Activity 4:

Observational based analysis and modeling development.

Activity Goal: Develop and test a hierarchy of observation-based analyses and models that use field observations and data to diagnostically address the science questions identified for NARSTO. *(Contributes to answering Science Questions 1a,b,d,f; 2a,d; 3a; 5)*

Major Tasks: ***Develop inventory of observation-based analysis and model development in use and under development and their data needs.

***Identify existing observational data sets that might be used to evaluate and compare results of different observation-based analyses and more traditional emissions-based approaches.

***Compare observation-based and emission-based approaches for consistency and precision. On the basis of these findings, develop basic protocol for integrating results of observation-based and emissions-based approaches as a means of assessing the robustness of findings.

***Apply observation-based and emission-based models to other data sets as appropriate.

Strategic Activity 5:

Determine deposition/removal.

Activity Goal: Determine the chemical and physical processes that control the loss of ozone, ozone precursors, and intermediates near the surface. *(Contributes to answering Science Questions 2a,c,d; 3a, 4c,f)*

Major Tasks: ***Measure the deposition of O_3 and NO_2 as needed for model development and simulations.

**Develop improved techniques for measuring deposition/removal rates of ozone, ozone precursors, and intermediates (e.g., carbonyls).

**Understand the dominant processes that control the uptake of ozone and its precursors by vegetation.

Strategic Activity 6:

Design and implementation of comprehensive field studies. *(Done in concert and in parallel with the Modeling, Data Analysis and Assessments, and Emissions Teams.)*

Activity Goal: To provide comprehensive field measurement data sets to support: 1) evaluation and development of emission-based models; 2) evaluation and development of observation based models; 3) evaluation of natural/biogenic and anthropogenic budgets; and 4) understanding of the fundamental chemical and physical processes that shape the atmosphere. *(Contributes to answering Science Questions 2; 4)*

Objectives: This research will be done through a sequence of comprehensive field studies done at a number of locations throughout North America. The objectives of the research are:

- Determine the role and relative importance of photochemical initiators (O_3, H_2CO, PAN, HONO, etc.) on the photochemical production of O_3 in rural and urban areas for various regions of North America.
- Develop a quantitative estimate of the role of vertical mixing in the redistribution of compounds between the boundary layer and the free troposphere.
- Obtain a quantitative estimate of the exchange of ozone and ozone precursors between urban and rural areas.
- Estimate the computational errors attendant to model simulations in regions having significant sub-grid scale sources of O_3-precursor emissions. *(Done in concert with "Chemistry and Modeling.")*
- Determine the physical and chemical processes that determine the importance of point-source emissions to: (1) urban air quality; (2) rural air quality.
- Understand the effect of the complex transport associated with the interface between the continental and marine boundary layers on regional and hemispheric ozone pollution.
- Understand how different meteorological regimes constrain ozone accumulation and design field program that capture these regimes.

Major Tasks: ***Determine study priorities; identify location and timing; determine the size of the region required to fully realize the science goals; determine the length of time required to achieve the science objectives; determine resources required to carry out the study. *(Note: Several studies have been suggested and are enumerated below. There may be others.)*

**Northeastern United States/Eastern Canada. Provide up-to-date, comprehensive data bases aimed at improving regional/local emission inventories and supporting model application in the Northeastern United States and Eastern Provinces of Canada.

- Study the evolution of a regional pollution event as it passes from the Midwest or the Southeast to and, subsequently, through the urban-matrix of the Northeast.
- Determine the export of ozone and ozone precursors from the Northeastern United States to the Maritime Provinces of Canada.

*Dallas Study. Elucidate the photochemistry in a region that is poor in natural VOCs but a more significant source of anthropogenic/biogenic NO_X.

*Midwest United States/Ontario-Quebec Corridor. Determine the factors that control the export of ozone and ozone precursors from the Midwestern United States into the southeastern provinces of Canada and the impact of the compounds on Canadian air quality.

*Mexico City. Initiate regional-scale field studies in Mexico aimed at improving our understanding of the processes that control the accumulation of ozone in Mexico (especially Mexico City).

*Mexico/Southwestern United States. Examine the impact of transborder transport of ozone and ozone precursors on the air quality of Mexico and the United States and the impact of economic expansion within Mexico upon its air quality and the air quality of the southern United States.

Strategic Activity 7:

Advance technology and develop innovative new approaches.

Activity Goal: Develop new science and technology needed to improve air quality management. *(Contributes to answering Science Questions 1-4)*

Major Tasks: ***Sponsor development of promising innovative combinations of new measurement and modeling techniques (e.g., mobile and airborne drone monitors).

TABLE I. OBSERVATIONS: RESOURCES REQUIRED (Dollars in millions)			
A. Near-Term:			
Activity	**1995**	**1996**	**1997**
Analysis of Existing Data	0.4 *** 0.4	0.4 *** 0.4	0.4 *** 0.4
PAMS Review and Enhancement	0.5 *** 0.5	1.0 *** 1.0+0.3/site	1.0 *** 1.0+0.3/site
Network Design	0.4	0.4	0.4
NE Scoping Study	0.3 *** 0.3	0.7 *** 2.6	0.7 *** 2.6
Ongoing Field Studies	? *** ?	? *** ?	? *** ?
A. TOTALS	**1.1 ***** **1.6**	**2.1 ***** **4.4+**	**2.1 ***** **4.4+**
B. Long-Term:			
Routine Measurements	0.5	0.5	0.5
Process Study Techniques	3.2 *** 4.0	3.2 *** 4.0	3.2 *** 4.0
Obs.-Based Emission Evaluation	0.5 *** 0.5	0.5 *** 1.0	0.5 *** 1.0
Obs.-Based Analysis and Model Development	0.5 *** 0.5	1.0 *** 1.0	1.0 *** 1.0
Deposition and Removal	0.2 *** 0.6	0.2 *** 0.6	0.2 *** 0.6
Comprehensive Field Studies	0.3	3.3	10
Innovative Approaches	0.1 ***	0.5 ***	0.5 ***
B. TOTALS	**4.5 ***** **7.0**	**5.4 ***** **10.9**	**5.4 ***** **17.6**
GRAND TOTAL (i.e., A+ B)	**5.7 ***** **8.6**	**7.5 ***** **15.3+**	**7.5 ***** **22.0+**

*** = Highest Priority

4. MODELING RESEARCH STRATEGY

Introduction

Air quality simulation models have become a cornerstone of the air quality management process. Air quality models are critical to explaining the function of local and regional emissions, meteorology, photochemical processes, and the transport of O_3 and O_3 precursors from adjacent areas on ozone levels. Models help analysts understand the source of a problem, who or what is contributing to it, and what types of controls would be expected to work. The air quality model is one of the major quantitative tools used in the regulatory process (state implementation planning) to establish the link between the regulatory control program and attainment of the ozone air quality standard.

A critically important component of air quality simulations models is the chemical transformation mechanism describing the reactions that VOC and NO_X undergo to produce O_3, other oxidants, HNO_3, H_2SO_4, and fine particulates. Meteorological factors, such as temperature, wind speed, synoptic weather, cloud transport, and interchange at the boundaries (stratosphere and Earth's surface) affect the potential for photochemical productions of ozone.

Although significant progress has been made over the past several decades in our understanding of the physical and chemical processes that affect and are responsible for photochemistry, substantial uncertainties remain. Specifically, we only poorly understand the oxidation pathways for a variety of biogenic and anthropogenic organic species commonly found in the atmosphere and thought to be important contributors to ozone formation. Many important meteorological variables and forcing features of motion are only resolved at coarse scales or poorly approximated in current air quality models. Coupled interactions between meteorology and chemistry at fine spatial and temporal scales are ignored. The lack of understanding severely limits our ability to provide accurate assessments of the ozone production capacity of biogenically- and anthropogenically-emitted chemical species.

There is a need, therefore, to develop a comprehensive research strategy to define the scientific research required in critical physical and chemical areas that will advance our air quality modeling tools and our ability to more effectively address the key policy concerns and associated science questions outlined in the introduction to the NARSTO Plan. The following sections provide a summary of the objectives and the approach. A more complete description of the approach is provided in Appendix 4 Modeling.

This summary and the appendix only indicate the future scientific work in the Modeling Section of the NARSTO Program requiring **additional** or redirected resources to accomplish an overall program. The summary highlights research areas and tasks from the overall program that are deemed critical, broken into near-term and long-term tasks. The near-term research addresses those projects that are currently in the "pipeline" that can be focused to produce near-term pay-off for the NARSTO program. Many efforts in the long-term category require immediate attention, however. Hence, there is no priority implied in the division between long-term and near-term research. The approach is consistent with the recognition that managing air quality requires long range commitments.

Objectives

The photochemical system is a large, complex, nonlinear open system. Our observations of it are very limited in terms of space, time and species. The time scales of transport and mixing (meteorology) and chemical production overlap and span many orders of magnitude. Interpretation and understanding of the processes occurring in the real world are made difficult by the lack of repeatability of meteorology. Models are important vehicles for consolidation of our understanding and for study of the interactions and interrelationships of the physical and chemical processes. The emissions-based model is, essentially, a numerical laboratory. Models are also fundamental to prediction and assessment. An important use of the emissions-based models is to test possible abatement strategies for ozone pollution and determine their relative effectiveness. To be successful, the scientific understanding incorporated in the emissions-based models needs to be up-to-date and have a tolerable degree of uncertainty. No model is perfect, because of the complexity of the system being represented and the sparseness of the data coverage available for testing. The degree and character of uncertainty in emissions-based model predictions due to limits in our understanding or ability to represent it in the current models needs to be quantified. Nevertheless, in spite of recognized uncertainty, it is important to bring the best science to bear on the societal problems being addressed in NARSTO.

With these perspectives, the modeling team has enunciated three major objectives for the NARSTO Modeling Program. The objectives of the modeling team are:

- Advance our understanding of the physical-chemical system and explain observations and the sources of uncertainty;
- Quantify and reduce to the extent possible key uncertainties in emissions-based models; and
- Provide models adequate for assessment.

Meeting these objectives requires a coordinated, interrelated program of science improvement, and air quality model development and evaluation.

The relevance of the research stems from the direct improvement to the air quality models as cornerstone tools for assessment. The objectives address several NARSTO policy and science questions simultaneously and cover different facets of them, spanning from interpretive understanding to quantitative tools. The main NARSTO Policy Concerns addressed are: "What part of the problem is tractable?" (P-2), "What more should I be doing?" (P-4), "What are the international implications?" (P-5), and "How can communication be improved?" (P-6). The main NARSTO Research Issues addressed are: "How can we better understand and explain the fundamental processes?" (S-2), "How can we incorporate and use the evolving scientific understanding in diagnostic and prognostic tools?" (S-3), and "How do we evaluate the relative contribution of VOC's and NO_X and their control to ozone accumulation?" (S-4). The modeling research activities have components that are closely coupled with other research sections of the NARSTO plan. The fundamental work of the modeling section and its associated practical mechanistic and modeling components will serve the NARSTO mission as well as many of the broader scientific challenges facing the atmospheric research community.

Approach [1]

Three aspects of research are to be addressed. First, to improve the descriptions of the physical-chemical processes in key areas that have known uncertainties. Second, to develop the modeling systems into quantitative, numerical tools and use them to identify and diagnose areas

---

[1] The priorities that were determined for the tasks during the Boulder Workshop (June 6-8, 1994) are shown before each major task and project. The priorities are: *** (first or highest); ** (second or next); * (third or lowest).

needing new or further attention. Third, to improve our ability to evaluate, diagnose and explain model behavior and improve our ability to communicate model results. These relate to traditional activities of science process development, model development, model evaluation and model application. Five strategic research areas have been identified with the first activity of science process development, and a single strategic research area is identified with each of the latter three activities, totalling eight. The eight Strategic Research Areas are:

1. Influence of Biogenic VOCs
2. Chemistry of Anthropogenic VOCs
3. Vertical Mixing and Transport Processes
4. Heterogeneous Processes
5. Fine-Scale Phenomena
6. Development of Modeling Systems
7. Model Evaluation, Corroboration and Diagnosis
8. Application of Modeling Systems

Improving the basic scientific understanding for incorporation into the models underpins the program.

The atmospheric chemistry research within the NARSTO strategic plan addresses the development of practical, credible scientific chemical transformation mechanism(s) which provide a quantitative understanding of the formation of ozone through the chemical reactions of biogenic and anthropogenic species found in the atmosphere. These mechanism can be used in conjunction with a variety of tools including air quality simulation models and observational based modeling approaches.

The meteorological research within the NARSTO strategic plan addresses the development of improved, credible meteorological models that provide the necessary quantitative descriptions of the meteorology of greatest importance to periods of elevated photochemical production, that is, weakly forced systems. Most weather-related meteorological model development is for strongly forced systems, i.e., storms. The air quality community must forge its own direction to support the modeling of photochemical ozone production.

Advancement of model evaluation techniques to test the science incorporated in the models in a scientifically rigorous fashion is also addressed. Because the photochemical system is large and complex, we are only able to sample and probe a portion of it for the testing of theory and models. The modeling research needs to coordinate with development of innovative techniques for studies of atmospheric chemistry and interpretation of observations to achieve sufficient rigor and diagnostic understanding out of necessarily sparse field data coverage.

Near-Term

Goal:

Near-term research efforts are aimed at quantifying model output uncertainty resulting from uncertainty in model inputs and at producing improvements in the regional and urban air quality models in the next 2-3 years (by 1997) to reduce their uncertainty in the simulation of ozone production. This work depends on research already under way. Greater detail is provided in Appendix 4 on Modeling. (The near-term research activities contribute underpinnings to answering policy questions P-2, P-4, and P-6; they contribute to answering science questions S-2 and S-4)

Strategic Activity 1:

Influence of Biogenic VOC's *(Done in concert with the Observations Team)*

Activity Goal: Improve the chemical mechanisms for biogenic VOC's in the air quality models using existing data.

****Major Task 1.3:* **Development of Chemical Oxidant Mechanisms**

***Develop an improved mechanism for isoprene using existing kinetic/mechanistic data and smog chamber data.

**Develop an improved mechanism for the monoterpenes using the existing (although limited) kinetic/mechanistic data and smog chamber data.

Strategic Activity 2:

Chemistry of anthropogenic VOC's *(Done in concert with the Observations Team)*

Activity Goal: Improve the chemical mechanisms for anthropogenic VOC's in the air quality models using existing data.

****Major Task 2.2*: **Smog Chamber/Atmospheric Observations Research**

***Obtain smog chamber data for testing chemical oxidant mechanisms for ethanol, methyl tertiary butyl ether (MTBE) and ethyl tertiary butyl ether (ETBE).

****Major Task 2.3*: **Development of Chemical Oxidant Mechanisms**

***Expand the VOC chemistry included in existing mechanisms so the mechanisms can be used for diagnostics of current air quality model predictions.

***Develop an improved mechanism for the reaction of alkenes with O_3 and OH radicals.

Strategic Activity 3:

Vertical mixing and transport processes *(Done in concert with the Observations Team)*

Activity Goal: Develop the process-level information to advance our understanding of the individual vertical mixing, transport and boundary processes important to the regional and urban meteorological influence on photochemical production.

****Major Task 3.1*: **Meteorology: Transport and Mixing**

***Develop improved parameterizations of soil moisture and surface/canopy heat flux exchange for the meteorological models.

***Evaluate and improve parameterizations of the planetary boundary layer used currently in meteorological models.

***Major Task 3.3*: **Enhance Coupling of Met.-Chem.- and Emissions**

**Incorporate new, high-resolution land-use information consistently into models especially biogenic emissions and meteorological models.

Strategic Activity 5:

Fine-scale phenomena *(Done in concert with the Observations Team)*

Activity Goal: More accurately describe the coupled interactions between chemistry and meteorology at fine temporal and spatial scales.

****Major Task 5.1*: **Process Parameterization/Module Development**

***Develop an advanced plume-in-grid capability for regional and urban air quality models for incorporation into current chemical transport models.

Strategic Activity 7:

Evaluation, corroboration and diagnosis *(Done in concert with the Observations and Emissions Teams)*

Activity Goal: Determine the strengths and weaknesses of the emissions-based models and quantify their uncertainty relative to applications questions. Help characterize our level of understanding of the photochemical processes. Provide guidance to efficiently target resources to the most critical monitoring methods and network and field study design issues.

*** *Major Task 7.1*: **Application of Diagnostic Tools**

***Compile existing and ongoing sensitivity/uncertainty studies and process pathway analyses; identify major holes to fill and initiate studies to identify points of sensitivity and their consequences.

*** *Major Task 7.2*: **Diagnostic Comparisons Against Field Data**

***Evaluate improved planetary boundary layer parameterizations in 3-D simulation models using detailed data sets, such as those from SJVAQS/AUSPEX and SOS.

*** *Major Task 7.3*: **Field Study Design and Support**

***Coordinate with Observations Team on aircraft support for measurements of full chemistry aloft and measurements by ozone LIDAR during the 1995 Nashville Intensive to develop a high quality data base for model evaluation. Provide measurement support for a second isoprene measurement site as part of the 1995 Nashville Intensive.

***Coordinate with the Observations Team on field study design work for the Northeast.

Strategic Activity 8:

Application of modeling systems *(Done in concert with the Analysis and Assessment, Observations, and Emissions Teams)*

Activity Goal: Provide model analyses for the Assessment Team. Help to define the uncertainty in assessment linkages and answers.

*** *Major Task 8.2*: **Quantification of Uncertainty**

***Characterize/quantify the effects of model uncertainties on predictions of control strategy effectiveness.

*** *Major Task 8.3*: **Advanced Model Assessment**

***Compare results from improved models with those from current model regarding predicted effectiveness of control strategies.

Long-Term

Goal:

The objective is to define and carry out the basic long-term scientific research required to improve our understanding in critical physical and chemical areas. Greater detail plus a listing of Major Tasks for long-term research can be found in Appendix 4 on Modeling. (The long-term research activities contribute underpinnings to answering policy questions P-2, P-4, P-5, and P-6; they contribute to answering science questions S-2, S-2 and S-4)

Strategic Activity 1:

Influence of biogenic VOC's *(Done in concert with the Observations Team)*

Activity Goal: Substantially improve our understanding of the chemical kinetic and mechanistic processes important to the chemistry of biogenic VOC's. Acquire new, more-advanced data on the complex reaction system associated with atmospheric photochemical oxidation processes both in the laboratory and in the atmosphere. These data are to support the development and evaluation of chemical mechanisms used in the air quality models. The desired outcome is, first, acquisition of the elementary kinetic and mechanistic data needed to construct reliable chemical transformation modules; second, acquisition of a comprehensive database of smog chamber and atmospheric observations that can be used to evaluate chemical reaction mechanisms; and, third, reliable chemical transformation modules that can be used in the next generation of air quality models.

*** *Major Task 1.1*: **Chemical Kinetic and Mechanistic Studies**

*** *Major Task 1.2*: **Smog Chamber/Atmospheric Observations Research**

*** *Major Task 1.3*: **Development of Chemical Oxidant Mechanisms**

Strategic Activity 2:

Chemistry of anthropogenic VOC's *(Done in concert with the Observations Team)*

Activity Goal: Substantially improve our understanding of the chemical kinetic and mechanistic processes important to the chemistry of anthropogenic VOC's. Acquire new, more-advanced data on the complex reaction system associated with atmospheric photochemical oxidation processes both in the laboratory and in the atmosphere. These data are to support the development and evaluation of chemical mechanisms used in the air quality models. The desired outcome is, first, acquisition of the elementary kinetic and mechanistic data needed to construct reliable chemical transformation modules; second, acquisition of a comprehensive database of smog chamber and atmospheric observations that can be used to evaluate chemical reaction mechanisms; and, third, reliable chemical transformation modules that can be used in the next generation of air quality models.

*** *Major Task 2.1*: **Chemical Kinetic and Mechanistic Studies**

*** *Major Task 2.2*: **Smog Chamber/Atmospheric Observations Research**

*** *Major Task 2.3*: **Development of Chemical Oxidant Mechanisms**

Strategic Activity 3:

Vertical mixing and transport processes *(Done in concert with the Observations Team)*

Activity Goal: Develop more accurate understanding and parameterizations of the individual vertical mixing, transport, boundary and large-scale meteorological processes that have an important influence on regional- and urban-scale photochemical production. Develop means to more accurately represent the meteorological processes in mathematical models. Improve the linkages among meteorology, emissions and chemical transport models. Provide new developments to improve the meteorological modules/drivers in the air quality modeling systems.

*** *Major Task 3.1*: **Transport and Mixing**

*** *Major Task 3.2*: **Data Assimilation/Large-Scale Interactions**

*** *Major Task 3.3*: **Enhanced Coupling of Meteorology-Chemistry-Emissions**

Strategic Activity 4:

Heterogeneous processes *(Done in concert with the Observations Team)*

Activity Goal: To elucidate the role heterogeneous processes play in the transformation and deposition of atmospheric species that are important to oxidant formation.

*** *Major Task 4.1*: **Transformation and Removal in the Aqueous Phase**

** *Major Task 4.2*: **Transformation and Removal on Aerosols and the Earth's Surface**

*** *Major Task 4.3*: **Development of Aqueous-Phase Oxidant Mechanisms**

Strategic Activity 5:

Fine-scale phenomena *(Done in concert with the Observations Team)*

Activity Goal: Develop innovative techniques that provide a more accurate description of the fast photochemistry occurring at the turbulence time scales. Develop new modules for incorporation into the air quality models that can account for sub-grid effects in current models and more accurately describe the coupled interactions between chemistry and meteorology at fine temporal and spatial scales.

*** *Major Task 5.1*: **Parameterization of Sub-grid Processes into Modules**

** *Major Task 5.2*: **Identification and Study of Sub-grid Processes**

Strategic Activity 6:

Development of modeling systems

Activity Goal: Incorporate the improvements in process-level understanding into the emissions-based air quality models (model modules). Incorporate improvements in model infrastructure to provide tools for more insightful model evaluation and to allow easier and more appropriate model applications and interpretations of results.

** *Major Task 6.1*: **Model System/Numerical Improvements**

** *Major Task 6.2*: **Enhanced Coupling Across System Elements**

Strategic Activity 7:

Model evaluation, corroboration and diagnosis *(Done in concert with the Observations and Emissions Teams)*

Activity Goal: Determine the strengths and weaknesses of the emissions-based and observations-based models relative to applications questions. Help to characterize our level of understanding of the photochemical processes. Help to efficiently target resources to the most critical monitoring methods and network and field study design issues.

*** *Major Task 7.1*: **Develop and Apply Diagnostic Tools**

*** *Major Task 7.2*: **Diagnostic Model/Module Comparisons Against Field Data**

*** *Major Task 7.3*: **Field Study Design and Support**

Strategic Activity 8:

Application of modeling systems *(Done in concert with the Analysis and Assessment, Observations, and Emissions Teams)*

Activity Goal: Provide model analyses for the Assessment Team. Help to define the uncertainty in assessment linkages and answers.

** *Major Task 8.1*: **Policy Study Design Analysis**

*** *Major Task 8.2*: **Policy-Related Uncertainty Analysis**

** *Major Task 8.3*: **Model Intercomparisons**

5. EMISSIONS RESEARCH STRATEGY

Introduction

The Emissions Team of the NARSTO organization aims to develop a comprehensive strategy to accomplish policy-relevant scientific research in the areas of:

- Base emission estimates
- Emission inventory accuracy assessment
- Emission projections

This section of the document discusses the research needed to address the key policy concerns and the associated science concerns outlined in the introduction to the NARSTO Working Draft Plan. The following subsections describe: (1) the objectives that the Emissions Team aims to accomplish; and (2) the research that is suggested to accomplish the objectives. This section draws heavily from the U.S. Environmental Protection Agency's (EPA's) early 1993 draft proposal on a Coordinated North American Research Strategy for Tropospheric Ozone, which includes input from much of the emission research community in Canada, Mexico, and the United States.

The work described in this section will need to be coordinated with other technical Teams. The Observations Team will need to develop measurement methods and implement monitoring programs that provide data to chemically speciate emission estimates and independently assess the accuracy of emission inventories. The Modeling Team will need to define data needs for emission-based models so that the Emissions Team can provide emission inventories of sufficient accuracy and of adequate spatial, temporal, and chemical resolution. Finally, the Analysis and Assessment Team will need information on emission control strategies that are practical from both technological and economic viewpoints.

It is encouraging to see the increased cooperation over the last few years between various government and industry groups that deal with emission inventory and control strategy issues. Hopefully, NARSTO can provide a mechanism for improved coordination of ongoing and future research in order to maximize productivity and insure success.

Objectives

The emission inventory is a key component of air pollution control programs. It includes information on the types of emission sources, quantities of emissions, the temporal and spatial characteristics of emissions, chemical speciation, and reductions resulting from emission control devices. Air pollution control agencies use emission inventories to identify potential control measures and sources that would be subject to controls, to determine control program effectiveness, and to predict future air quality through air quality simulation models. This information is used to develop air quality management plans for attaining ambient air quality standards. To be effective, the air quality management plans must be based upon emission inventories that are reasonably complete and accurate. However, the uncertainties associated with emission inventories are not well-characterized since most emission estimates are based upon models, engineering analyses, and limited test data rather than on systematic measurements of actual or "real-world" emissions. Underestimation of current emissions or overly optimistic estimates of the benefits of emission controls can lead to underprediction of emissions, which in turn can lead to false expectations for improvement in air quality in future years.

The accuracy of emission estimates has taken on a new level of significance under recent United States and California Clean Air Act legislation. The 1990 amendments to the U.S. Clean Air Act require states to track emissions reductions in order to show "reasonable further progress" towards attainment of U.S. air quality standards. The California Clean Air Act of 1988 requires air pollution control districts in nonattainment areas of California to develop plans to achieve annual reductions in emissions of 5 percent. These emission-tracking requirements have focused the spotlight on emission inventories and have reinforced the need for better estimates of overall uncertainties.

In recognition of the need for a thorough assessment of uncertainties in current emission inventories, the U.S. EPA, the California Air Resources Board, the Coordinating Research Council, and other government agencies and industry groups have committed substantial resources over the long-term for improving emission inventory methods and estimates of emission inventory uncertainty. The initial focus has been on on-road mobile sources because of recent studies that suggest that current emission factor/activity models underestimate nonmethane organic compound (NMOC) and carbon monoxide (CO) emissions. The plan for this long-term effort involves two approaches to the problem - the "classical" emission model approach and independent assessments of mobile source emission inventory accuracy. The "classical" approach relies upon refining present emission models and methodologies for estimating emission and activity factors. The assessment approach seeks to evaluate the inventory by making independent estimates of emissions, such as reconciliation of emissions with air quality measurements. The emission inventory will be deemed reliable when both estimates are in reasonable agreement. These parallel approaches should be adopted for other categories of emissions.

A number of other emission categories are also in need of study and improvement. Emissions of NMOC from solvent usage, oil and gas industry operations, and other stationary area source categories are difficult to characterize because of the large number and variety of sources. Electric utilities and other point sources that are large sources of nitrogen oxides (NO_X) have emission factors that are uncertain. Nonroad mobile sources are major emitters of NMOC and NO_X and are thought to be under-reported. Biogenic NMOC emissions and "natural" emissions of NO_X from fertilizer applications are receiving a great deal of study because of their perceived contribution to rural, and in some areas, urban ozone problems.

It is not enough to just improve the accuracy of emission estimates. In order to develop better control strategies, it is important to understand the emission processes themselves. A methodology that uses mathematical modeling together with data, rather than the traditional interpolation/extrapolation of data alone, can incorporate our understanding of mechanisms that are important in determining emission factors. The disaggregation available in a model can provide for a dynamic response to changes as diverse as those in technology or social behavior without the need of an additional expensive study of emission factors. More important, it can anticipate the future emissions for a variety of scenarios of demographic, economic, or regulatory changes. These mechanistically based models of emissions can be developed for a range of sources.

A series of objectives for NARSTO's Emissions Team has been formulated based on the two general principles described above (*i.e.*, the need to develop emission inventories with emission factor/activity models and conduct independent assessments) and the need for a mechanistic understanding of emission processes. These objectives are:

1. Develop an accurate mechanistic understanding of emission processes and prepare timely estimates of emissions that are:

a) quantified;

b) resolved in time and space; and

c) chemically speciated.

2. Assess the accuracy of emission estimates with independent techniques.

3. Project the effects of future activity and alternative controls on emission estimates.

The need for improved emission estimates was recognized several years ago (*e.g.*, NAS report), and a great deal of work is already underway (*e.g.*, Emission Inventory Improvement Program). The function of NARSTO will be to initiate new research efforts in coordination with existing programs.

Approach

The scientific approach is an attempt to achieve the objectives stated above in an ambitious ten-year timeframe. The strategic activities are not in priority order as a partial implementation cannot achieve the objectives; it will take the complete package of projects. Thus all major tasks are assigned the highest priority (***). The cost estimates are strictly an estimate, and **do include** on-going work.

Strategic Activity 1:

On-road Mobile Source Emission Model Development *(Done in concert with the Modeling Team)*

Goals: Develop on-road emission models that are capable of representing separate modes of vehicle operation and the resultant modal emissions for specific roadway sections and parking areas *(contributes to addressing Science Concerns 3a, 4c and 5).*

Background: Mobile source emissions are estimated by multiplying an emission rate (from an emission factor model) by an activity factor (from a travel demand model). It is now recognized that current models do not adequately represent situations such as "off-cycle" driving modes (*e.g.*, hard accelerations, high speeds, and road grades), "high-emitters," evaporative losses, etc. Studies are underway to develop more representative driving test cycles, to determine the contribution of high-emitters, and to establish a representative fleet of vehicles for testing, but the U.S. EPA and others recognize that the situation calls for a complete re-design of the mobile source emission models. In addition, the situation has become much more complicated with the introduction of new fuels and vehicle technologies in response to regulations being implemented in Canada, Mexico, and the United States.

Major Tasks: ***Survey mobile source emission inventory approaches on state and national levels. Determine if on-going work can be applied to other geographic areas. *(near term)*

***Evaluate the uncertainty of mobile source emissions inventories using present and future techniques with an integrated assessment of datasets used in developing emission and activity factors. Use this information to prioritize further research. *(ongoing)*

***Establish a framework for a research-grade mobile source emission model that provides estimates of emissions resolved temporally and spatially. The model will need independent emission factor and activity modules for various aspects of vehicular emissions (*e.g.*, fuel type, closed- and open-loop operation, cold and hot starts, evaporative losses, road grade, air conditioner use, age, tampering, driver behavior). Develop and test the approach for one city. After testing and validation for one city, expand to other cities in North America for more complete module development. *(near term)*

***Develop modal emission factors (exhaust and evaporative) for automobiles and light-duty trucks for all aspects of vehicle operation, vehicle condition, fuel parameters (*e.g.*, reformulated gasoline, oxygenated fuels), and driver behavior in the laboratory and under on-road conditions. *(near term)*

***Develop temporally and spatially resolved activity data for automobiles and light-duty trucks with improved travel demand models. The models must provide estimates of vehicle activity for each modal emission factor. *(near term)*

***Develop modal emission factors for medium- and heavy-duty trucks in the laboratory and under on-road conditions. Heavy-duty truck research would be *near term* because of their large contribution to NO_X emissions, while medium-duty truck work would be *long term*.

***Develop temporally and spatially resolved modal activity data (*e.g.*, idling time by season, load operations due to weight and grade) for heavy- *(near term)* and medium-duty trucks *(long term)*.

***Using a variety of on-road studies of in-use vehicles, determine how much vehicle activity is contributed by medium-, high-, and super-emitters and test how implementation of inspection and maintenance programs will affect their emissions. Investigate the variability in emission rates. *(near term)*

***Evaluate the "real world" effect of traffic control measures (TCMs) on reducing emissions for incorporation into prediction models. *(long term)*

***Analyze existing NMOC and NO_X (*e.g.*, NO_2, nitrous acid) speciation data to determine how well it represents emissions for important modes of vehicle operation. Develop new speciation data for "real world" emissions where existing data has gaps. This work can be integrated with other programs. *(near term)*

Strategic Activity 2:

Emission Inventories for Stationary Area Sources and Point Sources *(Done in concert with the Modeling Team)*

Goals: Develop new stationary area source and point source models or methodologies that are capable of estimating emission from all significant sources *(contributes to addressing Science Concerns 3a, 4c and 5)*.

Background: Stationary source categories include solvent usage, oil and gas industry operations, etc. The traditional "top-down" approach uses surrogate data for activity level, along with default spatial and temporal allocation factors and emission factors, to estimate emissions. This approach relies on information which may be out of date, of unknown accuracy, and never have been assessed by independent methods. Reports of emissions by major point sources may contain day-specific activity levels, but are often based on average emission factors. New or refined methods are needed for research-grade emission inventories. Better temporal, spatial, and chemical resolution of emissions, as well as knowledge of emissions for "event days" is also needed.

Major Tasks: ***Improvement of Data Analysis Methodologies**

Develop improved statistical methods for the purpose of emission estimation. Specific areas of concern include: 1) identification of the distribution of the data and the appropriate method of combining these data with parameters having other distributions; 2) treatment of data which is recorded as being below the level of quantification or below the level of detection (censored data); and 3) determination of the minimum number of measurements required for regressions and analysis of variance techniques. *(near term)*

***Assimilation of Compliance Data**: Title 70 of CFR 40 requires that owners or operators of all major sources in the U.S. obtain a permit. The regulation requires that permit facilities submit emission data to the regulatory agencies which proves that they have complied with all requirements and upon which they will pay the appropriate emission fees. In addition, the proposed Enhanced Monitoring rules of the U.S. EPA will require all sources which emit 30% or more of the amount which constitutes a major source to continuously monitor these emissions. The goal of this task is to develop a framework which will permit incorporation of these data into a national emissions inventory. This is a very near term project as implementation of 70 CFR 40 is scheduled for November 1995. *(near term)*

***Criteria for Development of Emission Factors**: Establish a comprehensive guideline which can be used for the development of emission factors. The guideline will incorporate experimental design, quality assurance, and data criteria by which one can judge the validity of emission factors. *(near term)*

***Unaccounted and New Sources**: Recent reviews have indicated that there are a large number of emission sources which are not included in emission inventories for a variety of reasons. The goal of this task is to identify such sources and estimate their emissions. The program is envisioned as a continuing one to permit tracking of new and changing sources. *(ongoing)*

***Stationary Area Source Data Inventory**: Identify and implement alternate and surrogate sources of data which can be used for stationary area source emission inventory development. Such data sources could include such diverse sources as trade organizations, market surveys, point of sale scanning data, local fuel (gas) distribution systems, etc. *(near term)*

***Stationary Area Source Data Surveys and Models**: The goal of this task is to conduct surveys for those sources where data is not directly available. The data from the surveys will be analyzed and incorporated in models to permit evaluating under differing econometric conditions. *(ongoing)*

***Semi-Mechanistic Emission Models**: Develop semi-mechanistic emission models for a range of industries. This novel approach to emission factor determination is required to account for and anticipate technological improvements, changes of work practices and economics. The models should be dynamic and flexible, and incorporate our understanding of mechanisms that are important in determining emission factors. For example, knowledge of NO_X formation can be used to quantify in detail NO_X emissions from different types of industrial furnaces with and without varying degrees of NO_X control. The methodologies would be applied to 10 to 15 industries per year. Of the order of 40 professionals will be required. *(ongoing)*

Strategic Activity 3:

Emission Estimates for Nonroad Mobile Sources *(Done in concert with the Modeling Team)*

Goals: Develop new models that are capable of estimating emissions from a wide variety of nonroad engines in use. Develop new stationary source models or methodologies that are capable of estimating emission from all significant sources *(contributes to addressing Science Concerns 3a, 4c and 5).*

Background: Nonroad mobile sources include some eighty categories of internal combustion equipment such as construction equipment, agricultural activities, airport operations, locomotives, marine vessels, pleasure water craft, lawn and garden equipment, etc. A 1991 U.S. EPA study found that much of the emission test data are incomplete and inadequate.

Major Tasks: ***Evaluate uncertainty of nonroad source emission estimates with an integrated assessment of datasets used in developing emission and activity factors. Use this information to prioritize research on specific source categories. Priority is expected to be placed on pleasure water craft and lawn and garden equipment since they appear to be the biggest nonroad contributors. *(near term)*

***Develop improved methodologies or models for nonroad mobile sources. The models will need independent emission factor and activity modules for various aspects of emissions. *(near term)*

***Develop modal emission factors and temporally and spatially resolved activity data for high priority source categories. Develop NMOC and NO_X speciation profiles. *(long term)*

Strategic Activity 4:

Natural Emissions Modeling *(Done in concert with the Observations and Modeling Teams)*

Goals: Develop natural source emission models that are capable of estimating NMOC (*e.g.*, isoprene, terpene, alcohol, aldehyde, other oxygenated) emissions over the seasonal cycle including (if applicable) leaf growth, maturation, and recession. Develop models of soil NO_X emissions due to natural processes and agricultural operations *(contributes to addressing Science Concerns 3a, 4c,g and 5)*.

Background: Emissions of biogenic NMOC may be a controlling factor in ozone formation in some areas. Uncertainties in biogenic NMOC emission inventories (approximately a factor of three) are associated with a variety of factors (*e.g.*, plant species, age, meteorology, stress effects) that can cause dramatic short-term changes in emission rates. In addition, microbial decomposition of industrial, household, and agricultural waste products may be a source of oxygenated NMOC. Summertime NO_X emission rates from fertilized agricultural fields may exceed anthropogenic NO_X emissions in some midwestern states, although uncertainties are also estimated to be roughly a factor of three.

Major Tasks: *****Vegetative NMOC Emissions**: Conduct field and laboratory studies of NMOC emissions from agricultural, urban, and natural landscapes. The purpose of these studies will be to develop and improve NMOC emission estimates and assess their accuracy. Model components that require investigation include emission factors, emission algorithms, source distributions, and driving variables (*e.g.*, light, temperature). *(ongoing)*

*****Natural NO_X Emissions**: Conduct field and laboratory studies of NO_X emissions from agricultural, urban, and natural soils and from lightning. The purpose of these studies will be to develop and improve NO_X emission estimates and assess their accuracy. Model components that require investigation include emission factors, emission algorithms, source distributions, and driving variables (*e.g.*, fertilizer application rates, soil type, soil moisture, temperature, chemistry, vegetation cover). *(ongoing)*

*****Other Natural NMOC Emissions**: Screening studies are required to assess the importance of NMOC emissions from disturbed vegetation (*e.g.*, lawn mowing, timber and crop harvesting, biomass burning), microbial decomposition (*e.g.*, landfills), and geogenic sources.

Emission models will be developed and evaluated for those sources determined to be significant. *(ongoing)*

*****Long-Term Changes in Natural Emissions**: Changes in climate or land use may have a significant effect on natural NMOC and NO_X emissions. Research is needed to assess potential changes and their impact on emissions. *(ongoing)*

Strategic Activity 5:

Independent Assessment of Emission Inventories *(Done in concert with the Observations and Modeling Teams)*

Goals: Corroborate emission inventories with independent estimates of emissions and evaluate the effectiveness of reformulated gasoline, enhanced inspection and maintenance, and other control programs to verify emission model estimates *(contributes to addressing Science Concerns 3a, 4c,f and 5)*.

Background: Large uncertainties often exist in emission inventories. Only by measuring levels of ozone precursors in ambient air can these inventories be confirmed. Approaches for independent assessments of emission inventories include: (1) tunnel studies and other roadway measurements; (2) spatial and temporal comparisons of ambient and emission inventory $NMOC/NO_X$ and CO/NO_X ratios; (3) comparisons of long-term trends in ambient pollutant concentrations and concentration ratios with emission inventory trends; (4) source apportionment of NMOG speciation profiles with receptor modeling; and (5) tracer and flux measurements. Previous studies have focused on mobile sources, but nonroad area sources and stationary sources deserve equal attention. However, efforts to study nonroad area sources and stationary sources have been hampered by the dominance of mobile sources at most monitoring sites and the lack of measurements of key NMOC species associated with stationary sources. The planned introduction of reformulated gasoline and the implementation of enhanced inspection and maintenance programs provide unique opportunities to observe and measure cause and effect relationships between emissions and atmospheric concentrations of pollutants.

Major Tasks: ***Analyze existing data to assess current emission inventories in urban areas of North America. Compare a variety of approaches, including tunnel and remote sensing studies, ambient ratio comparisons, and receptor modeling. Conduct field studies and sensitivity analyses to determine to what extent local determination of source fingerprints improves source reconciliation accuracy. *(near term)*

***Evaluate and improve assessment techniques. *(near term)*

***Conduct field studies before and after implementation of major control programs (*e.g.*, reformulated gasoline, enhanced inspection and maintenance) in different areas of North America in order to compare the observed effect on air quality with emission inventory projections. *(near term)*

***Design and execute field studies to evaluate the accuracy of stationary source NMOC emission inventories. Possible approaches include receptor modeling, "tracers of opportunity," upwind and downwind measurements, and other techniques that rely on ambient data. Develop and test the approach for one city. After testing and validation for one city, expand to other cities with different stationary source characteristics. *(near term)*

***Conduct periodic tunnel and street canyon studies to reconcile mobile source emission inventories and to track progress. Use tunnels or street canyons representing different mixes of fleet and driving conditions. *(long term)*

***Analyze the results from the studies described above to set priorities for further work to reduce the most important uncertainties in emission inventories. *(long term)*

***Upgrade the hydrocarbon channel and develop NO_X and temperature channels for remote sensing devices used for on-road monitoring of mobile source emissions. Validate the remote sensing devices under a variety of vehicle operating conditions. *(near term)*

***Determine the source(s) of the large amount of uninventoried whole gasoline found in ambient air. Perform a mass balance on all sources of gasoline in Los Angles, attempting to account for losses during production, storage, distribution, marketing, and combustion. Consider adding tracers at different points along the fuel cycle to verify the mass balance results. *(near term)*

***Quantify uncertainty in all emissions estimates. *(ongoing)*

Strategic Activity 6:

Emission Projections *(Done in concert with the Modeling Team)*

Goals: Project the effects of future activity and alternative controls on emission estimates *(contributes to addressing Science Concerns 3b, 4c and 5).*

Background: The U.S. EPA's Economic Growth Analysis System (EGAS) projects regional economic growth for each of the 30 current multi-state ozone nonattainment areas in the United States. The EGAS uses macroeconomic forecasts as a basis for developing the regional economic growth forecasts. The Multiple Projections System (MPS) is a another U.S. EPA product that adjusts baseline emission inventories for emission controls and for growth in the regional economy forecasted by EGAS. Both these systems need to be maintained.

Major Tasks: ***Develop regional economic models for ozone nonattainment areas, including maintenance and annual forecasts. *(ongoing)*

***Maintain existing U.S. EPA forecasting capability for stationary sources. *(ongoing)*

***Develop emission control reduction factors for alternative emissions control systems and keep the file updated as new technologies are developed. *(ongoing)*

***Develop emission control technology degradation factors for alternative technologies. *(ongoing)*

***Develop interfaces for integrating emissions projection models into the MODELS-3 modeling system. *(ongoing)*

APPENDIX A

NARSTO LIAISON TEAMS REPORT

NARSTO LIAISON TEAMS REPORT

The North American Research Strategy for Tropospheric Ozone (NARSTO) has been developed in response to the recommendation of a scientific committee of the National Academy of Sciences that significant "rethinking of the ozone problem in urban and regional air pollution" is essential to development of effective strategies for management of ozone near the ground during the remainder of this century and beyond.

At earlier planning meetings for NARSTO, the decision was made that the NARSTO program should:

- Concentrate its research and assessment efforts (and its financial and intellectual resources) mainly on improving scientific and public understanding of the chemical, meteorological , and precursor-emissions processes that lead to **accumulation of ozone** in the atmosphere near the ground and offer insights to management options for its control,
- Leave to other research communities the challenges of improving scientific and public understanding of two other aspects of the ozone problem:
  - **Effects of ozone** on human health, crops, forests, and engineering materials, and
  - **Control technologies** by which emissions of ozone precursor chemicals can be decreased, and
- Build-in a separate yet connected means for aiding the consideration of policy and management approaches by which leaders in industry and government can help decrease the harmful effects of ozone on society.

Accordingly, a NARSTO Liaison coordination function was established to develop and maintain organizational procedures, communication mechanisms, and decision-making mechanisms by which the ozone research and assessment activities **within the NARSTO program** can be closely linked and integrated with research, assessment and policy and management activities **outside the NARSTO program.**

These important and associated activities are conducted by the following communities of scientists and policy analysts:

- **Ozone-Effects Community**,
- **Control-Technology Community**, and
- **Ozone Management and Policy Community**.

At the June 1994 planning meeting for NARSTO, the following mission statement for the NARSTO Liaison Teams was recommended.

> **The Mission of the NARSTO Liaison Teams is to ensure that the knowledge generated in NARSTO and in the ozone-effects, control-technology, and ozone management and policy communities is drawn together and distributed so it can be used to manage the tropospheric ozone problems in various regions of North America.**

The representatives of all three communities that will remain outside of NARSTO also recommended at the June 1994 NARSTO Planning Meeting, that careful steps should be taken during the formative years of the NARSTO program (1994-1996) to accomplish the following six initial objectives of the NARSTO Liaison Teams:

1) Define what research and assessment activities are included (and what activities are not included) in the Ozone-Effects, Control-Technology, and Ozone Management and Policy Communities;

2) Identify leading persons within the Ozone-Effects, Control-Technology, and Ozone Management and Policy Communities (or appropriate sectors within each of these communities) who are able, willing, and interested to provide the quality of technical, scientific, and policy-relevant insight and leadership, and the quality of communications necessary to insure effective liaison between each community and NARSTO as a whole and the other relevant NARSTO Teams in particular (especially the Analysis and Assessment Team, Emissions Team, Modeling Team, Observations Team, and Organization and Management Team);

3) Define organizational procedures, timetables, and communication and decision-making mechanisms by which effective liaison between the Ozone-Effects, Control-Technology, and Ozone Management and Policy Communities and NARSTO itself (or specific NARSTO Teams within NARSTO) can be established, maintained, and adjusted over the projected 10+ year life-time of NARSTO;

4) Identify whatever specific research and assessment tasks should be undertaken jointly by the Ozone-Effects, Control-Technology, and Ozone Management and Policy Communities (or specific sectors within each community) and NARSTO, either as a whole, or through cooperation with one or more of the other NARSTO Teams;

5) Identify specific mechanisms for accomplishing desirable technology transfer under the NARSTO program for:

    a. Research and assessment findings developed within NARSTO and its several NARSTO Teams, and

    b. Research and assessment findings developed within the Ozone-Effects, Control-Technology, and Ozone Management and Policy Communities;

6) Work with the leadership of NARSTO during the remainder of 1994, and during 1995 and 1996, to bring to the attention of leaders within the Committee on Environment and Natural Resources (CENR) and its Subcommittee on Air Quality (SAQ) within the National Science and Technology Council (NSTC) of the Office of Science and Technology Policy (OSTP), specific proposals for:

   a. Further strengthening the relationships between NARSTO and the Ozone-Effects, Control-Technology, and Ozone Management and Policy Communities, with consideration given to potential inclusion of these three communities in the NARSTO program, and/or

   b. Developing effective working relationships between the Ozone-Effects, Control-Technology, and Ozone Management and Policy Communities within the construct of the CENR and SAQ.

This sixth objective of the NARSTO Liaison Teams was of particular concern and interest to representatives of the Ozone-Effects, Control-Technology, and Ozone Management and Policy Communities at the June 1994 Planning Meeting for NARSTO. The conveners of the June 1994 NARSTO Planning Meeting, pledged their support to work with the NARSTO Liaison Teams to fulfill this objective (number 6 above). They also indicated that they would use their influence with the other NARSTO research and assessment planners and members of the CENR and its SAQ, and thus seek their help, support, and further counsel about fulfilling objective 6. The conveners made this pledge conditional on the willingness of the Ozone-Effects, Control-Technology, and Ozone Management and Policy Committees to work effectively within the NARSTO Liaison Teams during the remainder of 1994, and during 1995 and 1996, while also working to fulfill the other objectives outlined above (numbers 1-5 above).

The representatives present at the June 1994 Planning Meeting for NARSTO proposed that the following research groups be formed, activities undertaken, budget support be provided, and organizational relationships be developed and used during the remainder of 1994, and during 1995 and 1996:

Ozone-Effects Research Group:

Ozone effects research in the United States, Mexico, and Canada is conducted in three general areas, all three of which are funded predominantly in public sector laboratories and cooperating universities:

- Ozone Health Effects Research is funded almost entirely by E PA and cooperating universities in the United States and by Environment Canada in Canada. Total funding in 1994 -- about $8 million US Dollars and about $1.5 million Canadian Dollars.
- Ozone Ecological Effects Research (including effects on both agricultural crops and forest trees) in the United States is funded mainly by the ecological effects research laboratory of EPA, the U. S. Department of Agriculture including the Agricultural Research Service and the Forest Service, the Electrical Power Research Institute, the Tennessee Valley Authority, and the National Park Service of the Department of Interior. Much of this research is accomplished through grants and contracts with cooperating research universities in the United States and by Environment Canada in Canada. Total funding in 1994 -- about $3 million US Dollars and about $0.5 million Canadian Dollars.
- Ozone Materials Effects Research is not currently being conducted by either private or public sector organizations in the United States, Canada, or Mexico.

One of the most important needs for close coordination of ozone effects research with NARSTO research is in determining actual exposure characteristics for:

- Various sectors of the human population (urban populations, rural populations, exercising school children, asthmatics, aging persons, and people in various out-door professions and recreational environments, etc.);
- Ecological resources (mainly crops, forests, and domestic and wild animals); and
- Engineering materials (mainly rubber products and other elastomers, paints, and plastics);

as a function of the following variables:

- Attainment areas vs non-attainment areas;
- Areas down-wind and up-wind from such attainment areas and non-attainment areas;
- Land-use type (remote, urban, near-urban, and rural areas);
- Elevation (monitions, plateau, coastal); and
- Region/ecosystem type (eastern vs western, coastal vs inland areas of various states, etc.).

These efforts should be undertaken as joint activities of the Ozone-Effects Research Group within the NARSTO Liaison Teams and the NARSTO Emissions, Modeling, Observations, and Analysis and Assessment Teams. The objective of these joint research and assessment activities should be to learn more about available data bases, information resources, modeling approaches, and the nature and magnitudes of impacts of ozone and other oxidants near the ground on people, ecosystems, and engineering materials.

To facilitate development of the above joint research and assessment efforts, the Ozone Effects Research Group will do the following three things:

1) Send the July 1994 version of the NARSTO Plan to representatives of all sectors of the ozone-effects research communities of Mexico, Canada, and the United States requesting input of two types:

   a. Identification of specific NARSTO research activities which are relevant to various sectors of the ozone-effects communities in Mexico, Canada, and the United States; and

   b. Submission of key research and assessment questions from the ozone-effects research communities which NARSTO and its several NARSTO Teams could address within the scope of its planned program.

2) On the basis of responses received to these two specific requests, plan and hold a series of one to three **Focused Workshops** involving selected participants from the NARSTO Teams and the public-health effects, ecological-effects, and materials-effects research communities to identify key policy relevant science questions which could provide the basis for decisions about research needs, research approaches, mechanisms for cooperation, and means by which to maintain dialogue between the ozone-effects community and NARSTO.

3) At the first NARSTO Annual Meeting, present the results of the **Focused Workshops** including cross-cutting issues, key policy relevant science questions, specific recommendations for joint activities, mechanisms for maintaining cooperation and future communications including both mutually agreed upon or still contentious issues and recommendations.

4) Maintain throughout the 10+ year long life of NARSTO a continuing dialogue with NARSTO scientists and engineers, sponsors, and stakeholders, about possible alternative forms of the primary (public health) and Secondary (public welfare) standards for ozone in various parts of North America.

Control Technology Research Group:

Control technology research in the United States is heavily funded by private sector research organizations such as the Electric Power Research Institute (EPRI) and the Gas Research Institute (GRI). Public Sector investments are dominated by the U. S. Department of Energy with a modest effort also being conducted by the U.S. EPA. The total investment in control technology research in the United States is about $500 million annually. Most of the ozone relevant portion of this investment is aimed at decreasing emissions of NO_X through modification of combustion processes and flue-gas-treatment processes in large point sources such as power plants and large industrial boilers. Relatively smaller investments are made in research on technologies for decreasing NO_X and VOC emissions from motor vehicles, and even smaller research investments are made on emissions from area sources of NO_X and VOC.

The primary mission of the Control Technology Research Group within the NARSTO Liaison Teams should be to facilitate communication about both research needs in control technology research and innovative ideas about control technologies that will be effective in decreasing emissions of ozone precursor chemicals in various parts of Mexico, Canada, and the United States. This mission will be fulfilled through the following three types of communication:

- Transfer of research and assessment findings from NARSTO to the control technology communities of the three countries,
- Transfer research and assessment findings from the control technology communities of each country to researchers with NARSTO, and
- Make sure the benefits of new technologies by which to decrease emissions of ozone precursors are measurable and well-known within the ozone management and policy communities of Mexico, Canada, and the United States.

Research initiatives to decrease emissions of NO_X and VOC are needed especially from the following three sources of these ozone precursors:

- Stationary sources, especially industrial boilers,
- Stationary engines and gas turbines,
- Off-road construction equipment and motor vehicles.

Since there is no apparent private-sector champion for research to decrease NO_X and VOC emissions from these three major types of sources, the NARSTO Control Technology Research Group needs to identify cooperators with sufficient funding to initiate such research and serve as a catalyst for continued future investment.

To accomplish these three communications goals and three new research initiatives, the Control Technology Research Group within the NARSTO Liaison Teams will do the following things in 1994 and 1995:

1) Send the July 1994 version of the NARSTO Plan to representatives of all sectors of the control technology research communities of Mexico, Canada, and the United States and arrange for one-on-one interviews with leaders of the most important NO_X and VOC control technology research programs in each country. The ultimate goal of these interviews should be to:

   a. Describe the benefits of NARSTO research and assessment activities for the control technology communities of each country, and

   b. Foster joint planning of control-technology research and, wherever it is advantageous to do so, arrange for collaboration and co-sponsorship of such research.

2) Establish NARSTO newsletter and arrange follow-up meetings, both among control technology researchers and between NARSTO and control technology researchers, to facilitate exchange of information about R&D priorities, budgets, and specific NARSTO and control technology research or demonstration projects.

3) Encourage cooperation and technology transfer both among control technology research programs and between these programs and the research activities being conducted by the Emissions, Modeling, Observations, and Analysis and Assessment Teams within NARSTO.

The major research organizations performing control technology research and to which the above three specific efforts should be addressed include the following:

***For NO_X Emissions*:**

U. S. Environmental Protection Agency
U. S. Department of Energy
National Aeronautics and Space Administration
Gas Research Institute
American Gas Association
Institute of Gas Technology
Electric Power Research Institute
Utilities Air Regulatory Group
American Society of Mechanical Engineers
American Institute of Chemical Engineering
Air and Waste Management Association
International Flame Research Foundation
American Flame Research Committee

Motor Vehicles Manufacturers' Association
Fuels Industry Association
Council of Industrial Boiler Owners
American Boiler Manufacturers' Association
Institute of Clean Air Companies
Portland Cement Association
Technical Association of the Pulp and Paper Industries
Other private industry associations in Mexico and Canada
Universities

For VOC Emissions:

American Plastics Council
National Printing Inks Association
National Association of Manufacturers
Roof Coatings Manufacturing Association
Chemical Specialties Manufacturing Association
Chemical Manufacturers Association
Halogenated Solvents Industries Association
National Paint and Coatings Association
Corresponding Canadian and Mexican industrial associations.

Ozone Management and Policy Group:

The ozone management and policy communities of Mexico, Canada, and the United States consists mainly of leaders in the power, transportation, and manufacturing industries of each country, and leaders in the federal, state or provincial, and municipal governments with specific responsibility for management of air quality near the ground. The most important groups within the ozone management and policy community includes the following:

- Leaders in Environment Canada and Mexico,
- Congressional and Parliamentary Committees,
- Officials within the Departments or Ministries of Environment, Energy, and Commerce,
- National Governors Associations in Mexico, Canada, and the United States,
- National Associations of County and Municipal Governments,
- State and Provincial Environmental Commissioners Associations,
- State and Territorial Air Pollution Prevention Administrators,
- Conferences of State and Provincial Legislators, and

- National Associations of Regional Councils in Mexico, Canada, and the United States.

The representatives of this broad community of air-quality managers and policy officials present at the June 1994 NARSTO Planning Meeting, offered the following recommendations for actions by the ozone management and policy communities within each country:

1) In 1994 and 1995, an opinion survey should be made within each state, province, or municipality within each country in North America to determine the following:
    a. Alternative forms of the ozone standards maintained by each state, province, or municipality;
    b. Methods used to model and monitor "unacceptable" exposures for human health, ecological resources, and engineering materials by each state, province, or municipality;
    c. Innovative ozone management approaches currently used (or under consideration) by each state, province, or municipality including the following:
        - Episodic controls based on forecasting of high-ozone events such as:
            - Curtailment of production,
            - Traffic management,
            - Telecommuting,
        - Least emissions dispatching in power plants,
        - Alternative power production and conservation options,
        - Coordinated land-use and traffic planning,
        - Etc.
2) During the autumn of 1994, the July 1994 version of the NARSTO Plan should be sent to air-quality decision makers in industry, legislative and executive departments of government, and public interest groups within each state and province of North America with a request for needs for improved scientific and policy information about ozone accumulation and effects.
3) During 1995 and 1996, conduct an analysis of State or Provincial Implementation Plans submitted to federal authorities with each country. The objective of this analysis should be to further refine NARSTO research priorities during the years between 1996 and 2000. Also, conduct workshops for ozone management and policy groups in various regions of North America to inform them more fully about current scientific knowledge about ozone accumulation and effects on human health, ecological resources, and engineering materials. These Workshops should be developed on the basis of NARSTO biennial state of knowledge assessments.
4) Develop public outreach educational materials about the ozone pollution problem for use

in reaching out to both the public at large and to school children whose lives and future life styles will be affected in both the short and long run both by ozone near the ground and by ozone management practices and procedures in various parts of North America.

Based on experience acquired through the above four activities, during 1997 and beyond, develop more effective mechanisms for optimizing interactions between NARSTO research and assessment activities and contemporary ozone-management approaches in various states, provinces, and municipalities in Canada, Mexico, and the United States.

Technology Transfer Recommendations:

At the June 1994 NARSTO Planning Meeting, the Liaison Committee was also asked to formulate recommendations for specific mechanisms by which scientific and assessment findings from the NARSTO research activities and related activities with the ozone-effects, control-technology, and ozone management and policy communities might be communicated to NARSTO clientele groups. The following ideas for technology transfer were proposed:

- In conjunction with the Analysis and Assessment Team poll both private-sector and public-sector decision makers by region to determine:
  - What policy and scientific questions they want answers to regarding the chemical, meteorological, biological, transportation, energy use, industrial, transportation, and recreational processes that lead to accumulation of ozone near the ground in their regions; and
  - What human-resource-development and technology-development problems they foresee in managing ozone near the ground in the remaining years of this century and the first few decades of the 21st Century.
- In conjunction with the Analysis and Assessment Team, using the results of this poll, develop an improved set of key policy questions to which NARSTO should devote its creative energies and talents, including development of state of science summaries, outlines of knowledge gaps, and research plans and budgets for NARSTO Teams.
- In conjunction with the Analysis and Assessment Team, develop plans for:

  NARSTO Biennial Assessments emphasizing the current state of knowledge about ozone accumulation near the ground and possibilities for more effective use of available scientific information in management of tropospheric ozone in particular and public decision making about air-quality management general; and

  Regionally focused **NARSTO Public Biennial Forums** with ozone decision makers, stakeholders in the tropospheric ozone issues, and leaders in public interest groups concerned with air-quality management in Mexico, Canada, and the United States.

The principal purpose of these three general technology-transfer recommendations, and especially the **NARSTO Biennial Assessments** and the **NARSTO Public Biennial Forums** should be to:

- Report progress in the principal NARSTO research and assessment programs,
- Receive feed-back from ozone decision makers, stakeholders, and public interest groups concerned with air-quality issues in various regions of North America; and
- Keep NARSTO in tuned with both the long-term and short-term air-quality policy needs of Mexico, Canada, and the United States.

Place of the NARSTO Liaison Teams in the Organization of NARSTO:

A Coordinator of NARSTO Liaison Activities should be appointed and should report directly to the NARSTO Management Coordinator and the NARSTO Science and Resource Planning Group. The duties of the Liaison Coordinator are addressed in the NARSTO Charter.

ATTACHMENT 1

Budget Needs of the NARSTO Liaison Work Teams:

Workshops (four altogether)	$90,000
Travel (especially by the Control Technology Group)	$60,000
Poll of Ozone Decision Makers	$80,000
Analysis of Liaison Opportunities (Mainly analysis of questionnaires and interviews with leaders in the Ozone-Effects, Control-Technology, and Ozone Management and Policy Communities)	$50,000
Development and Distribution of NARSTO Newsletter	$25,000
Communications and Publications	$20,000
Public Education and Outreach	$60,000
Total (over two years)	$385,000

APPENDIX B

REQUIRED RESOURCES, TASK PROTOCOLS, AND OUTPUTS/DELIVERABLES

B1. ANALYSIS AND ASSESSMENT

Resource Estimates

FY-95

- Complete assessment of results and lessons learned from all major and on-going field and modeling studies (follow-on from San Diego 1993 meeting). $300K
- Conduct 2 meetings on defining NARSTO assessment concepts and developing principles and protocols for conducting assessments, with reports from Workshops with recommendations. $120K
- Develop NARSTO data system requirements and recommendations. $80K
- Begin integrated overview of SIP tools and databases, as they become available $120K
- Dedicated Analysis and Assessment staff-person to coordinate across working teams, including the liaison teams in-kind or $120K
- Develop comprehensive design for reducing scientific uncertainty and minimizing risk in the air quality management process $200K

FY-95: $940K

FY-96

- Integrated overview of SIP tools and databases $300K
- Complete data system recommendations $80K
- Conduct 2 Analysis and Assessment meetings $120K
- Dedicated Analysis and Assessment staff-person in-kind or $120K
- Complete comprehensive design for reducing scientific uncertainty and minimizing risk in the air quality management process $200K
- Develop initial NARSTO assessment protocols $200K
- Conduct Workshop, in conjunction with Liaison Group, with associated communities (policy and air quality management, effects, control technologies) on developing linkages and communications plans $70K

FY-96: $1090K

FY-97 and beyond: ~$3M - $5M per year, as assessments begin to be conducted

B2. OBSERVATIONS

Near-Term:

Strategic Activity 1:

Analysis and Evaluation of Existing Data.

NARSTO should determine the current state of understanding concerning ozone trends and distribution. *(Done in concert with the Analysis and Assessment Team.)*

Activity Goal: Determine the current state of understanding concerning ozone and ozone precursor trends and distribution. *(Contributes to answering Science Questions 1d-f, 2c-e, 3a, and 4.)*

Major Tasks:[1] ***Provide an inventory of quality assured (i.e., retrospective QA/QC) data sets (in standard units and a standard data base format) that are available and accessible for O_3 and O_3-precursors.

***Establish a virtual data center for surface ozone measurements made in Canada, Mexico, and the United States. The center would provide NARSTO scientists with an on-line service that would provide ozone distribution and trends for North America. This data base should also include meteorological data.

***As a follow-up the National Academy of Science Report, "Rethinking the Ozone Problem in Urban and Regional Air Pollution," using measurements of O_3 and O_3-precursors obtained from various regional studies and monitoring networks, develop peer-reviewed articles indicating the present scientific understanding of the chemical processes that shape the ozone distribution in urban and rural areas of Mexico, Canada, and the United States.

***Develop and analysis strategy for use of data to determine processes and improve emission inventories.

- Undertake additional analysis to determine the influence of meteorological variables on urban and rural O_3 concentration. Statistical regression models should be used to identify meteorological conditions conducive to O_3 accumulation.
- Develop analysis strategies using air concentration data gathered by the regional studies as a cost-effective means to independently check emission inventories and understand photochemical pathways.

Task Protocol:

- Gather existing data set for O_3 and O_3-precursors. Determine measurement time periods.
- Data formatting: There is a need for data in common formats for future datasets. Determine quality assurance and quality control procedures.
- From the data available, provide up-to-date estimates of the reliability and uncertainty (bias and precision) in historical measurements.
- Establish protocol to access data.
- Analyze the data and interpret in terms of insights that these data provide in answering the key scientific questions posed by NARSTO.
- NARSTO sponsorship of an international scientific conference to describe the current understanding of local and regional ozone problems in Mexico, Canada, and the United States.
- Present findings in articles submitted to peer-reviewed scientific journals.
- Provide an inventory of available data sets, resume of scientific findings and a bibliography of the associated scientific publications to NARSTO.

Deliverables:

- Peer-review journal articles that indicate the relevance to understanding NARSTO science questions.
- Provide an inventory of available data sets, resume of scientific findings and bibliography of the associated scientific publications to NARSTO.

Resources:

FISCAL YEAR	1995	1996	1997
RESOURCE*			
Highest priority	0.4	0.4	0.4
Total required	0.4	0.4	0.4

* Resources are quoted in units of 10^6 US dollars. These resources are required to support experts in this field to cover the time they require to gather and quality-assure the data, to sponsor a scientific conference to describe the results, to present the information at this and other scientific meetings, write the papers, and pay page charges. Some of this support will be provided as in-kind contributions of Agencies involved in NARSTO. However, additional funds will be required to support the participation of experts from the academic, industrial, and public interest communities.

Strategic Activity 2:

PAMS review and enhancement.

The U.S. EPA is now beginning the implementation of a network of Photochemical Assessment Monitoring Sites (PAMS) in selected non-attainment areas for the purpose of monitoring trends in ozone, nitrogen oxides, and speciated VOCs (Federal Register, Vol. 57, No. 43, March 4, 1992, pp 7687-7690). NARSTO will review current plans for PAMS and then undertake a series of feasibility studies and short-term field measurements to determine minimum instrumentation requirements, optimal spatial (vertical and horizontal) and temporal sampling strategies, and a suitable hierarchy of diagnostic procedures and analyses to be used with the data from the PAMS network to address the policy-relevant scientific questions listed in the introduction to this plan. However, regulatory requirements must recognize that adequate skill level and technology availability are prerequisite to implementation of monitoring network measurements. *(Done in concert with Modeling Team and Analysis and Assessment Team)*

Activity Goal: Develop measurement and analysis strategy to enhance and maximize information and utility of the proposed network of Photochemical Assessment Monitoring Sites (PAMS). *(Contributes to answering Science Questions 1, 2c, and 4a-c, e, g.)*

Major Tasks: ***Provide advice for the design and implementation of a data archive for all PAMS data and derived products.

***Institute annual instrumentation-science course for training of local and state personnel responsible for implementation and maintenance of PAMS and encourage "monitoring partnerships" between local and state agencies and academic Centers of Excellence in air quality monitoring.

***Carry-out blind intercomparisons of measurements of ozone, NO, NO_X, and speciated VOC at selected urban sites using: 1) the proposed PAMS instrumentation and protocols; and 2) research-grade instrumentation and techniques with appropriately trained personnel. Based on these results, develop instrumentation requirements for PAMS network that will allow the program to accomplish its goals.

***Obtain observational data for the purpose of determining relative sensitivities of urban ozone plume to VOCs and NO_X emissions.

***Develop and test a hierarchy of diagnostic procedures and analyses that could make use of data from a PAMS network and review PAMS sampling strategy to optimize the compatibility of data-stream with the data input requirements of these diagnostic procedures and analyses.

- Identify analyses and diagnostic applications that will require PAMS data products and insure that the network will provide these data products.
- Utilize existing data where possible to aid in network assessment and enhancement.
- Carry-out measurements of ozone, NO, NO_X, and speciated VOC measurements in selected urban locations using densely-spaced networks and a complement of airborne platforms (airplanes, helicopters, sondes, etc.) to determine horizontal and vertical variability of ozone and precursor species in typical urban settings. Attention should be given to sampling during non-summer periods. During the winter meteorological conditions (low temperatures, low incident radiation), importance of alterative oxidation mechanisms probably aids process verification, determination of human-made precursor distribution and trends, and biogenic contribution limitations of those ozone precursors having natural sources or appearing as photochemical by-products.
- Based on these results, develop spatial and temporal sampling strategies for the PAMS network that will optimize the scientific output of the network.

***Develop diagnostic tools for the PAMS network based on insights gained from the above tasks.

***Develop improved data handling approaches. Large quantities of data will emerge from implementation of routine and comprehensive studies. Data analysis techniques, such as standard trend analysis, emerging regression methods to extract meteorological influences on data, and source-apportionment techniques, need to be in hand to provide quick and unequivocal interpretation of the measurements.

***Establish similar measurement capabilities and sites in Canada and Mexico.

**Begin implementation of improved and enhanced PAMS network based on insights gained from above tasks. Implement and maintain one or two rural PAMS-level demonstration sites for instrument research, demonstration, refinement, and instruction. Enhancements to potentially include: 1) Use of improved instrumentation; 2) Use of airborne measurement platforms and towers; 3) Expansion of network to include non-urban/rural measurement sites; 4) Measurements of additional chemical species and meteorological parameters; and 5) Other modifications that would improve utility of data for diagnostic analyses and model evaluation.

Task Protocol:

- Create and use a NARSTO/PAMS Working/Advisory Group to oversee activities.
- Provide summer instrumentation-science course for training of local and state personnel responsible for implementation and maintenance of PAMS.
- Establish and operate a prototype PAMS network in conjunction with comprehensive regional studies.

Deliverables:

- Information would be condensed in critical, peer reviewed reports that would provide analysis of the PAMS network design and implementation and recommendations for possible incorporation in the network and data-analysis approaches.
  - Report containing preliminary position papers - 10/95
  - Minutes of joint effects/atmospheric science workshop - 1/96
  - Submission of review papers and final report - 1/97
- Text book describing the operation of targeted instrumentation.

Resources:

FISCAL YEAR	1995	1996	1997
RESOURCE*			
Highest priority	0.5	1.0	1.0
Total required	0.5	1.0 + 0.3/site	1.0 + 0.3/site

* Resources are quoted in units of 10^6 US dollars. It is estimated that the specialized instrumentation that is required to upgrade each PAMS site to the levels required by NARSTO will cost approximately $0.3M in addition to funds already committed for this purpose. Beyond this initial cost, the operation, maintenance, data reduction and interpretation of the additional instrumentation in each PAMS station will cost approximately $0.3M per year.

Strategic Activity 3:

Network design for monitoring.

Basic inventorying of current monitoring capabilities and the information that is expected to be obtained from monitoring networks is required to plan effectively for implementing enhancements to the routine monitoring networks. Because the form of the existing ambient national air quality standards are highly sensitive to meteorological variations, they have been criticized as inappropriate metrics for monitoring the effectiveness of ozone abatement strategies.

NARSTO will cooperate in the design of monitoring networks to track "progress" toward attainment of air-quality standards that may be required in the future in Canada, Mexico, and the United States.

This task also recognizes: (a) that fundamental differences exist between monitoring networks for exposure, regulatory/compliance, and diagnostic air-quality monitoring; (b) that these differences may vary from region to region and (c) that all three types of monitoring may be necessary. Hence, this task will identify gaps/weaknesses of existing programs and provide guidance in improving monitoring networks. Among other criteria to be considered, the improved monitoring networks must enhance representativeness; provide for non-urban monitoring; add upper-air chemistry measurements; and add measurements of NO_y species and VOCs. *(Done in concert with the Analysis and Assessment Team and in coordination with the Effects program.)*

Activity Goal: Develop measurements and monitoring networks, and analyses needed to establish trends in ozone and its precursors and to shorten the time required to unequivocally observe a response in ozone and its precursors to mandated reductions in ozone-precursor emissions. Determine the implications for air-quality monitoring of an improved air-quality standard for ozone. *(Contributes to answering Science Questions 1, 2c, and 4a-c, e, g.)*

Major Tasks: **Develop an objective classification system needed to identify the various types of O_3 monitoring stations. Determine the similarities, differences, opportunities and trade-offs required to undertake adequate programs in exposure, regulatory/compliance, trans-boundary flow, and diagnostic monitoring of ozone and ozone-precursors.

**Provide support for the formulation of new ozone metrics that are statistically robust and account for other relevant factors such as the effects of meteorology.

**Determine if potential alternate statistical forms of reporting ozone air quality (both acute episodic and chronic long-term) will alter the characterization of ozone air quality compared to the current statistical form of the standards.

**Determine the chemical measurements appropriate to the needs of each network.

**Network design.

- Design a meteorological monitoring component that captures the role that meteorology and dynamics play in the redistribution of airborne chemicals. In addition to the standard complement of measurements, attention should be given to determination of solar flux and the dynamical structure of the boundary layer and lower free troposphere.

- Develop a comprehensive plan for quality control and quality assurance of the data to be acquired from this network.
- Determine a criterion to judge how representative ground based measurements are on various vertical and horizontal scales.
- Develop a strategy for determining the optimum location for monitoring ozone and ozone precursors.
- Determine the spatial resolution is needed to properly describe O_3 production, accumulation, and consumption on urban and regional scales.

Task Protocol:

- Assemble a committee of experts representing the four sections of the NARSTO program, and representatives of the effects and alternate fuels communities, to evaluate network requirements.
- Formulate preliminary position papers describing: (1) relation between near-surface ozone concentration and exposure; (2) description of ozone monitoring network that will best gauge exposure; (4) differences between deployment strategies used to develop appropriate and cost-effective exposure, regulatory/compliance and diagnostic networks for monitoring ozone and ozone-precursors; (5) observational approaches; and (6) data management.
- Conduct workshops involving members of the effects, control technology and atmospheric sciences communities to discuss the best combination of metrics and monitoring programs needed to achieve the goals of the three communities.
- Write peer-reviewed papers describing the approaches, their rationales and limitations, the options, and trade-offs.

Deliverables:

- This information would be condensed in critical, peer-reviewed reports that would summarize the strengths and weaknesses of existing monitoring networks and past intensive efforts with recommendations to be implemented in new monitoring networks and data-analysis approaches and future intensive studies.
    - Report containing preliminary position papers - 10/95
    - Minutes of joint effects/atmospheric science workshop - 1/96
    - Submission of review papers and final report - 1/97

Resources:

FISCAL YEAR	1995	1996	1997
RESOURCE*			
Highest priority	---	---	---
Total required	0.4	0.4	0.4

* Resources are quoted in units of 10^6 US dollars. These resources cover the time required to write position papers, to provide the peer review, and to hold a workshop. Some of the support will be provided as in-kind contributions of Agencies involved in NARSTO. However, additional funds will be required to support the participation of experts from the academic, industrial, and public interest communities, travel, and workshop arrangements.

Strategic Activity 4:

Northeastern Scoping Study *(Done in concert with Modeling Team and Analysis and Assessment Team.)*

Activity Goal: Provide information that would be of assistance states in the Northeast in the state implementation planning (SIP) process on attainment of the National air-quality standards for ozone, and to serve as a nucleus for more intensive studies in future years. Specifically the task will provide information that could be used: (1) to aid in the selection of algorithms for simulating the evolution of the mixed layer during ozone episodes; (2) to characterizing the import of ozone and precursors across boundaries of the modeling domains; (3) to scale the concentrations of reactants and products at downwind non urban locations, and (4) to assess the importance of deviations between simulated with observed concentrations of ozone precursors in non-urban areas. *(Contributes to answering Science Questions 1, 2c, and 4a-c, e, g.)*

Major Tasks: ***Review existing data taken from state air quality and acid rain research programs. Develop a retrospective quality control and quality assurance plan by assessing the merit of given data. Provide an inventory of quality assured data sets (in standard units and a standard data base format) that are available for O_3 and O_3-precursors in the Northeast.

***Implement and maintain PAMS-level sites in the Northeast for instrument research, demonstration, refinement, and instruction. Enhancements to potentially include: 1) use of improved instrumentation; 2) use of airborne measurement platforms and towers; 3) expansion of network to include non-urban/rural measurement sites; 4) measurements of additional chemical species and meteorological parameters; and 5) other modifications that would improve utility of data for diagnostic analyses and model evaluation.

***Design short and long-term field studies to understand the factors that control ozone accumulation in the Northeast.

**Implement short term studies.

- Measurements of upper air meteorology. Will provide data on wind direction, wind speed, shear, and mixing height throughout the atmosphere. Measurements will be made at several selected locations. The data from these locations will be combined with other related meteorological data in deriving the evaluation of the mixed layer during ozone episodes.
- Surface measurements of O3, NO, NO_y, VOCs, and meteorology. Measurements will be made at selected locations. The data from these locations will be combined with other related air quality data to determine how ozone concentrations relate to VOC and NO_X emissions in this region.
- Aircraft measurements of O3, NO, NO_y, VOCs, and meteorology. Will determine the spatial distribution of upwind boundary concentrations and assess the amount of interurban transport and photochemical processing during ozone episodes.

Task Protocol:

- Assemble observations in an accessible data archive that also includes other available and quality-specified observations that have been obtained in the Northeast Transport Region (NTR).
- Check the concentration of modeled emissions inputs of precursors with respect to the NO_y/VOC ratios for rural areas in addition to the urban areas already being evaluated.
- Use air meteorological data obtained at coastal and central locations to aid in the selection of computational algorithms that can most closely simulate the evolution of the mixed layer in the Northeastern transit region during ozone episodes. This includes the identification of meteorological regimes and synoptic flow patterns associated with ozone exceedances.
- Measure NO_y and VOCs in rural areas and compare with similar measurements in urban areas.
- Add rural ozone data to those available mainly for urban areas.
- Provide information at boundary and receptor locations that could be used to check estimates used in describing chemical composition and transport conditions at regional boundaries.

Deliverables:

- Develop peer-reviewed articles indicating the present scientific understanding of the chemical processes that shape the ozone distribution in urban and rural areas of the Northeast.

Resources:

FISCAL YEAR	1995	1996	1997
RESOURCE*			
Highest priority	0.3	0.7	0.7
Total required	0.4	2.6	2.6

* Resources are quoted in units of 10^6 US dollars. The largest estimated funds was directed to the implementation of the near-term scoping study. This task is initially given a second level priority. It is presumed that if a successful design for the study can be completed this task will also be given the highest priority.

Strategic Activity 5:

Continue existing/ongoing regional field studies.

Activity Goal: Better understand, further identify, isolate, and explain the fundamental physical, chemical, and meteorological processes responsible for ozone accumulation on local and regional scales in North America. *(Contributes to answering Science Questions 2; 4)*

Major Tasks: ***Develop a quantitative estimate of the role of vertical mixing in the redistribution of compounds between the boundary layer and the free troposphere. **(underway)**

***Obtain a quantitative estimate of the exchange of ozone and ozone precursors between urban and rural areas. **(underway)**

***Determine the physical and chemical processes that determine the importance of point-source emissions to: (1) urban air-quality; (2) rural air-quality. **(underway)**

***Determine the relative contribution of biogenic and anthropogenic NO_X and VOCs to O_3 formation in urban and rural areas in various areas of North America. **(underway)**

***Determine the identities of the natural and anthropogenic sources of NO_X and VOCs and, where possible, estimate the emission of VOCs and NO_X from these sources through ^{14}C measurements, chemical mass balance, principal component analysis and other receptor models, diagnostics and analyses. **(underway)**

***Promote development of observational based models (OBMs) and emission based models (EBMs). **(underway)**

***Provide a retrospective assessment of the problems and failures of existing regional studies to serve as additional guidance in formulating future field programs. **(underway)**

Resources:

FISCAL YEAR	1995	1996	1997
RESOURCE*			
Highest priority	?	?	?
Total required	?	?	?

* Resources are quoted in units of 10^6 US dollars. Although the tasks described within this strategic activity are of highest priority it is not possible at this time to estimate how much additional funds will be required to allow these regional studies to successfully complete their activities.

Long-Term:

Strategic Activity 1:

Development of techniques for routine measurement.

At present the measurement of CO, VOCs and NO_X/NOy are not routine and the skill required to make these measurement is limited to the scientists who have participated in the development of the current capabilities. In addition, the protocol that determines when and where the measurements of these compounds would satisfy a particular monitoring requirement has not been established.

Activity Goal: Develop adequate "routine" sampling techniques for monitoring CO, VOCs, NO_X/NO_y, and meteorology from surface locations and, where needed, above the surface. *(Contributes to answering Science Questions 1c,d, 2e, and 4f. Done in concert with the Modeling Team and the Analysis and Assessment Team.)*

Major Tasks: **Determine capabilities of current technology for precise and accurate routine measurements for speciated VOC, H_2O_2, NO, NO_2, and NO_y in urban and rural environments. Current techniques used for the routine measurement of these compounds are non-specific and lack the necessary sensitivity or selectivity. For example, the current reference method for NO lacks the sensitivity required to measure NO in the non-urban atmosphere and for

NO_X lacks sufficient specificity. The measurement of H_2O_2 is currently done only by research grade instruments that have not yet been critically evaluated by intercomparison. In addition, all presently available methods to measure VOCs are labor intensive and limit the number of measurements that can be made. Reliable data for NO_X, and VOCs are not sufficiently extensive, accurate and/or precise to define background conditions or establish robust photochemical relationships for either rural or urban areas. If atmospheric chemistry is to be better understood and the sources of these compounds are to be identified and better quantified, accurate and reliable measurement techniques with simple operating principles must be developed.

**A capability for atmospheric profiling of O_3, NO_2, NO_y, CO, VOCs, H_2O and aerosols must be developed. Routine measurements of vertical profiles of these compounds may be required at some sites. The profiles, using lofted instruments or ground-based sounders, should provide more detailed information concerning the structure of the atmosphere and the distribution of these compounds through the planetary boundary layer into the free troposphere.

**Develop and test methods for precise and accurate routine measurements of photolysis rates of NO_2, H_2CO, and O_3.

**Develop and test methods for precise and accurate routine measurements used for meteorological profiling.

**Develop methods to calibrate and audit these measurements and develop and maintain low-concentration calibration standards.

**Develop methods for short turnaround/real-time data handling and visualization of monitoring network data via telemetry or internet links.

Task Protocol:

- Use the NARSTO/PAMS Working/Advisory Group to advise on instrument improvements that will be needed for routine measurements.
- Solicit proposals for the development of straight-forward, simple, reliable techniques to measure speciated VOC, H_2O_2, NO, NO_2, and NO_y in urban and rural environments.
- Deploy, test and validate methods for profiling O_3, CO, H_2O and aerosols.
- Deploy, test and validate methods used for meteorological and dynamical profiling.
- Develop methods to calibrate these measurements and develop and provide low-concentration calibration standards.

Deliverables:

- Provide a quality-assured approach for calibration for the critical chemical measurements.
- Provide the necessary reliable low-concentration calibration standards.
- Peer-review journal articles that indicate the relevance to understanding NARSTO science questions.
- Provide an inventory of available data sets, resume of scientific findings and bibliography of the associated scientific publications to NARSTO.

Resources:

FISCAL YEAR	1995	1996	1997
RESOURCE*			
Highest priority	---	---	---
Total required	0.5	0.5	0.5

* Resources are quoted in units of 10^6 US dollars. The estimates include the allocations to defray the expenses required to undertake joint field testing and validation (informal intercomparisons) of any two techniques mentioned above and to meet and discuss the results.

Strategic Activity 2:

Development of techniques for process studies.

Identifying the chemical mechanisms involved in ozone formation as well as testing the analytical models used to predict rural ozone distributions require the development of new instrumentation to measure the key species. The development of reliable techniques for in-situ measurement of nitric acid, H_2O_2, oxygenated VOCs and odd-hydrogen free radicals (specifically, OH and HO_2), long-path measurements of O_3 and aerosols, and fast response measurements of CO, NO_X, and NO_y should receive the highest priority.

Activity Goal: To develop techniques that will provide: (1) comprehensive chemical and meteorological input for air-quality models (OBM and EBM) that test possible control strategies; (2) comprehensive chemical information to evaluate how well models simulate atmospheric processes; and (3) the ability to test whether models can: (a) accurately simulate the key species (peroxy radicals) that control the speed of the chemistry; (b) the micro-, meso-, and synoptic scale meteorological processes that control the transport and mixing of ozone and ozone-precursors in the atmosphere. *(Contributes to answering Science Questions 1c,d, 2c,e, and 4f)*

Major Tasks: ***To obtain an adequate emissions data base for concentrations of compounds typically found near sources or during aircraft measurements, faster response measurement techniques (measurement time 10 second or less) for NO_X, NO_y, CO, and O_3 must be developed. Development should aim to reduce the size, weight, and power needs of these instruments that have been successfully operated at the surface, and to allow a comprehensive suite of chemical and meteorological measurement to be made from airborne platforms.

***Sponsor unbiased evaluation and intercomparison of critical instrumentation and techniques.

***Develop reliable measurement techniques for oxygenated VOCs. In this regard, the carbonyls are a family of compounds that are produced by atmospheric oxidation of hydrocarbons. Formaldehyde is of special interest, since it is thought to be the most copiously produced of the carbonyls and, as such, is a significant intermediary in the formation of short-lived oxidizing free radicals. Since H_2CO photolyzes at longer wavelengths than O_3, H_2CO may play a particularly significant role in controlling atmospheric photochemistry in the spring and fall, and has the potential to determine whether ozone exceedances can occur during those seasons. In addition, the prominence of the carbonyls, and in particular formaldehyde, may increase substantially in the future, since these compounds can be the major byproducts of some alternative automotive fuels. However, at present there are no fully validated methods available for the accurate in-situ measurement of these compounds in the atmosphere.

***Develop new techniques or approaches to measure NO_3, HONO, and HNO_3. The nitrate radical, NO_3, represents an important intermediate in the formation of nitric acid at night, and acts as an oxidant during non-sunlit periods. Currently, there is no in-situ measurement technique to measure the concentration of this compound. Nitrous acid, HONO, may play an important role in the initiation of photochemistry in polluted atmospheres. At present there is no adequate technique for the measurement of HONO. Nitric acid plays a critical role in the transport of reactive nitrogen in the atmosphere. However, there are lingering concerns regarding the capabilities of present measurement techniques to adequately measure the concentration of nitric acid in the atmosphere. New techniques or approaches to measure nitric acid should be developed.

***Develop and deploy techniques to measure odd-hydrogen radicals. The chemistry in the atmosphere is driven by odd-hydrogen free radicals. Adequate testing of ozone production mechanisms awaits the development and deployment of techniques to measure these radicals.

***Develop and validate LIDAR measurement techniques for O_3 and aerosols. High resolution continuous profiles of ozone are needed to examine source-sink mechanisms, particularly those involving vertical mixing between surface and elevated sources. In addition, such measurement methods can provide the means to determine budgets, as well as thoroughly characterize boundary layer/free troposphere exchange.

***Develop long-path measurements for O_3, NO_2, H_2CO, H_2O_2, SO_2, and O_3, and OH.

**Develop and validate instruments for meteorological profiling.

***Develop calibration and audit procedures to be used with these techniques.

***Develop techniques to measure the heterogeneous uptake, processing and revaporization of trace chemical species by clouds and background aerosol.

**Develop improved statistical methods to evaluate the performance of existing chemical measurements.

Task Protocol:

- Carry out intercomparisons of the techniques to measure carbonyls including CH_2O, H_2O_2,
- Solicit proposals for the development of methods to measure alcohols, organic acids and HNO_3.
- Field test and validate fast response measurement techniques for NO_X, NO_y, CO and O_3 that are suitable for aircraft applications.
- Solicit proposals for the development of techniques to measure odd-hydrogen radicals including calibration procedures.
- Field test and validate instruments for meteorological and dynamical profiling.

Deliverables:

- Peer-review journal articles that indicate the relevance to understanding NARSTO science questions.
- Provide an inventory of available data sets, resume of scientific findings and bibliography of the associated scientific publications to NARSTO.

- Provide a quality-assured approach for calibration for the critical chemical measurements.

Resources:

FISCAL YEAR	1995	1996	1997
RESOURCE*			
Highest priority	3.2	3.2	3.2
Total required	4.0	4.0	4.0

* Resources are quoted in units of 10^6 US dollars. The estimates include the allocations to defray the expenses required to undertake joint field testing and validation (informal intercomparisons) of techniques mentioned above and the cost of holding meetings to discuss the results.

Strategic Activity 3:

Observation-based emission inventory evaluation.

A better understanding of the relation among human-made sources and between human-made and natural sources in determining local and regional air-quality is needed. This is required so that effective controls can be designed and efficiency maximized, avoiding over-regulation and the accompanying loss of economic competitiveness. In order to develop effective regional control strategies for ozone, the relation of the principal human-made and natural sources of VOCs and NO_X to the atmospheric concentrations of these compounds must be established. Measurement of VOCs and NO_X in conjunction with appropriate tracer or fingerprint compounds can identify the sources of the ozone precursors and indicate the amount of those precursors emitted by those sources. Correlation of ozone with this information coupled with other diagnostic, observational-based analysis can indicated the influences of these sources on the production of ozone. *(Done in parallel with the Emissions Team.)*

Activity Goal: Perform air concentration measurements to improve emissions inventories for ozone-related chemicals. *(Contributes to answering Science Questions 1b,f, 4a, and 4a,b,e,f,g.)*

Major Tasks: ***Determine the relative contribution of natural/biogenic and anthropogenic NO_X and VOCs to O_3 formation in urban and rural areas in various areas of North America.

***Determine the identities of the natural/biogenic and anthropogenic sources of NO_X and VOCs and, where possible, estimate the emission of VOCs and NO_X from these sources through ^{14}C measurements, chemical mass balance, principal component analysis, and receptor models, diagnostics, and analyses.

***Develop tracers to indicate origin of air-mass (i.e., upper atmospheric, stratospheric, marine, continental, etc.)

**Provide database and analysis methods suitable for use in the development of observational based models (OBMs) and emissions based models (EBMs).

Task Protocol:

- Measurement strategies, such as chemical mass balance and principal component analysis, along with more accurate and precise measurements of NO_X and VOCs will be used to verify the emission estimates of NO_X and VOCs.
- These measurements should be made in connection with comprehensive studies described below (c.f., Strategic Activity 6).
- Analyze the data and interpret in terms of insights that these data provide in answering the key scientific questions posed by NARSTO.
- Present findings in articles submitted to peer-reviewed scientific journals.
- Provide an inventory of available data sets, resume of scientific findings and a bibliography of the associated scientific publications to NARSTO.

Deliverables:

- Peer-review journal articles that indicate the relevance to understanding NARSTO science questions.
- Provide an inventory of available data sets, resume of scientific findings and bibliography of the associated scientific publications to NARSTO.

Resources:

FISCAL YEAR	1995	1996	1997
RESOURCE*			
Highest priority	0.5	0.5	0.5
Total required	0.5	1.0	1.0

* Resources are quoted in units of 10^6 US dollars. The estimates include the allocations to defray the expenses required to interpret existing atmospheric concentration measurements and develop new analysis approaches to extract emissions data from atmospheric measurements. A focused study of emission inventories should be done in connection with

NARSTO field intensives or monitoring activities. Additional funding is also suggested to help interpret the measurements.

Strategic Activity 4:

Observational based modeling development.

Because of the complexities and non-linearties inherent in the processes that cause the accumulation of ozone, a robust understanding of these processes and their interactions requires the availability of multiple, independent approaches. Toward this end, NARSTO will augment the traditional "emissions-based, gridded model approach" typically adopted in air quality studies, with observation-based approaches; i.e., analyses that use atmospheric measurements to diagnostically derive information and gain insights of relevance to NARSTO goals. These observation-based analyses might be used to 1) Infer temporal and spatial trends in ozone and precursors; 2) Separate meteorological and chemical forcing factors;3) Evaluate, test, and derive emissions inventories; 4) Infer key precursor species driving local and regional ozone production; 5) Test photochemical mechanisms; and 6) Diagnose degree of NO_X-limitation or VOC-limitation in local ozone production.

Activity Goal: Develop and test a hierarchy of observation-based analyses and models that use field observations and data to diagnostically address the science questions identified for NARSTO. *(Contributes to answering Science Questions 1a,b,d,f; 2a,d; 3a; 4)*

Major Tasks: ***Develop inventory of observation-based analysis and model development in use and under development.

***Identify existing observationally-derived data sets that might be used to evaluate and compare results of different observation-based analyses and more traditional emissions-based approaches.

***Compare observation-based and emission-based approaches for consistency and precision. On the basis of these findings, develop basic protocol for integrating results of observation-based and emissions-based approaches as a means of assessing the robustness of findings.

***Apply observation-based and emission-based models to other data sets as appropriate.

Task Protocol:

- Measurement strategies utilizing key indicator species or ratios of key species and/or groups of specie along with accurate and precise measurements of those species will be used to advance the understanding of ozone production and/or to verify the emission estimates. This analysis should be carried out in conjunction with the monitoring and measurement activities described elsewhere in this section (Near-Term, Strategic Activity 2; Long-Term, Strategic Activity 6).
- Analyze the data and interpret in terms of insights that these data provide in answering the key scientific questions posed by NARSTO. This includes the effects of meteorological patterns and the metric used to judge ozone-related air quality.
- Present findings in articles submitted to peer-reviewed scientific journals.
- Provide an inventory of available data sets, resume of scientific findings and a bibliography of the associated scientific publications to NARSTO.

Deliverables:

- The scientific findings related to the ozone air-quality problems in Mexico, the United States and Canada will be condensed in critical, peer reviewed review papers and manuscripts. The focus of these publications will be the new understanding and information provided by NARSTO research in answering the key scientific questions posed by NARSTO.
- Provide an inventory of available data sets, resume of scientific findings and bibliography of the associated scientific publications to NARSTO.

Resources:

FISCAL YEAR	1995	1996	1997
RESOURCE*			
Highest priority	0.5	1.0	1.0
Total required	0.5	1.0	1.0

* Resources are quoted in units of 10^6 US dollars. The estimates include the allocations to defray the expenses required to develop new approaches to develop and verify observational approaches and to identify indicator species, species ratio, and/or groups of species. In addition, resources are allocated to provide focused planning and interpretation of ground and airborne measurements done in connection with NARSTO comprehensive field studies or monitoring activities.

Strategic Activity 5:

Determine deposition/removal.

Develop field program to improve the understanding of the physical, chemical, and biological processes that control ozone and precursor deposition, and incorporate the representation of these processes into atmospheric models.

Activity Goal: Determination of the chemical and physical process that control the loss of ozone and ozone precursors near the surface. *(Contributes to answering Science Questions 1d-f, 2c-e, 3a, and 4.)*

Major Tasks: ***Measure the deposition of O_3 and NO_2 as needed for model development and simulations. Determine the types of terrain that need to be studied to provide for the formulation of representative deposition algorithms.

**Develop improved techniques for measuring deposition rates of ozone and ozone precursors including the role of wetted surfaces in accelerating the loss of ozone and turbulent exchange in areas of inhomogeneous surface cover. Studies of NO_2, PAN, CH_2O, and H_2O_2, will provide the first direct indications of how much the surface loss (at night, especially) removes these species from the atmospheric pool. Later studies should focus on odd-hydrogen radical deposition.

**Understand the dominant processes that control the uptake of ozone and its precursors by vegetation.

Task Protocol:

- Identify of the important ozone-precursor NO_y compounds (NO_2 and peroxy acetyl nitrate - PAN) and the VOCs (CH_2O, other carbonyls, H_2O_2, and the principal organic peroxides) that are surface-deposited, but insufficiently characterized.
- Develop and validate flux measurement techniques for these compounds.
- Carry out these measurement in concert with the comprehensive field studies described below (c.f., Strategic Activity 6)
- Analyze the data and interpret in terms of insights that these data provide in answering the key scientific questions posed by NARSTO.
- Present findings in articles submitted to peer-reviewed scientific journals.
- Provide an inventory of available data sets, resume of scientific findings and a bibliography of the associated scientific publications to NARSTO.

Deliverables:

- Peer-review journal articles that indicate the relevance to understanding NARSTO science questions.

- Inventory of available data sets, resume of scientific findings and bibliography of the associated scientific publications to NARSTO.

Resources:

FISCAL YEAR	1995	1996	1997
RESOURCE*			
Highest priority	0.2	0.2	0.2
Total required	0.6	0.6	0.6

* Resources are quoted in units of 10^6 US dollars. The estimates include allocations defray the expenses required to develop new approaches needed to determine deposition of the targeted compounds. It is assumed that focused studies of deposition processes will be done in concert with NARSTO comprehensive field studies or monitoring activities. Additional funds are allocated to help interpret these measurements.

Strategic Activity 6:

Design and implementation of comprehensive field studies.

Develop (i) a detailed "real-world" understanding of the physical, chemical, and meteorological processes responsible for ozone formation and (ii) incorporate these observations into mathematical models that can simulate the fate of compounds emitted into the atmosphere for the temporal and spatial scales of interest. In addition, these measurements will provide the data bases required for model evaluation. The research will involve a comprehensive suite of ground based chemical measurements, aircraft and tower measurements of key compounds using fast response instruments, and height profiles of the dynamical properties of the PBL and lower free troposphere using boundary layer radars. Comparison of results obtained from measurements made in different locations and seasons will identify processes that determine the regional distribution of ozone and its precursors and will assess how well models can simulate them. Avenues for additional research will be identified. *(Done in concert and in parallel with the Modeling, Analysis and Assessment, and Emissions Teams.)*

Activity Goal: To provide comprehensive field measurement data sets to support: 1) evaluation and development of emission-based models; 2) evaluation and development of observation based models; 3) evaluation of natural/biogenic and anthropogenic budgets; and 4) understanding of the fundamental chemical and physical processes that shape the atmosphere. *(Contributes to answering Science Questions 2; 4)*

Objectives: This research will be done through a sequence of comprehensive field studies done at a number of locations throughout North America. The objectives of the research are:

- Determine the role and relative importance of photochemical initiators (O_3, H_2CO, PAN, HONO, etc.) on the photochemical production of O_3 in rural and urban areas for various regions of North America.
- Develop a quantitative estimate of the role of vertical mixing in the redistribution of compounds between the boundary layer and the free troposphere.
- Obtain a quantitative estimate of the exchange of ozone and ozone precursors between urban and rural areas.
- Estimate the computational errors attendant to model simulations in regions having significant sub-grid scale sources of O3-precursor emissions. (Done in concert with "Chemistry and Modeling.")
- Determine the physical and chemical processes that determine the importance of point-source emissions to: (1) urban air-quality; (2) rural air-quality.
- Understand the effect of the complex transport associated with the interface between the continental and marine boundary layers on regional and hemispheric ozone pollution.
- Since comprehensive studies provide as significant data base, they can serve as a test bed to implement innovative measurement methodologies and strategies (see Strategic Activity 7)
- Understand how different meteorological regimes constrain ozone accumulation and design field program that capture these regimes.

Major Tasks: ***Determine study priorities; identify location and timing; determine the size of the region required to fully realize the science goals; determine the length of time required to achieve the science objectives; determine resources required to carry out the study. (Note: Several studies have been suggested and are enumerated below. There may be others.)

****Northeastern United States/Eastern Canada.** Provide up-to-date, comprehensive data bases aimed at improving regional/local emission inventories and supporting model application in the Northeastern United States and Eastern Provinces of Canada.

- Study the evolution of a regional pollution event as it passes from the Midwest or the Southeast to and, subsequently, through the urban-matrix of the Northeast.
- Determine the export of ozone and ozone precursors from the Northeastern United States to the Maritime Provinces of Canada.

***Dallas Study.** Elucidate the photochemistry in a region that is poor in natural VOCs but a more significant source of anthropogenic/biogenic NO_X.

***Midwest United States/ Ontario-Quebec Corridor.** Determine the factors that control the export of ozone and ozone precursors from the Midwestern United States into the southeastern provinces of Canada and the impact of the compounds on Canadian air quality.

***Mexico City.** Initiate regional-scale field studies in Mexico aimed at improving our understanding of the processes that control the accumulation of ozone in Mexico (especially Mexico City).

***Mexico/Southwestern United States.** Examine the impact of trans-border transport of ozone and ozone precursors on the air quality of Mexico and the United States and the impact of economic expansion within Mexico upon its air quality and the air quality of the southern United States.

Task Protocol:

- Each major regional study should be carried out on a schedule that requires approximately four years. The first year is devoted to: (1) planning and coordination; and development of ground level monitoring stations. The second year provides: (1) for scoping studies of chemistry and meteorology from the ground locations coupled with limited airborne and profiling measurements; (2) development of preliminary emissions inventories in the region under investigation; (3) development of a quality assurance plan for the measurements; (4) development of a data base management plan. The third year provides: (1) for detailed studies of chemistry and meteorology from the ground locations coupled with more elaborate airborne and profiling measurements; (2) development of detailed emissions inventories in the region under investigation; (3) implementation of a quality assurance plan for the measurements; (4) development of a managed data base. The fourth year is devoted to data analysis and interpretation with additional support for focused studies suggested from a first- look at the data and an assessment of the degree to which study objectives were accomplished.
- Establish a process for the periodic review of regional field studies to determine the "lessons learned."
- Present findings in articles submitted to peer-reviewed scientific journals.
- Provide an inventory of available data sets, resume of scientific findings and a bibliography of the associated scientific publications to NARSTO

Deliverables:

- The scientific findings related to the ozone air-quality problems in Mexico, the United States and Canada will be condensed in critical, peer reviewed review papers and manuscripts. The focus of these publications will be the new understanding and information provided by NARSTO research in answering the key scientific questions poised by NARSTO.

- Inventory of available data sets, resume of scientific findings and bibliography of the associated scientific publications to NARSTO.

Resources:

FISCAL YEAR	1995	1996	1997
RESOURCE*			
Highest priority	---	---	---
Total required	0.3	3.3	10.0

* Resources are quoted in units of 10^6 US dollars. These estimates are that required to fund one of the studies mentioned above. The estimates will depend on the scope of the study. The $0.3M for the first year is allocated to design the study. The $3.3M for the second year provides for a scoping study. The $10M for the third year is to fund the comprehensive study. It is presumed that a fourth year will be required to complete a study. That year would require approximately $5.0M for follow-up measurements and data interpretation.

Strategic Activity 7:

Advance technology and develop innovative new approaches

Activity Goal: Provide for the development of new science and technology in for understanding air-quality management. *(Contributes to answering Science Questions 1-5)*

Major Tasks: ***Sponsor development of promising innovative combinations of new measurement and modeling techniques (e.g., mobile and airborne drone monitors).

Task Protocol:

- Research to develop new methods would be provided by a peer-review grants process.
- The funding period would be sufficient to allow adequate time for the development of the research activity.
- Present findings in articles submitted to peer-reviewed scientific journals.

Deliverables:

- Peer-review journal articles that indicate the relevance to understanding NARSTO science questions.

Resources:

FISCAL YEAR	1995	1996	1997
RESOURCE* ***Highest priority*** ***Total required***	0.1	0.5	0.5

* Resources are quoted in units of 10^6 US dollars. The estimate is predicated on the assumption that a few percent of the available resources for the NARSTO effort should be available for advance study projects.

B3. MODELING

Near Term:

Goal:

Near-term research efforts are aimed at producing improvements in the regional and urban air quality models in the next 2-3 years (by 1997) to reduce their uncertainty in the simulation of ozone production. The recommendations stem from current understanding, developed from available diagnostic model evaluation investigations, of possible reasons for model uncertainty or poor performance. Recommendations are also directed at development of a better understanding of the effects of uncertainty on model predictions. A goal is quantification of model improvements that will significantly reduce uncertainty and implementation of those improvements in advanced, science models. This work depends on research already under way. These research tasks, therefore, aim at augmenting and adapting existing work to NARSTO objectives. (The near-term research activities contribute underpinnings to answering policy questions P-2, P-4, and P-6; they contribute to answering science questions S-2 and S-4)

Strategic Activity 1:

Influence of biogenic VOC's *(Done in concert with the Observations Team)*

Activity Goal: Improve the chemical mechanisms for biogenic VOC's in the air quality models using existing data.

*** *Major Task 1.3:* [1] **Development of Chemical Oxidant Mechanisms.**

***Develop an improved mechanism for isoprene using existing kinetic/mechanistic data and smog chamber data.

**Develop an improved mechanism for the monoterpenes using the existing (although limited) kinetic/mechanistic data and smog chamber data.

---

[1] The priorities that were determined for the tasks during the Boulder Workshop (June 6-8, 1994) are shown before each major task and project. The priorities are: *** (first or highest); ** (second or next); * (third or lowest).

Resources:

Year	95	96	97
$ (1,000's)	200	200	200

Strategic Activity 2:

Chemistry of anthropogenic VOC's *(Done in concert with the Observations Team)*

Activity Goal: Improve the chemical mechanisms for anthropogenic VOC's in the air quality models using existing data.

****Major Task 2.2:* **Smog Chamber/Atmospheric Observations Research.**

***Obtain smog chamber data for testing chemical oxidant mechanisms for ethanol, methyl tertiary butyl ether (MTBE) and ethyl tertiary butyl ether (ETBE).

****Major Task 2.3:* **Development of Chemical Oxidant Mechanisms.**

***Expand the VOC chemistry included in existing mechanisms so the mechanisms can be used for diagnostics of current air quality model predictions.

***Develop an improved mechanism for the reaction of alkenes with O_3 and OH radicals.

Resources:

Year	95	96	97
$ (1,000's)	500	100	100

Strategic Activity 3:

Vertical mixing and transport processes *(Done in concert with the Observations Team)*

Activity Goal: Develop the process-level information that is necessary to advance our understanding of the individual vertical mixing, transport and boundary processes important to the regional and urban meteorological influence on photochemical production. Develop parameterizations that will result in improved linkages among meteorology, emissions and chemical transport processes. This information is fundamental to development and/or improvement of the modules in the air quality models.

*** *Major Task 3.1:* **Meteorology: Transport and Mixing.**

***Develop improved parameterizations of soil moisture and surface/canopy heat flux exchange for the meteorological models.

***Evaluate and improve parameterizations of the planetary boundary layer used currently in meteorological models.

*Update air quality model modules of air-surface exchange (dry deposition) to reduce inconsistencies with the most recent observations, particularly for ozone, nitric acid and particles.

***Major Task 3.3:* **Enhance Coupling of Met.-Chem.- and Emissions**

Incorporate new, high-resolution land-use information consistently into models especially biogenic emissions and meteorological models.

Resources:

Year	95	96	97
$ (1,000's)	200	200	100

Strategic Activity 5:

Fine-scale phenomena *(Done in concert with the Observations Team)*

Activity Goal: Develop new modules for incorporation into the air quality models that can account for sub-grid effects in current models and more accurately describe the coupled interactions between chemistry and meteorology at fine temporal and spatial scales.

****Major Task 5.1:* **Process Parameterization/Module Development**

***Develop an advanced plume-in-grid capability for regional and urban air quality models for incorporation into current chemical transport models.

Resources:

Year	95	96	97
$ (1,000's)	150	150	0

Strategic Activity 6: Development of modeling systems

Activity Goal: Incorporate the improvements in process-level understanding into the emissions-based air quality models (model modules). Incorporate improvements in model numerics and infrastructure to provide tools for more insightful model evaluation and to allow easier and more appropriate model applications and interpretations of results.

*** *Major Task 6.1:* **Model system/Numerics Improvements**

***Upgrade the model codes and chemical solvers to be able to easily accept expanded chemical mechanisms of isoprene chemistry and expanded VOC species.

*** *Major Task 6.2:* **Coupling Across System Elements**

***Develop a multi-level air quality model nesting capability that is dynamically consistent with new multi-level nesting capabilities of the meteorological models.

***Introduce improved planetary boundary layer parameterizations into operational meteorological models, and where appropriate, make certain that turbulent mixing processes are represented in a similar way in chemical transport models.

***Upgrade and update the detailed chemical species lists for process and combustion emissions to support expanded species lists for enhanced chemical mechanisms.

*Incorporate improved soil moisture modules/parameterizations into the operational meteorological models and upgrade links with biogenic emissions models.

Resources:

Year	95	96	97
$ (1,000's)	200	200	200

Strategic Activity 7:

Evaluation, corroboration and diagnosis *(Done in concert with the Observations and Emissions Teams)*

Activity Goal: Determine the strengths and weaknesses of the emissions-based models and quantify their uncertainty relative to applications questions. Help characterize our level of understanding of the photochemical processes. Provide guidance to efficiently target resources to the most critical monitoring methods and network and field study design issues.

*** *Major Task 7.1:* **Application of Diagnostic Tools**

***Compile existing and ongoing sensitivity/uncertainty studies and process pathway analyses; identify major holes to fill and initiate studies to identify point of sensitivity.

*** *Major Task 7.2:* **Diagnostic Comparisons Against Field Data**

***Evaluate improved planetary boundary layer parameterizations in 3-D simulation models using detailed data sets, such as those from SJVAQS/AUSPEX and SOS.

*Collect a varied set of cases for model simulation from available field data periods and form into a data base. Adapt inputs to several advanced models to the data periods and make the advanced models available to the air quality community.

*** *Major Task 7.3:* **Field Study Design and Support**

***Coordinate with Observations Team on aircraft support for measurements of full chemistry aloft and measurements by ozone LIDAR during the 1995 Nashville Intensive to develop a high quality data base for model evaluation. Provide measurement support for a second isoprene measurement site as part of the 1995 Nashville Intensive.

***Coordinate with the Observations Team on field study design work for the Northeast.

***Define chemical species of critical importance to model evaluation from a diagnostic and observational-based model perspective. Communicate findings to methods projects within Observations Team.

Resources:

Year	95	96	97
$ (1,000's)	400	300	200

Strategic Activity 8:

Application of modeling systems *(Done in concert with the Analysis and Assessment, Observations, and Emissions Teams)*

Activity Goal: Provide model analyses for the Assessment Team. Help to define the uncertainty in assessment linkages and answers.

*** *Major Task 8.2:* **Quantification of Uncertainty**

***Characterize/quantify the effects of model uncertainties on predictions of control strategy effectiveness.

*** *Major Task 8.3:* **Advanced Model Assessment**

***Compare results from improved models with those from current model regarding predicted effectiveness of control strategies.

Resources:

Year	95	96	97
$ (1,000's)	300	400	400

Long Term:

Goal: The objective is to define and carry out the basic long-term scientific research required to improve our understanding in critical physical and chemical areas. The aim is to broaden and deepen the foundations of our understanding and achieve fundamental advances that will reduce the uncertainty in air quality model predictions. This research is considered fundamental to development of better answers for the policy and scientific questions of NARSTO. This long-term research also underpins the development of observational-based models. (The long-term research activities contribute underpinnings to answering policy questions P-2, P-4, P-5, and P-6; they contribute to answering science questions S-2, S-3 and S-4)

Strategic Activity 1:

Influence of biogenic VOC's *(Done in concert with the Observations Team)*

Activity Goal: Substantially improve our understanding of the chemical kinetic and mechanistic processes important to the chemistry of biogenic VOC's. Acquire new, more-advanced data on the complex reaction system associated with atmospheric photochemical oxidation processes both in the laboratory and in the atmosphere. These data are to support the development and evaluation of chemical mechanisms used in the air quality models. The desired outcome is, first, acquisition of the elementary kinetic and mechanistic data needed to construct reliable chemical transformation modules; second, acquisition of a comprehensive database of smog chamber and atmospheric observations that can be used to evaluate chemical reaction mechanisms; and, third, reliable chemical transformation modules that can be used in the next generation of air quality models.

*** *Major Task 1.1:* **Chemical Kinetic and Mechanistic Studies**

***Obtain further kinetic/mechanistic data for isoprene, the monoterpenes, and other biogenics (such as the oxygenates).

*** *Major Task 1.2:* **Smog Chamber/Atmospheric Observations Research**

***Acquire a more extensive smog chamber data base for isoprene and the monoterpenes.

*** *Major Task 1.3:* **Development of Chemical Oxidant Mechanisms**

***Develop improved mechanisms for isoprene, the monoterpenes and other biogenics (including the oxygenates) using the newly obtained kinetic/mechanistic data and smog chamber data.

**Test mechanisms developed for isoprene and the other biogenics against ambient observations.

Resources:

Year	95	96	97	98	99	00
$ (1,000's)	300	250	350	400	300	200

Strategic Activity 2:

Chemistry of anthropogenic VOC's *(Done in concert with the Observations Team)*

Activity Goal: Substantially improve our understanding of the chemical kinetic and mechanistic processes important to the chemistry of anthropogenic VOC's. Acquire new, more-advanced data on the complex reaction system associated with atmospheric photochemical oxidation processes both in the laboratory and in the atmosphere. These data are to support the development and evaluation of chemical mechanisms used in the air quality models. The desired outcome is, first, acquisition of the elementary kinetic and mechanistic data needed to construct reliable chemical transformation modules; second, acquisition of a comprehensive database of smog chamber and atmospheric observations that can be used to evaluate chemical reaction mechanisms; and, third, reliable chemical transformation modules that can be used in the next generation of air quality models.

*** *Major Task 2.1:* **Chemical Kinetic and Mechanistic Studies**

***Using new, innovative experimental approaches and analytical methodology, elucidate the products formed during the atmospheric oxidation of aromatic VOC's.

***Augment the laboratory kinetic/mechanistic studies by employing computational chemistry techniques to estimate degradation products for those gas-phase reactions that are difficult to study experimentally.

***Conduct further studies to elucidate the mechanism of alkene reactions with OH, NO_3, and O_3.

**Obtain reaction rates and identify products formed in reactions involving higher molecular weight organic peroxy radicals, including a better elucidation of nitrogen reservoirs.

**Elucidate the kinetics and mechanism of the reaction of OH radicals with the higher molecular weight alkanes.

**Acquire kinetic and mechanistic data needed for developing mechanisms describing the atmospheric reactions of alcohols, ethers, glycols, and components of reformulated gasoline.

**Obtain quantum yields, absorption cross sections, and reaction products for oxygenates (other than formaldehyde) that are emitted into the atmosphere as well as produced during the oxidation of other VOC's.

Resources:

Year	95	96	97	98	99	00
$ (1,000's)	900	1,400	1,400	1,200	1,000	800

*** *Major Task 2.2:* **Smog Chamber/Atmospheric Observations Research**

***Acquire data to better characterize chamber wall effects and other artifacts that are presently limiting the usefulness of smog chamber data for testing reaction mechanisms.

***Design innovative smog chambers that are well characterized and sufficiently artifact free to warrant studies at low VOC/NO_x ratios and low precursor concentrations.

***Conduct experimental studies in clean, well characterized smog chambers using precursor reactant mixtures and concentrations that are representative of those found in urban and regional/rural atmospheres. Use improved measurement techniques that will allow better carbon and nitrogen balances and acquire the data under nighttime as well as daytime conditions.

**Obtain smog chamber data for VOC species not previously studied that, by virtue of their high reactivity and/or high ambient levels, are expected to contribute significantly to urban oxidant formation.

*Using advanced *in situ* analytical devices, acquire atmospheric observations designed to elucidate or evaluate particular processes in oxidant mechanisms, including those occurring at night and in upper air and aged urban air masses. Acquire field data that can be used to test emission-based and observation-based models.

Resources:

Year	95	96	97	98	99	00
$ (1,000's)	600	1,700	1,400	1,400	800	800

*** *Major Task 2.3:* **Development of Chemical Oxidant Mechanisms**

***Develop new methods for representing generalized reaction schemes so that more information on VOC reactants and products can be included in the mechanisms used in air quality models.

***Develop state-of-the-science chemical transformation modules for use in emission-based models that incorporate all the kinetic and mechanistic data obtained in laboratory and computational chemistry studies. Evaluate the transformation modules against the entire data base of smog chamber experiments.

***Characterize the effect of uncertainties in our understanding and representation of chemical processes on oxidant predictions obtained with chemical transformation modules.

**Develop numerical algorithms that more efficiently solve the differential equations for chemical processes.

**Characterize the ability of chemical mechanisms to be extrapolated from the smog chamber to the ambient.

Resources:

Year	95	96	97	98	99	00
$ (1,000's)	300	500	600	700	500	400

Strategic Activity 3:

Vertical mixing and transport processes *(Done in concert with the Observations Team)*

Activity Goal: Develop more accurate understanding and parameterizations of the individual vertical mixing, transport, boundary and large-scale meteorological processes that have an important influence on regional- and urban-scale photochemical production. Develop means to more accurately represent the meteorological processes in mathematical models. Improve the linkages among meteorology, emissions and chemical transport models. Provide new developments to improve the meteorological modules/drivers in the air quality modeling systems.

*** *Major Task 3.1:* **Transport and Mixing**

Major Task Goal: Develop a more accurate description of the vertical mixing and transport occurring in the atmosphere and formulate for use in the meteorological models "driving" the chemical transport models. Requires advanced measurements of the physical processes occurring in the atmosphere and large-scale computer studies to define techniques to describe the processes. The desired outcome is more accurate meteorological modules that can be used in the evolving generation of air quality models.

***Develop improved algorithms and explanatory descriptions of vertical mixing and transport, including higher order turbulence closure schemes, to describe mixing throughout the planetary boundary layer, for daytime and nocturnal conditions, to improve modeling of the lower tropospheric vertical stability above the planetary boundary layer, and for use in the meteorological models "driving" the chemical transport models.

***Develop more advanced parameterizations of soil moisture and surface/canopy heat-flux exchange and incorporate them into modules for the meteorological models.

***Develop and incorporate explicit modeling of clouds and develop a smooth transition to scales requiring (convective) parameterizations of clouds in the meteorological models.

*Update air quality model modules and monitoring methods that currently predict air-surface exchange (dry deposition) using resistance analogues to reduce inconsistencies with the most recent observations.

*Explore the utility of variable grid or adaptive grid systems for the meteorological and air chemistry models.

*Develop approaches and algorithms for dynamic air-surface exchange (dynamic boundary conditions) beyond the current resistance analogue that acts as a sink. This would more realistically simulate the physical processes occurring and allow emissions fluxes as well as deposition fluxes to be consistently, dynamically modeled.

Resources:

Year	95	96	97	98	99	00
$ (1,000's)	200	400	600	600	600	600

*** *Major Task 3.2:* **Data Assimilation/Large-Scale Interactions**

Major Task Goal: Develop new techniques for assimilating key parameters into the meteorological models as the models compute the dynamics of the atmosphere, termed 4-dimensional data assimilation (4-DDA) and to incorporate these techniques into the models. It is imperative that the meteorological simulation of past conditions be as accurate as possible across all variables. Current prognostic models still have an unacceptable degree of error. The desired outcome is modules and methods for incorporation in the models that produce a more reliable representation of the physical-chemical processes. Develop improved descriptions of radiative transfer, especially its effect on actinic flux. Develop procedures to incorporate global-scale, boundary influences on the regional photochemistry. The desired outcomes are new or improved modules and new procedures for use in the evolving generation of air quality models.

***Develop techniques to incorporate remote sensing information from satellites on cloud and soil moisture, plus others, into the predictions of the prognostic meteorological models.

***Develop techniques to incorporate the higher resolution sounding information and NEXRAD radar data into the prognostic meteorological models through 4-dimensional data assimilation. The use of other data would also be explored.

**Developed improved descriptions of the radiative transfer functions that account better for cloud cover and for such variables as the global ozone column.

**Develop approaches to incorporate stratospheric exchange at the upper boundary of the regional air quality models. Develop methods to link with the stratosphere to appropriately incorporate global boundary conditions effects in the regional models.

*Characterize the accuracy of the new sounding data collected by the new remote sensing techniques and compare to current data used for 4-dimensional data assimilation.

Resources:

Year	95	96	97	98	99	00
$ (1,000's)	450	450	450	450	450	450

*** *Major Task 3.3:* **Enhanced Coupling of Meteorology-Chemistry-Emissions**

Major Task Goal: Develop new techniques for coupling meteorology and emissions that more accurately represent the physical processes occurring. Parameterize these techniques into algorithms or modules to be used in the meteorological and emissions models. The desired outcome is more accurate mathematical descriptions of the processes affecting emissions fluxes for use in new emissions models.

***Incorporate new, high-resolution land use information in the meteorological models. Update the interface with the boundary layer modules. Update the interface with air-surface exchange modules.

***Incorporate new, high-resolution land use information consistently into biogenic emissions processors and the meteorological models.

Coordinate development of an improved canopy model for more accurate estimates of heat, momentum and moisture for the meteorological model and adapt it for use with emissions models. Make the descriptions in all models consistent. This will result in improved estimates of dry deposition, biogenic emissions and mixing heights.

Resources:

Year	95	96	97	98	99	00
\$ (1,000's)	175	175	175	175	175	175

Strategic Activity 4: Heterogeneous processes *(Done in concert with the Observations Team)*

Activity Goal: To elucidate the role heterogeneous processes play in the transformation and deposition of atmospheric species that are important to oxidant formation.

*** *Major Task 4.1:* **Transformation and Removal in the Aqueous Phase**

Major Task Goal: Determine the aqueous properties, such as solubility and reaction kinetics, that control the transformation and removal of reactive pollutants in cloud, fog and on surface water.

**Determine the aqueous solubilities of oxygenated organics so their lifetimes against dry and wet deposition may be assessed.

***Investigate the kinetics of aqueous-phase reactions involving oxygenated organics, including their photolysis and reaction with O_3.

***Determine the extent of uptake of free radicals, oxygenated organics and nitrogen compounds in cloudwater, fog, and hygroscopic aerosols.

** *Major Task 4.2:* **Transformation and Removal on Aerosols and the Earth's Surface**

Major Task Goal: Investigate the surface reactions and deposition resistances that are important for the transformation and removal of gaseous pollutants on aerosols and at the Earth's surface.

**Investigate heterogeneous reactions pathways of nitrogen compound precursors responsible for the loss of NO_X and formation of nitrous acid.

**Determine surface deposition resistances for important trace species (e.g., oxidants, free radicals and their precursors) on typical terrestrial surfaces under controlled conditions.

*** *Major Task 4.3:* **Development of Aqueous-Phase Oxidant Mechanisms**

Major Task Goal: Develop mechanisms describing reactions in hygroscopic aerosols and cloudwater and merge these mechanisms with the gas-phase chemical oxidant mechanisms developed under Major Task 2.3.

***Develop an aqueous-phase chemical mechanism for hygroscopic aerosols and cloudwater.

***Integrate the aqueous-phase mechanisms with the efficient solvers and gas-phase chemical oxidant mechanisms developed under Major Task 2.3.

Resources:

Year	95	96	97	98	99	00
$ (1,000's)	500	500	500	500	500	500

Strategic Activity 5:

Fine-scale phenomena *(Done in concert with the Observations Team)*

Activity Goal: Develop innovative techniques that provide a more accurate description of the fast photochemistry occurring at the turbulence time scales. Develop new modules for incorporation into the air quality models that can account for sub-grid effects in current models and more accurately describe the coupled interactions between chemistry and meteorology at fine temporal and spatial scales.

*** *Major Task 5.1:* **Parameterization of Sub-grid Processes into Modules**

Major Task Goal: Develop new modules that can account for sub-grid effects in current models and more accurately describe the coupled interactions between chemistry and meteorology at fine temporal and spatial scales. Incorporate the modules in the evolving generation of air quality models, either in advanced operational models or in science reference models for benching the operational models. The desired outcome is a significant reduction in the uncertainty of the model predictions are an enhanced understanding of the importance of that uncertainty to model predictions.

***Develop improved understanding of plume chemistry within strong NO_X plumes and the interaction with the surrounding environment. Incorporate the new understanding into modules of plume-in-grid behavior for use in the air quality models.

*** *Major Task 5.2:* **Identification and Study of Sub-grid Processes**

Major Task Goal: Develop innovative techniques that provide a more accurate description of the fast photochemistry occurring at the turbulence time scales. Develop a computational, scientific benchmark of the detailed process interactions to assess the impact of sub-grid scale processes on the predictions of the urban and regional models. This work will address a key area of uncertainty in current model design and a major objective will be to better understand the subgrid-scale phenomena and quantify how the effects of processes that are not able to be described in operational models may bound predictions from the air quality models.

***Use explicit cloud modeling and/or Large Eddy Simulation (LES) to better understand cloud parameterizations and cloud dynamics (transport and venting), microphysics, aerosols (scavenging and nucleation), aqueous and heterogeneous chemistry, and radiative transfer.

*Develop an understanding of the interaction of turbulence and chemistry. Conduct Large Eddy Simulation (LES) modeling studies at small temporal and spatial scales to develop an understanding of the importance of simulating turbulent versus average behavior on chemical predictions of the air quality models.

*Develop approaches, such as a particle approach or mini-parcel approach, capable of describing the impact of subgrid-scale inhomogeneous chemistry.

Resources:

Year	95	96	97	98	99	00
$ (1,000's)	300	500	500	500	500	500
$ (1,000's)	If Intense:	800	800	700	500	500

Intense Means: extensive LES simulations are deemed essential

Strategic Activity 6:

Development of modeling systems

Activity Goal: Incorporate the improvements in process-level understanding into the emissions-based air quality models (model modules). Incorporate improvements in model infrastructure to provide tools for more insightful model evaluation and to allow easier and more appropriate model applications and interpretations of results.

***Major Task 6.1:* **Model System/Numerical Improvements**

**Upgrade the model codes and remove internal limits to be able to accept expanded isoprene chemistry and unlumped VOC's.

**Incorporate new chemical solvers and solver compilers that are flexible and modular.

**Incorporate sensitivity and uncertainty analyses into the model codes for easy use and develop flexible model versions for sensitivity testing.

**Develop a multi-level model nesting capability.

**Introduce new, third generation air quality models stemming from research supported by high performance computing programs into the NARSTO modeling process.

** *Major Task 6.2:* **Enhanced Coupling Across System Elements**

**Incorporate equivalent planetary boundary layer parameterizations in the meteorology and chemical transport models.

**Incorporate equivalent soil moisture, surface heat flux and land use characterizations into the meteorological and biogenic and evaporative emissions models.

**Upgrade and update the chemical species lists associated with process and combustion emissions in the emissions models to support expanded species lists for enhanced chemical mechanisms.

**Develop advanced emissions processing that is capable of dynamically matching scales with the meteorological and chemical transport models.

Resources:

Year	95	96	97	98	99	00
$ (1,000's)	200	300	400	600	600	400

Strategic Activity 7:

Model evaluation, corroboration and diagnosis *(Done in concert with the Observations and Emissions Teams)*

Activity Goal: Determine the strengths and weaknesses of the emissions-based and observations-based models relative to applications questions. Help to characterize our level of understanding of the photochemical processes. Help to efficiently target resources to the most critical monitoring methods and network and field study design issues.

*** *Major Task 7.1:* **Develop and Apply Diagnostic Tools**

Major Task Goal: Develop and apply diagnostics tools including methods for sensitivity, uncertainty and process pathway analysis. The objective is understand what is driving model results, identify points of sensitivity, and ultimately to prioritize further research aimed at improving descriptive and predictive capabilities. Examples of sensitivity studies that would be valuable include:

***Sensitivity of modeled concentrations to model design issues, such as vertical and horizontal resolution or the uncertainty in the formulations and/or parameterizations of the chemical mechanisms used in the operational models.

***Sensitivity of modeled concentrations to input uncertainties, such as emissions, to meteorology, such as mixing height, and to boundary conditions, such as air-surface exchange.

***Study of the pathways involved in ozone production and the species interactions as a function of grid size, urban/rural emissions and meteorology.

Resources:

Year	95	96	97	98	99	00
$ (1,000's)	Near	100	200	200	200	200

*** *Major Task 7.2:* **Diagnostic Model/Module Comparisons Against Field Data**

Major Task Goal: Produce structured protocols and evaluations of the emissions-based models or modules against field data. Provide interpretations of the evaluation results characterizing strengths and weaknesses with respect to emissions-based model applications. Examine the influence of model and field study design on the evaluation results. Develop interpretations that will provide the basis and directions for further model and module development. The desired outcome is a judgment on the quality of the models' ability to represent the physical-chemical processes underlying photochemical production and a translation into a judgments on the strengths and weaknesses of operational models relative to application questions.

***Evaluate UAM on 1992 Atlanta Intensive data from the Southern Oxidant Study, on the 1989 SCAQS data and other high quality, multi-species urban data bases.

***Continue to evaluate ROM and RADM on the special chemistry data at the surface and aloft from the Eulerian Model Evaluation Field Study data from 1988 and 1990.

***Evaluate ROM, RADM and NOM on the special chemistry data at the surface and aloft from the Southern Oxidant Study field studies of 1990 and 1992.

***Prepare a protocol for and carry out an evaluation of major urban and regional models on the Southern Oxidant Study 1995 Nashville Intensive data base.

***Prepare a protocol for and carry out an evaluation of major urban and regional models on new field study data collected under the NARSTO Program.

Resources:

Year	95	96	97	98	99	00
$ (1,000's)	Near	100	200	200	200	200
$ (1,000's)	If Intense:	200	500	500	500	500

Intense Means: formal evaluation project using large, new field data sets

*** *Major Task 7.3:* **Field Study Design and Support**

Major Task Goal: Develop recommendations for field study designs and field study support that will particularly improve the diagnostic quality of model evaluation efforts and enhance the ability to reduce uncertainties. The recommendations will include measurement programs and/or strategies, network design, needed advancements in situ analytical capabilities, and needed advancements in monitoring strategies. Develop recommendations for field study and monitoring designs in support of the other NARSTO teams' objectives.

***Define chemical species of critical importance to model evaluation from a diagnostic and observational-based model perspective. Communicate findings to methods projects within Observations Team.

***Define field study sequences that will support model evaluation needs, in collaboration with Observations Team. Use emissions-based models to help to design future NARSTO field studies.

***Define studies that can help reduce emissions uncertainty with the aid of the emissions-based models in collaboration with the Emissions Team. Among the many examples, a soil NO_X verification study is needed.

Resources:

Year	95	96	97	98	99	00
$ (1,000's)	100	100	100	100	100	100
$ (1,000's)	If Intense:	300	300	300	300	300

Intense Means: extensive design work for major field or emissions uncertainty study

Strategic Activity 8:

Application of modeling systems *(Done in concert with the Analysis and Assessment, Observations, and Emissions Teams)*

Activity Goal: Provide model analyses for the Assessment Team. Help to define the uncertainty in assessment linkages and answers.

** *Major Task 8.1:* **Policy Study Design Analysis**

**Develop and demonstrate modeling techniques and protocols for assessing effects of potential, new ambient air quality standards for ozone.

*** *Major Task 8.2:* **Policy-Related Uncertainty Analysis**

***Quantify the effects of model input uncertainties on control strategy results. Develop effective means of communicating the quantified results.

** *Major Task 8.3:* **Model Intercomparisons**

**Assess the differences in model response for various air quality models as a function of VOC and/or NO_X emissions reduction.

**Assess the differences in model characterization of expected airshed response to emissions reductions for various air quality models as compared to tested observation-based methods.

Resources:

Year	95	96	97	98	99	00
$ (1,000's)	300	300	300	500	500	500

B4. EMISSIONS

The scientific approach is an attempt to achieve the emissions research objectives stated earlier in an ambitious ten-year timeframe. The strategic activities are not in priority order as a partial implementation cannot achieve the objectives; it will take the complete package of projects. Thus all major tasks are assigned the highest priority (***). The cost estimates are strictly an estimate, and **do include** on-going work.

Strategic Activity 1:

On-road Mobile Source Emission Model Development *(Done in concert with the Modeling Team)*

Goals: Develop on-road emission models that are capable of representing separate modes of vehicle operation and the resultant modal emissions for specific roadway sections and parking areas *(contributes to addressing Science Concerns 3a, 4c, and 5).*

Major Tasks: ***Survey mobile source emission inventory approaches on state and national levels. Determine if on-going work can be applied to other geographic areas. *(near-term)*

***Evaluate the uncertainty of mobile source emissions inventories using present and future techniques with an integrated assessment of datasets used in developing emission and activity factors. Use this information to prioritize further research. *(on-going)*

***Establish a framework for a research-grade mobile source emission model that provides estimates of emissions resolved temporally and spatially. The model will need independent emission factor and activity modules for various aspects of vehicular emissions (*e.g.*, fuel type, closed- and open-loop operation, cold and hot starts, evaporative losses, road grade, air conditioner use, age, tampering, driver behavior). Develop and test the approach for one city. After testing and validation for one city, expand to other cities in North America for more complete module development. *(near-term)*

***Develop modal emission factors (exhaust and evaporative) for automobiles and light-duty trucks for all aspects of vehicle operation, vehicle condition, fuel parameters (*e.g.*, reformulated gasoline, oxygenated fuels), and driver behavior in the laboratory and under on-road conditions. *(near-term)*

***Develop temporally and spatially resolved activity data for automobiles and light-duty trucks with improved travel demand models. The models must provide estimates of vehicle activity for each modal emission factor. *(near-term)*

***Develop modal emission factors for medium- and heavy-duty trucks in the laboratory and under on-road conditions. Heavy-duty truck research would be *near-term* because of their large contribution to NO_X emissions, while medium-duty truck work would be *long-term*.

***Develop temporally and spatially resolved modal activity data (*e.g.*, idling time by season, load operations due to weight and grade) for heavy- *(near-term)* and medium-duty trucks *(long-term)*.

***Using a variety of on-road studies of in-use vehicles, determine how much vehicle activity is contributed by medium-, high-, and super-emitters and test how implementation of inspection and maintenance programs will affect their emissions. Investigate the variability in emission rates. *(near-term)*

***Evaluate the "real world" effect of traffic control measures (TCMs) on reducing emissions for incorporation into prediction models. *(long-term)*

***Analyze existing NMOC and NO_X (*e.g.*, NO_2, nitrous acid) speciation data to determine how well it represents emissions for important modes of vehicle operation. Develop new speciation data for "real world" emissions where existing data has gaps. This work can be integrated with other programs. *(near-term)*

Near-Term Outputs:

- Provide a catalog of on-going mobile source emission-related research. (10/95)
- Provide source category uncertainties and a prioritized list for subsequent research areas. (4/96)
- Provide a peer-reviewed framework for a research-grade mobile source emission model. (4/96)

Resource Needs ($M)

FY	95	96	97	98	99	00	01	02	03	04
1a	0.3									

1b	0.3			0.3			0.3			0.3
1c	1.5	2.2	1.5	0.7	0.4	0.2	0.2	0.2	0.2	
1d	2.0	2.0	1.5	1.5	1.0	1.0	0.5	0.5	0.5	0.5
1e	1.5	1.5	2.0	1.5	1.0	1.0	0.5	0.5	0.5	0.5
1f	0.4	0.5	0.8	0.5	0.4	0.2				
1g	0.4	0.5	0.8	0.5	0.3	0.3	0.5	0.3	0.5	0.3
1h	1.0	1.5	1.0	0.5	0.5	0.5		0.8		0.8
1i				0.5	0.3	0.3	0.3			
1j	0.2	0.4	0.4	0.2	0.5	0.5	0.2			
Total	7.6	8.6	8.0	6.2	4.4	4.0	2.5	2.3	1.7	2.4

Strategic Activity 2:

Emission Inventories for Stationary Area Sources and Point Sources *(Done in concert with the Modeling Team)*

Goals: Develop new stationary area source and point source models or methodologies that are capable of estimating emission from all significant sources *(contributes to addressing Science Concerns 3a, 4c, and 5).*

Major Tasks: *****Improvement of Data Analysis Methodologies**: Develop improved statistical methods for the purpose of emission estimation. Specific areas of concern include: 1) identification of the distribution of the data and the appropriate method of combining these data with parameters having other distributions; 2) treatment of data which is recorded as being below the level of quantification or below the level of detection (censored data); and 3) determination of the minimum number of measurements required for regressions and analysis of variance techniques. *(near-term)*

*****Assimilation of Compliance Data**: Title 70 of CFR 40 requires that owners or operators of all major sources in the United States obtain a permit. The regulation requires that permit facilities submit emission data to the regulatory agencies which proves that they have complied with all requirements and upon which they will pay the appropriate emission fees. In addition, the proposed Enhanced Monitoring rules of the U.S. EPA will require all sources which emit 30% or more of the amount which constitutes a major source to continuously monitor these emissions. The goal of this task is to develop a framework which will permit incorporation of these data into a national emissions inventory. This is a very near term project as implementation of 70 CFR 40 is scheduled for November 1995. *(near-term)*

***Criteria for Development of Emission Factors**: Establish a comprehensive guideline which can be used for the development of emission factors. The guideline will incorporate experimental design, quality assurance, and data criteria by which one can judge the validity of emission factors. *(near-term)*

***Unaccounted and New Sources:** Recent reviews have indicated that there are a large number of emission sources which are not included in emission inventories for a variety of reasons. The goal of this task is to identify such sources and estimate their emissions. The program is envisioned as a continuing one to permit tracking of new and changing sources. *(on-going)*

***Stationary Area Source Data Inventory:** Identify and implement alternate and surrogate sources of data which can be used for stationary area source emission inventory development. Such data sources could include such diverse sources as trade organizations, market surveys, point of sale scanning data, local fuel (gas) distribution systems, etc. *(near-term)*

***Stationary Area Source Data Surveys and Models:** The goal of this task is to conduct surveys for those sources where data is not directly available. The data from the surveys will be analyzed and incorporated in models to permit evaluating under differing econometric conditions. *(on-going)*

***Semi-Mechanistic Emission Models:** Develop semi-mechanistic emission models for a range of industries. This novel approach to emission factor determination is required to account for and anticipate technological improvements, changes of work practices and economics. The models should be dynamic and flexible, and incorporate our understanding of mechanisms that are important in determining emission factors. For example, knowledge of NO_X formation can be used to quantify in detail NO_X emissions from different types of industrial furnaces with and without varying degrees of NO_X control. The methodologies would be applied to 10 to 15 industries per year. Of the order of 40 professionals will be required. *(on-going)*

Near-Term Outputs:

- Provide guidelines for the analysis of data to be used in preparing emission factors, emission models, and emission estimates. (10/97)
- Provide a comprehensive guideline and criteria for use by industry and government in the development of emission factors. (10/97)

Resource Needs ($M)

FY	95	96	97	98	99	00	01	02	03	04
2a	0.2	0.2								
2b	0.3	0.2								
2c	0.2	0.2								
2d	0.4	0.4	0.4	0.4	0.2	0.1	0.1	0.1	0.1	0.1
2e	0.2	0.2	0.2	0.4						
2f	0.4	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
2g	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Total	5.7	5.6	4.8	5.0	4.4	4.3	4.3	4.3	4.3	4.3

Strategic Activity 3:

Emission Estimates for Nonroad Mobile Sources *(Done in concert with the Modeling Team)*

Goals: Develop new models that are capable of estimating emissions from a wide variety of nonroad engines in use. Develop new stationary source models or methodologies that are capable of estimating emission from all significant sources *(contributes to addressing Science Concerns 3a, 4c, and 5)*.

Major Tasks: ***Evaluate uncertainty of nonroad source emission estimates with an integrated assessment of datasets used in developing emission and activity factors. Use this information to prioritize research on specific source categories. Priority is expected to be placed on pleasure water craft and lawn and garden equipment since they appear to be the biggest nonroad contributors. *(near-term)*

***Develop improved methodologies or models for nonroad mobile sources. The models will need independent emission factor and activity modules for various aspects of emissions. *(near-term)*

***Develop modal emission factors and temporally and spatially resolved activity data for high priority source categories. Develop NMOC and NO_X speciation profiles. *(long-term)*

Near-Term Outputs:

- Provide source category uncertainties and a prioritized list for subsequent research areas, as well as a catalog of on-going research. (4/96)
- Provide a peer-reviewed framework for a research-grade nonroad area source emission model. (10/97)

Resource Needs ($M)

FY	95	96	97	98	99	00	01	02	03	04
3a	0.5	0.5	0.1							
3b	0.5	0.5	0.5	0.5	1.0	1.0	0.5	0.5	0.5	0.5
3c			0.5	1.0	1.5	1.0	1.0	0.7	0.3	0.3
Total	1.0	1.0	1.1	1.5	2.5	2.0	1.5	1.2	0.8	0.8

Strategic Activity 4:

Natural Emissions Modeling *(Done in concert with the Observations and Modeling Teams)*

Goals: Develop natural source emission models that are capable of estimating NMOC (*e.g.*, isoprene, terpene, alcohol, aldehyde, other oxygenated) emissions over the seasonal cycle including (if applicable) leaf growth, maturation, and recession. Develop models of soil NO_X emissions due to natural processes and agricultural operations *(contributes to addressing Science Concerns 3a, 4c,g and 5).*

Major Tasks: *****Vegetative NMOC Emissions**

Conduct field and laboratory studies of NMOC emissions from agricultural, urban, and natural landscapes. The purpose of these studies will be to develop and improve NMOC emission estimates and assess their accuracy. Model components that require investigation include emission factors, emission algorithms, source distributions, and driving variables (*e.g.*, light, temperature). *(on-going)*

***__Natural NO_X Emissions:__ Conduct field and laboratory studies of NO_X emissions from agricultural, urban, and natural soils and from lightning. The purpose of these studies will be to develop and improve NO_X emission estimates and assess their accuracy. Model components that require investigation include emission factors, emission algorithms, source distributions, and driving variables (*e.g.*, fertilizer application rates, soil type, soil moisture, temperature, chemistry, vegetation cover). *(on-going)*

***__Other Natural NMOC Emissions:__ Screening studies are required to assess the importance of NMOC emissions from disturbed vegetation (*e.g.*, lawn mowing, timber and crop harvesting, biomass burning), microbial decomposition (*e.g.*, landfills), and geogenic sources. Emission models will be developed and evaluated for those sources determined to be significant. *(on-going)*

***__Long-Term Changes in Natural Emissions:__ Changes in climate or land use may have a significant effect on natural NMOC and NO_X emissions. Research is needed to assess potential changes and their impact on emissions. *(on-going)*

Near-Term Outputs:

- Provide a catalog of on-going natural source emission-related research. (4/95)
- Provide a peer-reviewed framework for a research-grade natural source emission model. (10/95)

Resource Needs ($M)

FY	95	96	97	98	99	00	01	02	03	04
4a	1.0	1.0	1.0	1.0	1.0	0.8	0.8	0.6	0.6	0.4
4b	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.2	0.2	0.1
4c	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1		
4d	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2
Total	1.7	1.7	1.7	1.7	1.7	1.4	1.4	1.1	1.0	0.7

Strategic Activity 5:

Independent Assessment of Emission Inventories *(Done in concert with the Observations and Modeling Teams)*

Goals: Corroborate emission inventories with independent estimates of emissions and evaluate the effectiveness of reformulated gasoline, enhanced inspection and maintenance, and other control programs to verify emission model estimates *(contributes to addressing Science Concerns 3a, 4c,f and 5).*

Major Tasks: ***Analyze existing data to assess current emission inventories in urban areas of North America. Compare a variety of approaches, including tunnel and remote sensing studies, ambient ratio comparisons, and receptor modeling. Conduct field studies and sensitivity analyses to determine to what extent local determination of source fingerprints improves source reconciliation accuracy. *(near-term)*

***Evaluate and improve assessment techniques. *(near-term)*

***Conduct field studies before and after implementation of major control programs (*e.g.*, reformulated gasoline, enhanced inspection and maintenance) in different areas of North America in order to compare the observed effect on air quality with emission inventory projections. *(near-term)*

***Design and execute field studies to evaluate the accuracy of stationary source NMOC emission inventories. Possible approaches include receptor modeling, "tracers of opportunity", upwind and downwind measurements, and other techniques that rely on ambient data. Develop and test the approach for one city. After testing and validation for one city, expand to other cities with different stationary source characteristics. *(near-term)*

***Conduct periodic tunnel and street canyon studies to reconcile mobile source emission inventories and to track progress. Use tunnels or street canyons representing different mixes of fleet and driving conditions. *(long-term)*

***Analyze the results from the studies described above to set priorities for further work to reduce the most important uncertainties in emission inventories. *(long-term)*

***Upgrade the hydrocarbon channel and develop NO_X and temperature channels for remote sensing devices used for on-road monitoring of mobile source emissions. Validate the remote sensing devices under a variety of vehicle operating conditions. *(near-term)*

***Determine the source(s) of the large amount of uninventoried whole gasoline found in ambient air. Perform a mass balance on all sources of gasoline in Los Angles, attempting to account for losses during production, storage, distribution, marketing, and combustion. Consider adding tracers at different points along the fuel cycle to verify the mass balance results. *(near-term)*

***Quantify uncertainty in all emissions estimates. *(on-going)*

Near-Term Outputs:

- Provide a peer-reviewed assessment of current emission inventories and a prioritized list for subsequent research areas, as well as a catalog of on-going research. (4/96)

Resource Needs ($M)

FY	95	96	97	98	99	00	01	02	03	04
5a	0.3	0.3								
5b	0.2	0.2								
5c	3.0	3.0	0.5	0.5	3.0	3.0	0.5	0.5		
5d	0.5	1.0	2.0	1.0	1.0	1.0	1.0			
5e	0.3	1.5	0.3	1.5	0.3	1.5	0.3	1.5	0.3	1.5
5f	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
5g	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
5h*										
5i	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
5j		1.5	0.5	0.1	0.5	1.0	1.0	0.5	0.1	
Total	4.8	8.0	3.8	3.6	5.3	7.0	3.3	3.0	0.9	2.0

*Being performed by Observations Team.

Strategic Activity 6:

Emission Projections *(Done in concert with the Modeling Team)*

Goals: Project the effects of future activity and alternative controls on emission estimates *(contributes to addressing Science Concerns 3b, 4c, and 5).*

Major Tasks: ***Develop regional economic models for ozone nonattainment areas, including maintenance and annual forecasts. *(on-going)*

***Maintain existing U.S. EPA forecasting capability for stationary sources. *(on-going)*

***Develop emission control reduction factors for alternative emissions control systems and keep the file updated as new technologies are developed. *(on-going)*

***Develop emission control technology degradation factors for alternative technologies. *(on-going)*

***Develop interfaces for integrating emissions projection models into the MODELS-3 modeling system. *(on-going)*

Near-Term Outputs:

- Provide a catalog of on-going natural source emission-related research. (4/95)
- Provide a peer-reviewed framework for a research-grade natural source emission model. (10/95)

Resource Needs ($M)

FY	95	96	97	98	99	00	01	02	03	04
6a*	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
6b	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
6c	0.5	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
6d	0.5	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
6e	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	1.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4

* Assumes maintenance of existing models for 30 nonattainment areas. A $3.5 M development effort would be required for 380 areas should ozone ambient standard be reduced from 0.12 to 0.08 ppm.

Total Resource Needs ($M)

This estimate **does include** on-going or planned research and in-house activities which will account for approximately **one-third to one-half** of the totals shown below. Thus, on the order of $8-10M per year of new resources (plus the amount not included in the Observations Team budget for Task 5) are required for the first few years of the NARSTO Emissions program, with lesser amounts in later years.

FY	95	96	97	98	99	00	01	02	03	04
1	7.6	8.6	8.0	6.2	4.4	4.0	2.5	2.3	1.7	2.4
2	5.7	5.6	4.8	5.0	4.4	4.3	4.3	4.3	4.3	4.3
3	1.0	1.0	1.1	1.5	2.5	2.0	1.5	1.2	0.8	0.8
4	1.7	1.7	1.7	1.7	1.7	1.4	1.4	1.1	1.0	0.7
5*	4.8	8.0	3.8	3.6	5.3	7.0	3.3	3.0	0.9	2.0
6	1.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Total	22.1	25.3	19.8	18.4	18.7	19.1	13.4	12.3	9.1	10.6

*Co-funded with Observations Team.

APPENDIX C
NARSTO CHARTER

NARSTO CHARTER

The North American Research Strategy for Tropospheric Ozone (NARSTO) vision is that of a focused and coordinated research and development program established for the study of tropospheric ozone concentrations, sources, formation mechanisms and transport phenomena across the North American continent. This continental research program will involve scientists and policy makers from Canada, Mexico and the United States of America.

Whereas,

1) The undersigned public and private institutions desire to plan and implement a comprehensive tropospheric ozone research strategy to identify and resolve questions related to the complex chemical and physical processes affecting the formation, transformation, transport and accumulation of ozone, ozone precursors and smog products in the troposphere over many regions and principal urban centers in North America;

2) The undersigned have performed and/or have sponsored substantial research and development with respect to tropospheric ozone formation, transformation, transport and accumulation;

3) The undersigned possess certain advanced scientific skills, facilities, special equipment, information, computer software, and/or know-how pertaining to the monitoring, modeling, methods, emission inventories, and chemical and meteorological mechanisms related to tropospheric ozone and its precursor compounds, such as nitrogen oxides (NO_X), carbon monoxide (CO) and volatile organic compounds (VOC);

4) The undersigned are interested in the further understanding of ozone in the troposphere and the development of ozone and ozone precursor monitoring, modeling, methods and emissions control technologies and the utilization of these technologies by other private and public entities;

5) The undersigned view their collaboration with the Institutions to develop/evaluate technologies related to tropospheric ozone identification and understanding to be in the furtherance of the public interest;

6) Canada and the United States have agreed under the "North American Free Trade Agreement (NAFTA): Supplemental Agreements" and the Canada/US Air Quality Accord to cooperate to achieve their environmental mandates and goals;

7) A Canadian multi-stakeholder NO_X/VOC Science Program was initiated in 1992 with the objective to establish the scientific basis for measures to eliminate exceedances of the Canadian Air Quality Objective for tropospheric ozone;

8) Mexico and the United States have agreed under the "Integrated Border Environmental Plan" and the "North American Free Trade Agreement (NAFTA): Supplemental Agreements" to cooperate to achieve their environmental mandates and goals;

9) The Government of Mexico through the Secretariat of Social Development (SEDESOL) will continue to work toward fulfilling the Border Plan commitments, and the Commission for Environmental Cooperation established under NAFTA will facilitate effective cooperation for the conservation, protection and enhancement of the environment in the United Mexican States;

10) The NARSTO program has emerged as an effective and comprehensive vehicle for establishing a cooperative tropospheric ozone research program across the North American continent;

Therefore,

1) This Charter establishes the scope, goals, strategy, planning, organizational structure and governance for the NARSTO program;

2) The members of this public-private partnership propose a long-term, comprehensive tropospheric ozone research program coordinated among government (federal, state/provincial, and municipal), industry, academia, and other private-sector interests across North America;

3) The continental NARSTO organization will plan and coordinate independently sponsored programs that result in projects and tasks designed to identify and resolve science questions related to (a) anthropogenic and biogenic sources of ozone and ozone precursors, (b) the complex physical and chemical processes affecting the accumulation of ozone and other smog products in the troposphere, (c) monitoring studies and methodology development needed to verify mandated emissions control measures for ozone and the precursors of ozone, namely, nitrogen oxides (NO_X) and volatile organic compounds (VOC), and (d) the attainment of ozone standards; and

4) The overall scope and goals of NARSTO are:

   a. To provide for sustained coordination, collaboration, and leveraging of resources in tropospheric ozone research by the multiple organizations in North America (both public and private) sponsoring and participating in this research;

   b. To develop an organization and management structure that facilitates a high level of individual organizational ownership in the NARSTO program;

   c. To provide a comprehensive research program that builds on ongoing research and encourages and supports the critical short- and long-term research required within the research strategy;

   d. To provide a unified, cohesive, scientifically sound basis for planning and implementing ozone research that will help sustain sponsors' commitments to a long-term NARSTO program;

   e. To include representation within the NARSTO organization from all stakeholders, including the policy and air quality management, health and ecological effects research, and emissions control technology research communities, in order to maintain critical communications links with key customers and other interested parties;

   f. To develop and implement a research strategy reflecting both scientific and policy concerns;

   g. To conduct timely, productive, policy-relevant tropospheric ozone research with frequent and appropriate reporting of the research results to the science and policy and air quality management communities;

   h. To develop and deliver timely, useful, and scientifically credible assessment tools and guidance to the policy/air quality management community;

   i. To provide periodic state-of-science assessments of the North American ozone problems and their control, and to revise the NARSTO research strategy based upon the identified assessment needs and remaining scientific gaps and uncertainties; and

   j. To provide a clearinghouse of current technical information generated as part of NARSTO (i.e., data, publications, results);

5) The NARSTO organizational objectives are:

a. To provide the opportunity for participation to all parties interested in planning, sponsoring or performing tropospheric ozone research, as well as those interested in the outcome of this research.

b. To provide a NARSTO Charter that interested public and private institutions in Canada, Mexico and the United States of America may sign to signify their concurrence with the scope, goals, strategy, planning, management and liaison activities established for the NARSTO organization.

c. To provide a mechanism that sponsoring institutions may sign to (a) indicate senior-level management commitment to support long-term NARSTO objectives, (b) indicate specified levels of resources in support of NARSTO, (c) signify their agreement with the public-private cooperative management approach, and (d) signify their agreement to share data and information.

d. To provide the following guidelines for participation in the NARSTO program:

- The NARSTO Cooperative Research and Development Agreement (CRADA) under the authority of the Federal Technology Transfer Act (FTTA), 37 U.S.C. §3710a - 3710d will guide collaboration and cooperation among U.S. public/private sponsoring institutions, except sponsoring U.S. state environmental agencies.
- The Joint Policy Statement on State/EPA Relations developed and endorsed by the State/EPA Capacity Steering Committee will guide state environmental agency collaboration and cooperation with NARSTO.
- The North American Free Trade Agreement (NAFTA) will guide international NARSTO collaboration and cooperation between the United States, Canada and Mexico.
- Institutions subject to participation in the implementation phase of NARSTO (e.g., the university and contractor communities) are encouraged to sign the NARSTO Charter; however, these institutions will not sign the NARSTO CRADA or participate in the Executive Assembly to avoid potential conflict of interest issues.

6) The key steps in the NARSTO organization and management approach are as follows:

a. Each Charter organization is entitled to participate on one or more NARSTO Councils, Groups or Teams. However, participation on the NARSTO Executive Assembly is limited to institutions providing resources to sponsor NARSTO research and development.

b. Each sponsoring organization (including sponsors from U.S. state environmental agencies, Canada and Mexico) will be a member of the Executive Assembly.

c. The Executive Assembly will convene, physically if possible and in a timely manner, to select 7-11 of its members to serve on the "Executive Steering Committee".

d. The Executive Steering Committee will elect a Chairperson from its ranks, and will have the option to add non-voting members from the non-sponsoring stakeholder community.

e. The Executive Steering Committee will meet as needed or at least annually; and will select individuals/organizations (as appropriate) to serve in the following capacities:

- The "Science Advisory Council"

- The "Technical Program Team Leaders"
- The "Science and Resource Planning Group"
- The "Management Coordinator"
- The "Liaison Coordinator"
- The "Quality Systems Management Group"
- The "Data Management Group"
- The "Stakeholder Council"

f. Sponsors of NARSTO research will retain total control over their funds and personnel, and will bear the responsibility for planning, managing, and implementing that portion(s) of the NARSTO program they select. (NOTE: There will be no NARSTO membership fees or pooling of sponsor funds under the NARSTO organization. For example, it is anticipated that the position of Management Coordinator and support facilities and services for that position will be underwritten by one or more sponsors.)

g. Organizations will not be audited by NARSTO. Organizations will select work and promise to complete the effort to the best of their abilities and resources. These "promises" will be coordinated through the Science and Resource Planning Group.

THE UNDERSIGNED REPRESENTATIVES OF PUBLIC AND PRIVATE INSTITUTIONS FROM CANADA, MEXICO AND THE UNITED STATES CONCUR AS FOLLOWS:

Article 1: Organization

The NARSTO organization will consist of the functional units listed below. An organizational chart is given in Attachment 1.

- Executive Assembly
- Executive Steering Committee
- Stakeholder Council
- Science Advisory Council
- Science and Resource Planning Group
- Management Coordinator
- Liaison Coordinator
- Liaison Teams
- Quality Systems and Data Management
- Analysis and Assessment Team
- Modeling/Chemistry Team
- Observations Team
- Emissions Team

Article 2: Membership

Membership in the NARSTO organization is open to any agency or institution representing one or more of the following stakeholder communities:

- Industrial and Utility
- Academic
- Government (Federal/State/Provincial/Municipal)
- Environmental
- Contractor
- International

Article 3: Functional Units

The key functional units and the responsibilities under each NARSTO functional unit are presented below.

1) The **Executive Assembly** [1] shall:
   a. Convene a meeting (at the earliest opportunity) and select 7-11 member organizations to represent the Executive Assembly on the Executive Steering Committee (ESC)
   b. Establish the term of service for ESC members
   c. Appoint from each of the selected 7-11 organizations a qualified individual authorized to participate on the ESC
   d. Meet as required
   e. Periodically review the composition of the ESC
   f. Recommend replacements on ESC resulting from expired terms or other circumstances

2) The **Executive Steering Committee** shall:
   a. Establish the overall strategy (i.e., program vision, mission statement, major policy relevant science questions and objectives, and policy and science relationships)
   b. Establish the general rules and guidelines for all other NARSTO units
   c. Mediate conflicts
   d. Acquire resources, both monetary and in-kind, as needed
   e. Establish a process assigning resources to strategic activities
   f. Meet at least annually
   g. Establish a Science Advisory Council
   h. Select the Science and Resource Planning Group members and appoint the chairperson
   i. Select the Management Coordinator
   j. Approve Technical Program Team Leaders recommended by the Management Coordinator

---

[1] The Executive Assembly consists of all sponsoring organizations, including sponsoring U.S. state environmental agencies and institutions from Canada and Mexico.

k. Appoint a Liaison Coordinator who will also serve as a non-voting ex-officio member of the Executive Steering Committee

l. Approve Liaison Team Leaders recommended by the Liaison Coordinator

m. Establish or select an entity to coordinate NARSTO Quality Systems and Data Management

n. Approve NARSTO strategy documents, assessments, and other major NARSTO products

o. Appoint a Stakeholder Council to represent the interests of the following stakeholder communities: Research, U.S. Government, Canadian Government, Mexican Government, Industry and Utilities who will serve as the first point of contact between NARSTO and the stakeholder community at large

3) The **Stakeholder Council** [2] shall:

a. Review and comment on NARSTO draft products

b. Provide advice and guidance to the Executive Steering Committee and the Management Coordinator on:

- policy questions/concerns and timing
- integration and assessment
- short-/long-term balance issues and research priorities
- appointments

4) The **Science Advisory Council** [3] shall:

a. Provide peer review of the NARSTO research strategy and NARSTO associated draft products

b. Provide independent technical advice and guidance to the Executive Steering Committee and the Management Coordinator on:

- science questions
- integration and assessment
- short-/long-term balance issues and research priorities

---

[2] The Stakeholder Council consists of regulators, regulatees and other public/private parties which have interests in the outcome of NARSTO research.

[3] The Science Advisory Council consists of internationally recognized and qualified scientists acceptable to the Executive Steering Committee and nominated through an independent body such as the National Academy of Sciences.

5) The **Science and Resource Planning Group** [4] shall:

a. Balance program-level science/policy questions

b. Define and coordinate the research needed to address the science and policy questions

c. Prioritize program-level needs

d. Identify and prioritize program-level activities

e. Identify program-level funds

f. Recommend which sponsoring organizations might take responsibility for funding which activities

g. Meet at least twice annually

6) The **Management Coordinator** [5] shall:

a. Serve as Executive Secretary of the Science and Resource Planning Group

b. Recommend Technical Program Team Leaders to Executive Steering Committee

c. Coordinate the current-year and next-year technical program planning activities through collaboration with the Executive Steering Committee, Science Advisory Council, Stakeholder Council, and the Liaison Teams

d. Coordinate current year program activities

e. Oversee program data management and quality assurance

f. Coordinate program integration and assessment activities

g. Coordinate program outreach, information dissemination, communications and technology transfer activities

7) The **Liaison Coordinator and Liaison Teams** [6] shall:

a. Establish and maintain communication links with the public policy, effects, control technology and air quality management communities

b. Establish any necessary advisory teams associated with the above communities

---

4 The Science and Resource Planning Group consists of (a) the Team Leader from each Technical Program Team (i.e., Analysis & Assessment, Modeling/Chemistry, Observations and Emissions); (b) the Liaison Coordinator; (c) at least one Quality Systems & Data Management representative; (d) resource planners selected by sponsoring institutions; and (e) any other members selected by the Executive Steering Committee.

5 The Management Coordinator shall be selected by the Executive Steering Committee.

6 The Liaison Coordinator will be appointed by the Executive Steering Committee. The Liaison Team Leaders will be selected by the Liaison Coordinator and approved by the Executive Steering Committee.

c. Provide advice and guidance to the management Coordinator, the Science and Resource Planning Group and the Analysis and Assessment Team on:
   - policy and air quality management issues
   - effects research issues
   - control technology research issues

d. Provide guidance on science/technology transfer issues and information needs

8) The **Quality Systems Management and Data Management** [7] functions shall:

a. Ensure that relevant quality management systems are planned and implemented under the NARSTO program

b. Plan and conduct audits on the critical NARSTO program elements

c. Plan and coordinate NARSTO data management, data archival and data dissemination

Many of the NARSTO research activities will be planned and coordinated by four **Technical Program Teams** [8] that will for their respective areas of expertise: (a) identify the state-of-the-science, (b) identify any remaining science questions, (c) recommend programs with prioritization and budget estimates, (d) review research results and periodically revise plans, and (e) define the level of data quality desired. The roles of the individual Teams are described below.

9) The **Analysis and Assessment Team** activities will include:

a. Assessments of ozone and ozone precursor sources, transport, and concentrations

b. Assessments of ecosystem exposure

c. Recommendations for data management, archival and dissemination

d. Data analysis across Technical Program Teams

e. Spatial and temporal mapping of the ozone problem

f. Integration of NARSTO results and communication of findings to other Technical Program Teams, to policy-makers and to the public

---

7 The Quality Systems Management function will be independent of NARSTO data generation activities. Quality Systems Management and Data Management activities will be managed by one or more entities established or selected by the Executive Steering Committee with concurrence from the Science Advisory Council.

8 Membership on a Technical Program Team is open to any scientist who represents a NARSTO Charter organization and whose expertise and interest fall within the designated technical area. Membership on a Team may be achieved through self-selection.

10) The **Observations Team** activities will include:

a. Establishment of monitoring networks (including PAMS enhancements)
b. Intensive measurements
c. Methods development
d. Observations-based analysis

11) The **Modeling/Chemistry Team** activities will include:

a. Air quality and meteorological model development
b. Model applications research
c. Model evaluation
d. Laboratory and smog chamber studies
e. Chemical mechanism development

12) The **Emissions Team** activities will include:

a. Emissions model development
b. Process and activity analysis
c. Source and ambient emissions field studies
d. Emissions projections and control technology implications analysis

Article 4: Meetings and Conferences

Whenever possible, to enhance communications, summaries will be prepared for all NARSTO meetings and conferences, including the meetings conducted by all NARSTO functional units. These summaries will be (a) maintained for the duration of the estimated 10 year NARSTO program performance period and (b) filed in a manner that allows easy access and dissemination upon request to any interested parties in the public or private sectors.

The meetings of each functional unit will be conducted by the Chairperson (or Co-Chairperson in the absence of the Chair). Each functional unit will select a Secretary who will be responsible for preparing and maintaining the summaries of each unit meeting.

Each functional unit will establish the level of participation necessary to constitute a quorum for the conduct of business. Meetings will be scheduled by each functional unit on an as needed basis and will be planned in a cost effective manner (e.g., conference calls will be used, when feasible).

Article 5: Functional Unit Actions

This Charter presents the basic guidance for all NARSTO units. The establishment of specific rules, limits and controls will be left to the discretion of each group/committee. Decisions within a functional unit may be determined by majority vote or by consensus, as agreed upon by the unit. Where voting is required, unit members who represent a sponsoring organization may cast one vote each; non-sponsoring stakeholders who participate are non-voting members of the unit. Unresolved disputes may be raised to the next highest level in the NARSTO management chain.

Actions of the NARSTO functional units will consist of the decisions and the recommendations associated with the functions identified above, and neither the decisions of the unit nor its individual members will obligate the organizations or agencies they represent.

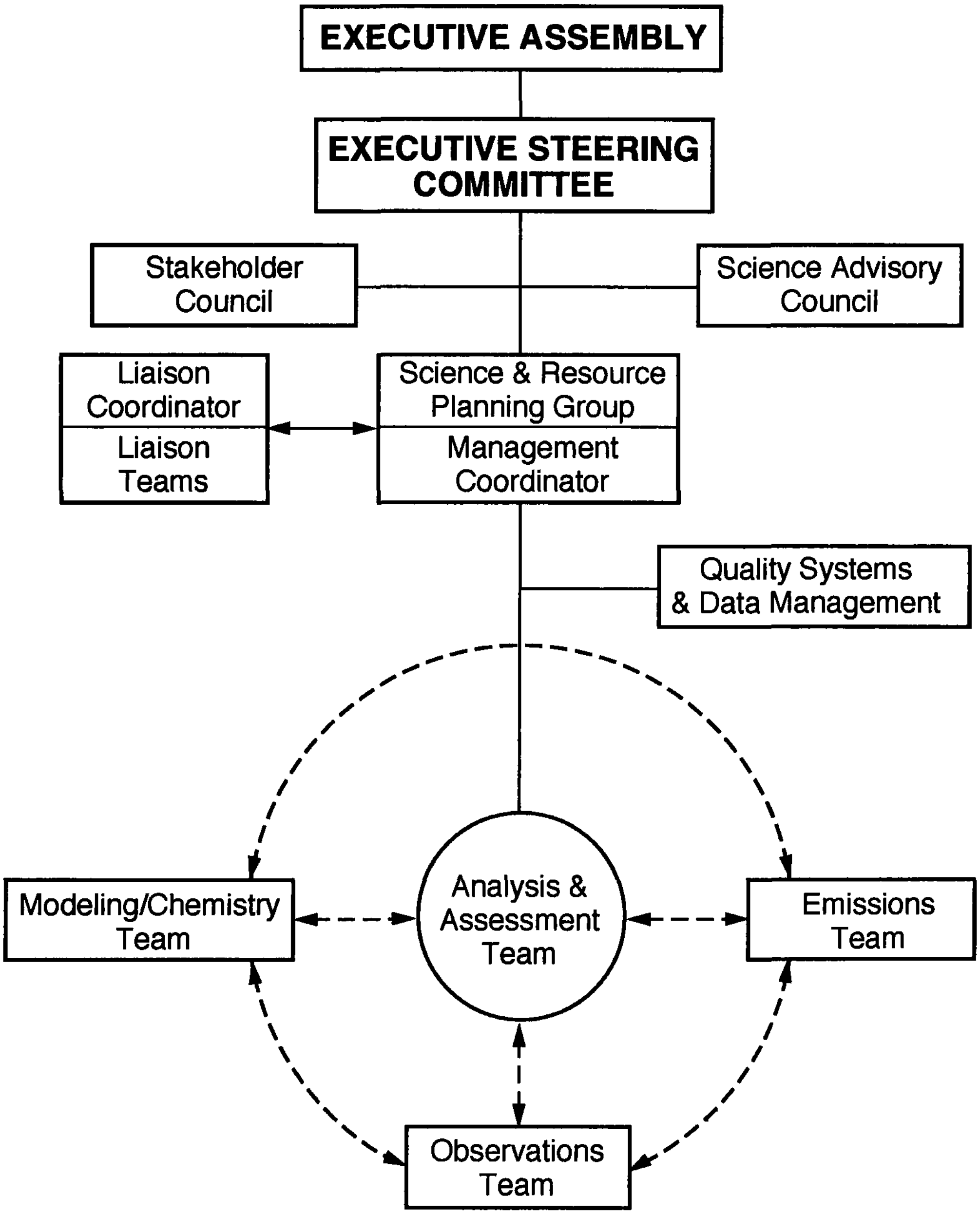
Article 6: Participant Qualifications

Each Stakeholder organization (including sponsors) is encouraged to ensure that their representatives are qualified for the positions they accept or select in the NARSTO organization. Due to the processes involved, the appointed and elected leadership positions will undergo a sufficient degree of scrutiny.

Those positions obtained through the self-selection process will go to individuals who represent a Stakeholder/Sponsor organization. That organization bears the brunt of the responsibility for ensuring the qualifications of their NARSTO representative.

ATTACHMENT 1

NARSTO ORGANIZATION CHART



NARSTO CHARTER MEMBERS

(Participants)

The undersigned organizations concur with the tropospheric ozone research needs, goals and approaches described in the NARSTO Research Strategy, and accept the NARSTO organizational structure and governance contained in this Charter:

NARSTO CHARTER MEMBERS

(Sponsors)

The undersigned organizations concur with the tropospheric ozone research needs, goals and approaches described in the NARSTO Research Strategy; accept the organizational structure and governance contained in this Charter; and agree to individually sponsor portions of the research and development described in the NARSTO Research Strategy on an annual basis, subject to the availability of funds: