NARSTO-1997-2

NARSTO Strategic Execution Plan

Part 2: Analysis and Assessment

March 1997

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INTRODUCTION

One of the more important early functions of NARSTO has been the preparation for implementation of the strategy outlined in the 1994 *Research Strategy and Charter* (NARSTO, 1994). This work has involved extensive discussions among the sponsors and the Science Teams, which emerged from a NARSTO general meeting and workshop held during November of 1995 in San Antonio, Texas. Along with a number of other activities, attendees at that meeting endorsed a commitment to prepare a major assessment of tropospheric ozone by 1998. This segment (Part 2) of the three-part NARSTO Strategic Execution Plan focuses specifically on the planning and work required to prepare the l998 NARSTO ozone Assessment Document.

The sister plans for NARSTO activity include a description of the resource allocation process (Part 1), and an interim science plan (Part 3), representing commitments to ongoing studies, as well as key new projects that need to be completed by l999 or shortly thereafter. Both the assessment plan (Part 2) and the interim science plan are designed to provide guidance for sponsored research that will lead to improved ozone-management strategies in North America, integrated with similar strategies for management of related pollutants. The Assessment in itself is not intended to produce new science; it will, rather, serve to synthesize and evaluate the state of science primarily generated since the late l980s. Both the research and the assessment activities will rely on current institutional funding commitments. Presently these are constrained critically by resource limitations.

The l998 Assessment will address, and be guided by, the science and policy questions posed in the NARSTO (l994) plan (cf. Part 1 of this Strategic Execution Plan). If the science can provide substantive and quantitative answers to these questions it will have fulfilled at least the initial goals of the program. The 1998 Assessment will address these science and policy questions using a subset of "assessment questions" to focus and define a collection of formal review papers, which in turn will be used as the technical basis for the Assessment report, itself.

The following sections describe the approach to preparation of the l998 NARSTO Assessment, the technical background for major elements to be included, and a description of specific studies that are required to produce a credible and useful Assessment report.

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ASSESSMENT ORGANIZATION AND STRATEGY

The 1998 Assessment will compile and evaluate the state of knowledge of tropospheric ozone and related chemical and physical processes, and will be the first major synthesis report produced by NARSTO. Its objectives are to:

(a) provide a synthesis and evaluation of policy-relevant scientific findings, methods, and recommendations that are timely and useful for regulatory initiatives and "mid-course" correction analyses;

(b) provide guidance for setting NARSTO priorities for longer-term research that will extend beyond the 2-3 year time frame;

(c) examine alternatives to current technical approaches for achieving ozone compliance; and

(d) ensure that information on ozone-precursor chemistry is well integrated with related pollutant issues, such as fine particulate matter, visibility impairment and acid deposition.

The Assessment will focus on answers to the NARSTO policy and science questions that appear in Part 1 of this Strategic Execution Plan and in the *NARSTO Research Strategy and Charter*. To further sharpen the Assessment's focus, these original questions have been distilled into the list of "assessment questions" that is summarized in Table 2.1 and presented in more detail in Appendix 2-A.

The l998 Assessment is planned to cover the topics outlined in Table 2.2, which can be considered, essentially, as an advance "table of contents" for the final document. As indicated by this table, the Assessment will examine advances in scientific knowledge of tropospheric ozone — especially those developments that have occurred since publication of the 1991 National Research Council report on tropospheric ozone (NAS, l991).

It should be recognized that although Canada and Mexico have a common interest with the U.S. in many of the unresolved science and policy questions related to tropospheric ozone, the 1998 NARSTO Assessment is driven largely by requirements of the U.S. Clean Air Act. The year 1998 is expected to be relevant to a number of regulatory initiatives in that legislation, and the opportunity for a "mid-course

Table 2.1: Questions to be Addressed in the 1998 NARSTO Assessment

A. POLICY QUESTIONS:

1. **What changes have occurred in tropospheric ozone science over the last decade that might alter (or confirm) the course of current ozone air quality management strategies?**

2. **How manageable is the ozone problem for a given area? (What portion of the problem is local and what portion is transported in? What portion of the problem is essentially irreducible and what portion is potentially controllable?)**

3. **Are existing emission-control measures helping to bring the ozone problem under control? (For a given area, if these control measures are continued, will they lead to ozone attainment? What is the best role of science in developing ozone air-quality management strategies?)**

4. **What are the alternate approaches for reducing current and future high ozone concentrations on urban and regional scales?**

5. **How can we best track and assess the progress and effectiveness of our ozone management efforts?**

6. **Will our efforts to manage ozone help or hinder efforts to mitigate other environmental problems, such as fine particles, global climate change and acid rain, and vice versa?**

B. SCIENCE QUESTIONS

1. **What are the most significant research developments in tropospheric ozone science over the last decade?**

2. **How does ozone accumulation on local and regional scales depend on the source dimension (scale) and location? How does it depend on the relative contribution from local and regional sources?**

3. **What are the most recent assessments of the relative contributions of VOCs, NO_x and CO to ozone accumulation on local and regional scales in North America?**

4. **What are the relationships between the scientific understanding of the tropospheric ozone system and the ongoing efforts to manage it?**

5. **What approaches are required to determine historic concentration trends of ozone and its precursors on local and regional scales? What is required to demonstrate the effectiveness of emission-control strategies over time?**

6. **What are the relationships between the control strategies designed to manage tropospheric ozone and those designed to manage other pollutant regimes of interest?**

Table 2.2: Preliminary Outline of Sections in the 1998 NARSTO Assessment

O. Executive Summary
- A. Summarize Answers to Assessment Policy Questions and Science Questions
- B. Identify Information Gaps
- C. Recommend Research Program

I. Introduction and Overview
- A. Objectives of NARSTO
- B. Purpose of Assessment
- C. Approach to Assessing State-of-Science in a Regulatory Framework
- D. Contents of Assessment Report
- E. Relationship to Other Pollution Issues Integrating Management Approaches

II. Regulatory Framework
- A. North American Issues and Strategies
- B. U.S. Concerns and Outlook
- C. Canada and Canadian Issues
- D. Mexico and International Concerns and Commitments
- E. Transboundary Issues

III.* Theory of Atmospheric Processes and Tropospheric Ozone
- A. Conceptual Picture of Tropospheric Ozone Formation and Dissipation
- B. Ozone and Related Chemistry
- C. Sources of Oxidant Precursors
- D. Transport and Dispersive Processes
- E. Integration of Knowledge through Models
- F. Key Scientific Findings in the Last Decade
- G. Critical Scientific Uncertainties

IV. Characteristic Emission Patterns for VOC and NO_x**
- A. Development of Emission Inventories (Limitations, past and future)
- B. Measurement Requirements and Models
- C. Methods of Projecting Future Emissions
- D. Critical Uncertainties and Issues

V.*,**,*** Ozone Accumulation on Local and Regional Scales
- A. Overview of Ozone and Ozone-Precursor Concentrations on Urban and Regional Scales
- B. Distributions of Precursor Emissions
- C. Observational Illustration of Local and Regional Interactions
- D. Model Analysis of Regional-Scale Ozone Behavior, with Embedded Local Chemistry (e.g., Mexico City -- a zero regional problem? Eastern U.S. -- an extreme of complexity)
- E. Related Pollutant Behavior and Ozone Precursors
- F. Interpretation of Observations and Modeling (Dependency on Source Scale and Location); Relative Contribution of Ozone from Local and Regional Sources (Examples--Eastern U.S., San Joaquin Valley, Southeastern Canada)
- G. Information Gaps and Recommended Research

Table 2.2, Continued

VI. *,,***Assessment of Relative Contributions of Precursors**

A. Atmospheric Chemistry and Local- and Regional-Scale Processes
B. Observational Basis for Assessing Relative Contributions of Precursors (Eastern N.A, California, Canada, and Mexico may offer unique examples)
C. Model Estimates of the Relative Significance of Precursors
D. Generalization of Evidence for Range of Climate and Geographical Conditions
E. Considerations for Related Pollutants
F. Information Gaps and Recommended Research

VII. *,,*** Application of Recent Results to Ozone Management**

A. Effectiveness of Current Emission Management Studies (Trends)
B. Implications of Proposed New U.S. Standard
C. Information Needs for Canadian and Mexican Management Programs
D. Historical Trends in Ambient Air Quality vs. Estimated Emission Reduction
E. Modeling Projections of Emission Reductions and Limitations/Uncertainties of Calculations
F. Options for Future Management Practice (Priority-Setting Included)
G. Dealing with Uncertainty: Risk Assessment and Management
H. Recommended Research to Improve Management Approaches

VIII. *,,*** Determination of Progress Toward Air-Quality Goals**

A. Observational Programs for Measuring Ambient Trends (Monitoring Networks Included)
B. Measuring Trends in Emissions
C. Estimating Measurement Network Limitations and Uncertainties in Emissions and in Ambient Air-Quality Trends
D. Use of Models to Interpret Observed Changes in Ambient Concentrations
E. Gaps in Measurement and Analysis Technology
F. Recommended Research to Improve Accountability

IX. *,,*** Integration of Management Strategies**

A. Overview of Potential for Integrated Management Strategies for Local and Regional Problems (Similarities and Differences in Pollutants and Standards)
B. Parallels in Emissions of Precursors and Other Pollutants
C. Options Under Consideration Based on FACA and Other Deliberations
D. Interpretation of Observations and Modeling Results Leading to Options for Integrated Management Strategies
E. Information Gaps for Integrated Management Strategies
F. Recommended Research Program

X. Summary and Conclusions

Assignments for NARSTO Science Teams: * Modeling and Chemistry Team,**Emissions Team,***Observations and Measurement Team,**** Data Systems and Quality Assurance Team

correction" of the U.S. emission management program. Canada is preparing its own assessment, expected in 1997, as part of its NO_x/VOC Management Plan's scientific program. This 1996 Assessment will be used as scientific input to help guide the next steps in Canadian NO_x and VOC emission controls. This activity does not imply that the 1998 NARSTO Assessment is irrelevant to Canadian policy and its development; on the contrary, its conclusions will be examined closely for Canadian policy implications. In view of the noted motivations for the 1998 NARSTO Assessment, however, it should be recognized that the emphasis on specific questions in this plan may differ somewhat from those of the 1996 Canadian Assessment.

In addition, the Assessment will examine the applications of this new knowledge to the decision-analysis processes that are anticipated for the next several years, with the objective of critically evaluating the quality of that knowledge as well as associated uncertainties in the prediction of ozone concentrations and exposure. Analysis of the relative risks and benefits of alternative air-quality management options is also an important component of this evaluation. Finally, the Assessment will establish the directions, by priority, of future research on ozone and related pollutants.

2.1 Technical Issues

A major difficulty in communications between the science community and the policy/regulatory community is related to the open-ended nature of knowledge acquisition for atmospheric processes and their influence on air pollution. The steady but sometimes unpredictable progress of science is usually superseded by decision-making needs on a regulatory agenda. In this context, a mutual sense of inadequate communication has existed for some time. The 1991 NRC report, as well as other recent reviews of ozone national ambient air-quality standards and guidelines, illustrate the many advances in basic knowledge now available to support decision analysis. It is also clear, however, that many key technical issues remain unresolved, and that considerable uncertainty exists in the projection of future ozone conditions as a consequence of management-strategy decisions. Strategy revisions need to account for the concerns that, in many locations, past strategies have not been successful in attaining relevant national standards for ozone. At the same time, at least one of these standards is being considered for change, and this will undoubtedly modify the application of existing knowledge. Even after more than three decades of research on tropospheric ozone, there is still important uncertainty as to which components of tropospheric chemistry are most critical for the reliable establishment of location-specific management strategies.

Until only a few years ago, pollution management was considered mainly an urban issue. Stimulated largely by field campaigns emphasizing ozone, acid deposition, and regional haze, however, decision makers have come to recognize that regional-scale tropospheric phenomena are often critically important considerations for effective ozone and related pollutant management. At the same time, the impacts of biogenic, or natural emissions of VOC and NO_X are becoming appreciated as important factors mediating ozone formation in some locations. This recognition, in combination with an evolving appreciation for the varying influence of atmospheric processes, the limitations of models, and the uncertainties in emission inventories, has raised important concerns that current regulatory processes do not adequately assimilate essential, available information in management-strategy development. Given the current environment of rapid scientific development, periodic assessments are essential for continued progress in facilitating the practical implementation of advanced knowledge in this regard. The l998 Assessment is the first in a NARSTO-sponsored series aimed at informing and enhancing these decision processes.

Appendix 2-B lists a proposed set of topics that are presently believed crucial to improvements in understanding tropospheric ozone behavior. Intended as an aid for initial planning purposes, this list indicates priority areas needing evaluation in the l998 Assessment, with the assumption that they are critical to improving the ability to project the effectiveness of ozone and related pollutant management options in achieving clean air. Subject to change as the assessment process develops, this list provides a starting point for prioritizing the NARSTO review activities, which are described below.

2.2 Approach to Assessment Preparation

Aggressive use of available expertise will be necessary to prepare the 1998 Assessment, given the current marginal state of existing and additional resources. In keeping with this requirement, NARSTO has initiated the assessment planning and preparation process using an ad hoc approach. Indicated schematically in Figure 2.1, this process is designed to be initiated through a workshop with the A&AT and the authors of reviews and special "white papers," employing Science Team workshops as needed. These meetings will produce detailed outlines of topics to be covered in the reports, upgrading and solidifying the outline of Table 2.2 in the process. The "critical" reviews will serve as the principal consolidated information resource for preparation of the final Assessment Document. The special projects are intended to complement the reviews, and provide additional insight from ongoing work, filling information gaps that are critical to Assessment preparation. The critical reviews and special-study results will be integrated by a synthesis team composed of senior investigators, representing different elements within NARSTO and the stakeholder community.

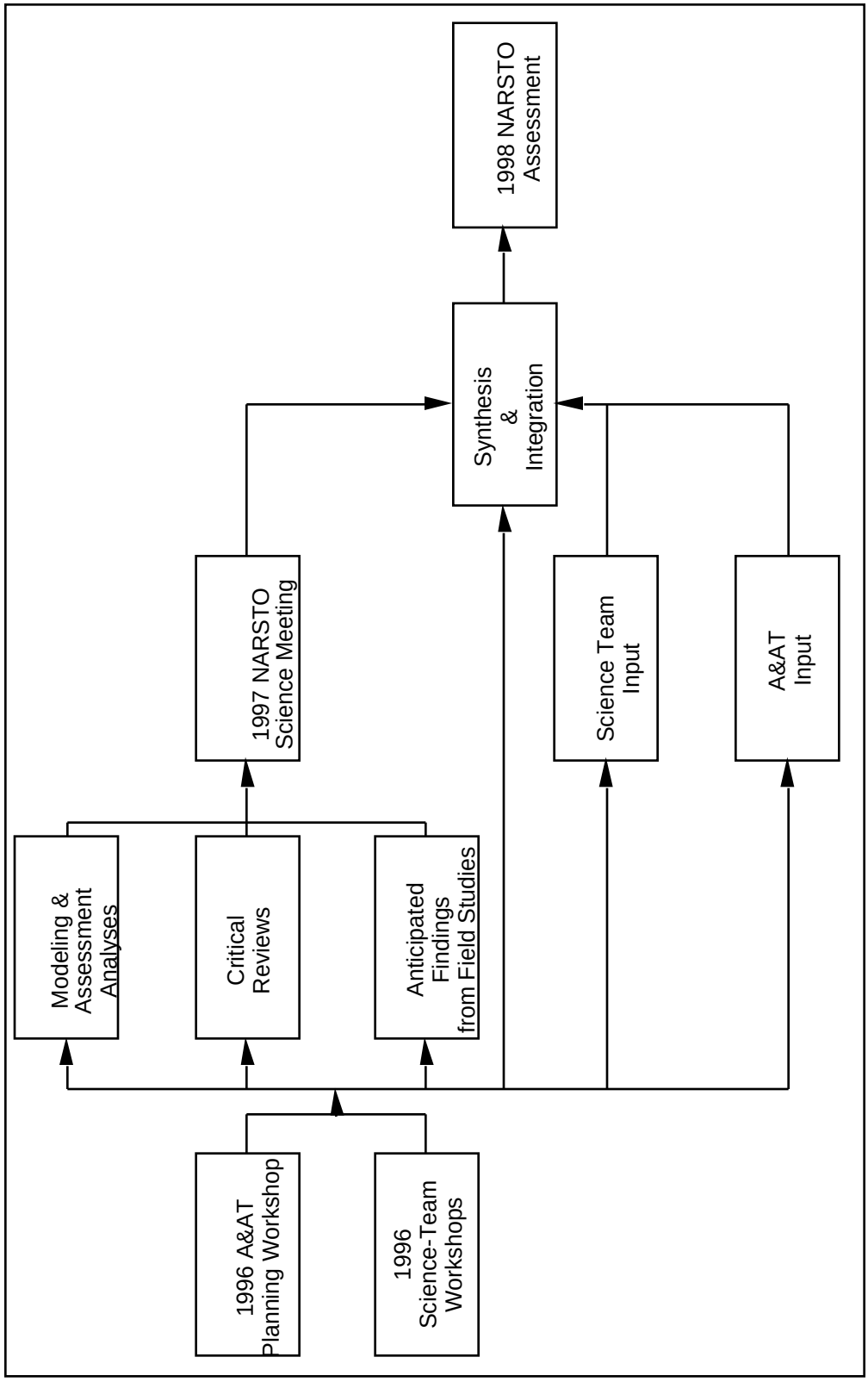

Figure 2-1: Flow Chart for NARSTO Assessment

All of the above contributions will be subjected to a peer-review process, which will have two important parts. The first will rely on the formal review of a selected technical journal, which will produce a common-volume publication of the NARSTO critical review papers. The second will consist of a major NARSTO sponsored scientific meeting in l997 to discuss the review papers and their implications, while submitting them for peer comment.

The process began with the scheduled Analysis and Assessment Team workshop in April 1996, which determined the proposed critical-review paper topics and provided planning guidance for the remaining NARSTO Science Teams. Immediately following this Analysis and Assessment workshop, a special meeting of the Science and Resource Planning Group (S&RPG) was called to activate established NARSTO selection and funding procedures, adopt or modify the A&AT recommendations, and commission preparation of the critical reviews. The S&RPG also prioritized the list of special projects, to select those critically needed for the Assessment. The A&AT considers that all of the listed critical reviews are necessary to provide a credible, high-quality Assessment Document. The summaries of specific elements for this program are summarized in detail in the last section of this plan. Estimates of required financial support and staffing were submitted separately to the S&RPG, to aid their decision process.

Using the critical review papers and other information provided through extraction from ongoing work and possible short-term projects, the draft NARSTO Assessment Document will be prepared in early l998. After internal NARSTO review and endorsement, this report will be submitted for external review to the National Academy of Sciences.

Figure 2.2 shows a schedule for Assessment preparation. This ambitious plan is based on the assumption that the final report is to be delivered and published in late l998. This dictates that the critical reviews must be submitted for journal publication by late l997. In turn, this means that the reviews must be commissioned by late summer or fall of l996, and other short-term support projects for the Assessment will need to be initiated at that time.

Specific projects or resources that are needed to produce the assessment include:

a. a planning workshop (April l996); a Science-Team leaders' meeting (October l996 or earlier); an A&AT meeting with authors of critical reviews and special projects, and Science Team meetings if necessary (fall, 1996); interim meetings as needed with Science Team members and representatives from the A&AT (1997); a synthesis and integration workshop (spring 1997); a general science meeting

(fall l997), and a synthesis and integration meeting (winter l997).

b. synthesis and integration staffing and publications;
c. resources for a study group for risk-based modeling.

These projects are discussed in more detail in the last section.

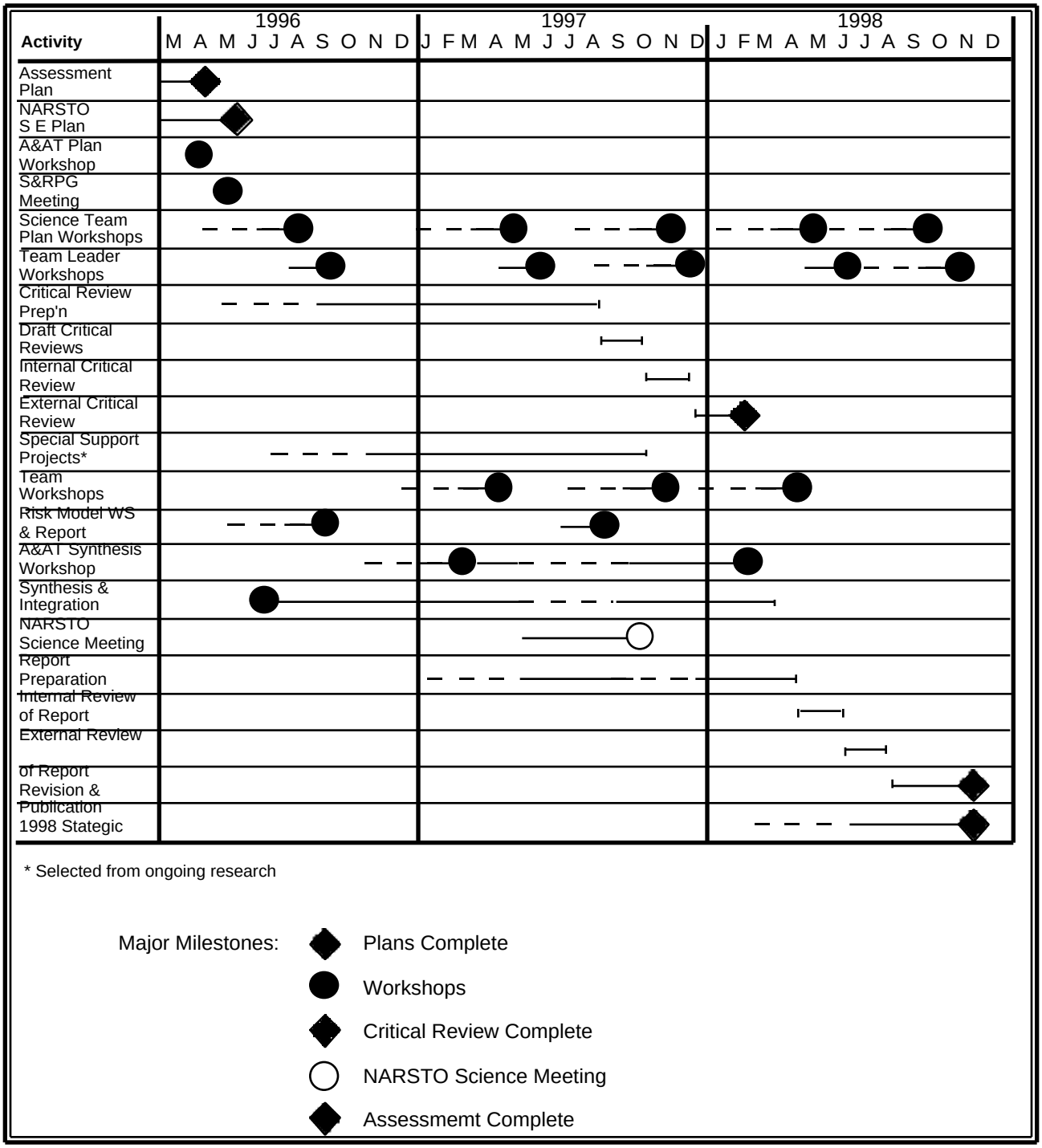

Figure 2.2: Assessment Schedule

3

CHARACTERIZATION OF EMISSIONS

The tropospheric chemistry of ozone and related pollutants is driven by photochemical reactions of its precursor species: nitrogen oxides (NO_x), and volatile organic compounds (VOCs). These species are emitted from natural origins as well as from man's activities. The U.S. Clean Air Act, as well as international initiatives, initially focused on localized emission patterns of nitric oxide (NO) and VOCs. Developing scientific knowledge, however, later revealed the important connections between ozone formation and the oxidation of nitrogen oxides and other gases such as sulfur dioxide; these produced important co-pollutants in the urban atmosphere, resulting in haze formation and high suspended particle concentrations. Chemistry studies on regional and continental scales indicated other phenomena, such as acid rain, are linked with ozone chemistry. Indeed ozone itself was found to be influenced by phenomena extending over several days and over thousands of kilometers and involving both anthropic and natural emissions. Thus the l998 NARSTO Assessment needs to account for both natural and man-made emissions of ozone precursors.

The 1998 Assessment will address two major aspects of emission characterization. First, it will examine the methods to create emission inventories and associated models to describe past, present, and future conditions. Second, it will address the strengths and weaknesses of the current emission descriptions. The Assessment will attempt to provide quantitative guidance for the limitations and uncertainties involved in emission inventories, and will indicate the significance of these to management-strategy development using projections of future conditions.

In the first category, the following will be described and evaluated:

a. analysis of emission processes and variability,
b. significant results from recent measurement and characterization experiments,
c. development of emission models,
d. quality of current emission inventories and models,
e. quality of methods for projecting future emission patterns.

This evaluation will form the basis for recommending preferred approaches to using current emission inventories and projections for regulatory strategy development. Further the results will supply a series of recommendations for longer-term work to refine and improve emission characterizations in terms of the components that are likely to be most critical to modeling support for strategy analysis.

3.1 Approach to Assessment

Consistent with the overall assessment planning, the Emissions Science Team will undertake the emission-oriented reviews required for this NARSTO activity. The reviews will be initiated through a workshop in summer of l996, which will follow up on the April A&AT planning meeting. Using the assessment questions in Table 2.2 as a framework in conjunction with the critical area priorities in Appendix B, the direction and content of critical reviews will be established for three major categories, (a) natural emissions, (b) mobile sources, and (c) stationary sources. The reviews will be written or coordinated by lead authors, who will be supported by appropriate expertise to survey progress on emission characterization topics, as listed above.

Substantial work is underway to refine methods for estimating emissions, as well as the design and implementation of improved emission models. The reviews will survey this ongoing work in Canada, Mexico, and the United States, and will need to take into account work at the federal, state and local levels to improve emission data, as well as to establish uncertainties in existing methods. This effort will require substantial investment in acquisition of the gray-literature documentation of testing and evaluation, that exists in government and industrial laboratories. The challenge to the reviewers will be to generalize results from studies that cover a very wide range of source categories, measurement methods, as well as estimation techniques that incorporate laboratory testing, along with "real world" human activity and variability of maintenance and replacement practices.

In the case of natural emissions, the review must cover not only microscale biogenic behavior and other emission sources (e.g., thunderstorm production of NO_2), but also land-use distributions, climate factors, and agricultural practices.

Major uncertainties in emission estimation will be documented based on recent studies. Examples of important limitations, such as those associated with motor-vehicle emissions and diffuse, small stationary-source contributions, will be included. The methods adopted to check the reliability of conventional estimation methods will be examined, including consistency checking with ambient observations. This component will require coordination with the Measurement and Observations team, as well as with experts in receptor modeling for source identification.

Because the significance of uncertainties in emission inventories will be determined by sensitivity analyses in conjunction with chemical-transport models, close coordination of this group and the Modeling and Chemistry Team will be required. In addition, the Emission Team must coordinate their work with an A&AT subgroup examining risk-based modeling and analysis for management-strategy selection. The aim of analyses will be to establish more concisely the critical nature of uncertainties in

both VOC and NO_x emissions in estimating reliable selection of ozone and related-pollutant management strategies on local and regional scales.

3.2. Specific Needs

As a first line of attack, the Assessment's characterization of emissions will draw on the expertise provided by ongoing studies in government and private laboratories. The reviewers will seek assistance from investigators associated with these studies to obtain key information pertaining to the assessment questions and priorities. This activity will be performed on a voluntary basis, with a minimum of requested detailed analysis beyond that available in published reports. Noting that none of these ongoing studies have been designed specifically to create input to the NARSTO process, access to the investigators will depend on mutual cooperation in information exchange and on NARSTO providing travel or nominal assistance to assist in the workshops and/or the review process.

Stated uncertainties and projections for future work, or future shifts in emission patterns, will be examined through at least one workshop convened in 1997, prior to the general science meeting in the fall. This meeting also will be used to define a strawman plan for longer-term research and studies in critical areas of emission characterization based on the review results.

The new resources required to develop the emission components of the Assessment are:

a. prepare three critical reviews related to ozone precursor emissions;
b. conduct a planning workshop in l996;
c. conduct a study workshop in l997;
d. conduct or participate in a test series of sensitivity analyses with the modeling and chemistry team;

These activities and projects are described in more detail in the final section of this plan.

4

MEASUREMENTS AND OBSERVATIONS

Measurements and observations of atmospheric characteristics serve as the primary basis for determining the nature of the tropospheric ozone formation phenomenon, as well as linking it to human activities. Measurements also provide: (a) direction to the modeling community for theoretical development, (b) information to the public about the significance of the phenomenon to human health and biota exposure, and (c) verification of the effectiveness of management-strategy implementations.

Over the past thirty years, considerable effort has been committed to developing appropriate measurement technologies and techniques to obtain credible and defensible quantitative information about ozone and related pollutants. Routine monitoring programs have been supplemented by large field studies, adding knowledge concerning the details of ozone formation and dispersion in most areas of the United States and many areas of Canada and Mexico.

Despite these noted efforts, remaining deficiencies in measurements and methods severely inhibit analysis and interpretation. At the surface, particularly in non-urban locations, routine measurements of the key ozone-forming catalyst, NO_2, are not yet practical. In many circumstances major uncertainties exist in the reliable determination of partially oxidized organics, which often constitute significant fractions of the oxidizable, ozone-producing compounds in the atmosphere. For example, direct measurements of organic acids and carbonyls, which are important atmospheric co-pollutants and also key components of ozone-formation chemistry, are not yet possible. Similarly, reliable measurements of the oxidizing free radicals that are responsible for ozone formation are not available at the present time. Finally, all air-quality measurements made from airborne platforms are substantially more difficult, uncertain, and less satisfactory than similar measurements made at the surface. The typically marked vertical variability of pollutant and meteorological fields, and its associated relevance to ozone analysis and assessment, renders this a consideration of utmost importance in a sampling context.

Monitoring networks, which have proven to be of great importance in determining exposure to tropospheric ozone and establishing trends with changes in emission levels, have not achieved their full potential. Spatial and temporal coverage is generally inadequate for ozone an its precursors. This is especially true for rural environments and for measurements of precursors such as NO_2 and speciated organic compounds which, owing to their difficulty, are generally much more sparse than those for ozone itself. These features, combined with the almost total lack of measurements of ozone and its precursors aloft, strongly limit definitive interpretation.

In addition, analysis of routine network data generally fail to determine relationships between regions and locations associated with differences or similarities in emission patterns and meteorological conditions. Monitoring networks are often deployed without full consideration of potential multiple uses of the data, especially with regard to understanding the fundamental physical and chemical processes that shape atmospheric composition or determining the atmospheric fate of other co-pollutants. In some cases, there are large bodies of data that have been exposed to little or none of the sustained analysis that is required to determine uniformity of data quality.

In addition to routine monitoring, numerous major experimental programs have been organized and implemented in the past decade to add knowledge of ozone and related pollutant behavior in many areas where severe pollution levels are thought to exist. These programs have added significantly to the information that is required to improve our understanding of ozone chemistry and air-quality models. Much is yet to be learned from the continued analysis of results of these individual programs. In addition, more must be done to integrate and generalize the findings from the various studies.

Despite the substantial new understanding obtained from recent measurements and observations, the channeling of this new information to support air-quality policy formulation has remained limited. The topics outlined below are intended to remove this limitation and provide guidance for future air-quality policy in the context of the 1998 Assessment Document.

4.1. Approach to Assessment

For the Assessment, there are a number of topics that bear on the application of measurements and observations to guide future air-quality management. These include:

a. A survey of observations of ozone and precursors since the mid-l980s to characterize spatial and temporal concentration trends typical of cities experiencing significant photochemical smog, and indicating the status of regional air quality in North America.

b. A review of measurement methods to describe the state of science in measurement technology, including strengths, weaknesses and inherent uncertainties.

c. A description of data archiving and management practices, with a summary of methods to access data bases.

d. A review of monitoring networks in North America, including their purposes, locations and instrumentation, as well as their limitations for routine and special studies.

e. A review of insights about physicochemical processes that are derived from field observations.

f. A discussion of the use of observations to verify the estimates of emission rates and emission sources for ozone and related pollutant precursors.

g. Development of recommendations and priorities for further refinement of measurement methods, for maintenance or adjustment of existing monitoring programs, and for a new series of field studies aimed at gaps in knowledge.

4.2. Specific Needs

The Critical Review Papers concerning measurements and observations will apply knowledge from ongoing programs as a primary information base. The first of these papers will address measurement methods and techniques, while the second will deal with air-quality measurement networks. The third Critical Review paper will review the recent findings on physicochemical processes derived from observations taken in field campaigns. Incorporation of existing knowledge by these reports will be facilitated with a Science Team meeting in the fall of 1996 to discuss with the authors a detailed topical outline for the papers.

In addition to the Critical Review Papers noted above, a special study is proposed to enhance the measurement and modeling reviews and reinforce the reliability of observations from monitoring systems. This is a formal evaluation of the evaluate the quality and usefulness of the Photochemical Assessment Monitoring System (PAMS), which will be discussed in more detail in the final section of this document

5

MODELING AND CHEMISTRY

Ultimately the knowledge of ozone chemistry must be translated into mathematical constructs (models) to facilitate predictions of future conditions, given hypothesized anthropogenic precursor-emission management. This generally has been done by incorporating knowledge of relevant atmospheric physical and chemical processes into air-quality models, which spatially and temporally translate emissions into ambient concentrations and exposures through simulation. The models synthesize in a condensed manner emission distributions, photochemical processes, and meteorological phenomena, which include vertical mixing, wind fields, and radiation conditions. Simulations at the urban scale are known to be greatly influenced by their specified or modeled regional boundary conditions, and almost all models are designed to calculate conditions for periods of a few days under clear-sky conditions, rather than over seasonal or longer periods. Regional models, however, are less affected by initial and boundary conditions than urban models, and they are capable of simulating periods of a few days to a few weeks.

Air-quality models have progressively improved, and have become increasingly sophisticated over the past thirty years. They represent a synthesis of much of our understanding of physical and chemical atmospheric processes. Their reliability in projecting concentration distributions, however, remains ill-defined. It is generally not well established which among many meteorological and chemical processes significantly affect the accuracy of the models' predictions. As with any scientific discipline, there are deficiencies in knowledge of virtually every process that is embedded in the models. Some of these are more important than others. Our ability to test for these deficiencies will be significantly improved by recent advances in measurement methods. Deficiencies in knowledge of the appropriate scales at which to operate the models for management predictions are being addressed by the efficient design and implementation of newer models.

Despite their limitations, air-quality models have been, and will continue to be essential tools to aid the interpretation of atmospheric observations in terms of processes influencing ozone, and have been applied widely for emission-management strategy development throughout North America.

In the next decade, urban- and regional-scale models are expected to become more fully "multipollutant-complete," simulating the interactions and feedbacks among, for example, acidic deposition, fine particles, oxidants, and toxics. Also, increasing attention will be given to embedding compressed, parameterized, coarsened, or even full air-quality models into socioeconomic and health-risk simulation systems to

provide improved means of creating "optimized" choices based on environmental and economic or other societal considerations.

For decision makers, it is important that the current status of air-quality models be reviewed, and the strengths and weaknesses of available tools and methods be articulated. The regulatory community needs to have an appreciation for important progress in process description and models, as well as have an understanding of the current limitations of knowledge as it is applied to management strategy development. In general this kind of information is not forthcoming, but the 1998 NARSTO Assessment will attempt to make these considerations more clear, and will recommend an agenda for continuing research in this area.

5.1 Approach to Assessment

Like the other Assessment components, preparation of this section will rely heavily on the expertise actively engaged in process studies, model evaluation, and applications. We will take advantage of ongoing work to supply a perspective on knowledge gained from studies underway in the 1990s (e.g.,SAQM, UAM-V, Models-3, and URM development), as well as extensive modeling activities associated with local and regional planning development (e.g., state implementation planning and exercises of organizations like the Ozone Transport Assessment Group (OTAG)).

Important modeling- and chemistry-related topics to be addressed that are directly relevant to the assessment questions include:

a. state of knowledge about critical meteorological processes, and their parameterization;

b. state of knowledge about key chemical processes, especially, biogenic VOC reactions, aromatic reactions, secondary chain reactions of high molecular-weight VOC species, and aerosol - cloud interactions;

c. state of knowledge about deposition processes and air-surface exchange that are relevant to ozone and related pollutant concentrations.

d. state of development of air-quality modeling systems, especially their abilities to examine processes, treat multiple scales and treat complex meteorology;

e. state of model evaluation and its development;

f. characterization of current model performance and assessment of model capabilities for application to ozone management strategies;

g. sensitivity of model results, particularly control strategy results, to input or process uncertainties within different scales or climate conditions;

h. analyses using models to explore specifics of the NARSTO assessment science questions;

i. status of applications of modeling to ozone management strategies; recommendations for modeling approaches and best or recommended models for future applications, particularly regarding requirements to address new standards.

j. state of knowledge about integrating strategies for ozone and related pollutants, using existing models and other information.

5.2 Specific Needs

There are a number of modeling and chemistry projects that are expected to be completed or ongoing during the Assessment period and are directly relevant to the Assessment's needs. The EPA cross-model evaluation study is particularly important in this respect. Five critical review papers and two special projects are planned, which will require additional resources. The critical reviews will be closely associated with the topics listed above, and address the following subjects:

a. atmospheric chemistry and chemical mechanisms,
b. meteorological processes and modeling,
c. atmospheric chemistry and air/surface exchange
d. photochemical air-quality models and their evaluation, and
e. model applications to decision analysis.

The two special projects will deal with a. model sensitivity studies, and b. risk analysis and uncertainty in decision making. It is expected that the EPA cross-model evaluation will provide an additional report for the Assessment, but will not require additional resources beyond those currently allocated,

The reviews will be associated closely with the first five topics listed in Section 5.1, above. The two short-term model exercises will focus on topics f. and g., while the cross-model evaluation project will take responsibility for synthesizing results for the 1998 Assessment.

To address the synthesis topics concerning modeling and chemistry, we plan to use the knowledge from ongoing, newly completed projects, and assessment-targeted "in-house" studies as well as the special, commissioned model exercises as the basis for the reviews. Accessing this knowledge will be facilitated by organizing a workshop in late summer of 1996 to bring together experts in modeling with the Science Teams to discuss preparation of components of the 1998 assessment. As in the case of the other Science Team workshops, authors and contributors will prepare an outline of topics to be covered with representatives of the A&AT in the fall of 1996, At the workshop, planning for the white paper on risk analysis and uncertainty will be prepared, and contributing authors will receive their assignments. The details of the specific projects for the assessment are given in the next section.

6

SPECIFIC ASSESSMENT PROJECTS

The funding and scheduling constraints currently imposed on NARSTO, combined with efficiency considerations, require that the l998 Assessment be prepared with maximum in-kind assistance from investigators of ongoing projects. However, the planning for the Assessment has identified several important new projects that need to be undertaken as quickly as possible to meet the l998 schedule. These projects are classed in the two following groups:

(a) critical reviews of scientific progress based on current literature and on emerging results from studies up to mid-l997, and

(b) special "white papers" that will address key topics that are considered important supplements to the Assessment and as input in strategic planning for the next decade.

The critical reviews identified for the l998 Assessment are summarized in Table 6.1, and the special topical papers are listed in Table 6.2. The projects and estimated funding resources are described in the following sections.

Critical reviews of twelve specific subjects are under consideration. These will provide surveys of current knowledge in each of the designated areas, and in aggregate will form the central scientific resource for the synthesis and integration process leading to the l998 Assessment Document. Specific subjects to be addressed range from measurements and monitoring networks, through basic atmospheric processes, to modeling and projects for the future. Uncertainty estimation, as well as information limitations requiring continuing and future NARSTO attention, will be important elements of each of these reviews.

In addition to the critical reviews and the assessment report itself, four special white papers are proposed. These will cover:

(a) the requirements for a sustained monitoring program such as the PAMS,
(b) the intercomparison of results from recent field studies and campaigns,
(c) the sensitivity of air-quality model results to technical uncertainties, and
(d) the emergence of risk and uncertainty analysis of strategy options as an important adjunct to decision making.

Proposed guidelines for preparation of the critical reviews and white papers are included in Appendix C.

Table 6-1: Proposed Synthesis Project and Critical Reviews for the l998 NARSTO Assessment

A. **Synthesis and Integration**

-- Representative team to conduct synthesis and integration of ozone science and policy implication.

B. **Critical Reviews**

1. ***Trends in Ozone and Precursors***
   -- Review of new findings on ozone and precursor changes which relate to VOC and NOx emissions management.
2. ***Measurement Methods and Techniques***
   -- Critical survey of available techniques for observing ozone air quality, and precursor relationships
3. ***Air Monitoring Networks***
   -- Critical survey of existing North American monitoring programs
4. ***Process Insights from Major Field Studies***
   -- Review of results from major field studies that have made an impact on addressing regulatory issues, or have changed scientific views of ozone behavior
5. ***Emissions from Mobile Sources***
   -- Review of methods and results for characterizing mobile source emissions
6. ***Emissions from Stationary Sources***
   -- Review of methods and results for specifying stationary source emissions
7. ***Emissions from Biogenic Sources***
   -- Review of new knowledge characterizing biogenic VOC and NO_x emissions
8. ***Atmospheric Chemistry and Chemical Kinetic Mechanisms***
   -- Review of current knowledge of atmospheric chemistry and its application to refinement of chemical mechanisms
9. ***Meteorological Processes and Modeling***
   -- Critical survey of advances in knowledge about key meteorological processes affecting ozone and related pollutants
10. ***Atmospheric Deposition and Removal Processes***
    -- Review of new knowledge of deposition and removal processes that affect projections of ozone behavior
11. ***Photochemical Air Quality Modeling***
    -- Two reviews on the current state of the art on photochemical air quality modeling and a critical survey of model usage to support regulatory decision making

Table 6-2: Special Studies Supporting the l998 Assessment

1. ***PAMS Data Analysis and Evaluation***
   -- First systematic look at PAMS data to determine its quality and its capability to meet goals set for the network.
2. ***Intercomparison of Results from Major Field Studies***
   -- Review of results from major field studies that have made an impact on addressing regulatory issues, or have changed scientific views of ozone behavior
3. ***Model Assessment Studies***
   -- Key air quality model sensitivity studies that bear on NARSTO science assessment issues and explore important uncertainties
4. ***Risk Analysis and Uncertainties in Decision Making***
   -- Critical survey of progress towards developing risk based modeling tools for decision making, including incorporation of uncertainties in critical information, such as emission projections, and meteorological and chemical data.

Successful preparation of the l998 Assessment is predicated on the assumption that a number of ongoing NARSTO projects will contribute substantially to the effort. Several North American activities are addressing knowledge gaps related to the projection of ozone levels associated with proposed emission-management practices. In addition, a substantial number of programs are underway that employ field campaigns, emission characterization, and air-quality modeling and analysis, which need to be included and evaluated in the NARSTO assessment. Finally, and as noted in Section 1, the Canadian government is completing its own ozone assessment this year. This work will serve as a major background resource for preparation of the 1998 NARSTO Assessment Document.

6.1 Project Descriptions

6.1.1. Synthesis and Integration

The Synthesis and Integration Team will be responsible for distilling the material from the critical reviews and topical papers, and preparing the final Assessment Document. This small team will be composed of senior people capable of integrating the scientific facts and concepts that are important to the broad, overarching issues posed by the NARSTO policy and science questions. This team, along with a small support staff, will work with the authors of the critical reviews and the special topical papers to distill the policy-relevant information needed to create the Assessment Document. The

Synthesis and Integration Team will have representation from the major NARSTO constituencies, allowing for a balanced approach to Assessment preparation. These constituencies are listed below.

S&I Team Constituencies

Science Community
- University
- Government
- Private Sector

Stakeholder Community
- State/Local
- Industry

Policy Making Community
- Canada
- Mexico
- United States

Synthesis Team Facilitator
Publications Coordinator

The Synthesis Team will also be supported in their work by a core group from the Analysis and Assessment Team (A&AT), co-chaired by K. Schere and G. Hidy and by two additional individuals: (a) a facilitator responsible for organizing the team, ensuring program tracking, and facilitating communications, and (b) a publication specialist, responsible for editing and coordination of critical review and Assessment-Document publications.

It is important that the members of the Synthesis and Integration Team be selected early in the process to enable the members to follow closely the progress of the reviews and the topical papers, as well as to participate in meetings of the author panels and the Science Teams. Additional meetings for the Synthesis and Integration Team will be required as they begin their work in earnest in l997.

6.1.2. Critical Reviews

A. Trends in Ozone and Precursors

This critical review paper will focus on trends analysis that helps track the progress and effectiveness of control measures in achieving tropospheric ozone reductions. The paper will cover trends in ozone and its precursors, trends in urban versus rural areas, trends in background ozone, and meteorological filtering methods. Trends in other related trace gases and particles may also be considered. Relationships between the concentrations of ozone and its precursors in the trends will be discussed. Other than tracking the progress and effectiveness of control strategies, trends analysis will focus on examining trends in longer-term concentrations (8-hr avg, seasonal metrics), evaluating model-predicted changes in ozone air quality, examining how well the emissions inventory reflects the impact of control measures, seeking ambient signatures reflecting the impact of particular emissions strategies, etc. A comparison of the trends in emissions with the trends in ambient air quality will be made.

B. Measurement Methods and Techniques

This critical review paper will deal with the ability to make reliable measurements - now and in the recent past - of ozone, speciated nitrogen oxides, speciated hydrocarbons and oxygenates, and other oxidant-related constituents. It also will review the state of measurement technology for meteorological parameters important for air quality, especially from remote sensors. The paper will address the veracity of data acquired with these instruments. The uncertainties of measurement and questions of instrument performance and reliability will be discussed. Recommendations for future technology development needed for improved observations will be outlined.

C. Air Monitoring Networks

This critical review paper will assess the state of current monitoring networks from the perspective of measurement-method reliability, location of stations, purpose of networks, and the potential utility of the data being collected for regulatory accountability, advancing understanding of tropospheric ozone phenomena, and projection of emission management strategies. The data taken by North American monitoring networks are of critical importance to future progress in managing air quality. These data are used to determine trends and assess the progress and effectiveness of emission-management programs. The data are also used to evaluate models and establish their reliability as management tools. As monitoring data take on more multi-purpose aspects, such as at the PAMS sites, higher level diagnostic analysis is possible. The methods employed will be reviewed for their robustness and

tractability in routine monitoring operations. Site-selection, density, and parameters measured will be assessed in relation to monitoring-network objectives. Recommendations will be made for future improvements to meet regulatory and scientific goals.

D. Process Insights from Intensive Field Campaigns

Over the last decade a number of intensive field campaigns have taken place in North America focusing on photochemical oxidants, such as the Southern Oxidants Study, the NARSTO-NE, the San Joaquin Valley study, the North Atlantic Regional Experiment, and others. Analysis of the data taken during these campaigns sheds further light on fundamental processes important for tropospheric ozone accumulation. This critical review will address new insights into ozone formation and radical chemistry, deposition, and integrated analyses including mass budget studies, based on data collected in recent ambient field studies. The application of observations-based models, a form of high-level diagnostic analysis will be reviewed. Implications for NO_X versus VOC limitation for ozone accumulation will be discussed. Also oxidant relationships with fine particles including organic sulfate and nitrate, acid deposition, and other pollutant regimes will be addressed.

E. Emissions from Mobile Sources

This review will examine the current state of knowledge on emissions from on-road and off-road mobile sources in North America. The review will cover the methods used to develop emission factors from measurements, vehicle-use patterns, fleet age and replacement, vehicle miles traveled, pollution control deterioration, etc. Consideration will be given also to the development of emission models, and their use in air-quality calculations, including models such as MOBILE, and EMFAC. Parameters of interest include speciated nitrogen oxides, volatile organic vapors, carbon monoxide and particulate matter. The uncertainties in current emission inventories will be noted, and methods for reconciliation with ambient data will be evaluated. The limitations of emission inventories will be discussed, and possible techniques for their improvement recommended. Differences between vehicle fleets in Canada, Mexico and the United States will be evaluated. Methods of projection for future-year mobile source emissions inventories will be discussed.

F. Emissions from Stationary Sources

This review covers the state of knowledge for VOC and NO_X emissions from stationary sources and their projections, and complements the mobile-source review described above. Stationary sources cover a wide variety of sizes and configurations, ranging from large fossil-fueled power plants and oil refineries to diffuse area sources,

including domestic activity and commercial and small industrial operations. Emission factors for these sources depend on the type of equipment used as well as feed streams, including fuels, chemicals or other raw materials. In most cases standard approaches, described in EPA's AP-42 manual, have been adopted for calculations. As with mobile sources, significant concerns remain regarding inadequate reconciliation between reported inventories and ambient measurements, including chemical element and species balances. The intent of this review will be to describe recent progress in improving emission information and the limits and uncertainties in current inventories.

G. Biogenic Sources

This review will address current knowledge of biogenic emissions, including both VOC and NO_x. Considerable progress has been made in the last decade on developing and describing biogenic emission processes and inventories. Recent work has indicated that VOC emissions especially can have significant influence on regional ozone processes. It remains uncertain whether natural emissions of NO_x, for example from agricultural soils or from lightning, can be significant contributors when projecting emission management strategies. The intent of this review is to critically evaluate the current state of knowledge of natural emissions, as well as their uncertainties and limitations. In coordination with the modeling and chemistry evaluations of this Assessment, an attempt will be made to investigate more deeply the significance of reactivity of key species and their end products, especially aerosols, in relation to the reactions and time scales expected to be important for natural ozone formation. Recommendations will be made for future research in this area to improve an understanding of biogenic emissions.

H. Atmospheric Chemistry and Chemical Kinetic Mechanisms

This critical review will cover the topics of kinetic and mechanistic studies, smog-chamber and other laboratory studies, and the continuing development of chemical kinetic mechanisms. Areas of emphasis will include a review of aromatic VOC reactions, biogenic VOC reactions, secondary chain reactions of higher molecular-weight VOCs, alkene reactions with O_3 and NO_3, peroxy-radical chemistry, and heterogeneous processes, including possible aerosol reactions, and hydrometeor reactions. Smog-chamber and laboratory studies will be reviewed, with special emphasis on emerging data sets acquired at low VOC/NO_x ratios, and low VOC and NO_x concentrations applicable to tropospheric conditions. The state of science in chemical mechanisms will be evaluated, including currently operational mechanisms such as CB-IV, SAPRC, RADM2, LACTOZ, as well as the new "morphecule" mechanism currently under development.

I. Meteorological Processes and Modeling for Air Quality Assessment

This review paper will address the state of science in meteorological processes and modeling that are relevant to ozone and related pollutants. Key issues include the assessment of which processes are important at various spatial and temporal scales of interest, what methodologies exist for generating mathematical characterizations of meteorological fields suitable for air-quality assessment (including diagnostic and prognostic models), and what requirements are needed to reduce uncertainties in meteorological characterization. The latter subject will include discussions of measurements and observational data assimilation, improved process parameterization, numerical methods, and model evaluation. Particular issues of linkage between meteorological models and air-quality models will be addressed.

J. Atmospheric Deposition and Removal Processes

This critical review will assess the state of knowledge relating to the physicochemical removal processes for photochemically significant trace gases. These processes are known to significantly affect ozone behavior on regional scales, and under conditions where buildup of pollution takes place over extended periods. Both dry and wet deposition will be considered. Land-use characterization, surface resistance, turbulent transfer, and biological and chemical influences on deposition will be addressed. Wet removal processes and relevant aspects of aqueous and heterogeneous chemistry and cloud microphysics will be reviewed. Parameterization schemes for deposition and their attendant uncertainties will be included.

K. Photochemical Air Quality Modeling

At least two review papers addressing air quality modeling are contemplated. The first will be concerned with describing current models, their components, and their performance evaluations. The second will address their applications to regulatory issues. This paper constitutes the first of the two. It will cover the current state of science in modeling, including recent improvements in process simulation, development of multi-scale models, numerical techniques, process integration, data requirements and preparation, the structure and description of current modeling systems, and the limitations of current systems. The model evaluation component will review recent efforts to compare air-quality model results with ambient data collected from monitoring networks and intensive field campaigns, both on urban and regional scales. Emphasis will be placed on diagnostic evaluation. Model sensitivity to measured and/or modeled input data will be reviewed in this report. The needs for focused research to fill key gaps of information on modeling will be addressed to indicate productive directions for new work.

The second critical review for air quality modeling will cover important aspects of model applications for regulatory decision making that have taken place, especially for recent Canadian and Mexican evaluations of their photochemical pollution, and for U.S. national strategy development and state implementation planning since the 1990 CAAA. Major results from these calculations and model studies that provide direction and level of control for different regions and urban areas will be noted. The results will be critiqued in the light of uncertainties in the applications of models based on input data, boundary conditions, and choice of meteorological conditions for design cases. Also noted will be results of model sensitivity testing for different regulatory scenarios, emissions uncertainty, and variable ambient chemical conditions. Considerations will be given to the requirements for modeling that will develop from adoption of new national standards in the U.S., and the capabilities of existing models to address these requirements.

6.1.3. Special Topical Papers

In addition to the Critical Review Papers outlined above, several special "white papers" on selected topics are considered desirable to provide a complete documentation of our understanding relevant to tropospheric ozone and its management. These are listed in the subsections immediately below and are prioritized into categories 1 and 2 respectively, depending on whether a specific paper is felt to be an "essential" or merely "desirable" component of the assessment process.

A. PAMS Data Analysis and Evaluation

The Photochemical Assessment Monitoring Stations (PAMS) program is a new effort by the U.S. EPA and individual States to provide a long-term, high-quality data base within and surrounding specific urban areas that continue to have problems meeting ambient air-quality standards for ozone. The PAMS measurements include not only ozone, but also its primary precursors, NO (also NO_x), speciated hydrocarbons, and carbonyls, as well as meteorological variables at the surface and aloft. These measurements have long been needed to verify the progress and effectiveness of emission-control programs in the U.S. Many of these measurements, however, do not lend themselves easily to routine monitoring, and questions remain as to the accuracy and precision of the data being collected. PAMS results are only now becoming available, so there has been little chance thus far to perform diagnostic analyses and evaluation of the data. At the same time, severe budget constraints on federal and state governments are putting pressure on the PAMS program to slow or cut back its implementation.

The PAMS network represents an important national resource for air-quality management. It is very important that the data being collected be evaluated in a timely manner, so that problems in collection methods, instrumentation, maintenance, calibration, archiving, etc. can be identified and corrected as soon as possible. Methods for improved diagnostic evaluation and screening of the PAMS data are needed. This special project will examine the 1994-1996 PAMS data sets and develop evaluation procedures and protocols for various aspects of the data. Level-1 analyses will be performed to evaluate the accuracy, precision, and consistency of data at individual sites. Level-2 analyses then will compare data across PAMS sites in time and space to assess network problems and look for persistent patterns of behavior in the data. Analyses will include statistical evaluation of spatial and temporal features as well as the physical and chemical relationships between measured variables.

Priority: 1, based on urgent need for NARSTO to insure that the PAMS network is operating effectively, that the data will be used to maximum advantage in the 1998 Assessment, and that PAMS results will be examined and used by the regulatory and technical community.

B. Intercomparison of Results from Major Field Studies

Over the last decade several major field studies of tropospheric ozone have been conducted in North America, as well as at locations abroad. Each has been designed and executed in a closed geographical setting with specific objectives in mind, but usually without consideration for generalization of results. Embedded in these study results is a rich database as well as individual analysis sets which, when integrated, will add substantially to our extended knowledge of ozone formation and dissipation. Evaluation and integration of these findings will require substantial effort beyond simply a literature survey, because many of the details appear only in narrowly distributed informal reports, working papers, and partially completed analyses by individual investigators. This work needs to be examined carefully and systematically in the light of the 1998 Assessment Questions.

The incorporation of integrated information from the major field studies and their respective analyses will require supplemental resources beyond the scope of the critical reviews described in the previous section. The field studies to be considered include SCAQS, SJVAQS, EMEFS, SOS, NARSTO-NE, COAST, LMOS, Canadian campaigns in British Columbia and Ontario, and ongoing Mexico City studies. Examination of the findings of these studies is planned in the following sequence:

1) A literature survey will be conducted describing the experimental designs and data bases, and reported results will be assembled with the assistance of the

study investigators.

2) The results will be organized and classified according to the duration of each study, associated climate conditions, key meteorological conditions for high and low ozone concentrations, speciated VOC and NO_X emission profiles, VOC and NO_X emissions and ambient concentration ratios, regional transport conditions, peak ozone VOC and NO_X concentrations and times of occurrence, apparent ozone formation rates, steady state ozone NO_X conditions, pollutant statistics, and related chemistry conditions.

3) The assembled results will be compared on a cross-study basis. Similarities and differences will be linked with emission profiles, meteorological conditions geographical location.

4) Using the results of Step 3, additional examination and analysis will be attempted in the context of specific Assessment questions.

The observational results will be combined with those form modeling studies and adjunct laboratory experiments. Environmental features anticipated to be of particular interest in this cross-integration include:

a) localized urban vs. regionally dominated meteorologically similarities,

b) persistent atmospheric stagnation regimes,

c) similarities in VOC and NO_X emissions and/or ambient concentration profiles, and

d) chemical process conditions, for example sunlight duration and intensity or cloud cover.

Results of this cross-study integration will provide key information for the NARSTO Assessment as well as an important framework for designing future field campaigns.This special project must be initiated in mid 1996 to ensure its completion in 1997 and its incorporation in the Assessment.

Priority: 2 based on expected value if only a comparative literature survey is to be undertaken; 1 if additional analysis or comparative interpretation is to be undertaken.

C. Model Assessment Studies

Many of the NARSTO science questions can be addressed most expediently from the air quality modeling perspective via model sensitivity studies. Sensitivity analysis is an invaluable tool to dissect assessment-related issues. A major transition in air quality models has occurred since the NAS report, combining urban and regional modeling into a single system. Assessment studies with the new generation of modeling systems are fragmented and few, if any, have been reported. Thus, gaps exist in our understanding about system behavior, as embodied in the air quality models, relating to the NARSTO science questions. A major value added to the NARSTO science assessment will be gained by conducting timely, well-targeted model assessment/sensitivity studies that provide answers to important assessment questions. Illustrative examples are:

- Major uncertainties in mobile source emissions exist regarding both magnitude and location (fleet characteristics are very different in different sections of urban areas). Key question: How important are these uncertainties to urban ozone predictions (peak magnitude, peak location, integrated exposure)?

- Key application question: What is the zone of influence of emissions from a given source region on ozone?

- Key policy-oriented model evaluation questions: How closely do results from different models correspond? Are perceived differences due to inputs, and/or model physics and chemistry, and/or vertical and horizontal grid resolution?

- Chemical mechanism formulation uncertainties (particularly for biogenic and aromatic chemistry) may lead to incorrect ozone response under control scenarios. Key question: How may these uncertainties bias predictions of O_3 and predictions of control strategy response in urban and rural areas?

Topics representing major gaps relating to key assessment questions would be collected by the Modeling and Chemistry Team. Ideas would be solicited for model studies to address the gaps, representing either extensions of current work, additional work under current programs, or new efforts. The ideas would be reviewed and the best selected at the next modeling workshop. The selected set would be a mix of work under existing programs (no new resources) and new work (up to three commissioned studies). The results of all studies would be presented at the NARSTO 1997 Science Meeting and concurrently prepared for peer review and publication.

Priority: 1 based on a continuing need to inform decision makers about sensitivity and limitations of current photochemical air quality models as part of assessment.

D. Risk Analysis and Uncertainties in Decision Making

Uncertainty permeates all aspects of air quality science and management practice. Central to the air quality community's motivation is effective management of the air resource, which in turn depends on the wisdom brought to play by decision makers, scientists and engineers, and policy analysts in identifying, understanding, quantifying and acting within bounds of uncertainty. As environmental regulation has matured, increased concerns for socioeconomic factors have come into play, which add complexity to decision making, and add uncertainty in selecting appropriate options to optimize management choices and timing.

Efforts to understand and quantify uncertainty have been limited and sporadic. No guidelines, explicit or implicit, for estimating and reporting uncertainty have emerged from the limited efforts undertaken. Yet, now, more than ever, the need for addressing and communicating uncertainty is clear and timely given an increasing plethora of socioeconomic priorities, only one of which is environmental protection. It is important that the next steps toward ozone management foster and account for risk based decision making opportunities.

The purpose of this proposed white paper is to:

a. Review the literature pertaining to air quality that addresses decision analysis, risk assessment, uncertainty estimation and sensitivity analysis
b. Assess current analytical capabilities pertaining to these topics
c. Identify information gaps and needs, and
d. Recommend a research agenda for achieving substantial progress in the short and intermediate term for developing capabilities of direct use to decision makers.

Specifically, the white paper will:

a. Present a full slate of policy and scientific questions related to uncertainty and risk assessment that the community proposes to address in the longer term
b. Review efforts in decision analysis, risk assessment, uncertainty estimation and sensitivity analysis that have been conducted to date
c. Assess accomplishments and report limitations and concerns
d. Delineate the existing gaps between needs and accomplishments
e. Clarify and further define needs
f. Assess the extent to which the gaps can be reduced significantly and the nature of the efforts required
g. Identify efforts that should be conducted, the levels of effort required, the anticipated returns, and

h. Consider the implications to decision making of adding risk based methods to ozone management strategy analysis vs. not pursuing such efforts.

Priority: 1 based on potential for stimulating new ideas and approaches to modeling and risk analysis applied to decision-making for air-quality management.

References

National Research Council (1991). *Rethinking the Ozone Problem in Urban and Regional Air Pollution.* National Academy Press, Washington, DC.

NARSTO (1994). *Research Strategy and Charter.*

Appendices to Part 2

Appendix 2-A

Detailed Science Questions for NARSTO 1998 Assessment

Science question 1. *(Addresses Policy question 1.)*

What are the most significant research developments in tropospheric ozone science over the last decade?

- o How have these developments confirmed or changed our conceptual picture of tropospheric ozone processes?
- o What are the principal remaining scientific uncertainties?
- o Are there any scientific breakthroughs on the horizon in the next few years?
- o Would these breakthroughs/developments alter the way we are managing the ozone problem?

Science question 2. *(Addresses Policy questions 2,3,4.)*

How does ozone accumulation on local and regional scales depend on the source dimension and location? How does it depend on the relative contribution from local and regional sources?

- o What are the relationships among point source, urban, regional, and larger scale processes and tropospheric ozone levels?
- o What are the regional transport influences on urban-scale ozone and the urban influences on regional tropospheric ozone?
    - > How large a region must be considered; do we know how large is large enough?
    - > What do modeling analyses and measurements tell us about transport scales of regional, urban, and point source emissions influences?
    - > What is the sensitivity of urban ozone to regional transport of ozone, of NO_2/PAN, of VOCs/carbonyls?
    - > What spatial and temporal resolutions are required for modeling to assess regional transport effects on an urban area experiencing high ozone concentrations?
    - > What measurements are needed, where are they needed, and what degree of accuracy is needed to assess regional transport effects on an urban area experiencing high ozone concentrations?

- o 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?
  - > What are ambient measurement programs revealing about fundamental processes?
  - > What are modeling studies revealing about fundamental processes?
  - > What are laboratory studies revealing about fundamental processes?
- o What is the influence of stratospheric ozone on tropospheric ozone concentrations?

Science question 3. *(Addresses Policy questions 3,5.)*

What are the most recent assessments of the relative contributions of VOCs, NO_x, and CO to ozone accumulation on local and regional scales in North America?

- o Is the accumulation of ozone limited by the availability of VOCs or NO_x?
  - > 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?
  - > What portion of the ozone precursors are from natural (biogenic) sources, and how will these emissions change with meteorological variability, land-use, and climate change perturbations?

Science question 4. *(Addresses Policy questions 2,3,4.)*

What are the relationships between the scientific understanding of the tropospheric ozone system and the on-going efforts to manage it?

- o How do regional versus urban emissions controls affect local, urban ozone?
  - > What are results of modeling analyses indicating effects of regional versus local emissions controls?
  - > What measurements can be made to assess the adequacy of modeled estimates of emissions control impacts on ozone?

- What are the critical limiting factors (uncertainties) in current models for assessing and managing urban and regional ozone problems?
  - How do strengths and limitations affect the way emissions-based air quality models are best applied?
  - Are emerging multi-scale air quality modeling systems more accurate and more useful than their predecessors in estimating regional/urban ozone, precursor, and other key species concentrations?
  - Can single (urban) scale models be used to assess regional/urban interactions?
  - What is the sensitivity of modeled ozone management strategies to the accuracies of emissions inventories?
  - What confidence do we have in model-predicted changes in ozone given a change in precursor emissions?

- What are the critical limiting factors (uncertainties) in current measurement methods for assessing and managing urban and regional ozone problems?
  - How do strengths and limitations affect the way measurements are best used?

- How might an efficient approach toward ozone management be constructed that combines observational analysis and modeling techniques?
  - How might such an approach be made operational?
  - What is needed for a successful modeling study in support of air quality management?
  - How can observational methods and emissions model techniques be combined to reduce uncertainty and risk? How can these risks best be communicated to decision makers?

- What are the scientific implications of assessing ozone and strategies for its control over periods longer than an episode (up to a season or year)?
  - How will emissions control impacts change under a new primary standard, such as an 8-hr averaging period?
  - How many episodes must be analyzed to assess against the new primary standard? Is episodic modeling meaningful?
  - What new measurement and modeling methods might be required to assess a potential secondary (seasonal) ozone standard?
  - Can we characterize the seasonal ozone "baseline" or clean continental concentration for different regions?

Science question 5. *(Addresses Policy questions 3,4,5.)*

What approaches are required to determine historic concentration trends of ozone and its precursors on local and regional scales? What is required to demonstrate the effectiveness of emissions control strategies over time?

- o What measurements are needed, and where, to track the impact of emissions, meteorology, ozone and precursors over time to detect a signal in each component?
- o What techniques can be applied to observed concentration trends to minimize the confounding influence of the meteorological signal?
- o What do models tell us about the confounding influence of the meteorological signal on pollutant concentration trends?
- o Since urban ozone trends are generally downward, is the basic management strategy a sound one but with need for fine-tuning, or are there more fundamental problems?
- o What do we know about ozone trends in rural areas? What is the urban ozone influence on rural concentrations?
- o What approaches are required to evaluate ozone exposures of humans and ecosystems?
- o How can measurements be best utilized?

    - > What are the most important additions/improvements in PAMS and similar monitoring to facilitate emissions inventory evaluation and improvement, air quality model evaluation and improvement?
    - > What types of method development efforts, field studies, and training are needed to maintain high quality data from PAMS and similar networks?
    - > What data analysis techniques are most useful, for scientific or regulatory purposes, in eliciting information from the PAMS and similar data?
    - > How can the long-term sustained effort in PAMS or other monitoring be used to establish progress in achieving improved air quality?
    - > What improvements are needed in the long-term monitoring effort in rural areas?

Science question 6. *(Addresses Policy question 6.)*

What are the relationships between the control strategies designed to manage tropospheric ozone and those designed to manage other pollutant regimes of interest?

- What are the linkages and feedbacks between other pollutants of concern (especially, fine particles, regional haze, acid deposition, and airborne toxics) and tropospheric ozone?
- Can future operational assessments be performed in an integrated manner across different pollutant regimes?

Appendix 2-B
Areas Critically Affecting Development of Ozone Management Strategies Based on Today's Knowledge

(Assigned Priority based on Impact of New Knowledge on Predictions of Photochemical Behavior in Air Quality Models)

Processes	**Priority**
Meteorology	
--Coupling of ground and aloft (Mixing, flux characterization, clouds)	2
--Spatial and temporal scaling	2
Chemistry	
--Aromatics (especially secondary reaction steps)	2
--Biogenic compounds	1
-- Long chain alkenes and alkanes (secondary steps)	3
--Aerosol and aqueous processes	3
-- Reactivities and other potential oxidants (role of HONO; Cl,...)	3
Measurements	
Spatial and Temporal Coverage	
--Sustained long term monitoring (precursors and oxidants)	1
-- Regular, sustained measurements aloft	1
Chemical Speciation and Mass Balances	
-- Speciated nitrogen (closure of N balance)	2
-- Radical Pool and Other Oxidants	3
-- Oxygenates and Organo-Nitrates	3
Emissions	
Mobile Sources	
-- Vehicle Fleet under driving conditions	1
-- Effective modeling and uncertainty with duty cycle and daily variations	1
-- Off Road Vehicles (incl. marine activity)	2
Stationary Sources	
-- Large source characterization and uncertainties	1
-- Small, diffuse sources, particularly VOCs	2
Biogenic and Natural Sources	
--VOCs (especially for regional cases)	1

-- NOx sources (soils, and lightning,...)	3
Emissions Projections	
--Accounting for future socio-economic and technological changes	1
Models	
Formulation, Testing, and Verification	
-- Simulation of seasonal oxidant climatology and stochastic characterization of variability	1
-- Diagnostic limitations and uncertainties in simulating ambient concentrations	2
-- Accounting for scaling questions (multi-scale requirements	1
Applications for Decision Making	
-- Reliance on one design episode, and one model	1
-- Accounting for uncertainties and variability	2
-- Use of multi-scale models or algorithms	2
-- Development of integrated assessment framework	2
-- Application of decision-risk models and approaches for integrated assessment	3

Appendix 2-C

Guidelines for Review Paper Preparation

Twelve Critical Review Papers are being prepared as part of NARSTO's 1998 Ozone Assessment process. Their topics have been selected carefully to include all source-receptor phenomena influencing tropospheric ozone exposure, with the intent that the collective product will provide a complete and in-depth scientific distillation of current knowledge on the subject. This ensemble of papers will be used as the primary scientific information base for preparation of the 1998 Assessment Document, which is intended for extensive use by the policy-analysis community. The basic information flow associated with this process is depicted schematically in Figure C-1.

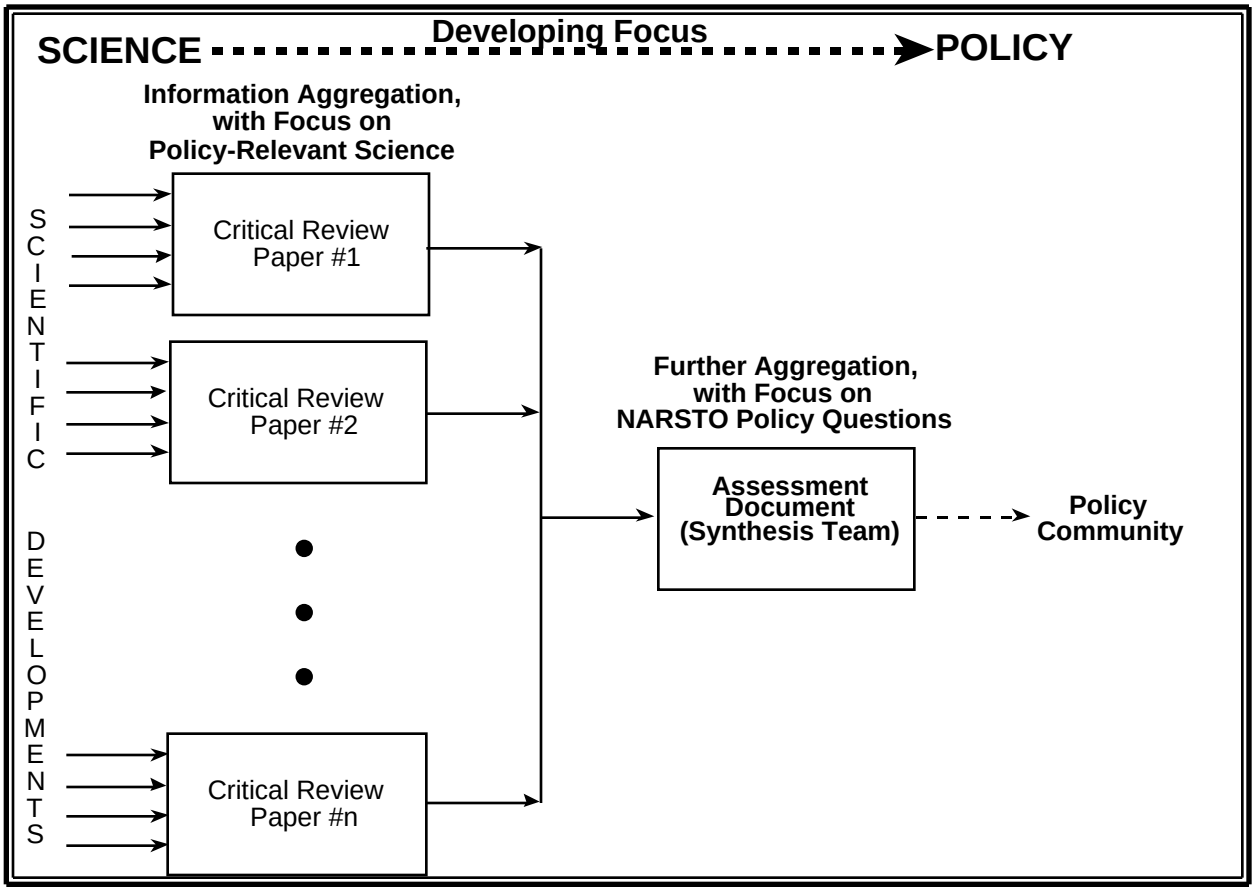

Figure C-1: Schematic of Information Flow for Assessment Document Preparation

The NARSTO **Synthesis Team** is composed of a group of individuals, who are directly responsible for writing the Ozone Assessment Document. As can be noted from Figure 1, the Synthesis Team is the **primary audience** for the Critical Review Papers. Other important audience elements include the **general scientific community** as well as **anyone else who desires to examine in detail the scientific underpinnings of statements made in the Assessment Document.**

Authors should be familiar with the general background information used as historical input to the SIP process, as well as with the contents of the recent draft US criteria document for ozone and the (forthcoming) Canadian assessment. The Critical Review Papers should not attempt to duplicate these earlier documents but rather should be more concise and selective reports that draw from these earlier works, noting significant areas of agreement and disagreement. Several additional guidelines for preparing the NARSTO Critical Review Papers are given as follows:

1. As their name implies, the reviews should be *critical*, in the sense that they focus substantial attention on key information gaps and sources of uncertainty that make a difference for regulatory decision making. Quantitative estimates of these features should be given whenever possible, as well as evaluation of associated impacts on ozone management and its reliability for the different national interests and concerns.

2. The reviews should be formatted in a manner such that their initial sections present a *broad picture* of the material to be covered and its *practical relevance* to local and national concerns regarding ozone management. These initial sections should set the stage for the more focused and detailed material, which should appear in later sections.

3. The reviews should aggregate and distill all policy-relevant scientific information that is pertinent to their respective review topics. Substantial emphasis should be on scientific developments later than those captured in the NAS report (ca. 1985 and beyond); however, earlier information should be included as necessary to promote readability and completeness.

4. The reviews should support the transition in focus between science and policy that is indicated in Figure 1, above. While the reviews are intended to be scientifically oriented, they should present this information in a form that facilitates, in as much as possible, further aggregation and extraction of its policy-related content into the Assessment Document.

5. The NARSTO Science and Policy Questions, and the relevance of Critical Review-Paper content to these questions, should be kept in mind continually as the framework for preparation of the reviews.

6. The reviews should include lists of definitive "findings" statements. For each review, the total list of these statements should encapsulate the essence of the paper. These "findings" lists should appear in both the conclusions section and in the executive summary. Findings should call attention to important results that will make a difference in, or alternatively, reinforce, the current policy direction.

7. The reviews should maximize use of pertinent existing reviews and aggregations. These should be noted and summarized in the Critical Review Papers, but should not be re-created in them.

8. The reviews (and the Assessment) should not be written in a manner so as to, either explicitly or implicitly, channel the evaluation into any particular control paradigm (such as the SIP approach, for example). Rather, they should promote the flexibility to consider other, possibly more cost-effective paradigms, if these should become practical.

9. Current plans call for publication of the Critical Review Papers in a common volume (or volumes) of an open-literature periodical, pending normal journal review. Although this journal is not yet determined, it appears appropriate that page count of the Papers should be limited to about 50 single-spaced typewritten pages, including figures.

Comprehensive formatting rules for the Papers will be announced in the future. For the present, and in reflection of the above guidelines, the following rough presentation outline is provided for initial author guidance:

1. INTRODUCTION
   a. Statement of Scope
   b. Statement of Objectives
   c. Definition of Terms (as appropriate)
   d. Relevant Chemical Species (as appropriate)

2. SCIENTIFIC RELEVANCE (How are the scientific features of this topic relevant to ozone management? . . . Conceptual picture of relevance: use graphic if possible)

3. STATE OF SCIENCE (Subdivided by category, as appropriate)
   a. General State of Scientific Understanding
   b. Recent Developments and their Implications to Ozone Management (Problems should be addressed that were identified in the last 10 years including statements regarding how they were resolved, if indeed they have been resolved. If not, some statement should be given regarding the directions and further resources required for resolution. Examples: VOC mobile emission controversy; biogenic precursors; etc.)

4. CRITICAL ANALYSIS
    a. Uncertainties and Information Gaps (quantitative)
    b. Corresponding Uncertainties in Ozone Management

5. CONCLUSIONS (Include itemized list of definitive "findings")