Final Report

REGIONAL AIR POLLUTION STUDY: A PROSPECTUS

Part I — Summary

Prepared for:

THE ENVIRONMENTAL PROTECTION AGENCY
NATIONAL ENVIRONMENTAL RESEARCH CENTER
RESEARCH TRIANGLE PARK, NORTH CAROLINA

CONTRACT 68-02-0207

SRI Project 1365

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FOREWORD

This Prospectus was prepared by Stanford Research Institute for the Environmental Protection Agency under Contract No. 68-02-0207. While this Prospectus has been reviewed by the Environmental Protection Agency and approved for publication, approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency, nor is it intended to describe the Agency's program.

The complete Prospectus for the Regional Air Pollution Study is presented in four parts.

Part I	Summary
Part II	Research Plan
Part III	Research Facility
Part IV	Management Plan

A table of contents for all parts is provided in each of the four parts to facilitate the use of the Prospectus.

ACKNOWLEDGMENT

This Prospectus was prepared at the Institute by a project team representing the full range of disciplines necessary for the comprehensive analysis of problems of air pollution. Research team members were drawn from four of the eight Institute Research Divisions, including the following:

Electronic and Radio Sciences
Physical Sciences
Information Science and Engineering
Engineering Systems

Because of the interdisciplinary nature of the effort, the contributions and research findings of many team members are distributed throughout this Prospectus rather than concentrated in one or more specific chapters. Accordingly, contributions are acknowledged below by general areas associated with the study of air pollution problems.

This Prospectus was prepared under the supervision of R.T.H. Collis, Project Director. The Project Leader was Elmer Robinson (now of Washington State University) until 15 January, when Richard B. Bothun, who had been Deputy Project Leader, succeeded him.

The main contributions were as follows:

- Elmer Robinson--Project leadership and the formulation of the Research Plan

- Richard B. Bothun--Project leadership and administrative management and the formulation of the Management Plan.

Technically, the principal contributions were:

- Richard B. Bothun--Management, scheduling, costing, planning

- Leonard A. Cavanagh--Air quality instruments, atmospheric chemistry

- Ronald T. H. Collis--Meteorology, remote sensing, research planning
- Walter F. Dabberdt--Transport and diffusion modeling, meteorology, instrumentation
- Paul A. Davis--Solar radiation, tracer studies
- Roy M. Endlich--Meteorological models, satellite systems
- James L. Mackin--Helicopter and aircraft systems
- Elmer Robinson--Meteorology, instrumentation, atmospheric chemistry, research planning
- Sylvin Rubin--Data processing systems
- Konrad T. Semrau--Source inventory and emissions
- Elmer B. Shapiro--Communication systems
- James H. Smith--Atmospheric chemical transformation processes
- Eldon J. Wiegman--Synoptic climatology

Valuable contributions were made in the latter stages of the project by Dr. W. A. Perkins and Mr. J. S. Sandberg, consultants.

The Institute wishes to express its appreciation for the assistance and provision of information by many staff members of the Environmental Protection Agency, especially Charles R. Hosler, Contracting Officer's Technical Representative; Dr. Warren B. Johnson, Jr., Chief, Model Development Branch; Robert A. McCormick, Director, Division of Meteorology; and Dr. A. P. Altshuller, Director, Division of Chemistry and Physics.

Additionally, the constructive criticism and comment provided by members of the Meteorology Advisory Committee of the Environmental Protection Agency during the preparation of the Prospectus were of significant value, and our indebtedness is hereby acknowledged.

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PART I - SUMMARY

I THE BASIC PREMISE

Both implicitly and explicitly, the Air Quality Act as Amended (1970) accepts the premise that air quality improvement can be planned scientifically. Specifically, it presupposes that emission standards can be set by reference to the desired ambient air quality standards, taking into account the manner in which the combined products of various sources in any particular area are dispersed or concentrated by physical, chemical, or meteorological processes. Following its announced policy of emphasis on enforcement, the Environmental Protection Agency is aiding state and local agencies to develop strategies to ensure compliance with such air quality standards as have been set. EPA is also following a policy to extend control procedures to achieve improved air quality standards as they are specified.

This overall concept will fail or succeed to the extent that the basic premise is true. Can air quality improvement be planned scientifically, at least to a useful degree, with existing knowledge and capabilities? If not, what is lacking? By what time can any shortcomings be rectified? The procedures, such as developing Implementation Plans called for under the Air Quality Act (or of filing Environmental Impact Statements under the National Environmental Policy Act), take for granted that existing knowledge and capability are at least minimally adequate for planning. Those who challenge this belief feel that all that can usefully be done at the present time and in the near future is to reduce all emissions to the minimum possible within the state of the art, regardless of any postulated requirements to meet what they may consider to be artificial air quality standards.

In either case, it is clear that room exists for considerable improvement in the knowledge and capability that are necessary for confidently relating cause and effect both between emissions and air quality and between control strategies and air quality.

There also can be no doubt as to the value of such a capability. Without such a basis, intelligent direction cannot be given to improving the state of the art of emission control; nor can correct decisions be made between alternatives in control strategies that do not depend on emission suppression and in allocating priorities and assessing cost-effectiveness in either case.

II SCIENTIFIC AIR QUALITY MANAGEMENT

The Basic Tool--The Mathematical Model

The central element of the concept of scientific air quality management is the mathematical simulation model. With this tool, the result of certain actions or inaction can be predicted. If the models are accurate and the data input correctly known or forecast, their output will show the effects of change, whether it occurs without specific intervention or as the result of such intervention. The accuracy of the models will depend on the degree to which the processes used are understood and can be described within the constraints of the mathematical technique. Accuracy will also reflect the inherent uncertainties of the statistical approach. In addition, since the atmosphere is the medium in which pollutants are dispersed, the only too well known difficulties in describing and predicting meteorological conditions must be recognized.

The Processes to be Modeled

However, before a simulation model can be formulated, it is necessary that the physical, chemical, and meteorological processes that are entailed be understood. In the very simplest form, models will consider only the gross relationships between emissions and air quality and will be correspondingly imprecise. More detailed and comprehensive models can be developed for certain processes, but they may be limited in their application by difficulties in providing adequate input data. The latter, particularly in regard to emissions, are often difficult to obtain at any price, and certainly their collection poses critical questions as to costs. Such factors become pertinent when the usefulness or value of any given model is considered. Will more timely and voluminous input data improve the accuracy of the models' output? Will more highly developed formulations of complex physical, chemical or meteorological processes more accurately describe and predict what is happening in the real world? How accurate are such descriptions and predictions anyway? These questions must be faced and satisfactorily answered if the models are really to play a key role in air quality management.

Accuracy

A most important question is the accuracy of the models. If control strategies with far-reaching economic and social effects are to be imposed on the basis of a simulation model, it is more than desirable that the model's output be accurate and sufficiently precise to enable the effects of the strategies to be evaluated. In dealing with control and abatement procedures that require large increases of investment in plant or of costs of operation, especially where the relationship between such procedures and the hoped for improvement in air quality is not linearly related, it is not enough to know that the model is accurate in general terms. It must be capable of providing more precise information on the benefits in air quality to be derived from the costs of the control and abatement procedures proposed. Without such a capability, the procedures could be very uneconomical and absorb effort and resources that could be used more profitably elsewhere. These aspects become increasingly important as the more obvious control and abatement procedures are adopted and attention is turned to the more marginally productive strategies.

Above all, in the use of modeling techniques in air quality management, the need is most urgent to ensure that all concerned have confidence in the approach. With large financial involvements, with the livelihood of whole communities at stake, with the tremendous pressures on limited resources to plan, implement, and enforce control strategies, it is imperative that decisions are not only wisely taken but also that they are readily seen and recognized as being wisely taken. Sound modeling capability serves all aspects of this obligation and provides the evidence on which sound enforcement strategies can be sustained.

Current Limitations of Modeling

As noted above, the position regarding air quality modeling at the present time is far from satisfactory. A wide diversity of such models exists or is being developed, and these models cover a range from quite limited problems--such as diffusion from a single point source--to the extended scale covering large urban complexes. Only in a few cases that are concerned with fairly simple problems are the models well tried and sufficiently verified to warrant confidence in their use.

There are many reasons for this state of affairs. The major reason, quite simply, is that solving the problem has just not been undertaken on an adequate scale. Progress made with the limited funds and resources available to date has lagged far behind the need, which itself has been recognized as urgent only in the last year or so. As indicated, the development and verification of suitable models are very difficult, especially on a major scale, and depend strongly on the availability of adequate data on which to base the formulation and to develop its application. It is possibly even more difficult to assess its capability and measure its precision accurately, especially where long time periods are needed to provide an adequate basis of comparison.

Steps to Improve Models

The steps taken in conceiving, developing, and proving an air quality model are shown diagramatically in Figure 1. To the present, most progress has been made in understanding the processes and in formulating the model, even though the item in the diagram--"Observations of Various Conditions"--has been limited if not thoroughly inadequate. For the latter reasons, operation of the model both for description and prediction has generally been constrained, and the comparison and evaluation of its results against observations have frequently been inconclusive or inadequate, if indeed they have been attempted at all.

The decisive limitation in the whole process lies in the first area noted in the diagram--"Observation of Various Conditions." This area is fundamental to all aspects of the problem, and its shortcomings cripple every subsequent endeavor. Thus, many existing models are based on the very limited data that have been acquired routinely for quite different purposes, e.g., airway weather forecasts, and are woefully inadequate in both extent and spatial and temporal resolution for the development and verification of models or even, in some cases, for developing an adequate understanding of the processes involved.

The limitation of basic data results from the fact that the collection of such data on a sufficiently continuous scale in space and time and over a large enough area for long enough periods is extremely costly, even if suitable sensing devices exist. (The situation is much worse when there is no practical or reasonably economical way to make even the individual observations--as is the case with certain pollutants.) Even when attempts have been made in certain circumstances to set up special networks of observational facilities and carry out intensive data collection programs, the results have often left much to be desired and reflect the shortcuts that have been taken because of cost in instrumentation and in collecting and handling the data. Particularly in the past, when much reliance had to be placed on manual procedures of data collection and analysis, the data acquired under such programs were limited and somewhat piecemeal--serving

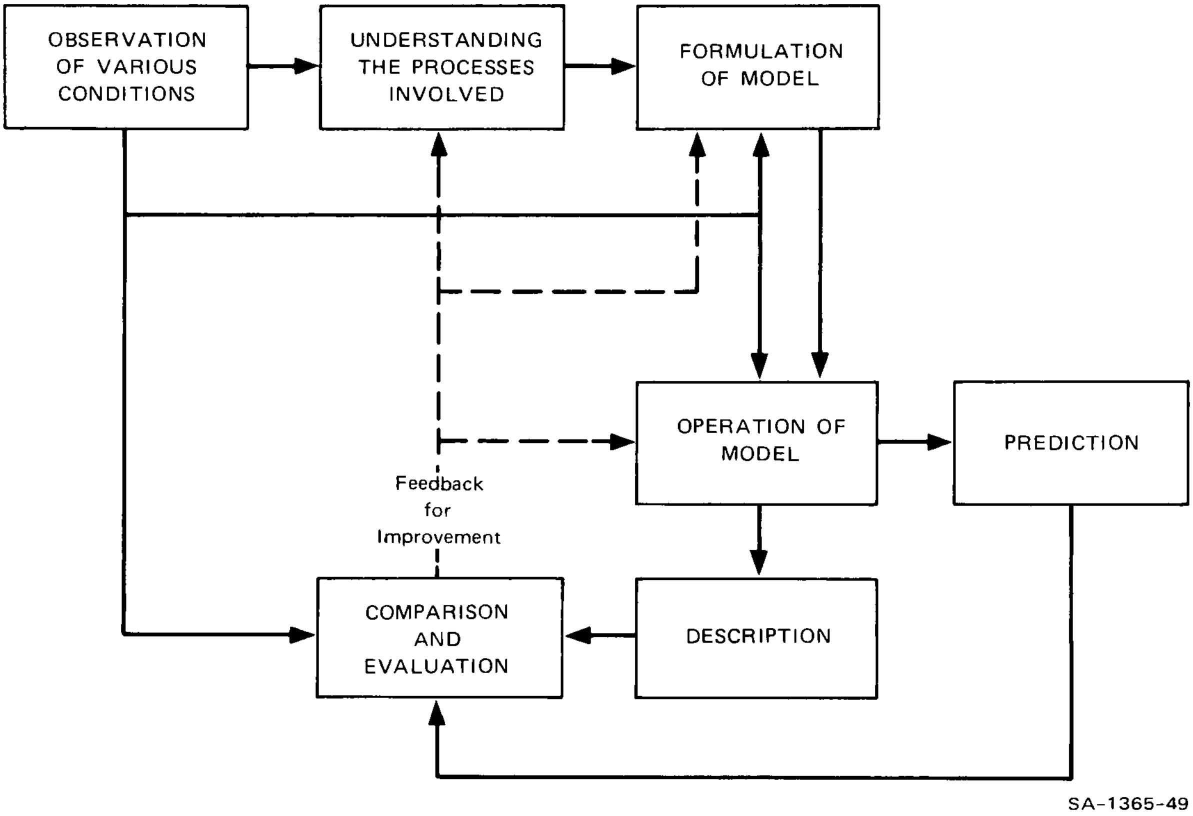

FIGURE 1 STEPS IN THE AIR QUALITY MODEL

only the immediate purpose for which they were collected--and remaining of little value for use in other investigations.

Even with the emergence of relatively moderately priced automatic data processing facilities, the acquisition of basic data remains a considerable and costly undertaking, especially on a major and extended scale. But to those considering the major and pressing problems of air quality management, it has become increasingly clear that little progress can be made in the solution of such problems unless they are treated on a major and extended scale. Only by fully recognizing the magnitude of the technical problems in the way in which current legislation and EPA policies have recognized the whole question of air quality, can adequate tools be developed for scientific air quality management.

The Regional Scale

The difficulties of air quality management are apparent in the context of Air Quality Regions, where emission standards within the region are to be related to air quality standards. For these purposes it is necessary that at all scales, from the local to the extended regional scale, there is an adequate understanding of how emission from the several sources combine and react to produce concentrations of specific pollutants throughout the area. This is particularly the case where the air quality of large rural and suburban areas is greatly affected by emissions from remote urban centers that may be up to 100 miles away. Control and abatement procedures must take these indirect effects into account. To formulate economical and realistic strategies for such procedures, however, it is necessary also to consider the less direct aspects of health, economics, land use, and community planning in the urban/rural complex.

III THE REGIONAL AIR POLLUTION STUDY (RAPS)

Concept

The problem of effectively managing air quality within the framework of current legislation on a regional basis is thus seen to be extensive and complex. The need to evaluate and improve control strategies already adopted or to identify new approaches must be considered on this basis. Realization of this, together with the recognition that much of the existing understanding is based on limited and piecemeal data, has led to the concept that it is necessary to make a new large scale integrated attack on the total problem. By effectively coordinating efforts on a number of interrelated problems, a combination of resources can be brought to bear in an economical and productive manner. This concept is particularly applicable to the problems of air quality management on the regional scale, where it is necessary to relate the effects of the urban center on the suburban and rural environs.

Only within such a framework can the necessary basic data on emission sources, meteorological factors, and other physical and chemical effects be studied in appropriate relationships and used to improve the basic understanding and formulation of the appropriate air quality models. Only on such a basis can the results of such models be evaluated by comparison with adequate data on the true nature of conditions. Only with such a background of relevant data can the ramifications of air pollution in the urban/rural complex be adequately understood in terms of health, economics, land use, and community planning so that control strategies can be formulated and ordered with maximum effect.

It is the purpose of this Prospectus to identify the separate elements constituting such an undertaking and to describe how it can be carried out.

In this Part I--General Summary--the major concept of RAPS is presented, with an outline description of the Research Plan, the Facility, and the Management Plan (which includes budgetary information). Subsequent sections, following the same pattern, provide fully detailed descriptions. Where appropriate, the rationale for the approach proposed is discussed.

Purpose

The initial purpose of the Regional Air Pollution Study is to evaluate and demonstrate how well the effectiveness of air pollution control strategies on all scales appropriate to air quality within a region can be assessed and predicted. Its further purpose is to serve as the basis for developing improved control strategies that can be applied generally.

Both purposes require the development of a better understanding of the chemical, physical, and biological processes that are entailed in determining the concentration of pollutants and the modification of air quality. They also require a better understanding of certain human, social, and economic factors that are significant in formulating control strategies. Above all, however, they require the testing, verification, evaluation, and improvement of mathematical simulation models that are the basic tools of scientific air quality management and a knowledge of how such models can be used the most effectively.

It should be noted that the overall purpose of RAPS is to provide the basis necessary for the formulation of control strategies rather than to develop control and abatement procedures as such. Its relationship to the analytical and decision-making processes in formulating control strategies is illustrated diagramatically in Figure 2.

Organization

Since the organiztion of the RAPS program by design is an integration and combination of endeavors, it cannot be described briefly. However, its essential structure follows from the purposes noted. Within this structure, key tasks with well defined objectives and a series of sub-tasks that are often interrelated and interdependent can be identified. Some of the activities constituting these tasks are in fact part of ongoing programs within the existing research organization of EPA. Following basic management principles, it is proposed that the work of the overall study be identified and organized as separate tasks, for each of which the objectives are specified, the purposes described, and the responsibility clearly defined. These taks will be arranged in a series of levels that will reflect the dependence of one activity on another and will establish the chain of responsibility of the task leaders. This responsibility is functional rather than administrative and relates to the technical accomplishment of the research task.

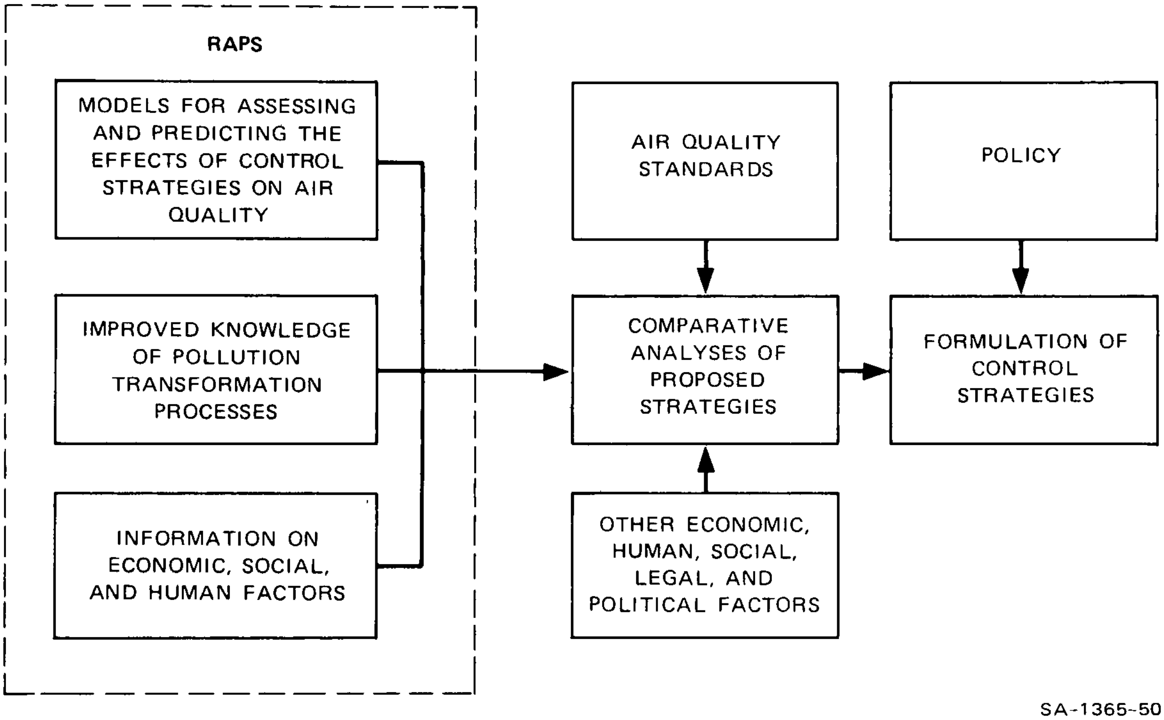

FIGURE 2 RAPS ROLE IN THE OVERALL EPA FUNCTION OF FORMULATING CONTROL STRATEGIES

The material to be used in these research tasks will be provided by the facilities and support elements of RAPS, some of which will have a general role to play only, while others will be substantially engaged in specific research tasks. Again, EPA groups outside the RAPS organization will provide some support and facilities.

The various facility and support elements will be the responsibility of designated leaders, but here the responsibility is administrative as well as functional. Thus, the manager, say, of a data acquisition network will be responsible administratively for the performance of the personnel and equipment assigned for this purpose and for the quality of the product of the network. Functionally, his responsibility is to provide data as required for the various research tasks, of one or more of which he may be the leader. The general scheme is indicated in Figure 3.

The organization of the research tasks and the functional roles of the support and facilities elements are set out in the Research Plan. The organization and the administrative structure of the support and facilities elements are set out in the Management Plan. In both cases, only the roles and responsibilities of the participants in relation to RAPS are considered. Thus, the contribution of other EPA research programs to the RAPS must be identified in terms of specific functional contributions as described in the research tasks.

The costs of such participation by personnel of other EPA research programs, as would also be the case with facilities and support provided from outside the RAPS organization, are included in the RAPS budget for the purposes of this Prospectus (interdepartmental adjustments can readily be effected by transfer procedures as necessary).

The general data base acquired under RAPS and, subject to availability after meeting primary responsibilities, the resources and facilities of RAPS will be available to other research programs of EPA, or for that matter, to other agencies. Any additional costs incurred would naturally be a charge on such other programs and budgeted accordingly.

By design, this Prospectus is based on the principle that RAPS should be an independent, self-sufficient activity of EPA, certainly for planning purposes. The possibility that other research programs and operational activities could make valuable contributions has been considered, especially in the selection of the site. In the data collection and observational programs, however, such contributions have been considered as supplementary rather than complementary, otherwise the tasks of specifying facilities and assessing costs could not have been accomplished at this time.

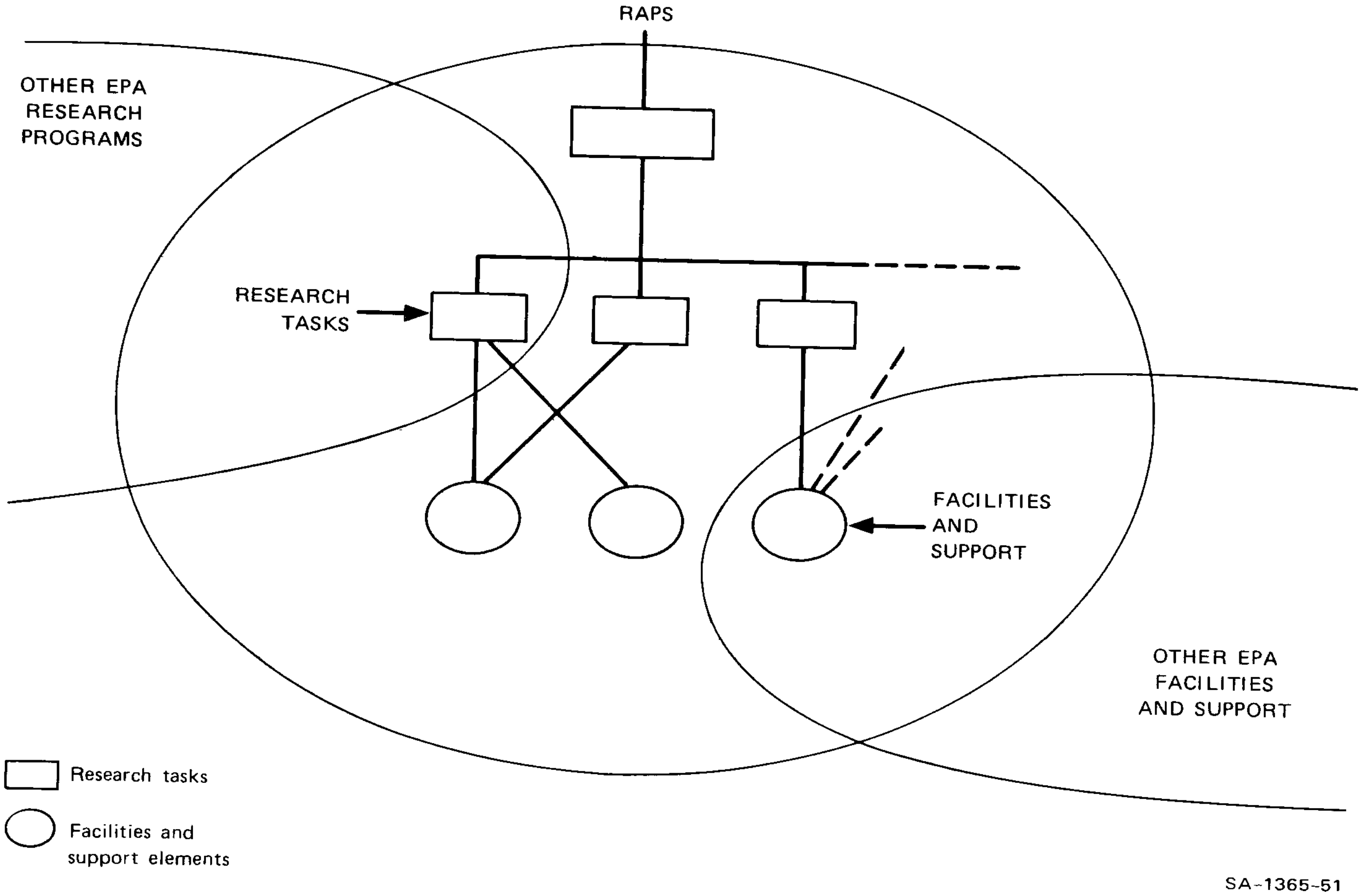

FIGURE 3 GENERAL SCHEME OF THE RAPS RESEARCH TASKS

In any case, although some economies and improvements might result from integrating the resources and research efforts within RAPS and with those of other programs planned for the St. Louis area, it is considered that the scope and importance of the RAPS program require that it be carried out as a principal endeavor. Any proposals to share resources with other programs should be carefully evaluated to ensure that efforts are not deflected from the main goals of RAPS.

In this context, it should be stressed that in the other programs noted the emphasis is primarily on the scientific aspects of the problems attacked or on operational problems quite different from those of RAPS. RAPS is concerned with the development of improved air pollution control strategies--and this concept must dominate all its research tasks.

Objectives

The overall objectives of the RAPS are to:

(1) Demonstrate and evaluate how well the effectiveness of air pollution control strategies may be assessed and predicted within an air quality region.

(2) Provide a basis for developing improved control strategies.

The specific objectives of the four principal tasks under which the overall objectives will be accomplished are described below. Each principal task is divided further into a structure of subordinate tasks as discussed later in Section V in which are presented the objectives of each subordinate task, together with details of the problems to be solved, the approach to be followed, the schedule, budget, and interrelation to other tasks.

The objectives of the four principal tasks are to:

- Test, verify, and evaluate the capability of mathematical simulation models to describe and predict the transport, diffusion, and concentration of both inert and reactive pollutants over a regional area. (100 series*)

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* These refer to a numerical classification system of tasks within the Research Plan.

- Develop an improved understanding of the chemical, physical, and biological processes that are entailed in determining the concentration (the dispersal) of polltants and the modification of air quality. (200 series)

- Develop a better understanding of factors of significance to the design of improved control strategies in the urban/rural complex, including health and economic effects and the role of land use and community planning. (300 series)

- Develop improved technology that can be applied in local and regional control agency operations, including techniques for emission inventories, air quality and meteorological measurement, data handling and analysis, and the objective assessment of effectiveness. (400 series)

IV SITE SELECTION

The best site for the RAPS program is centered in St. Louis, Missouri This selection was based on the need to find a large city lying within the central United States, which was away from oceans and mountains and which typified the coal-burning industrial nature of many urban areas yet which lay in an extended region of suburban or rural country. Some 33 Standard Metropolitan Statistical Areas (SMSAs) larger than 400,000 population were considered in terms of the following criteria:

- Surrounding area--This criterion includes measures of the isolation of the SMSA from other SMSAs to gauge interarea pollutant tendencies, measures of the rural fringe to be anticipated, and similar location factors. Clear-cut relationships and interactive mechanisms between the urban and rural areas are essential. The absence of a surrounding area with a low level of development, e.g., agricultural, eliminated an area from further consideration, as did the proximity of large bodies of water.

- Heterogeneous emissions--Several tests were applied for this criterion, including fuel used, types of industry in the region, and the current pollution mix. An important specific factor was the extent of coal usage because of its relation to both sulfur oxides and particle emissions. A lack of sulfur oxide emissions eliminated an area.

- Area size--This criterion gave a general measure of the expected scope and magnitude of the Regional Study for each candidate site.

- Pollution control program--The various candidate areas had considerable variation in their existing control programs. It appeared desirable that the Regional Study be carried out at a site where the control program is generally well developed. Such a site would provide a background of data and general experience that could be used to establish the Regional Study. In addition, a Central District program could provide initial contacts with industrial sources for the gathering of source inventory data.

- Historical information--Historical data, including meteorological and pollution, applicable to a site also varied widely. In general, a site tended to be more attractive as the quantity of historical data increases. Care was exercised to distinguish between quantity and quality.

- Climate--The site should possess a climatic representative of a large section of the nation or other potential sites. Moreover the climate should permit experimental work throughout the greatest possible portion of the year.

The comparison of the characteristics of the 33 candidate areas with these criteria reduced the group to four most appropriate possible areas. These are Birmingham, Cincinnati, Pittsburgh, and St. Louis.

A final review of the respective merits of the four candiate sites led to the following comparative assessment

Criterion	Birmingham	Cincinnati	Pittsburgh	St. Louis
Surrounding area	Fair	Poor	Good	Good
Heterogeneous emissions	Fair	Fair	Fair	Good
Area size	Good	Good	Good	Good
Pollution control program	Poor	Good	Good	Good
Historical information	Poor	Good	Fair	Good
Climate	Good	Fair	Fair	Good

On this basis, St. Louis emerged as the obvious prime choice.

V THE RESEARCH PLAN

Introduction

The Research Plan and its rationale are outlined in broad terms, followed by a detailed specification of the task structure that will be set up to accomplish the objectives of the plan.

The scope of research efforts in the field of boundary layer simulation modeling centers in the need to understand, describe, predict, and ultimately control air quality in the lowermost stratum of the atmosphere. Simulation modeling provides the necessary link between inferences gleaned from air quality data obtained at isolated, single-point monitoring stations and the broad, yet detailed, picture of air quality that is required over an entire urban region; it also permits assessment of the ramifications of actual or projected growth (zoning) patterns and emission control (proportional versus selective) prodecures.

Simulation modeling of the boundary layer refers precisely to physical or mathematical modeling of the atmospheric planetary boundary layer--the lowermost stratum of the atmosphere (on the order of 1 km in depth) in which the effect of surface friction on the wind field is manifested. From a more practical standpoint, it is also the layer in which atmospheric pollutants are generally emitted, transported, diffused, and transformed. Mathematical models include, generally, gradient-transfer, similarity, Gaussian plume and puff, and statistical formulations, while physical modeling is done with the aid of wind or water tunnels. The utility of the mathematical models lies in their ability to describe and parameterize the physics of the problem over a large region and to predict meteorological and air quality changes that may occur either in time (as a result of the progression or development of weather systems) or from the alteration of emission patterns. Ideally, mathematical models are capable of achieving arbitrary degrees of temporal and spatial resolution to solve specific problems. High resolution, for example, may be necessary when considering pollutant concentration in urban core areas, whereas relatively low spatial resolution may be required for the study on the mesoclimatic scale. Physical models perhaps are less flexible yet are ideal for evaluating the gross features of, for example, pollutant distributions in extremely homogeneous or complex locations.

It is highly desirable that the RAPS program evaluate the ability of the more promising models to simulate the atmospheric environment on both the micro- and mesoscales. In this regard, the models should be evaluated according to the specific function that they may serve. Specifically, evaluation programs are recommended for the following three functional model types: (1) diagnostic, (2) predictive, and (3) climatic. The primary emphasis at this time should be placed on the diagnostic model types, because the current or steady-state distribution of pollutants on the mesoscale must be described before detailed prognostic models can be developed. Prognostic or predictive models in this sense do not include diagnostic models, which may be input with anticipated meteorological and emissions data to simulate an expected condition. Rather, predictive models use current initial conditions to predict (on the order, say, of one or two days) meteorological and perhaps emission fields, thereby predicting the level of air quality for some time in the future. Moreover, emphasis must be given to the development and evaluation of dynamic climatological models that have the ability to describe the mesoclimate and changes that may result from mesoscale urbanization.

Toward achievement of these goals, it is essential that the various models be evaluated (and refined as appropriate) with "real" data collected in the field. Such data collection will further one's ability to understand and simulate the lower atmosphere on the mesoscale (on the order of 250 km). But unless one is able to observe the process he is attempting to describe, simulation modeling may be little more than an esoteric exercise. A vast amount of effort has been expended in the development of the various mathematical models and in their subsequent evaluation. In almost no case have the observed data been obtained on a scale compatible with the resolution of the model computation. Virtually all meteorological and air quality data collected on a routine basis for purposes other than model verification are the result of single point measurements (or, at the very best, several adjacent points). As such, the observation is a representation of very localized conditions and, in perspective, is a measure of the integrated effect of various scales of motion: micro, meso, and macro. In many cases, it is the microscale phenomena that predominate and there can be little surprise at the inability of numerical models to simulate the observation when the model, in fact, may predict only average conditions over a broad area, say a one kilometer square or larger. Therefore, another objective of the program should be the definition of the spatial variability of ambient air quality, as well as the spatial resolution of the simulation models. In practice, a feedback between observations and computations should result whereby the observations define the appropriate time and space scales that the models need to achieve, and eventually the models are used to describe spatial and temporal variations on the basis of a few representative measurements.

Federal air quality guidelines define levels of air quality on several time scales: hourly, eight-hourly, daily, and annual. On the basis of results from the observation/modeling programs, spatial criteria also may need to be established. It appears equally necessary to define criteria where the air quality is evaluated in parallel over various lengths (or areas or volumes) and time scales. In this regard and in consideration of the requirements of model verification, the data collection program must also concern itself with the potential of remote (long-path) observation techniques where a particular contaminant can be measured on the appropriate spatial scale.

In summary, an extensive air monitoring network is required to define the scope of the problem and to evaluate and refine the mathematical models that are to simulate the level of air quality over a broad region. As such, the network should be not only extensive but also flexible so that it will serve the many purposes of the simulation program. It must be capable of providing data from the substreet microscale to the regional mesoscale. The observations will also be used to evaluate these models on a variety of temporal scales: simulation of existing conditions (diagnostic requirement), prediction of short term changes (prognostic requirement), and evaluation of potential mesoclimatic alterations (extended prognosis). (Physical modeling techniques could be used to supplement the field observation program in urban core areas where the complexities of building structures may severely limit routine in-situ measurements on a practical basis, but this approach is more appropriate for studying specific and linked problems).

<u>Model Evaluation and Verification Program</u> (100 Series)

The various simulation models can be evaluated most efficiently by considering the models in terms of the functions that they may be expected to serve. For convenience, these functions may be divided into three parallel types: (1) the time frame and resolution of the model, (2) the spatial frame and resolution, and (3) the class of contaminants to be considered. Therefore, the models may be classified according to whether they simulate the quality of the air in terms of the concentration distribution of inert, reactive, or particulate contaminants over either localized or expansive regions for current or forecasted conditions. Accordingly, there are about a dozen functions that a model or models may be expected to fulfill; that is, there may be localized, diagnostic models for inert pollutants that have application in planning and evaluation studies or regional, prognostic models of reactive contaminants required for emissions control procedures. Figure 4 illustrates this concept, as well as the subsequent steps in a model evaluation and verification program

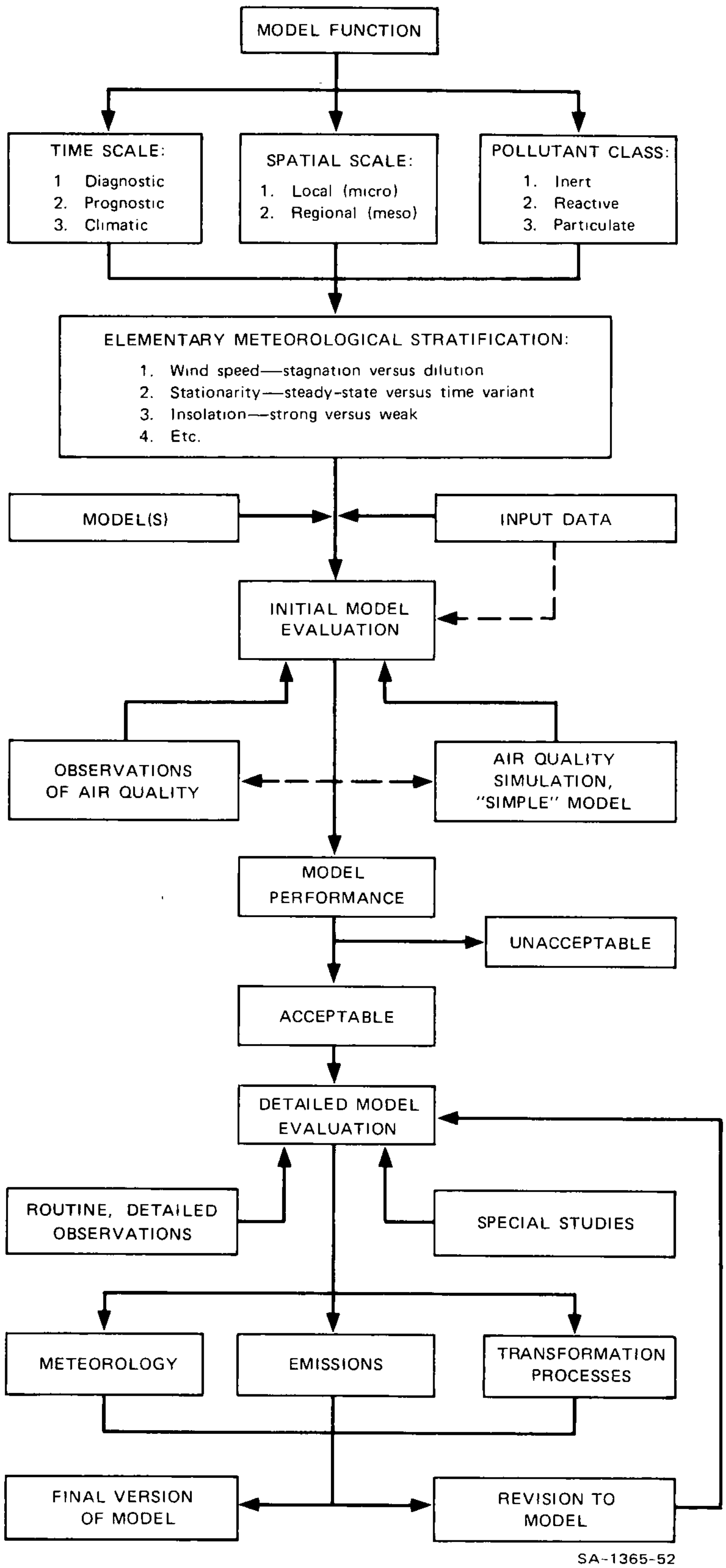

FIGURE 4 MODEL VERIFICATION PROGRAM

It may be further desirable to test the various models under a variety of distinct meteorological conditions. One such stratification could be the separation of low and moderate-to-high wind speed cases (isolation of stagnation conditions); other distinctions may be made between near steady-state and strong advective conditions or strong versus weak insolation.

At this point, the purpose of the simulation will have been defined and certain forcing physical criteria established; specific models falling within this framework can then be introduced for evaluation and subsequent verification. It is strongly recommended that the performance of the models initially be evaluated against both observed measures of air quality and the predictions of a simple standard (or reference model or models). The simple model used by Hanna (1971)* or a relatively simple box or Gaussian formulation (see Chapter III in Part II) should be considered. Quantitative, statistical techniques then should be applied to test the model against the reference and the observations. If the test model cannot show significant superiority to the reference, it can be safely excluded from the later, detailed evaluation program. Emphasis should also be placed on a qualitative assessment of the extent and nature of the required input data. If a given model performs well but requires input data that may not be readily available at the present or in the foreseeable future, then alternative formulations or parameterization may be necessary for further consideration.

Having initially demonstrated its feasibility, the model should be evaluated in detail to define both its strong and weak points so that refinements may be made. This detailed model evaluation program should include both fundamental and applied research tasks for the testing of the basic components of the model, namely, metorological, emissions, and transformation processes. The applied tasks are, in effect, individual evaluation programs for the three process areas (or submodels). Submodel predictions of wind, turbulence, stability, emissions, plume rise, reaction rates, and so forth would be compared with routine observations from the research network (which may not be strictly routine for nonresearch programs). The sensitivity of each model and submodel should be evaluated with regard to the response of the output (model prediction) to variations of the input parameters. In addition to these direct or applied tasks, there is an acknowledged need for complementary research programs of a more fundamental nature. These would be directed toward providing a

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* See Hanna, S. R., "Simple Methods of Calculating Dispersion from Urban Area Sources," paper presented at the Conference on Air Pollution Meteorology, Raleigh, N.C., Sponsored by Amer. Met. Soc., April 1971.

better understanding of the physical nature of the various physical processes so that the models may be revised accordingly and in conjunction with the requirements resulting from the applied program. Many of these fundamental programs can be anticipated; however, others, will result only as output requirements of the initial, detailed evaluations. The fundamental programs or special studies are given in detail in Part II.

Meteorological Factors

The transport and diffusion of pollutants in the atmospheric boundary layer is a basic aspect. The RAPS program will include a comprehensive network of observing stations at the surface, throughout the regional area, that will provide the data from which trajectories and stream line flow patterns can be calculated and used to determine the transport of pollutants. Practical models usually will be based on less sophisticated wind transport data, and thus the availability of this detailed information will permit a candidate meteorological submodel to be evaluated independently and, if necessary, modified and retested.

Since total atmospheric transport of air pollutants is not always adequately depicted by surface meteorological measurements, it will be necessary to define the important transport weather parameters above the surface to altitudes between 1000 m and 1500 m. The RAPS program proposes to do this by extensive use of instrumented aircraft with supplemental use of balloon sounding systems.

Regionwide measurements are not totally adequate to interpret the meteorological conditions within the meteorological boundary layer and several specific research studies are incorporated in the RAPS program to define in more detail a number of important boundary layer transport processes. It is generally recognized that mixing and transport conditions depend strongly on the nature of the underlying surface and that built-up urban areas and relatively smooth rural and agricultural areas can affect an air mass differently as it moves across these areas of different roughness. To a certain degree, these effects can be predicted, but how to account for changing conditions within an air mass as it moves from one roughness regime to another is relatively unknown.

Specific experiments using specially dispersed tracer materials, constant-altitude balloons, and special aircraft instrumentation will be carried out to develop techniques for including changes in surface roughness in the meteorological boundary layer submodel. Within an urban area, building temperature, as well as the changes in building height and density, affect the meteorological transport processes, and thus special care will be given to experiments that will greatly improve understanding of the interactions between urban surface characteristics and the pollutant transport processes.

The RAPS program will also include studies of meteorological dispersion of effluents from specific single sources to characterize the interactions between these effluents and environmental factors. One very significant study topic is that entailing the dispersion of pollutants from tall stacks across very rough areas characteristic of an urban area. From this type of study, a better understanding can be obtained of pollutant transport in an urban area and this information can be used as a "feedback loop" in the evaluation and further development of diffusion models.

Pollutant Source Estimates

Pollutant emissions from both moving and stationary sources are an obvious ingredient of any air pollution situation. The RAPS program must have as an integral part a detailed, ongoing air pollutant inventory program. This program must include, in addition to data on source emission rates, the development of techniques by which these emission rates can be estimated for specific periods of time. These time periods may be as specific as a given hour for a particular day and will be necessary to support the short time simulation modeling efforts. Thus the emission estimation submodel will have two major components: the inventory of source emissions and the development of techniques by which this inventory can be used to estimate emissions over specific time periods.

It is expected that the RAPS emission estimation techniques, including the programs for inventorying, data handling, and data storage, will also have wide applicability to regional air pollution control programs because of the general importance of emission assessment in a control operation. Thus the techniques for emission assessment will be a significant and relatively early area of RAPS technology development that can be applied to the nation's air pollution control programs.

Air Quality Measurements

The acquisition of air quality data is another major RAPS activity. Air quality data are incorporated in model verification studies through the development of either average concentrations at a given set of points or average concentration patterns over a given test area. The RAPS program will include model verification studies of a variety of pollutants but especially for major pollutants for which quality criteria have been or will be published. These pollutants currently include SO_2, CO, NO/NO_2, photochemical oxidants, hydrocarbons, and suspended particles. Air quality criteria are expected to be published for lead aerosols and fluorides. There is also considerable air pollution control interest in mercury, H_2S, nonspecific odors, asbestos, toxic heavy metals, and polynuclear aromatic compounds. Over the five-year research period estimated for the RAPS program, it can be expected that the simulation model verification program will require regionwide data on ambient air concentrations for each of these materials. To meet these needs for air concentration data, the RAPS design provides for an extensive program of air quality monitoring, including a network of continuously operating telemetering stations.

Atmospheric, Chemical, and Biological Processes (200 Series)

In pollutant dispersion modeling studies, the transformation or loss of pollutants in the atmosphere after emission from the source and before arrival at the receptor point has been either ignored, i.e., pollutants are assumed to be stable, nonreactive compounds, or treated in a very simple manner, i.e., application of a simple "half-life" term. It is known from both theoretical and experimental studies that pollutant compounds in an ambient atmospheric environment are affected by a variety of complex reaction processes. These processes can rapidly reduce the concentrations observed in the atmosphere, i.e., precipitation will scrub contaminants out of the air at a rate dependent on precipitation characteristics and on the nature of the pollutant. There are also situations in which pollutants are formed in the atmosphere by reactions containing one or several other pollutant compounds. Notable in this category are the photochemical processes used in the formation of photochemical smog where both gases and aerosols are formed in the atmosphere by chemical reactions.

The RAPS program will carry out specific research studies to determine how pollutants are transformed or scavenged in the atmosphere with special reference to the major pollutants--SO_2, NO, NO_2, CO, hydrocarbons, and particulate materials. These transformation studies will include reactions with other atmospheric constituents and the formation of aerosols in the cases of SO_2, NO_2, and hydrocarbons. Photochemical reactions are involved with SO_2, NO, NO_2, and hydrocarbons. For CO, the scavenging mechanisms appear to be centered in the biosphere, although atmospheric chemical reactions may also occur.

A typical research study in this transformation task program will be the "mass balance" design in which the pollutant, e.g., SO_2, will be followed through the atmospheric reaction processes--SO_2 to H_2SO_4 or $(NH_3)_2SO_4$

to sulfate in rain--and the various reaction rates and other parameters determined. Surface reactions and vegetation pickup can also be important. The result will be a set of transformation submodels that provides a technique to predict the atmospheric transformation of the major pollutants.

Precipitation is generally considered to be a major process bringing about the removal of both gaseous and particulate material from the atmosphere. As such, it is a major scavenging process. However, this pollutant scavenging can also have a major effect on the chemical content of precipitation and through this on the regional environment. Recently "acid rain" in Sweden received wide publicity, and it is likely that important changes in precipitation chemistry as a result of air pollutant emissions also could occur in the United States. The RAPS program will include a significant study of precipitation chemistry and its relation to regional air pollution emissions, with the goal of obtaining quantitative measures of the interaction between precipitation processes and pollutant emissions.

Within an urban area that is adversely affected by air pollution, visible pollutants from sources and as a general urban haze cloud are probably a major public complaint. The particles that constitute this visible urban pollution can come from two pollutant sources--from the direct emission of solid and liquid particles such as dust, fly ash, fumes, or smoke and from the formation of particles in the atmosphere as a result of reactions among various gaseous pollutant emissions. Photochemical smog reactions in the atmosphere constitute one source of the haze that can afflict urban areas. Transformation of SO_2 into a sulfate aerosol is considered to be another common source of urban haze.

In the RAPS program, a major effort will be directed toward finding the reasons for the formation and dispersion of urban haze. The ultimate goal beyond the RAPS program would be the development of means by which the formation processes could be abated. While such an abatement goal could be expected to require the reduction of source emissions, until the formation process can be described, the specification of a source control program can be little more than educated guess work.

The RAPS aerosol study program will include extensive sampling of aerosol constituents and the characterization of size distribution. Detailed emission data will be available as will comprehensive information on atmospheric chemical composition. Translation of these observational results into a haze formation submodel will depend on relating these field data to laboratory and theoretical studies of aerosol formation and the development of rational hypotheses for urban haze formation. The solution of urban pollution haze problem is probably the most difficult of the several RAPS tasks. By contrast, it seems quite probable that the general public will consider it vital to find solutions to visible pollution and urban haze formation before success can be claimed for an urban air pollution control operation.

Human Social and Economic Factors (300 Series)

In the decision-making processes used in formulating air pollution control strategies, it is necessary to consider factors other than the basic cause and effect relationship between sources and air quality. Human, social, and economic factors are involved, either directly, as when they are manipulated to effect reduction of pollution, or indirectly, in terms of the costs and benefits of control strategies. To provide a better understanding of such factors, it is intended to take advantage of the unique facility provided by the RAPS organization to collect relevant data in an economical, well focussed manner.

Data would be acquired on both human and social factors (e.g., health, population distribution, land use, and labor force characteristics) and the economic aspects (i.e., the cost of air pollution and of control and abatement procedures).

Particularly in connection with the source inventory surveys, it is hoped to collect information (subject to legal and other constraints regarding privacy) that may contribute to a better assessment of the costs entailed in staffing and operating control and abatement devices or in the costs that result from modifications of the productivity of the plants in question.

This element of the research plan would relate to the specific conditions in a given study area and would be made available for studies directly related to this area. The material acquired and the lessons learned in collecting it also would be used to develop more generally applicable information and methodologies in Task Area 400 described below, which is concerned with the transfer of technology acquired in RAPS for use in wider contexts.

RAPS Technology Transfer (400 Series)

It clearly is desirable that the knowledge and technology developed in the RAPS program be made available for air pollution control purposes as early and as effectively as possible.

This requires passing on improvements and innovations in the techniques of measurement, data handling, and utilization in a direct form. It also entails conversion and distillation of the knowledge and technology developed in RAPS in the specific test region to a generalized form so that it can be applied in other regions and for other problems with minimum difficulty. Above all, this task provides the basis for the development of improved control strategies, by national, state, and local agencies.

The approach follows four main lines. The first approach is the development and description of techniques and criteria by which the basic air pollution factors can be assessed and monitored on an operational (as distinct from research) basis. Particular attention will be given to identifying and developing new techniques of monitoring atmospheric and air quality conditions on extended scales appropriate to regional and subregional control strategies so that the costs may be minimized. The use of aircraft and remote probing techniques either from such aircraft or from the surface are especially suited to this purpose, and every attempt should be made to advance their applicability.

The second approach is the provision of tested, effective simulation models suitable for other areas and conditions. The third approach is the development of a methodology for assessing the validity (in terms of confidence, accuracy, precision) of the preferred models for varying degrees of input data quality. The fourth approach is the provision of methodologies for determining and assessing other factors such as health effects and economic costs and benefits relevant to the formulation of improved control strategies.

First priority will be to consider current data resources, deficient though these may be, with emphasis on the optimum methods of providing more complete data for input to models and for air quality monitoring and model verification purposes. The needs of the states and local authorities (and EPA) to improve and extend Implementation Plans will be treated first, with concurrent though subordinate attention to environmental impact statement requirements. The first milestone will be the advancement of interim capabilities for these purposes. Thereafter, a more complete and detailed facility will be developed, covering all aspects of control strategies formulation then current and capable of extension to other pollutants and so forth as the need arises.

Schedules and Task Specifications for the Research Plan

Introduction

The following schedules and specifications show how the Research Plan would be accomplished within the proposed 5-year period. They follow a structure reflecting the principal objectives of the study. Thus, each principal objective is approached within principal tasks numbered 100, 200, 300, and 400, respectively. Separate research tasks are assigned numbers within the 100, 200, 300, and 400 series, and a further division into subtasks is provided by adding numbers after the decimal point. For example, Task 101 Boundary Layer Meteorology is a task within the 100 series which is concerned with Model Verification. (Task No. 100.) Task 101.1 Area Climatology is an element of Task 101.

A task specification is given for each task, which states the objective and purposes and scope of the research element concerned. It is intended that professional responsibility for each task be assigned to an individual, who would be charged with accomplishing his task in terms of its objective. The Principal Tasks 100, 200, 300, and 400 in fact would be carried out by the senior personnel of the project as part of their assigned responsibilities. However, the leaders of the subordinate tasks and subtasks (e.g., 101 and 101.1) would be engaged in the day-to-day accomplishment of the work specified, each task leader of a separate task (e.g., 101) being responsible for the product of the subtask leaders (e.g., 101.1) and responsible to the principal task leader (e.g., 100).

Specifications for these tasks follow. Also presented are schedules showing the general timing of the activity within the five-year period. In both cases, the amount of effort that has been used as a basis for planning and costing is indicated in terms of man-years of professional and subprofessional effort.

100 MODEL VERIFICATION

	1972	1973	1974	1975	1976	1977
101 Boundary Layer Meteorology (2.5 p)	xx	xxxx	xxxx	xxxx	xxxx	xx
101.1 Area climatology (.5 p, .5 s)	xx	xx..	....	....	....	..
101.2 Prior diffusion data (.5 p, .5 s)	xx	xx..	....	....	....	..
101.3 Compilation and analysis of upper air data (2.1 p, 2.1 s)	..	.xxx	xxxx	xxxx	xxxx	xx
101.4 Compilation and analysis of near-surface data (2.1 p, 2.1 s)	..	.xxx	xxxx	xxxx	xxxx	xx
101.5 Balloon-tracking experiment (.5 p, 1.5 s)	..	....	.xx.	....	....	..
101.6 Diffusion tracer experiments (.5 p, 1.5 s)	..	....	....	.xx.	....	..
101.7 Weather satellite applications (1.5 p, .75 s)	..	....	....	xxxx	xx..	..
101.8 Forecast models (2 p, 2 s)	..	....	....	..xx	xxxx	xx

Total effort 12.25 man-years--professional (p)
11.00 man-years--subprofessional (s)

	1972	1973	1974	1975	1976	1977
102 Emission Inventory (5 p)	xx	xxxx	xxxx	xxxx	xxxx	xx
102.1 Emission inventory design (1 p, 1 s)	.x	x...	....	....	....	..
102.2 Collection of emission data for stationary sources (5.25 p, 5.25 s)	..	xxxx	xxxx	(xxxx	xxxx	xx)
102.3 Collection of emission data for mobile sources (.5 p, 5.25 s)	..	.xx(x	xxxx	xxxx	xxxx	xx)
102.4 Emission model for stationary sources (1 p, 1 s)	..	.xxx	xxxx	x...	....	..
102.5 Emission model for mobile sources (1 p, 1 s)	..	..xx	xxxx	xx..	....	..
102.6 Emission source test (6 p, 6 s)	..	..xx	xxxx	xx(xx	xxxx	xx)
102.7 Analysis of status of source controls (1.25 p)	..	.xxx	....	....	....	..
102.8 Emissions inventory of agricultural data sources (.25 p, .25 s)	..	.xx.	....	....	....	..

Total effort 20.25 man-years--professional
19.75 man-years--subprofessional

		1972	1973	1974	1975	1976	1977
103 Air Quality Measurement (4.25 p)		xx	xxxx	xxxx	xxxx	xxxx	xx
103.1	Data base (.25 p)	.x	x...	....	....	....	..
103.2	Air quality data from local agencies (1.18 p, 4.75 s)	.x	xxxx	xxxx	xxxx	xxxx	xx
103.3	Analysis of air quality and meteorological data acquired by RAPS (4.5 p, 8.5 s)	.x	xxxx	xxxx	xxxx	xxxx	xx
103.4	Analysis of air quality data acquired by aircraft (1.06 p, 2.1 s)	..	.(xxx	xxxx	xxxx	xxxx	xx)
103.5	Fine scale spatial variation of air quality (.75 p)	..	xxxx	xx..	....	....	..

Total effort 12 man-years--professional
15.35 man years--subprofessional

100 MODEL VERIFICATION (Concluded)

		1972	1973	1974	1975	1976	1977
104 Model Calculation and Verification (2.5 p)		xx	xxxx	xxxx	xxxx	xxxx	xx
104.1	Evaluation of selected models (30 p, 70 s)	xx	xxxx	xxxx	xxxx	xxxx	xx
104.2	Model modification and improvement (2 p, 2 s)	..	..xx	xxxx	xxxx	xxxx	xx
104.3	Methodology for determining model accuracy (1.88 p)	..	...x	xxxx	xxxx	xxxx	xx
104.4	On-site computation and data display (2 p)	..	..xx	xxxx	xxxx	xxxx	xx

Total effort 38.35 man-years--professional
72 man-years--subprofessional

200 ATMOSPHERIC, CHEMICAL, AND BIOLOGICAL PROCESSES

	1972	1973	1974	1975	1976	1977
201 Gaseous Chemical Processes (5 p shared with 202)	xx	xxxx	xxxx	xxxx	xxxx	xx
201.1 Hydrocarbon analyses and monitoring (2.06 p, 5.63 s)	..	....	xxxx	xxxx	xxxx	..
201.2 Development of hydrocarbon classifier instrumentation (1.38 p)	xx	xxxx	....	....	....	..
201.3 Total aldehyde-formaldehyde monitoring program (.19 p, .31 s)	..	....	xxxx	xxxx	xxxx	..
201.4 Determination of peroxy-acetyl nitrate (.44 p, .75 s)	..	....	....	xxxx	xxxx	..
201.5 Ammonia monitoring program (1 p, 3.12 s)	..	...x	xxxx	xxxx	xxxx	xx
201.6 CO, SO_2, and NO_2 mass flux measurements (.81 p, .88 s)	..	....	..xx	xxxx	xxxx	xx
201.7 Origin of atmospheric CO (106 p, .75 s)	..	....	....	..xx	xxxx	xx
201.8 Atmospheric odor identification (.75 p, 1 s)	..	....	....	....	...x	xx

Total effort 11.69 man-years--professional
12.45 man-years--subprofessional

	1972	1973	1974	1975	1976	1977
202 Atmospheric Aerosol Processes (Shared with 201)	xx	xxxx	xxxx	xxxx	xxxx	xx
202.1 Determination of total nitrate in aerosol samples (.31 p, 1.5 s)	..	....	xxxx	....	....	..
202.2 Determination of total sulfate in aerosol samples (.31 p, 1.38 s)	..	....	xxxx	....	....	..
202.3 Determination of aerosol size-distribution (.69 p, 2.75 s)	..	....	xxxx	xx..	....	..
202.4 The NO_2NaCl reaction in aerosol (.25 p, .13 s)	..	....	.xxx	xxxx	xxxx	xx
202.5 Isotope ratios of sulfate aerosols (.56 p, .75 s)	..	....	....	..xx	xxxx	..
202.6 Organic compounds in particulate material (.75 p, .88 s)	..	....	....	xxxx	xx..	..
202.7 Experimental measurements of deposition velocity (.56 p, 2.5 s)	..	....	....	....	xxxx	xx

Total effort 3.44 man-years--professional
9.87 man-years--subprofessional

		1972	1973	1974	1975	1976	1977
203 Other Pollutant Related Processes		xx	xxxx	xxxx	xxxx	xxxx	xx
203.1	Radiation balance modification (.69 p, 1 s)	..	..xx	xxxx	xxxx	....	..
203.2	Visibility reduction in urban and rural areas (.69 p, 1 s)	..	....	....	xxxx	xxxx	..
203.3	Transport of atmospheric odors (.25 p, .25 s)	..	....	....	....	..xx	xx
203.4	Trace metals and toxic trace materials (.69 p, 2.5 s)	..	....	....	xxxx	xxxx	..
203.5	Agricultural chemical distribution (.25 p, .75 s)	..	....	....	..xx	xxxx	xx
203.6	Natural sources of air polluted compounds (1.13 p, .19 s)	..	....	xxxx	xxxx	xxxx	..

Total effort 3.69 man-years--professional
5.69 man-years--subprofessional

200 ATMOSPHERIC, CHEMICAL, AND BIOLOGICAL PROCESSES (Continued)

	1972	1973	1974	1975	1976	1977
204 Atmospheric Scavenging by Precipitation						
204.1 Instrument development for pH and chemical sampling (.50 p, .5 s)	xx	xxxx	....	....	....	..
204.2 Rainfall pH measurement (.53 p)	..	....	xxxx	xxxx	xxxx	xx
204.3 Measurements of rainfall chemistry (.88 p, 5.25 s)	..	....	.xxx	xxxx	xxxx	xx

Total effort 1.90 man-years--professional
5.75 man-years--subprofessional

	1972	1973	1974	1975	1976	1977
205 Air Pollutant Scavenging by the Biosphere						
205.1 Chemical content of vegetation (.5 p, 2 s)	..	....	.xx.	..xx	xxxx	..
205.2 Atmospheric pollutant concentrations related to vegetation absorption (.5 p, 1.5 s)	..	....	....	..xx	xxxx	xx

Total effort 1 man-year--professional
3.5 man year--subprofessional

	1972	1973	1974	1975	1976	1977
206 Atmospheric Processes (1.5 p, 3 s)						
206.1 Source factors in pollutant dispersal (.5 p)	..	..xx	xxxx	xxxx	xx..	..
206.2 Terrain and surface roughness effects (.38 p)	..	....	.xxx	....	....	..
206.3 Extraregional and synoptic scale circulation (.75 p)	..	....	...x	xxxx	xx..	..

Total effort 3.12 man-years--professional
3 man-years--subprofessional

300 HUMAN, SOCIAL, AND ECONOMIC FACTORS

	1972	1973	1974	1975	1976	1977
301 Human and Social Factors						
301.1 Data on epidemiology and health effects (4.5 p, 4.5 s)	Continuing low scale effort					
301.2 Data on population and land-use characteristics						
301.3 Data on labor force utilization						

Total effort 4.5 man-year--professional
4.5 man-year--subprofessional

	1972	1973	1974	1975	1976	1977
302 Economic Factors						
302.1 Costs of inferior air quality to industrial and general population (4.5 p, 4.5 s)	Continuing low scale effort					
302.2 Costs of control strategies						
303.3 Data collection surveys of specific effects						

Total effort 4.5 man-years--professional
4.5 man-years--subprofessional

400 TRANSFER OF RAPS TECHNOLOGY FOR CONTROL AGENCY APPLICATIONS AND THE FORMULATION OF CONTROL STRATEGIES

	1972	1973	1974	1975	1976	1977
401 Source Inventory Procedures (1 p, 1 s)						
401.1 Techniques for making source inventory procedures						
401.2 Techniques for inventory storage and retrieval						
	..	....	....	xx..	....	xx
401.3 Techniques for updating the source inventory						
401.4 Relating source inventory to control strategy						

Total effort 1 man-year--professional
1 man-year-subprofessional

400 TRANSFER OF RAPS TECHNOLOGY FOR CONTROL AGENCY APPLICATIONS AND THE FORMULATION OF CONTROL STRATEGIES (Continued)

	1972	1973	1974	1975	1976	1977
402 Atmospheric Monitoring						
402.1 Basic network principles (.5 p)	..	....	..xx	....	....	xx
402.2 Criteria for organization and maintenance of observational networks (.5 p)	..	....	xx..	....	....	xx
402.3 Station siting and instrument exposure criteria (.25 p)	..	....	....	xxxx	xxxx	xx
402.4 Methodology for modernization of monitoring networks (.25 p)	..	....	xx..	....	....	xx
402.5 Evaluation of new aircraft measurement techniques (1.63 p)	..	..xx	(xxxx	xxxx	xxxx	xx)
402.6 Evaluation of remote measuring techniques (2.75 p, 3 s)	..	..xx	(xx	xxxx	xxxx	xx)

Total effort 5.89 man-years--professional
3 man-years-subprofessional

	1972	1973	1974	1975	1976	1977
403 Data Handling						
403.1 Optimize techniques for data acquisition, storage, and retrieval (.5 p)	..	....	..xx	....	....	xx

Total effort .5 man-year--professional

	1972	1973	1974	1975	1976	1977
404 Modeling Technology						
404.1 Significance of modeling to the formation of control strategies and their implementation (2.25 p)	xx	xxxx	xxxx	xxxx	xxxx	xx
404.2 Implementation Plan applications (.75 p, .75 s)	..	....	xx..	....	..xx	xx
404.3 Environmental Impact Statement applications (.75 p, .75 s)	..	....	xx..	....	..xx	xx
404.4 Methodology for assessing model validity in control agency operations (.75 p, .75 s)						

Total effort 4.5 man-years--professional
2.25 man-years--subprofessional

400 TRANSFER OF RAPS TECHNOLOGY FOR CONTROL AGENCY APPLICATIONS AND THE FORMULATION OF CONTROL STRATEGIES (Concluded)

	1972	1973	1974	1975	1976	1977
405 Other Significant Factors in Control Strategy Formulation						
405.1 Liaison and interaction with other environmental research programs						
405.2 Techniques of assessing social and economic factors						
405.3 Methodology of assessing operational costs of control strategies	Continuing low scale effort					
405.4 Methodology of assessing resultant costs of control strategies						
405.5 Institutional aspects						

Total effort 4.5 man-year--professional
4.5 man-year--subprofessional

100 Model Verification

Objective

The objective is to test, evaluate, and verify the capability of mathematical simulation models to describe and predict the transport, diffusion, and concentration of both inert and reactive pollutants over a regional area.

Purpose and Scope

The purpose of this series is to investigate the performance of a series of selected mathematical simulation models in circumstances such that as many variables as possible are known. In this way the validity of the model can be determined, or its deficiencies identified, and methods of measuring input or verification data can be optimized for use in subsequent operational applications. The program will investigate emission source assessment, the modeling of admospheric physical and chemical factors, and the methods of verifying and evaluating the operation of the models.

The approach follows two major lines. The first approach is development of the most complete description possible of the meteorological conditions, emissions, and air quality. The second approach applies the appropriate input data to a series of selected models and examines their product against observed data.

The selection of models will follow an evolutionary program, starting with the models ready for immediate testing (FN). Where possible, competing models will be applied to the same data sets. Subsequent tests will be made of improvements of such models on an iterative basis, or in combinations of the most successful features of such models. Major emphasis will be on models relating to the regional scale, but subscale models will be treated in time. First priority will be given to the development of useful tools for reviewing and assessing Implementation Plans. The similar need for Environmental Impact Statements will be given concurrent but subordinate attention. Subsequently, the aim will be to provide fully tested optimum models, the performance of which can be objectively assessed, at each scale for each main class of pollutants.

Consideration will also be given to the role of modeling in connection with air pollution episode prediction.

101 Boundary Layer Meteorology Program

Objective

The objective is to collect meteorological data on the parameters that affect the dispersion of atmospheric pollutants in the St. Louis region.

Purpose and Scope

The purpose of this task is to:

- Provide the meteorological data that are required as inputs to air quality simulation models.
- Obtain data with which to evaluate model computations of meteorological parameters.
- Provide supplemental measurements of meteorological parameters for study of fundamental meteorological processes for subsequent use in the revision of various model components.

The program will commence with the collection of historical climatological and experimental diffusion data for the St. Louis area. Later, data from the various routine RAPS meteorological facilities will be assembled and compiled in a meaningful format using standard metric units; the routine facilities include the basic surface network and the upper air (aircraft and balloon) systems. The program will also include collection and compilation of data from special research programs.

102 Emission Inventory

Objective

The objective of this task is to develop and maintain a comprehensive source inventory.

Purpose and Scope

Numerous components of the Research Plan will require a complete inventory of all emission sources in the study area. This will include both fixed and mobile sources of all major pollutants and perhaps selected minor materials. Emission levels must be described for selected times ranging from yearly to hourly intervals. The inventory should serve in the validation of models, analysis of control strategies, and the investigation of air quality impacts on the human, social, and economic systems of the area.

103 Air Quality Measurement

Objective

The objective of this task is to provide as complete and detailed a description as possible of the distribution (both in space and time) and concentration of air pollutants in the St. Louis region.

Purpose and Scope

The purpose of this task is to provide the data on pollutant distribution necessary for the verification of simulation models of various scales (in space and time) and for various types of pollutant (i.e., both reactive and nonreactive) and various types of source.

Data will be obtained from past records, from routine measurements already being made in the St. Louis area, and from the special measurement networks of the RAPS facility.

104 Model Calculation and Verification

Objective

The objective of this task is to operate, evaluate, and modify a series of air quality simulation models and identify the models that are most suitable for use in formulating air pollution control strategies.

Purpose and Scope

Purposes of this task are to:

- Provide evidence and information as to the effectiveness of a series of selected candidate models so that optimum models can be selected for each aspect of air pollution control.

- Develop techniques of categorizing models in terms of their applicability in respect to both the temporal and spatial resolution and the type or class of pollutants for which they are appropriate.

200 Atmospheric, Chemical, and Biological Processes

Objective

The objective of this series of tasks is to develop an improved understanding of the chemical, physical, and biological processes that are entailed in determining the concentration (the dispersal) of pollutants and the modification of air quality.

Purpose and Scope

Purposes of these tasks are to:

- Investigate in a number of parallel programs the various mechanisms entailed in the transport, transformation, and removal of pollutants not now well understood.

- Develop techniques of describing (or better describing) such mechanisms so that they can be accounted for in existing models or models to be developed to accommodate them.

- Identify conditions or processes that are significant in formulating control and abatement strategies to provide air quality amelioration.

The approach follows three major lines. The first approach is the acquisition of a better quantitative knowledge of processes already recognized as significant but that have not been adequately described for modeling purposes. The second approach is development of a better understanding of the significance of various processes in terms of adequately modeling complex air quality factors. The third approach is investigation of pollutants and pollutant processes that are not yet considered in control strategies, and assessment of their importance so that appropriate strategies can be formulated.

201 Gaseous Chemical Processes

Objective

The objective of this task is to develop an improved understanding of the gaseous chemical processes that are important in determining the concentrations of air pollutants and in the design and specifications of simulation models dealing with the transport of gaseous pollutants.

Purpose and Scope

Purposes of these tasks are to:

- Investigate through a number of discrete but interrelated projects various mechanisms that are important in the transformation and scavenging of gaseous air pollutants.

- Carry out specific sampling programs designed to better describe the concentration field of various important pollutants that are not covered by the regular monitoring system.

- Develop special measurement techniques and automatic instrumentation that can be used to describe in more detail the atmospheric concentration fields of specific air pollutants.

- Relate the processes and conditions observed in the field program to existing or potential simulation models and to abatement strategies.

202 Atmospheric Aerosol Processes

Objective

The objective of this area of the program is to develop improved understanding of, and expanded data on, the nature of atmospheric urban aerosols and the processes that are important in determining (1) the chemistry and concentrations of these materials and (2) the application of this information in the design and specifications of simulation models dealing with the transport and transformation of atmospheric aerosols.

Purpose and Scope

The purposes of this task are to:

- Investigate through a number of individual but interrelated projects the various mechanisms that are important in the formation, transformation, and scavenging of atmospheric aerosol particles.

- Carry out specific sampling programs designed to better describe both the chemistry and concentration fields of various atmospheric aerosols and to relate these measurements to the routine measurements obtained by the regular monitoring system.

- Conduct a coordinated program of gaseous and particulate sampling experiments with the goal of describing the specific mechanisms by which atmospheric aerosol particles are formed from gaseous contaminants.

- Develop special measurement and instrumentation techniques that through automatic operation can be used to describe in more detail the atmospheric concentration fields of specific particulate materials.

- Relate the processes and conditions relative to the formation and transport of atmospheric aerosols to existing and future simulation models and to abatement strategies.

The individual projects within this program area fall into three general categories: (1) special monitoring programs for specific aerosol materials, including size distribution studies, aerosol chemistry, and studies of the interaction of aerosols and gaseous contaminants; (2) development of instrumentation and analytical techniques to improve the effectiveness of aerosol monitoring programs and to provide the data necessary for simulation modeling applications; and (3) special transport and scavenging research studies aimed specifically at delineating atmospheric processes that serve to determine the characteristics of atmospheric aerosols in urban and rural areas.

For the most part, research in atmospheric aerosols is hampered by the fact that relatively little automatic instrumentation can be used to obtain detailed data on the chemical constituents that make up the atmospheric mass. As a result, most of the programs are based on a gathering of specific field samples followed by a period of laboratory analysis to determine the nature of the collected samples. This means that the samples generally have poor time resolution because of the length of time necessary to collect enough material for adequate analysis, and because the number of samples that can be collected practically is limited because of lack of available manpower and laboratory facilities. If suggested instrumentation development is successful, some of these problems may be ameliorated; however, since the suggested instrumentation is not new but has been recognized for a number of years, a higher degree of hope cannot be expressed for the successful resolution of this instrumentation design problem.

203 Other Pollutant Related Atmospheric Processes

Objective

The objective of this task is to develop an improved understanding of a wide range of atmospheric processes that are important in understanding the transport, transformation, and final removal processes of atmospheric pollutants.

Purpose and Scope

The research effort will investigate through a number of individual research projects various atmospheric processes and mechanisms that are related to the understanding of pollutant distribution over an urban and rural area. These atmospheric processes cover a range of applicable conditions and have not been readily classifiable into other areas of this research prospectus.

The individual research projects carried out within this section, while dealing with specific and identifiable objectives, will generally relate in some detail to one or more of the other research projects described in other parts of this Prospectus.

204 Atmospheric Scavenging by Precipitation

Objective

The objective of this task is to develop an improved understanding of the nature of precipitation scavenging of atmospheric pollutants and to relate these processes to other environmental factors such as water quality.

Purpose and Scope

Purposes of this task are to:

- Investigate through sampling and analytical projects the extent and processes of precipitation scavenging of atmospheric pollutants.

- Relate the observed precipitation scavenging processes to pollutant emissions and downwind pollutant concentration patterns and to develop models by which the impact of precipitation scavenging can be included in simulation modeling of the transport and dispersion of atmospheric pollutants.

- Develop special instrumentation where necessary to sample and analyze precipitation for scavenged air pollutants.

The individual projects within this program area include instrument development and sampling programs directed toward the measurement of precipitation chemistry. After analytical results are available, the data will be related to air quality concentration patterns and to meteorological conditions to develop a better understanding of the nature of the precipitation scavenging process.

205 Air Pollutant Scavenging by the Biosphere

Objective

The objective of this task is to develop an improved understanding of the relationship of the biosphere to air pollutant dispersion and transport and in particular the effect that the biosphere has on the scavenging of air pollutants from the atmosphere.

Purpose and Scope

Atmospheric transport and dispersion processes serve to bring air pollutants in contact with large amounts of biological material, and it is known that plants are effective absorbers of trace chemical materials from the atmosphere. This program will conduct projects designed to provide quantitative estimates of the scavenging mechanisms that are effective within the biosphere in removing air pollutants from the atmosphere.

The research effort also will relate the scavenging processes observed in the field to existing or potentential simulation models and to an evaluation of the interaction between air pollution and the biosphere.

Purpose and Scope

During its life cycle, vegetation has a large intake of atmospheric air and this forms a very large part of the plant life cycle. During the intake of atmospheric air, pollutants are also brought into the plant where they are retained; in addition, plant surfaces are exposed to the flow of air, and as such they provide areas where pollutants may be deposited or absorbed even though not being brought directly into the plant tissues. These are loss mechanisms that in some cases have been shown to be significant and to cause measurable changes in the ground level concentrations of specific air pollutants. This research project will attempt to quantify these absorption or removal mechanisms.

206 Atmospheric Processes

Objective

The objective of this task is to provide an additional understanding and description of physical atmospheric processes not already accounted for in generalized boundary layer meteorological modeling.

Purpose and Scope

The research for this task will extend the capability of general boundary layer theory to include anomalous physical factors of significance in the dispersal of pollutants. These factors include smaller scale phenomena, such as the effects of special emission conditions (i.e., at the stack) on the behavior of effluent plumes, or the local variation of surface roughness (i.e., different terrain or land use conditions) on air flow--or larger scale phenomena, such as the influence of extraregional features or synoptic scale circulations on the air flow characteristics within the Region.

Inputs will be obtained from other ongoing research programs or from special studies conducted within the RAPS program. Consideration will be given to conducting physical modeling studies in the laboratory where appropriate.

300 Human, Social, and Economic Factors

Objective

The objective of the tasks in this series is to develop a better understanding of factors of significance to the design of improved control strategies in the urban/rural complex, including health and economic effects and the role of land use and community planning.

Purpose and Scope

Purposes of this research program are to take advantage of the unique facility the RAPS organization provides to collect data on human, social, and economic factors in an economical and well focused manner to complement the purely physical aspects of RAPS, for the subsequent formulation of improved control strategies. The data will provide the additional basis that will be needed to apply the lessons learned in the RAPS in improved control strategies that are effective and acceptable in terms of priorities, costs of implementation, and value of results.

The resources of field teams, data analysts, and data processing facilities will be made available to collect human, social, and economic data identified as significant to the purpose noted. Data will be collected either by adding elements to other data collection surveys or by initiating special surveys. Steps will be taken to ensure that the data are compatible with the physical data collected so that interpretation and evaluation of the data on effects will be facilitated.

301 Human and Social Factors

Objective

The objective of this task is to provide a data base of relevant information on human and social factors that can be used in RAPS and in developing methodologies for using such data in other areas.

Purpose and Scope

Purposes of the task are to:

- Take advantage of the data handling and analysis capabilities of a RAPS organization to gather data on epidemiology, mortality, and the like.

- Determine population concentrations and land use characteristics.

- Provide information on the utilization of the labor force and its skills and mobility.

302 Economic Factors

Objective

The objective of this economic research is to provide a data base of relevant information on economic factors that can be used in RAPS and in developing methodologies for using such data in other areas.

Purpose and Scope

The purpose of the task is to take advantage of the data handling and analysis capabilities of the RAPS organization to gather data on the various costs of air pollution to the industrial and general population (e.g., depression of property values, damage to property, loss of productivity due to sickness) and also the cost of air pollution control strategies, in terms of both plant modification and increased costs of production.

400 Transfer of RAPS Technology for Control Agency Applications and the Formulation of Control Strategies

Objective

The objective of this series of tasks and supplies is to develop improved technology that can be applied in local and regional control agency operations, including techniques for emission inventories, air quality and meteorological measurement, data handling and analysis, and the objective assessment of control strategy effectiveness.

Purpose and Scope

The purpose of this research area is to ensure that the knowledge and technology developed in the RAPS is transferred widely to the air pollution control community at large as early and effectively as possible. This requires passing on improvements and innovations in the techniques of measurement, data handling, utilization in a direct form. It also includes the conversion and distillation of the knowledge and technology developed in RAPS in the specific test region to a generalized form, so that it can be applied in other regions and for other problems with minimum difficulty. Above all, however, this task provides the basis for the development of improved control strategies, by national, state and local agencies.

The approach follows four major lines. The first approach is development and description of techniques and criteria by which the basic air pollution factors can be assessed and monitored on an operational (as distinct from research) basis. Particular attention will be given to identifying and developing new techniques of monitoring atmospheric and air quality conditions on extended scales appropriate to regional and subregional control strategies so that the costs may be minimized. The use of aircraft and remote probing techniques either from such aircraft, or from the surface are especially suited to this purpose and every attempt should be made to advance their applicability.

The second approach is the provision of tested, effective simulation models, suitable for operational use on a generalized basis (that can be readily modified and adapted), for other areas and conditions. The third approach is development of a methodology for assessing the validity (in terms of confidence, accuracy, and precision) of the preferred models, for varying degrees of input data quality. The fourth approach is to provide methodologies for determining and assessing other factors such as health effects and economic costs and benefits relevant to the formulation of improved control strategies.

First priority will be to provide data applicable to current data resources, deficient though these may be, with emphasis on the optimum methods of providing more complete data for input to models and for air quality monitoring and model verification purposes. The needs of the states and local authorities (and EPA) to improve and extend Implementation Plans will be treated first, with concurrent although subordinate attention to Environmental Impact Statement requirements. First milestone will be the achievement of interim capabilities for these purposes. Thereafter, a more complete and detailed facility will be developed, covering all aspects of control strategies formulation then current and capable of extension to other pollutants and the like as the need arises.

401 Source Inventory Procedures

Objective

The objective of the task is to provide guidelines for the development and maintenance of source inventories as derived from the experience in the Regional Study.

Purpose and Scope

The source inventory for the Regional Study is likely to be the most comprehensive such inventory yet developed. The methods by which the source data are acquired and updated, and the manner in which the inventory is organized, stored, and retrieved should prove to be of considerable value to others faced with the task of preparing sources inventories. Accordingly, this component of the Research Plan includes efforts required to prepare guidelines and reports for the benefit of others, covering the techniques developed in the Regional Study for the management and use of source inventories.

402 Atmospheric Monitoring

Objective

The objective of this task is to improve the technology and technique of monitoring atmospheric conditions, particularly on extended scales, so that control strategies can be better implemented.

Purpose and Scope

The purpose of this task is to make available for use in all types of air pollution control operations as early as possible, the lessons learned and the techniques developed in the RAPS.

Basic principles for designing measurement networks for control agency operation and criteria for the siting of monitoring stations and instrument exposure, will be developed on the basis of experience with the RAPS data collection network.

Criteria for the organization and maintenance of extended networks of measuring instruments, with special reference to calibration and standardization, will be established. This research effort also will develop a methodology by which newly acquired data, using new techniques, can be related to older data so that the value of the latter is fully realized, even if strict continuity is not maintained.

Remote probing systems will be tested and evaluated, in comparative trials as candidate systems become available. Such tests will be conducted in conjunction with both the standard RAPS data collection system and special programs that provide especially detailed knowledge of meteorological conditions or the concentration of pollutants.

In particular, use will be made of helicopter soundings and other aircraft acquired data. The application of remote probing techniques from aircraft, as well as of aircraft in situ measuring techniques, is an additional and important study subject.

403 Data Handling

Objective

The objective of the data output task is to develop optimum techniques for acquiring, storing, and retrieving data on an extended scale for use in air pollution control agency operations.

Purpose and Scope

The purposes of the task are to:

- Make available the lessons learned and techniques developed in RAPS regarding the handling of all types of data collected and used in an extensive monitoring network and emission inventory.
- Develop and publish Standard formats as used in RAPS that are suitable for general use.
- Develop and publish manuals and computer programs for all major types of data collection and initial processing, suitable for use in air pollution control agency use.
- Provide guidelines on quality control procedures for use in collecting data.

404 Modeling Technology

Objective

The objective of this task is to provide the best available modeling capability for use in operation in air quality management.

Purpose and Scope

The purpose of this task is to extract from the research and experience of RAPS a number of models that have been tried and demonstrated and to show how these can be adapted and used for a range of specific operational requirements in an optimum fashion.

A most important major task is to evaluate the significance of modeling techniques to the formulation of control strategies and their implementation. This entails an assessment of the accuracy and precision of the models output as a function of the degree of completeness of the input. Given that the resources for data collection and monitoring in the general case will be far less complete than those for RAPS, it will be necessary to analyze the way in which limitations of the input can compromise the output of the models. Any shortcomings or uncertainties of the predictions derived from the models must be fully assessed and understood in terms of the control strategies based on them--especially where such strategies have significant economic or social impacts.

In addition to models suited to regional areas in general for the range of significant pollutants, special attention must be paid to providing suitable models for use in formulating or checking Implementation Plans, as well as for use in Environmental Impact Statements, and the requirements of air pollution episode prediction.

For all these purposes it will be necessary to:

(1) Select and publish a series of models relating to appropriate scales or pollutants in a form in which they can be readily applied in an operational role.

(2) Develop and provide a methodology for assessing the sensitivity of such models to practical limitations--such as the quantity or quality of input data, and qualifying topographical features.

(3) Develop and provide a methodology for measuring the accuracy of predictions based on such models, using either existing or specially provided (but limited) additional measurement facilities.

In general the detailed tasks, covered within the 404 series are scheduled well along in the Research Plan at a relatively low level of effort. Accordingly, their ultimate detailed content tends to be somewhat more speculative than tasks presented elsewhere in the Research Plan, so that presentation of their content in detail does not appear warranted at this early time.

405 Other Significant Factors in Control Strategy Formulation

Objective

The objective of the other tasks concerned with strategy formulation is to ensure that all knowledge and experience acquired under the RAPS program is made available for use by the air pollution control community in general and those concerned with formulating improved control strategies in particular.

Purpose

The purpose of these other efforts is to take care that both during the RAPS program and at its conclusion, fullest advantage is taken of other research in progress (both by EPA and other agencies) and also that the products of RAPS not directly connected with its principal objectives nevertheless are made available in appropriate form to potential users. Five principal components are involved.

(1) Liaison and interaction will be required with other research programs, both inside EPA and in other agencies, particularly those being carried out in the St. Louis area, such as METROMEX.

(2) Techniques should be developed to assess and evaluate social and economic factors in control strategy formulation, using as a base the data collected in 302 and 302.

(3) A methodology for assessing operational costs of control strategies should be developed for use in areas where available data are less complete than in the RAPS area.

(4) Similarly, the development of a methodology for assessing the resultant costs in terms of lost production and increased production costs of proposed strategies will be appropriate.

(5) Investigations on the basis of study and experience in the St. Louis region should be carried forward to identify the interaction of local government and other institutional aspects that are relevant to the formulation of effective control strategies and their enforcement.

In general the detailed tasks, covered within the 405 series are scheduled well along in the Research Plan at a relatively low level of effort. Accordingly, their ultimate detailed content tends to be somewhat more speculative than tasks presented elsewhere in the Research Plan so that presentation of their content in detail does not appear warranted.

VI THE FACILITY

Rationale

Basic Operations

Since the RAPS research and development program is planned as a five year integrated operation, it is discussed in this chapter in terms of a general time sequence of project initiation. As a point of departure, it is assumed that the total RAPS program will be initiated in July 1972 and that research operations can be started at this time.

The RAPS program is such that two types of field operations are necessary. One type of field operation is the research expedition, characterized by the fact that it has a limited or single objective and requires relatively short periods of field operation for data acquisition. The second type of field operation is the ongoing research study, characterized by a need for routine data acquisition over an extended period of time. The four basic RAPS task areas include projects in both field operational categories; however, since the provision of a data acquisition network for routine, ongoing research operations results in a major investment of both funds and personnel, the needs for such an investment will be examined.

Basis for Monitoring Network

A major objective of the RAPS program is the verification and evaluation of simulation modeling techniques. To fulfill the RAPS goals, this verification process must include much more than a statistical comparison of observed and model-predicted pollutant concentrations in the area around a source region. The RAPS program must also provide the opportunity to evaluate separately the several submodel routines that are component parts of all simulation modeling systems. The comparison of the submodel routines, e.g., the transport wind direction field, with the actual conditions prevailing during the verification test operation, will permit the identification of specific weaknesses in the simulation programs and procedures. Follow-up research leading to modifications in the simulation procedures can then be conducted to improve and extend the candidate simulation techniques.

This necessity to be able to understand why a candidate simulation model produces a given result requires detailed knowledge of the meterological, air quality, and emission fields in the test area. One way to obtain detailed meteorological and air quality data is through establishment of a comprehensive network of observational stations throughout the verification test area. Verification and data acquisition studies carried out to date usually have been limited either by having to use existing monitoring network data where the network had not been established to meet the needs of a verification program or by establishment of a special test program where funding and other practical problems limited the amount and time-span of the data acquisition program.

Since the objective of the RAPS program is the verification of a variety of current and future candidate model systems, it cannot be adequately carried out if the verification data acquisition system is not geared specifically to the range of verification problems that the RAPS program is expected to solve. Thus the RAPS verification data acquisition system must: (1) include detailed meteorological and air quality measurements, (2) give adequate coverage over distances of up to 150 km from the source area, and (3) provide these data on average ambient conditions for periods as short as one hour and as long as one year. In this context, detailed air quality data include ambient air concentration information for pollutants that are covered by current and proposed air quality criteria, including but not limited to SO_2, Co, No, NO_2, oxidants, hydrocarbons, suspended particles, lead aerosols, and fluorides, because model verification studies are expected to be concerned with these individual pollutants.

When all these factors are considered, the installation of a sophisticated monitoring system is the optimum way to meet the needs of the RAPS model verification program for regionwide air quality and meteorological data.

The RAPS program also is directed toward providing new data and an improved understanding of atmospheric chemical reactions, pollutant scavenging, and other atmospheric processes. Such a goal also requires a basic foundation of detailed data on atmospheric pollutant concentrations that a monitoring system can provide most effectively. The needs of this program are generally parallel to the basic components needed for the model verification program. The planned monitoring system design incorporates some components and design features that are specifically directed toward supporting chemical transformation studies and scavenging projects.

The RAPS program is also specifically charged with improving available technology in the area of air monitoring networks through the development of optimum designs and operational techniques.

Thus establishment of an air quality and meteorological monitoring network is justified on the basis of the requirements that have been placed on the RAPS program in the areas of air pollution simulation model verification, atmospheric transformation processes, and improved control agency technolgoy. Because of the area to be covered and the number of variables that are to be monitored, a telemetering, computer-controlled network has been designed for this RAPS program. Instrumentation components are, in general, the newer designs now being specified for local and regional use, although they have not generally been placed into general service by local control agencies. The proposed research program is based on the monitoring network being operational about 18 months after the RAPS program is initiated.

The special objective, expedition-type, data acquisition program can be fairly closely specified--both in terms of the type and nature of the data collected and the periods over which such data are needed. The more general, comprehensive data collection program, designed to meet the known, anticipated, or potential requirements of a number of studies, cannot be so closely specified. In proposing to maintain a continuous data collection facility to meet the general need, it is recognized that a danger exists accumulating large masses of data that could have little or no use; therefore, great care must be taken in setting up the general data acquisition program to avoid wasted costs and dissipated effort. However, some redundancy is both inevitable and desirable in a data acquisition program of this type.

To ensure that adequate data are available for investigations that cannot be defined a priori or to be sure that no data of a specific type are missed or imperfectly collected, it will be necessary to make extensive and continuous collections that will include some material that may be used quite infrequently; their importance in achieving the program objective may nonetheless be great. This principle is well recognized in many observational activities--especially where weather is involved. With modern data acquisition and processing systems, however, the unit cost of collecting additional data decreases rapidly once the initial investment in equipment and in setting up procedures has been made. Indeed, if data are to be collected at successive times throughout the year, even if considerable intervals can be anticipated, it is almost certain that little or no saving in overall costs could be made by operating intermittently, since the costs of shutting down and opening up would outweigh any minor savings by not running continuously on a routine basis.

The St. Louis Regional Monitoring Network

The St. Louis facility is conceived as consisting of a system of air quality and meteorological instrument stations established within an area roughly enclosed by a circle of 100-km radius with the St. Louis arch as its center. A central support facility is also planned that includes data-handling and processing equipment, office and laboratory space and repair and maintenance shops. Most instrument stations are expected to be linked to the central facility by telephone circuits to permit automated remote data recording at the central facility.

The St. Louis facility is planned as the basic instrument system of the Regional Study. It could be operated in a fully continuous or part-time mode to develop a comprehensive data base of air quality and meteorological conditions. Detailed statistical and other analyses then could be performed as required by the various elements of the Research Plan. During the field studies and data-acquisition efforts covered in the Research Plan, the facility would be operated to support these efforts most effectively. Support could include equipping the instrument stations with additional instruments, locating transportable stations as specified by the research group, preparing and operating specialized data processing programs, and providing instrument and experimental technician support.

Six types or classes of instrument stations are included in the facility. These range from the permanently installed Class A_1 stations with 30-meter instrument towers equipped with a full complement of air quality and meteorological instruments to the trailer-mounted Class C_2 stations having no air quality instruments and a single meteorological instrument. The principal characteristics of the stations are summarized in Table 1.

Stations of Classes A_1, A_2, and B_1 are visualized throughout the Regional Study as permanently sited, although this is certainly not a fixed requirement. These stations are considered the basic units for the long term observational program. The Class B_2 stations have the same instrument complement as the Class B_1 stations, but they are transportable units housed in trailers. The Class C_1 stations are denoted as transportable units since a trailer is used for instrument installation. However, the fact that the station is equipped with a 30-meter tower, suggests less frequent movement than the other transportable stations.

The Class C_2 stations are a hybrid unit. As part of the central facility they include the trailer unit, tower, and digital data terminal equipment. They will be used by the various groups carrying out field experiments and data-gathering efforts associated with the various research efforts presented in Part II. Additional instrumentation required at a

Table 1

CLASSIFICATION OF THE REGIONAL STUDY INSTRUMENT STATIONS

	Class of Station					
	A_1	A_2	B_1	B_2	C_1	C_2
	Number of Instruments					
Air quality instruments						
Carbon monoxide methane hydrocarbon	1	1	1	1	--	--
Hydrogen sulfide-sulfur dioxide	1	1	1	1	--	--
Total sulfur	1	1	--	--	--	--
Ozone	1	1	1	1	--	--
Nitrous oxide - oxides of nitrogen	1	1	1	1	--	--
Nephelometer	1	1	1	1	--	--
Carbon monoxide (NDIR)	1	1	--	--	--	--
Hi-vol sampler	2	2	2	2	--	--
Meteorological instruments						
Temperature	1	1	--	--	1	--
Wind direction and speed	3	3	1	1	3	1
Pyranometer	1	--	--	--	1	--
Pressure transducer	1	--	--	--	1	--
Mercury barometer	1	--	--	--	1	--
Net radiometer	1	--	--	--	1	--
Dew point hygrometer	1	--	--	--	1	--
Rain - snow gauge	1	--	--	--	1	--
	Station Characteristics					
Tower height						
30-meter	x	x			x	
10-meter			x	x		x
Data recording						
Remote	x	x	x	x		
Local					x	x
Mobility						
Fixed	x	x	x			
Transportable				x	x	x
Total quantities	9	8	24	8	4	24

Class C_2 station in support of these field efforts would be considered a part of the particular research effort rather than of the St. Louis facility. Accordingly, the instrumentation of the Class C_2 stations would be expected to vary widely during the Regional Study. This same concept would also apply to instruments added to other classes of stations set up in support of field activities.

Data acquisition and handling in the St. Louis facility are expected to be automated to the greatest possible extent. Instrument observations at all but the Class C_1 and C_2 stations are planned to be transmitted by telephone circuits to the central facility for automatic computer-controlled recording. The Class C_1 and C_2 stations are currently planned to have local data-recording facilities, but further analysis might indeed indicate these also could use a remote reporting capability efficiently.

The digital data terminal equipment of the remotely reporting instrument stations interrogates each air quality and meteorological instrument at a predetermined frequency, converts the analog instrument output to its digital equivalent, and stores the digital data in a relatively small-capacity magnetic core memory. On command from the central facility, expected to occur at about 15-minute intervals for each station, the stored data are automatically transmitted to the central facility. Calibration curves of all instruments are stored in the data-processing system at the central facility so that immediate conversion is made from the digital data format to engineering units for archiving.

Each air quality and meteorological instrument would be equipped with a solid-state, nonerasable memory unit to serve as an identifier of each instrument. A unique serial number, or equivalent, of each instrument would be coded into the identifier with the identifier then mounted on the instrument. At each interrogation of each instrument, the identifier would respond immediately before or after the instrument reading was acquired so that the instrument reading and its identification would always be together. This procedure should result in an absolute minimum of data ambiguity and erroneous interpretation and is judged to be far superior to customary procedures using instrument log books and other manual methods.

The principal data-handling and processing function at the central facility would include the recording and archiving of all instrument station data and other field and experiment information. The archival tapes would be forwarded to Research Triangle Park or other EPA installations as appropriate or to contractors for use in their analyses on a particular research project. Minimal detailed data analysis is expected to be carried out at the St. Louis facility, and the electronic data-processing equipment is sized accordingly. Selected research experiments may require limited data processing during their execution, and the St. Louis facility should have the required capability. But large scale data processing covering data acquired over a period, say, of the spring and summer seasons would be expected to be undertaken on the larger computer systems existing at the Research Triangle Park and elsewhere.

The instrument stations constituting the St. Louis facility are planned to be located within a circle of about a 100-km radius centered generally on the St. Louis arch. Eight Class A stations are symmetrically located around the 100-km circle, while an additional eight are symmetrically deployed on a 40-km square with the arch as its center. The final Class A station is planned at the arch itself. Depending on actual conditions at the arch site, advantage might well be taken of nearby taller television or other towers.

The Class B_1 stations are planned for installation on a uniform square grid about the arch with station spacings of about 12 km.

The remaining stations are considered to be transportable and would be deployed as required to support a given field data-acquisition program. This is particularly true for the Class C_2 stations. The stations other than the Class C_2 would generally be expected to provide the overall or ambient observations of air quality, meteorological, and other parameters of interest on an areawide basis. Observations in detail within a specific smaller area would be carried out by deployment of the Class C_2 stations within the area of interest.

Since the precise station locations will depend on the availability of suitable sites, the pattern presented here must be regarded as tentative. Instrument station sites must be selected with respect to several important factors, including freedom from unique or overriding micrometeorological effects, general absence of nearby significant pollutant sources, convenient access to electric power and communication utility services, and free access at all times. Only a detailed field survey will reveal sites possessing these and other necessary characteristics.

In addition to the routine surface-based data acquisition network, upper air measurements of meteorological and air quality parameters will be undertaken both on a routine and special task basis. The primary meteorological system will use METRAC or an equivalent precision automated balloon-tracking system. With METRAC, it is proposed that vertical soundings of wind, temperature, and possibly humidity, pressure, and/or net radiation be made at a four- to six-hour interval at a minimum of two stations (typically urban and rural). The system has the capability to track simultaneously up to six different balloons (both vertically-rising and constant-level) providing detailed wind information and data from four different sensors on each balloon. As such, it can also support a variety of special purpose programs. Air quality data will be obtained on a regular basis through the use of a helicopter monitoring system. Flights will be made on two or three days per week with two (three-hour) flights each day. In addition to the air quality observations, supplemental meteorological data, such as radiation measurements, will also be made. Fixed-wing aircraft are recommended for use only on a nonroutine basis and in support of special-task programs.

VII MANAGEMENT AND SCHEDULING

Introduction

The Regional Study will constitute the largest and most comprehensive scientific investigation and analysis of the phenomenology of air quality and pollution yet undertaken. Field data describing air quality, meteorology, and other pertinent factors will be obtained by an instrument and data processing system unprecedented in the study of air pollutants. This critically important effort will require the most careful planning and management both before and during its execution to ensure effective utilization of the facilities and personnel assigned to the Regional Study and the most appropriate expenditure of funds.

This chapter of Part I presents findings largely applicable to scheduling, management, and staffing of the St. Louis facility. It is certain that the scope of the Regional Study is such that continual review and modification will be required of all the estimated schedules, costs, and other factors presented in this Prospectus. This tends to be of particular importance in regard to the estimated activation schedule, since many policy and design considerations are present, not all of which can be anticipated or evaluated at this time. Moreover, several important aspects of the schedule and perhaps certain costs will depend on the actual conditions found to exist in St. Louis after authorization of the Regional Study. Accordingly, the planning factors presented are regarded as having an accuracy and reliability suitable for the planning purposes of this Prospectus and for the purpose of providing a working format for additional and more detailed planning efforts.

Facility Activation Schedule

The activation schedule of the St. Louis facility is viewed as having three principal components. The first covers the design, installation, and shakedown and acceptance of two prototype instrument stations. The second includes the activation of all Class A and B stations. The third provides for completion of the Class C stations.

The overall schedule adopted for the St. Louis facility activation will depend on a number of critical factors. These include the urgency for initiation of the research experiments requiring the full instrument system and the magnitude of funds allocated for the Regional Study. Also, a number of alternative methods or rationales may be used to develop the geographical pattern of station location. In one case all stations could be installed in a continuous sequential schedule on the basis of currently available emission source data and air quality and meteorological information. In the other case, stations might be installed at a far lower rate, so that the first group of stations would be allowed to acquire significant air quality and meteorogical data from which possible guidance would be derived for the second group, and so on. The basic concepts of scheduling under each procedure should be essentially the same; the continuous schedule has been selected for purposes here.

The design installation, and operational acceptance tests of the instrument prototype stations is estimated to require on balance about 44 weeks. The critical path through the scheduling network consists almost exclusively of the digial data terminal equipment. This situation is caused primarily by the fact that all air quality and meteorological instruments are considered to be standard catalogue items with relatively short procurement times, whereas the digital data terminal equipment consists of a combination of standard and specially designed equipment. The latter group of digital data equipment causes much of the length of the critical path, especially when combined with the design decisions associated with the telephone communication system design.

Two alternatives have been identified for scheduling the activation of all Class A and B stations. One alternative is to delay all activation until the prototype station has been thoroughly tested and all components have been accepted. Scheduling on this basis is estimated to require an additional 33 weeks for final station completion, or 77 weeks for full activation of the St. Louis facility.

The other alternative is to initiate activation before prototype station acceptance. In this case, activation could be started at the end of the acceptance tests of the prototype station air quality instruments, which is estimated to occur 23 weeks after authorization of the Regional Study. Since, as noted above, the prototype station critical path is estimated at 44 weeks, initiation of system activation after prototype operation of the air quality instruments is likely to achieve considerable economies in time. Such overlapping is estimated to bring full system operation 18 weeks earlier than the former schedule, with completion at 59 weeks.

Moderate risk is estimated to exist in continuing station activation without full completion of the prototype stations. This risk arises with the design of the equipment linking the meteorological and air quality instruments with the bulk of the digital data equipment. However, in view of the inherent flexibility of digital data circuitry designs and equipment, any incompatibilities revealed in prototype station design undoubtedly can be corrected in the digital data equipment before installation in the remaining stations.

The Class C station essentially can be scheduled independently of the other stations, since their digital data terminal equipment provides for local rather than remote recording. The Research Plan indicates a need for approximately ten Class C_2 stations about eight months after authorization of the Regional Study with the remainder following soon thereafter. Accordingly, initiation of the digital data equipment procurement cycle can be initiated ten weeks after authorization with station activation beginning 12 weeks later. At an activation rate of one per week, all stations will be completed in 51 weeks after authorization with the first ten available 33 weeks after authorization.

These activation schedules are based on the assumption that the central facility and all instrument stations sites have been acquired before the time of scheduled station activation. This is regarded as a most critical assumption, and the lack of instrument sites could indeed cause serious delay in system activation. Immediate field survey initiation following authorization of the Regional Study and preferably before, appears essential to permit station activation to proceed on schedule.

Permanent Management and Staffing

Of the 54 permanent personnel assigned to the Regional Study, nine are estimated to be located at Research Triangle Park and 45 in St. Louis. The organizational structure is summarized in Figure 5.

The significance of the Regional Study is such that the establishment of the position of Deputy Director for Regional Studies appears appropriate The Deputy Director will report directly to the Director, National Environmental Research Center, Research Triangle Park. The Deputy Director will be supported by three staff groups as follows.

- Office of Programs--This Office will provide EPA coordination, budgeting, and planning support throughout the study. A minimum of two professionals are estimated to be required.

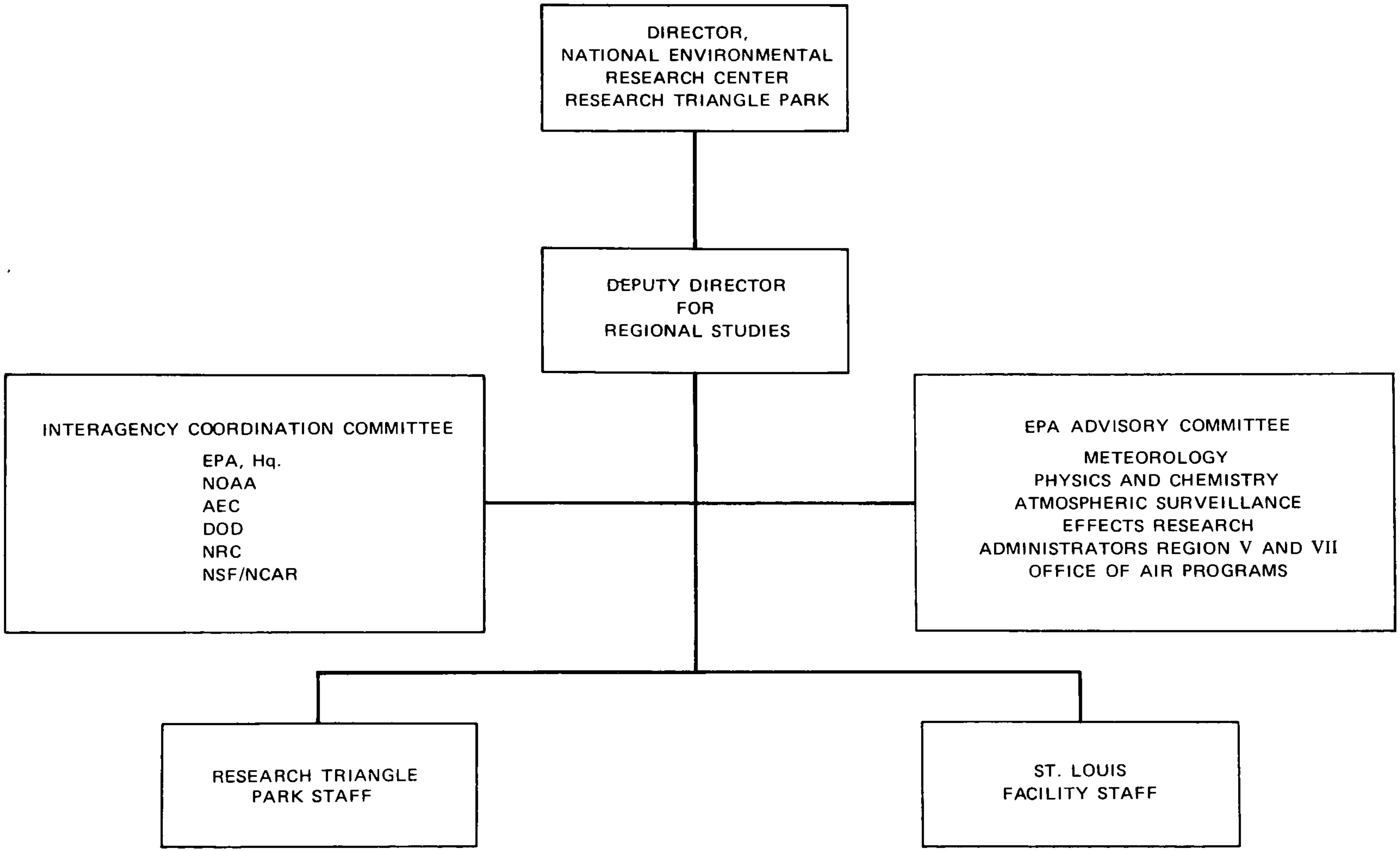

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FIGURE 5 SUMMARY ORGANIZATION OF THE REGIONAL STUDY

- Office of Interagency Coordination and Technology Transfer--This Office will be charged with providing full coordination among all agencies dealing with problems of air pollution. The broad scope of the Regional Study is such that programs of other organizations and agencies will be continually monitored to determine possible interfacing points, cooperative ventures, and other modes of joint operation. Conversely, the Office will have the principal task of advising other agencies of the programs planned for the Regional Study to again promote full cooperation. The Office will have the additional responsibility of continual review of findings developed in the Regional Study for application to other areas and experimental efforts. The Office is estimated to require one professional in the early phase of RAPS, increasing to three professionals after the first year.

- Office of Research Operations--This Office is expected to provide the very important technical link between the research divisions at Research Triangle Park and the St. Louis facility. The Office would consist of at least one representative from each division but would remain administratively within the division. The chief responsibility of each representative would be to organize and supervise the research programs within his division that will make use of the St. Louis facility. He will be responsible for data acquisition quality control, as well as for execution of the subsequent analysis. Three professionals are estimated to be required in this Office in addition to the Division representatives.

The St. Louis staff will be largely responsibile for the operation of the facility and support of the field research experimental effort. The staff consists of nine professionals and 36 nonprofessionals with 17 of the nonprofessionals engaged in instrument station maintenance and calibration. The professional staff includes the following:

- Facility Director--The facility director will be responsible for all St. Louis operations, reporting to the Deputy Director for Regional Studies.

- Research Coordinator--The research coordinator provides all logistic and facility support to special research groups carrying out field data gathering programs.

- Instrument Engineer--Two engineers are estimated for system operation, maintenance, and modification during the five-year program.

- Meteorologist--Two meteorologists are estimated to be required to provide sustained analysis of meteorological conditions in the St. Louis area and direct support to field groups for specific purposes.

- Computer System Engineer--One engineer is estimated to be required for supervision of data handling and recording procedures, special computer program preparation, and related duties.

- Control Engineer--The control engineer will be responsible for development and maintenance of the St. Louis emission inventory.

- Effects Research--An on-site professional is estimated to be required to provide direct support for all effects research in the St. Louis area; he will arrange for acquisition of all pertinent local data necessary for the program.

VIII COST SUMMARY

Permanent Facilities and Staff

Initial costs of the St. Louis facility have been estimated at about $3.94 million. This includes all instrument stations, the central facility, and other equipment estimated to be required. These initial costs are summarized in Table 2.

Table 2

ESTIMATED INITIAL COSTS OF THE ST. LOUIS FACILITY BY PRINCIPAL INSTALLATION
(Thousands of Dollars)

Instrument Stations	
A_1	$ 771.3
A_2	625.6
B_1	1,370.4
B_2	455.2
C_1	134.0
C_2	367.2
Subtotal	$3,723.7
Central facility	121.0
Vehicles	98.9
Total	$3,943.6

The estimated initial costs can also be summarized in terms of the principal system components as shown in Table 3.

Table 3

ESTIMATED INITIAL COSTS OF THE ST. LOUIS FACILITY BY SYSTEM COMPONENTS (Thousands of Dollars)

	Cost
Air quality instruments	$1,606.0
Calibration equipment and accessories	392.2
Meteorological instruments	234.2
Instrument spare parts	220.5
Site preparation, housing, fixtures	501.5
Digital data terminal equipment	769.2
Data processing and communication	81.0
General facilities	40.0
Support vehicles	98.9
Total	$3,943.6

The air quality instruments account for almost one-half the initial costs at $1.6 million, with the digital data terminals at somewhat less than 18% of the total. One of the lowest cost elements is attributable to the data processing and communication facilities and accounts for slightly more than 2% of the total costs. Significant advances in the state of the art and high volume production of computers and peripheral equipment have combined to create dramatic reductions in cost over the past two to three years.

The annual operating cost once full operational status has been achieved is estimated at about $1.5 million. This cost includes the staff at both Research Triangle Park and St. Louis and all standard operating supplies at St. Louis. These costs are summarized in Table 4.

The estimated personnel costs clearly constitute the chief element of the annual costs, accounting for almost 80% of the total. The remaining elements stand at 6% or less. A particularly uncertain cost is that for rental of the central facility and especially land for the instrument stations. A cost for instrument station sites was taken nominally at $1000 per site. Undoubtedly, large variations will be found in this unit estimate which can only be known with certainty following the actual field survey.

Table 4

ESTIMATED TOTAL ANNUAL OPERATING COSTS OF THE ST. LOUIS FACILITY AND PERMANENT STAFF
(Thousands of Dollars)

Personnel	
Research Triangle Park	$ 225.0
St. Louis	990.0
Subtotal	$1,215.0
Instrument replacement and parts	91.8
Motor vehicle operation	14.5
Telephone communication system	38.4
Building and land rental	78.4
Calibration gases	98.0
Electric power	12.7
Total	$1,548.8

The activation schedule of the St. Louis facility is estimated to span about five calendar quarters following authorization of the Regional Study. The overall expenditure schedule for both the initial and operating costs by quarter is summarized in Table 5. The operating costs in the fifth quarter are judged to typify all subsequent quarters.

Table 5

ESTIMATED INITIAL AND OPERATING COSTS DURING IMPLEMENTATION OF THE ST. LOUIS FACILITY
(Thousands of Dollars)

	Quarter				
	1	2	3	4	5
Initial costs	$ 48.8	$347.1	$2,770.2	$470.9	$306.6
Operating costs	99.1	163.3	288.7	349.0	387.2
Total	$147.9	$510.4	$3,058.9	$819.9	$693.8

Helicopter and Mixing Layer Observational Program

The estimated costs of the mixing layer observational program are presented in detail in Chapter XIV of Part III. The costs cover the acquisition and operation of one helicopter and a balloon-borne instrument system known as METRAC. Operational costs of the helicopter are based on 18 hours of operation during the period March through November and 12 hours per week for the balance of the year. Total helicopter costs on a quarterly basis for this operational schedule are shown in Table 6.

Table 6

ESTIMATED COSTS OF HELICOPTER OPERATION BY QUARTER (Thousands of Dollars)

Quarter	Cost
January-March	$19.3
April-June	24.1
July-September	24.1
October-December	16.9
Total	$84.4

Research Plan

The following sections present the estimated requirements for personnel, major equipment, and the costs of these programs. Although these estimates are judged to be suitable for the planning purposes of this Prospectus, they will require continual review and modification in further planning of the Regional Study and during its execution. This is especially important for the estimates in the later time periods. The estimates are intended to cover the requirements of each particular program component, and all are considered a part of the Regional Study. Further consideration of the Research Plan and perhaps the EPA policy considerations may result in the transfer of part or all of certain program components from the Regional Study to other components of the ongoing EPA research program.

The estimated costs of the Research Plan as presented in Chapter XXI of Part IV total $9.7 million and are summarized later in Table 11. By far the bulk of the costs are attributable to personnel, accounting for 85% of the total. About $900,000 is estimated to be required for specialized instruments for selected components of the Research Plan. Because of their somewhat specialized nature or because they require additional development to achieve operational status they were not considered as part of the permanent facility.

Personnel

Requirements

Requirements estimated for personnel stemming from the Research Plan are summarized in Table 7. Scheduling is shown on the assumption that the Regional Study is authorized by July 1, 1972. More than 311 man-years of professional and technical support personnel are estimated to be required to carry out the Research Plan. Almost one-half the personnel requirements stem from the 100-series tasks--Model Verification--alone. Within this series about one-half of the personnel are associated with the critical 104 component which covers the specific efforts associated with model verification. The 100 and 200 series have a ratio in the range of two-thirds to three-fourths between professional and technical support personnel which tends to be appropriate in view of the extensive laboratory and field efforts expected. The 300 to 400 series tend to require considerably fewer technical support personnel compared with the number of professionals, because far lower field efforts are expected.

Table 7

SUMMARY OF PERSONNEL REQUIREMENTS FOR THE RESEARCH PLAN
(Man-Years)

Program Element	Professional	Support	Clerical	Total
100	83	118	14	215
200	25	40	4	69
300	9	9	2	20
400	16	5	3	24
Total	133	172	23	328

Each of the four major program elements is expected to be coordinated by the various Research Division representatives in the Office of Research Operations. Major program components, especially those continuing throughout the life of the Regional Study, would necessarily have full-time supervisors within the respective interested Research Divisions. The extent to which contractor participation will be necessary and appropriate is difficult to state and would likely depend on the balance between program requirements in terms of scheduling and capability and the available resources within EPA. Total personnel requirements, however, should remain substantially identical regardless of the manner in which the effort is conducted.

Professional and technical support personnel were estimated on a task-by-task basis from their descriptions in Part II. An additional component of the staffing would include clerical support. For planning purposes, clerical personnel requirements are estimated on the basis of one per six professionals, bringing the total requirements to 328 man-years.

Costs

The total estimated costs of personnel associated directly with the tasks included in the Research Plan are presented in Table 8, based on the requirements shown in Table 7. The estimated costs, as discussed in Chapter XIX of Part IV are based on a unit cost of $25,000 per year per staff member, regardless of his labor or job classification With the mix of classifications estimated to be required, the aggregated estimates should be valid. Estimates for the smaller components of the Research Plan that do not have a balanced staffing pattern would tend to be less reliable. The unit cost includes direct salary, benefits, travel, and all other funds necessary for support.

Total personnel costs directly associated with the Research Plan are estimated at about $8.3 million.

Table 8

ESTIMATED COST OF PERSONNEL REQUIRED BY THE RESEARCH PLAN
(Thousands of Dollars)

Calendar Year	100	200	300	400	Total
1972	$ 383.6	$ 24.9	--	--	$ 408.5
1973	1,112.7	87.3	$208.4	$105.0	1,413.4
1974	1,202.0	445.0	108.4	180.3	1,935.7
1975	1,128.5	490.5	108.4	149.9	1,877.3
1976	1,035.2	525.6	108.4	156.3	1,825.5
1977	507.1	157.4	54.2	154.7	873.4
Total	$5,369.1	$1,730.7	$487.8	$746.2	$8,333.8

Instrumentation and Equipment

The bulk of the instrumentation and equipment necessary for execution of the Research Plan is included in the St. Louis facility as discussed in Chapters XI-XII of Part III and Chapter XVIII of Part IV. These items are generally expected to function throughout the life of the Regional Study. However, several major items of equipment are included more appropriately in the costs of the Research Plan rather than in the St. Louis facility. The first includes the METRAC balloon-borne instrument system discussed in Chapter III of Part II and Chapter XIV of Part III for observations in the mixing layer.

Costs for additional research and development were estimated at $100,000 in the first year after authorization of the Regional Study. If the development is successful, an additional cost of $376,000 was estimated for full implementation of the system having a capability to simultaneously track six balloons. The estimated costs by quarter are shown in Table 9. Program element 200--Atmospheric Chemical and Biological Processes--is estimated to require certain additional instrumentation and equipment not included in the St. Louis facility. Their costs are included within the costs of the Research Plan rather than the St. Louis facility. Table 9 presents the estimated costs of these instruments and equipment by program component and date of acquisition. Compared with personnel costs, these expenditures tend to be modest except perhaps for the gas chromatograph-mass spectrometer estimated at $100,000.

Table 9

ESTIMATED COSTS OF SPECIALIZED EQUIPMENT FOR THE RESEARCH PLAN
(Thousands of Dollars)

Program Component	Equipment Description	Quantity	Cost	Acquisition Date Year/Quarter
103	METRAC system development	--	$100.0	1972/4
	METRAC procurement and installation		376.0	1974/1
201	Gas chromatograph	3	18.0	1975/1
	Electron capture gas chromatograph	3	14.0	1975/1
	G. C. mass spectrometer	1	100.0	1975/1
	Correlation spectrometer	1	10.0	1975/1
	Recorders for gas chromatographs	6	6.0	1975/1
	Sample vessels, valving, standard units	--	10.0	1975/1
	Total		$158.0	
202	Electron mobility counter	2	40.4	1974/1
	Royco photometer counter	5	41.3	1974/1
	Anderson impactor	5	5.6	1974/1
	Total		$ 87.3	
203	Atomic absorber	1	4.0	1975/1
	Transmissometer	3	27.0	1975/1
	Radiative balance instruments		50.0	1973/3
	Total		$ 81.0	
204	Digital pH meter	5	5.0	1974/2
	Tipping bucket rain-gage	10	3.2	1974/2
	Fabrication of precipitation pH measurement and calibration	5	2.5	1974/2
	pH meter	1	1.8	1974/2
	Chemical electrodes	7	1.4	1974/2
	Total		$ 13.9	
406	Thermosonde	3	120.0	1973/2
	Acoustic sounder	2	40.0	1973/2
	Total		$160.0	

This unit would be installed at the central facility with the bulk of the remaining items installed mainly at selected Class A and B stations as discussed in the Research Plan.

Finally the research effort under program element 402--Atmospheric Modeling--will require the use of two atmospheric sounders and three thermosondes early in 1973. The estimated costs of these units are also presented in Table 9.

Operations

Execution of the Research Plan will entail certain direct operating costs in both the 100 and 200 series. In the 100 series, significant costs are estimated to be associated with the 101 component for the operation of the METRAC system during wind transport and tracer studies. The Research Plan indicates the execution of the wind-tracking experiment during the second and third quarters of 1974 and tracer studies in the same quarters in 1975.

As noted in Chapter XIV of Part III the estimated operating costs of the METRAC system are $8000 per month per balloon launch point for an intensive experimental effort. Thus, if the METRAC system is taken as having four launch points, the total operating costs would be $32,000 per month. Under the research schedule shown above, the quarterly METRAC operational costs expected are shown in Table 10.

Table 10

ESTIMATED OPERATIONAL COSTS
OF THE METRAC SYSTEM
(Thousands of Dollars)

Year--Quarter	Cost
1974--2	$ 92
1974--3	92
1975--2	92
1975--3	92
Total	$368

Operating costs of the efforts in the 200 series are expected to cover consumable and expendable laboratory supplies and equipment. The costs of these items should be insignificant in comparison to personnel costs, for example, so that a detailed estimate here does not appear warranted. Accordingly, an average cost of $4000 per quarter will be taken as the cost of these consumable and expendable items.

Total Cost of Research Plan

The total estimated cost of the effort covered by the Research Plan is summarized in Table 11 by quarter. A total of $9.7 million is estimated, with about 85% attributed to personnel. On an annual basis, costs tend to peak in 1974 at $2.6 million, caused primarily by higher costs of equipment acquisition and operations.

Total Costs of RAPS

The total estimated cost of the Regional Study is summarized in Table 12 by quarter and is almost $21.2 million. The schedule is based on the assumption that the Regional Study would be authorized on July 1, 1972, and that activities are initiated immediately. The greatest part of the total costs are attributable to personnel, with about two-thirds of the total costs. Except for the quarter in which the St. Louis facility is largely completed, the cost within any category does not exceed personnel costs. The research staff costs tend to lie in the range of 1.5 times the permanent staff. Combined instrument costs of the St. Louis facility and the Research Plan are close to $5.0 million, or almost 25% of the total estimated cost.

Table 11

TOTAL ESTIMATED COSTS OF THE RESEARCH PLAN
(Thousands of Dollars)

Year-Quarter	Personnel	Instruments	Operations	Total
1972-3	$ 175.6		$ 4.0	$ 179.6
-4	232.9	$100.0	4.0	336.9
Subtotal	$ 408.5	$100.0	$ 8.0	$ 516.5
1973-1	304.2		4.0	308.2
-2	338.9	160.0	4.0	502.9
-3	395.9	50.0	4.0	449.9
-4	374.4		4.0	378.4
Subtotal	$1,413.4	$210.0	$ 16.0	$1,639.4
1974-1	480.1	463.3	4.0	947.4
-2	504.5	13.9	96.0	614.4
-3	476.9		96.0	572.9
-4	474.2		4.0	478.2
Subtotal	$1,935.7	$477.2	$200.0	$2,612.9
1975-1	479.1	189.0	4.0	672.1
-2	470.8		96.0	566.8
-3	467.7		96.0	563.7
-4	459.7		4.0	463.7
Subtotal	$1,877.3	$189.0	$200.0	$2,266.3
1976-1	465.7		4.0	469.7
-2	444.2		4.0	448.2
-3	448.6		4.0	452.6
-4	467.0		4.0	471.0
Subtotal	$1,825.5		$ 16.0	$1,841.5
1977-1	442.9		4.0	446.9
-2	430.5		4.0	434.5
Subtotal	$ 873.4		$ 8.0	$ 881.4
Total	$8,333.8	$976.2	$448.0	$9,758.0

Table 12

ESTIMATED TOTAL QUARTERLY COSTS OF THE REGIONAL STUDY
(Thousands of Dollars)

			Operating Costs					
	Initial Costs		Equipment			Personnel		
Year-Quarter	St. Louis Facility	Research Instruments	Helicopter	St. Louis Facility	Research Plan	Permanent Staff	Research Staff	Total
1972-3	$ 48.8			$ 2.0	$ 4.0	$ 97.0	$ 175.6	$ 327.4
-4	347.1	$100.0	$ 16.9	12.1	4.0	151.2	232.9	864.2
Subtotal	$ 395.9	$100.0	$ 16.9	$ 14.1	$ 8.0	$ 248.2	$ 408.5	$ 1,191.6
1973-1	2,770.2	160.0	19.3	51.0	4.0	237.7	304.2	3,546.4
-2	470.9	50.0	24.1	57.0	4.0	292.0	338.9	1,236.9
-3	306.6		24.1	83.5	4.0	303.7	395.9	1,117.8
-4			16.9	83.5	4.0	303.7	374.4	782.5
Subtotal	$3,547.7	$210.0	$ 84.4	$ 275.0	$ 16.0	$1,137.1	$1,413.4	$ 6,683.6
1974-1		463.1	19.3	83.5	4.0	303.7	480.1	1,353.7
-2		13.9	24.1	83.5	96.0	303.7	504.5	1,025.7
-3			24.1	83.5	96.0	303.7	476.9	984.2
-4			16.9	83.5	4.0	303.7	474.2	882.3
Subtotal		$477.0	$ 84.4	$ 334.0	$200.0	$1,214.8	$1,935.7	$ 4,245.9
1975-1		189.0	19.3	83.5	4.0	303.7	479.1	1,078.6
-2			24.1	83.5	96.0	303.7	470.8	978.1
-3			24.1	83.5	96.0	303.7	467.7	975.0
-4			16.9	83.5	4.0	303.7	459.7	867.8
Subtotal		$189.0	$ 84.4	$ 334.0	$200.0	$1,214.8	$1,877.3	$ 3,899.5
1976-1			19.3	83.5	4.0	303.7	465.7	876.2
-2			24.1	83.5	4.0	303.7	444.2	859.5
-3			24.1	83.5	4.0	303.7	448.6	863.9
-4			16.9	83.5	4.0	303.7	467.0	875.1
Subtotal			$ 84.4	$ 334.0	$ 16.0	$1,214.8	$1,825.5	$ 3,474.7
1977-1			19.3	83.5	4.0	303.7	442.9	853.4
-2			24.1	83.5	4.0	303.7	430.5	845.8
Subtotal			$ 43.4	$ 167.0	$ 8.0	$ 607.4	$ 873.4	$ 1,699.2
Total	$3,943.6	$976.0	$397.9	$1,458.1	$448.0	$5,637.1	$8,333.8	$21,194.5