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9. ABSTRACT

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A description of the RANN Program and identification of 48 RANN projects that could have special relevance to the needs of developing countries. RANN stands for Research Applied to National Needs. The purpose of this National Science Foundation program is to focus scientific and technological capabilities on selected U.S. societal problems of national importance to facilitate their practical solution. RANN places special emphasis on problems of improving productivity and economic growth, as well as the quality of the environment. The discussion of the 48 RANN projects clarifies their technical significance for developing countries and illustrates possible types of spin-off benefits. The topics discussed include energy research, disaster and natural hazards, urban technology, and environmental systems and resources. Discussed are ways in which developing countries might benefit from RANN research. These include adapting U.S. energy models to local needs; coupling RANN studies to local needs; coupling RANN studies to local solar energy programs; establishing local automotive industries; conducting collaborative field work on tsunami warning systems; and collaboration on site search in tropical waters for power generation utilizing ocean thermal gradients.

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RANN PROGRAM

Potential Benefits to Developing Countries

Office of Science and Technology
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PREFACE

RANN stands for Research Applied to National Needs -- an expanding program of the National Science Foundation designed to stimulate the harnessing of science in the service of man. The purpose of RANN is to focus scientific and technological capabilities on selected U.S. societal problems of national importance with the objective of facilitating their practical solution. RANN places special emphasis on problems of improving productivity and economic growth, and the quality of the environment and life in the United States.

The expanding scope and practical orientation of RANN programs toward areas which hold promise of technological, social, or economic pay-off through the application of scientific knowledge, suggested that results from some of these programs might be useful also in the developing countries. This report identifies 48 individual RANN projects -- from over 300 investigated -- that could have special relevance to the needs of developing countries. It clarifies their technical significance to these countries and illustrates possible types of spin-off benefits. The report is being circulated broadly to officials in developing countries and development assistance agencies as part of a continuing effort by the Office of Science and Technology to disseminate information on U.S. scientific and technological efforts relevant to international development.

The report was prepared by Dr. Harry Y. H. Choi, an industrial consultant, in collaboration with the staff of the Office of Science and Technology. Grateful acknowledgement is extended to Dr. Sidney Sternberg, Deputy Assistant Director for Research Applications, and Mr. Charles T. Owens, Special Assistant to the Assistant Director for Research Applications, of the National Science Foundation for their cooperation.

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I. THE RANN PROGRAM

Purpose

The Research Applied to National Needs (RANN) programs of the National Science Foundation are aimed at focusing U.S. scientific resources on selected problems of national importance. Special emphasis is given in the selection of programs to their problem-orientation and potential national benefit of anticipated results. The planning and implementation of programs are guided by criteria such as these:

Importance:	Are the significance and urgency of the problem great in terms of their potential for the nation?
Payoff:	Are the societal benefits to be realized significantly higher than the anticipated costs of dealing with the problem?
Leverage:	Can science and technology have a unique and substantial impact on the problem?
Readiness:	Is a problem-focused research effort timely in terms of the availability of scientific and technical manpower?
Capability	Do the institutions exist or can they readily be developed to mount such a research effort?
Need for Federal Action:	Is Federal support for such research required because the economic incentive is not sufficient in relation to the risk of failure for private industry?

Currently, the principal efforts in RANN programs are directed toward these problem areas:

-- energy, because of its importance to increasing national productivity and economic growth, its limited availability in fossil fuel forms, and its impact on the environment;

-- regional environmental systems, because of their importance to national life support in terms of air, water, food and other natural resources, including land; and

-- municipal systems and services, because of the importance of improving their effectiveness in responding to problems of increasing population density, functional complexity and diversity of human resources.

Organization

RANN programs are organized under a Directorate of Research Applications. Within the Directorate, three major divisions have been established to deal with the selected problem areas. These are:

1. Division of Advanced Technology Applications

The division has the responsibility to develop the knowledge base for new or improved technologies to enhance economic productivity, to exploit the potential contribution to the nation of advances in science and technology, and to stimulate technological applications that will contribute to the solution of major national problems. It currently has the following programs:

-- energy research: energy resources, conversion technologies and overall systems, including transmission systems;

-- disaster and natural hazards: earthquake engineering and fire research;

-- urban technology: excavation and tunneling technology, and also urban systems technology (application of new technologies to

the overall and component design of communities; and

technological opportunities: specific technologies expected to have near-to intermediate-term payoffs in providing major productivity improvements and reduced pollution; initial efforts on enzyme technology, extractive metallurgy and instrumentation technologies.

2. Division of Environmental Systems and Resources

The division has the responsibility to develop an improved understanding of environmental systems and to develop the knowledge required to prevent environmental degradation, to utilize national resources wisely, and to accommodate man's activities to environmental constraints. Its current programs are:

-- regional environmental systems: investigations of special problems of coastal regions, river basins, urban-rural environments, and semi-primitive areas;

-- weather modification: new weather modification concepts with special effort on developing a reliable hail suppression technique; and

-- environmental aspects of trace contaminants: heavy metal contaminants such as mercury and lead.

3. Division of Social Systems and Human Resources

The division has the responsibility to develop an improved understanding of social systems and social data that will help increase the effectiveness of efforts to deal with major societal problems and more effectively realize the potential of individual citizens in their various roles and social units. It currently has the following programs:

municipal systems and services: technological applications to the delivery of municipal services, aimed at increasing the cost-effectiveness of this delivery; and

social data and community structure: developing and analyzing baseline data on the socio-economic characteristics of population groups and on the social structure of American communities.

In addition to the three divisional programs, an Exploratory Research and Problem Assessment Program has been designed to identify and assess emerging societal problems and the potentials of science and technology to contribute to their practical solution. It includes studies of the present and future impacts of technologies on society, and experimental efforts to develop better techniques for technology evaluation and forecasting.

Program Summary--Fiscal Years 1971, 1972, and 1973

A summary of active RANN projects and related outlays is given below:

	FY 1971 (Actual)	FY 1972 (Actual)	FY 1973 (Estimated)
Total number of grants and contracts	219	346	450
Total in millions, U.S. dollars	34.2	53.6	70

A breakdown of RANN activities by division/program for fiscal year 1972 (July 1, 1971-June 30, 1972) shows the following:

	Million U.S. $		Percent
Advanced Technology Application		18.9	35.2
Energy Research	8.9		
Disaster and Natural Hazards	4.3		
Urban Technology	1.5		
Technological Opportunities	4.2		

	Million U.S. $		Percent
Environmental Systems and Resources		19.6	36.6
Regional Environmental Systems	10.1		
Water Modification	4.5		
Trace Contaminants	5.0		
Social Systems and Human Resources		10.5	19.6
Municipal Systems & Services	6.0		
Social Data & Community Structure	3.6		
Exploratory Research and Problem Assessment		4.6	8.6
Total		53.6	100.0

II.

RANN PROJECTS OF POTENTIAL INTEREST TO DEVELOPING COUNTRIES

The identification of RANN projects having potential spin-off benefit to developing countries was based on the following criteria:

- -- possibility of industrial spin-off benefit in developing countries;
- -- possibility of R & D spin-off benefit in developing countries;
- -- applicability of methodology or model to situation in developing countries; and
- -- informational value to planners or researchers in developing countries.

No attempt was made to identify how a specific research project might benefit a particular developing country. Rather, the attempt here is to indicate in a general way the nature of the potential benefit to developing economies within the context of technology transfer. Some developing countries have or will have the R & D capability to tie-in directly with selected RANN projects. Others will benefit by being made aware of the important scientific and technological trends and by initiating programs to develop manpower and facilities in line with these trends and their own order of national priorities.

The research underway in the major RANN programs, except for the Social Systems and Human Resources programs, is described below. The Social Systems and Human Resources programs are not included because they are largely concerned with the special socio-economic needs and issues of U.S. communities, which have very limited relevance in developing countries. Each program text is accompanied by a discussion and commentary on individual projects relevant to needs of developing countries.

Energy Research

In the area of energy research and technology, current research includes:

projection of increases in energy demands and the environmental impacts of alternate means for meeting these demands;

development of new knowledge for optimizing power plant siting;

identification of new technologies needed to make more efficient use of available energy resources;

development of thermal batteries of the lithium-sulphur type capable of energy storage densities and operational power densities an order of magnitude greater than those of existing lead-acid batteries;

development of technology to utilize solar power on a vastly larger scale than is currently available, including the development of new optical coatings to trap solar energy at high temperatures, and a system analysis determination of the most attractive technologies for collecting, storing, and converting solar energy to produce fuels such as methane and hydrogen; and

development of new means for reducing power losses in transmission systems, including the use of cryogenic and super conducting technologies in underground systems.

Among this wide range of efforts, those judged to be of particular interest to developing countries are the research on energy models, with the possibility of adapting models to local energy situations, and work on solar energy, especially the prospect of biological conversion using solar energy.

In the project entitled "Dynamics of Energy Systems" (1)*, the aim is to construct a broad scale energy model, incorporating the time phasing of events and feed back effects in the energy industries. The objectives are to give planners more effective tools for assessing the consequences of various energy policy

*Number refers to project list in the Appendix

options and to develop tools for more detailed studies of a single industry or region to yield insight into growth patterns and technology needs. The study will concentrate upon the U.S. energy picture, but will include the global supply of fuels and the global impact of energy use upon the environment. A related study by the same research group is entitled the "Analytical Tools and Modeling Studies for the Gas Industry" (2).

These study techniques should be applicable to assessing energy problems in the developing countries. In most of these countries, whether they are at an early stage of development such as Indonesia or at a relatively advanced stage of industrialization such as India, power is one of the basic constraints to economic growth. As a consequence, energy planning is of the highest priority concern in their national plans, for agricultural as well as industrial sectors.

Energy supply and demand are very complex, and in order for the problem to be examined in a manner simple enough to be understood, modeling is necessary. Through modeling, the consequences of various policy decisions can be more effectively assessed. The proposed model has particular merit, in that it is built around dynamics of interactions in the market place, taking into account demand and supply elasticity, resource limitations, and sensitivity of the components of GNP to energy use.

As an example of how a developing nation might participate in, and benefit from the research, it is suggested that the feasibility of this particular approach might be more easily demonstrated using a less complex energy situation of a developing country (provided the necessary data are locally available). The research is at an early enough stage that the inclusion of one or more developing countries in the study might be possible.

In "Power Plant Siting"(3), the objective is to clarify the environmental issues and to recommend criteria and guidelines for optimizing power plant siting. The study is being conducted under auspices of the National Academy of Engineering which attaches

the highest sense of urgency to this national issue. The report should be of informational value to energy industries in the developing countries.

Other studies on the subject of energy and environment are "Management of Heat Rejected from Large Power Plants" (4), "Ocean-Sited Power Plants"(5) and "Electrical Energy and Its Environmental Impact "(6). The environmental aspects of energy use are not yet of urgent concern in developing countries, although they should be, for there are serious environmental problems in many of these countries. But perhaps governments concerned with the energy question from the standpoint of keeping their people one or two steps ahead of starvation cannot be expected to be greatly alarmed over environmental consequences at this time. Governments are more concerned with the effective transfer of existing technology rather than new, more costly, environmentally-safe technology. Nevertheless, the projects cited above are believed to have transferable benefits for developing countries, since a partial explanation for the tendency to accept pollution with industrialization is inadequate information on means being developed to minimize these impacts.

Reference (4) deals with the environmental consequences of rejected heat from power plants and comprises studies of heat transfer across large air-water interfaces, heat transfer from water droplets and thin films (performance of cooling towers), prediction of temperature distributions resulting from the discharge of hot submerged jets of water into large bodies of water, and experimental evaluation of the extent to which such discharge raises the temperature of a water body. Scientists and engineers in R & D establishments in many developing countries are capable of adapting this research to local situations.

Reference (5) examines a number of pollution-free energy sources, and has as one of its major objectives an investigation of the technological and economic feasibility of power generation from ocean thermal gradients. The need for boiler and condenser temperatures of about 75-80 degrees F. and 40-50 degrees F., respectively, requires tropical waters. A comprehensive engineering study will be conducted of a complete ocean power

generation system located somewhere in the Gulf Stream off the coast of the United States, incorporating the novel concept of using the velocity of the ocean current to move warm water across the boiler and minimize marine fouling of heat exchangers. The analysis will cover the type of engine cycle and fluid to be used, the subsystems, and overall system optimization. A key milestone of the study is the location of a plant site with desirable year-around current velocity and temperature distribution characteristics for the extraction of energy. The prospects are long-ranged, but should interest many developing countries in or near the tropics.

Battery-powered rail cars are used for suburban services in Germany, and battery-powered buses are technically feasible. However, the requirements for family automobiles are more demanding and the present state-of-the-art suggests that these requirements can best be met by the so-called thermal batteries, under intensive development in many laboratories. Cells for such batteries consist of lithium sulfur electrodes immersed in a molten-salt electrolyte operating at temperatures about 500 degrees F. The objectives of "Research and Development on Lithium/Sulfur Secondary Batteries" (7) are to develop a better understanding of the cell electrochemistry and to examine the properties of electrolytes and other cell materials from the standpoint of optimizing cell performance or minimizing cell cost. Possible applications include battery-powered automobiles and whole-house auxilary power supplies.

At present, the auto industries in most developing countries are at infant stages of development. Since they do not have major vested interests in piston-type internal combustion engines, they have the policy option of moving directly to battery power or other new "clean" power systems, and thereby benefit from experiences of the industrialized nations. RANN research programs might thus have some impact on planning in the transportation sector in developing countries.

Five projects on solar energy are cited in the Appendix, references (8)-(12). The conversion of solar energy to electric power has not been notably successful to date. Aside from the problem of high initial capital facilities cost, there are critical technical problems such as low conversion efficiency due to low operating temperatures and heat losses within the system. "Thermal Conversion of Solar Energy for

Electric Power Production" (8) and "Research Applied to Solar-Thermal Power Systems"(9) investigate the possibility of achieving a practical system by new advances in the development of an absorbing surface that is "selective" (absorbs sunlight and inhibits reradiation) and operates at high temperatures. The system proposed in (8) may be able to achieve a conversion efficiency of 25 percent and thermal output at about 1000 degrees F. which should be suitable for interfacing with conventional steam turbine generating equipment.

Solar power may have great potential as an energy source for developing countries in or near the tropics. Whereas RANN projects are oriented to the requirements for economically competitive solar power systems in the United States, the developing countries could employ smaller units. The feasibility of coupling RANN research to experimental solar energy programs in these countries should be explored.

"Computer Modeling and Simulation of Solar Heating and Cooling Systems" (10) is a study on solar energy for residential applications. An interesting aspect of this study is the development of a computer simulation program to study the effects of major design parameters on system performance, including collectors, storage units, and water heater units. Although solar heating and cooling of buildings may not be the highest priority application in developing countries, design information on the various subsystems could have value in the development and optimization of related systems, such as solar heaters and refrigerators.

Most attention in solar energy applications, including those cited above, is given to thermal processes. There is some evidence that biological conversion of solar energy into chemical energy (combustible gases such as methane or hydrogen) through photosynthesis may be feasible. In "Technology for the Conversion of Solar Energy to Fuel Gas" (11) and "Hydrogen Production by Photosynthesis and Hydrogenase Activity--An Energy Source"(12), studies are aimed at producing combustible gaseous fuel from solar energy by using micro-organisms growing on organic material, such as municipal, agricultural, and domestic wastes. One

by-product could be a nutritionally valuable protein. In a typical full-scale application, organic wastes would be transported by water or other means into large ponds where the photosynthetic organisms are grown. The organisms fix solar energy efficiently. They would be concentrated by separation and introduced wet or dry into controlled fermenters, for decomposition and release of nutrients and gases. The efficiency of the process would depend on the algal species utilized and other operational parameters of the system.

If scaling-up from laboratory to pilot and full-scale systems can be achieved, this technique might lead to useful applications in developing countries. The R & D laboratories in some countries might consider undertaking research in this field, experimenting with local species of algae, because the efficiency of energy conversion can vary by an order of magnitude for different species.

The RANN program also supports conferences and workshops. The conference on "Energy Research Priorities" (13) brings together leading experts to review the state of knowledge and past studies on energy priorities in an attempt to establish a consensus on research priorities and to indicate how such research is to be funded and conducted. The "Workshop on Energy and Environment" (14) will report the findings of four panels: energy technology, technological options, growth in energy use, and institutional mechanisms for dealing with energy problems. These conferences are cited for general reference; energy planners and researchers in developing countries will want to know about the critical problems behind the growing U.S. energy crisis and how the country proposes to deal with them. While it is true that energy industries in the developing countries are built upon established technologies, it is also true, that they might well benefit from recent U.S. research on energy resource development and utilization.

Disaster and Natural Hazards

Major efforts in this area cover earthquake engineering and fire research. In earthquake engineering, support has been provided for research on:

-- soil and foundation response to earthquake motions;

-- dynamics and damage of structures, to develop improved design and construction techniques;

-- effects of quakes on coastal and inland waterways;

-- earthquake resistant designs for utilities and communication systems; and

-- socio-economic effects and costs of earthquakes.

The emphasis in the earthquake program is on engineering studies; these are studies concerned with the effects of earthquakes, as opposed to geophysical studies concerned with the origin of earthquakes and what they reveal about the structure of the earth. For developing countries in the seismically active regions, the program should be an important source of practical information on soil and structure failure during earthquakes. Soil failure by liquefaction or landslides is reasonably predictable, but code provisions are generally poor or lacking on soil effects. Similarly, despite limitations of knowledge on how structures respond to earthquakes, much is known that has not found its way into building codes and construction practice. Specialists in developing countries might adapt information from RANN-supported studies to local soil conditions and building practices, and thereby help to establish standards for improved earthquake resistance in new construction.

In this connection, the "National Information Service for Earthquake Engineering" (16)(17), supported by RANN programs at the California Institute of Technology and University of California at Berkeley, should be particularly useful sources for obtaining current information. In addition to providing basic library services, Caltech will concentrate on collecting and evaluating data about earthquake strong motions and on instruments to measure them, while Berkeley will concentrate on computer methods for structural analysis, dynamic tests of soils and structure, and a literature abstract service.

Several representative earthquake research projects are listed in the Appendix, (15)(18)(19)(20). "An Engineering Feasibility Study of an Ionospheric Technique to Improve Tsunami Warning Systems"(19) could offer some countries the opportunity for collaborative field work, since the effect of tsunamis (or seismic sea waves) depends importantly on local submarine topography. The research on "Earthquake Induced Transient Pore Pressures in Earth Dams"(20) is aimed at determining the loadings on the upstream sloping faces of earth dams due to water motion in the reservoir induced by earthquakes. The study involves the coupling of the hydrodynamic response of the reservoir, the structural dynamic response of the dam, and the dynamic soil properties of dam material. The solution should ultimately yield design parameters governing the stability of such dams. Earth dams are important in developing countries and this particular RANN project should interest the many competent hydrodynamicists working in these countries.

The fire research supported by RANN is focused on reducing the flammability of structural materials, fluids, and fabrics through better understanding of flame propagation mechanisms and improvement of fire suppression technology. The emphasis of special relevance to many developing countries is fabric flammability, since textile products are major export items of these countries and the U.S. Government has recently initiated action to regulate the flammability of fabrics incorporated in children's clothing. Commencing July 1973, all flammable children's sleepwear size 6 and under will be banned from sale in the United States; the action could eventually extend to other apparel classifications. The projects "Flammability and Burn Potential of Fabrics"(22) and "Flammable Fabrics" (23) are both aimed at developing test methods for predicting hazards from burning apparel.

The studies will cover the probability of ignition and flame-spread behavior of fabrics, including their various geometric and heat transfer properties, under conditions expected in actual use. A key parameter is the dimensionless flame spread velocity. It is not known yet whether this number should be based on the rate of gas phase mass transfer or on the rate of heat conduction in solids. A wide variety of fabrics will be tested, including cotton, wool, nylon, acrylic, and acetate.

Ultimately, the studies will establish new test standards, involving the laboratory measurement of two or more flammability parameters, and techniques for extrapolating laboratory results to conditions expected in use Textile industries in the developing countries might benefit directly from these projects and may desire to establish parallel programs of their own, to assist in meeting future flammability standards and protecting export markets.

"Fire Safety for Low Cost Housing"(21) is a multidisciplinary study of problems of fire safety in high-density urban housing, including material and design factors, detection techniques, and human factors. Some problems arise from the use of new construction materials in new ways, such as extensive use of plastics and fiberboard in low-income housing. The information should serve architects and the construction industry in developing countries, where fire in crowded metropolitan areas is a frequent and tragic occurrence, by providing them with the best current knowledge of fire hazards and by introducing them to some new design methods for fire safety.

"Flame Spreading Across Liquid Fuels"(24) and "Flame Spread Over Liquid Fuel"(25) deal with the safe storage and handling of liquid fuels. The research which is largely theoretical, assumes that the flame spreading mechanism is essentially governed by hydrodynamic convection induced by surface tension and/or buoyancy forces. An appropriate mathematical formulation is sought to explain the flame propagation process. Engineering researchers in developing countries, many of whom are theoreticians, may wish to contribute to the solution of this important industrial problem.

"Forest Fire Statistical Problems"(26) is concerned with developing a basic simulation model for forest fire control. The studies will include assessing fire starts relative to probable cause and terrain, forecasting the occurrence of large fires relative to terrain and weather conditions, and designing an efficient data base and means for rapid retrieval of associative data. A fully implemented model should be able to predict the number of fire occurrences for a region, given the terrain, weather conditions, and time of the year. The

use of systems analysis as an aid to advanced planning in fire control should interest developing countries with important forest resources.

Urban Technology

The purpose of urban technology programs is to develop new technologies for improving the services and physical attributes of new and existing communities. The major research efforts are in the field of excavation, tunneling, and urban systems technology.

In excavation and tunneling technology, the primary objective is to reduce the cost of developing underground space in urban areas with minimum disruption to surface functions. Research efforts have focused on the following needs:

- -- geophysical exploration methods for better location of tunnels and methods to provide knowledge of what will be encountered ahead of the face of the cut during the excavation process;
- -- improved methods of advancing through hard rock;
- -- on-site instrumentation of tunnels to provide engineering data that will lead to improvement in current tunneling technology and design; and
- -- systems studies of the entire excavation process, including economic and social factors.

In urban systems technology, the objective is to contribute to the understanding, development, and application of new technologies to the overall and component design of communities. Immediate targets of the program are the development of the buckle shell roof system, providing a new method for construction of open-span structures; and development of an urban information system for rapidly processing municipal data.

Five urban technology projects are listed in the Appendix, (27)-(31), for general reference in developing countries. "A Model for Systems Analysis of Tunneling and Excavation"(27) proposes to develop a cost simulation model of tunneling-excavation processes that will facilitate rapid and accurate cost estimates and assess the impact of new construction methods. The proposed model should have broader applicability than the few special programs in existence (such as the COHART program of the U.S. Department of Transportation for a high-speed rail transportation system in the Northeast corridor), but it should be noted that tunneling costs are highly dependent on geologic conditions as well as construction methods. Nevertheless, the study should interest city planners in some of the more advanced developing countries who are forced by urban congestion to give increasing attention to underground space, e.g. the subway system under construction in Seoul, Korea.

"Tunneling and Tunnel Lining Behavior"(28) will utilize field measurements from actual construction projects to prepare an Instrumentation Guide which will detail the types of observations that should be made, and the choice and use of instruments under various conditions of tunnel construction, including how to install, maintain, calibrate, and read the instruments. The Guide should be useful as a reference manual in some developing countries to help promote safety in underground construction.

"Effectiveness of Underground Construction"(29) and "Advisory Conference on Excavation Technology"(30) are aimed at determining research needs and priorities in these fields. Reference (29) might be of particular value to R & D laboratories in some developing countries because it includes a review of the state of the art in underground construction and an inventory of research in progress and completed during the past five years in the United States.

"Studies on Systems for the Non-polluting Disposal and Economic Utilization of Solid Waste"(31) will perform a critical assessment of the technical merit of existing and proposed processes for the disposal of solid waste and sewage. The processes to be covered include conventional incineration, high pressure combustion,

bacterial and enzymatic digestion, recycling, and extreme pressure compaction. The assessment will provide interested planners and researchers in developing countries with a comprehensive review of the technological, economic, and ecological aspects of solid waste disposal.

Technological Opportunities

This program focuses on specific technologies expected to have near to intermediate term payoffs in providing major productivity improvements and reduce pollution. It supports research on new instrumentation technologies and the development of new and improved methods of industrial processing. Support to date has been provided in the areas of enzyme technology and extractive metallurgy.

Enzyme technology may be on the threshold of an advance that could revolutionize the modification and transformation of matter for human use. Recent advances offer the possibility of using enzymes to control reactions at the molecular level, as in natural processes, rather than forcing compounds to react with each other at high pressures and temperatures. Notable progress has been made in enzyme synthesis, large scale isolation of enzymes (in kilogram quantities), improving knowledge of how enzymes function catalytically, and procedures for attaching enzymes or enzyme analogs to inert matrices for industrial use. As a result of these developments, many important and wide scale applications of enzymes are likely to emerge in the coming decade in food processing, pharmaceuticals, and industrial processing. The use of enzymes for technological purposes is not a recent phenomenon, however. The best known is use of yeast, for fermenting wine and beer and making bread, and the use of proteolytic enzymes in modern detergents. Less commonly known is the role of enzymes in making cheese, in removing fur from hides, and in tenderizing meat with an enzym derived from papaya fruit.

Much of the active research in enzyme technology today is aimed at discovering better techniques for producing, purifying, and immobilizing enzymes and designing enzyme reactors. "Enzyme Systems and Their Practical Utilization"(32) is concerned with designing a reactor which will remove phenol from industrial effluent water, and detecting minute amounts of it in the environment.

In "Use of Immobilized Enzymes in Food Processing, Waste Treatment and Pharmaceutical Preparations" (33), a variety of industrial processes using enzymes will be investigated, based on a novel immobilization technique of electro-codeposition of enzyme and collagen. In this technique, enzymes are complexed in a natural way to a collagen membrane without hindrance of their catalytic activity; the membranes are then shaped into convenient reactor configurations. "Enzyme Systems and Technology for Large-Scale Synthesis" (34) investigates the use of enzyme systems as an energy source in large-scale biochemical synthesis. Also, other activities in enzyme applications are supported by RANN, including "An Information Exchange in Enzyme Technology" (35), under which a digest on current research activities and literature will be published three times a year.

Enzyme technology is expected to have far-reaching impact on chemical, food-processing, and pharmaceutical industries. In the production of dextrose from starch, immobilized enzymes offer the possibility of replacing conventional batch processes with continuous processes. A dextrose plant using immobilized enzymes, offers advantages of lower capital investment and operating costs and improved standardization in processing. Continuous processing can be employed in the modification of starch and in the conversion of dextrose into fructose, which is used by the manufacturers of corn syrup, which in turn is used by a variety of food processing and pharmaceutical industries.

Enzymatic procedures can also be used to accomplish preferred synthesis of chemical compounds such as drugs, and to catalyse the decomposition of industrial wastes, such as lignin compounds from the pulp and paper industry, into useful products. The key to recovering useful products from wastes is the development of cheap and efficient processes such as might be achieved with enzyme technology.

Some developing countries with relatively advanced technological capabilities might wish to monitor this RANN research and consider the orientation of their own programs to benefit from current and expected advances in enzyme applications.

In "Modelling and Optimization of the Ironmaking-Steelmaking Operational Sequence" (36), the objective is to develop a generalized optimal plan for the ironmaking steel-processing operational sequence, encompassing the manufacture of coke and iron at one end and the handling of flat rolled products at the other. A linear model will be constructed of a large, integrated steel mill, with material flows as variables. The constraints are unit capacities, product quality, and production requirements. The model will be used to develop optimal policies for a variety of contingencies, such as drastic changes in the price of raw materials, the breakdown of processing units, and plant expansion.

Process optimization techniques are routinely used in the chemical and petroleum industries, but very little work has been done to optimize metallurgical operations. Therefore, this study might have an important impact on the steel industry. Many developing countries already have or plan to have modern, integrated steel mills. Such mills require a large investment of scarce domestic resources, and the type of contingencies allowed by the model, such as drastic changes in scrap prices, do occur with some frequency in these countries. The proposed model is basic and flexible, and should be directly applicable to the design of mills in developing countries. Also, conceptually similar techniques could be applied to the operation of foundries and rolling mills.

RANN also supports investigations dealing with pollutant monitoring. In some of the more industrialized developing countries, environmental pollution is already a serious problem; for example, in Seoul, Korea, sulphur pollution is significantly above the allowable level in the United States. While environmental pollution is not the highest national priority in these countries, some scientists and engineers may desire to monitor RANN research to learn about the latest advances in pollutant monitoring instrumentation.

"A Survey of Instrumentation for Environmental Monitoring" (37) provides information on instrumentation in loose-leaf folders that can be purchased from the Lawrence Laboratory at Berkeley. Information on instrumentation for monitoring radiation and sulphur dioxide is currently available; work is in progress on describing other instrumentation related to monitoring atmospheric and water pollutants.

In the "Applications of Cryogenic Techniques to Problems in Air Pollution" (38), the objective is to develop cryogenic trapping techniques for concentrating and measuring low-level molecular pollutants in air. Within the existing state-of-the-art, the measurement of residual gases below one part per million is not possible; the cryogenic traps can concentrate some of these gases by a factor of 400. The design information for these traps should be of interest to R & D laboratories in some of the developing countries concerned with the problems of pollution and related instrumentation development.

The project "Evaluation of the Ecological, Resources and Socio-Economic Impacts of Advanced Automotive Propulsion Systems" (39) proposes to define and evaluate the major ramifications of a transition from present internal combustion engine technology to any of the potential alternatives. Assuming a transition from the internal combustion engine to battery power or to a hybrid heat engine/battery system, some ramifications deserving consideration are the effect of increased power consumption on the electric power industry (power availability and distribution, shift in peak power point, etc.), the effect on the petroleum industry, the redistribution of labor force, the changes in demand for materials and prospective ripple effects.

In many countries in Latin America and Asia, the automotive industry is an important factor in their industrialization effort. Some, with assembly-only operations, might be able to move directly to "clean" engines without any serious transition problems. Others, with an integrated domestic program, will face the question of engine alternatives and should begin to consider major implications of these alternatives. This study, therefore, should be of considerable interest to the automotive and related industries, as well as automotive sector planners, in many developing countries.

Environmental Systems and Resources

There are three major programs in this area: regional environmental systems, weather modification, and trace contaminants.

The regional environmental systems program is concerned with coastal regions, river basins, urban/rural regions, and semi-primitive areas. Its objective is to focus research on the scientific and technical bases for resolving specific regional environmental problems and for forecasting environmental consequences of regional growth and alternative resource development. While the studies are geographically specific (e.g., Chesapeake Bay, Eastern Tennessee Valley, Chicago, etc.), they may have some benefit in demonstrating a methodology applicable to circumstances of some developing countries.

In the weather modification program, the major effort is on research to develop a reliable hail suppression technique. Additional studies relate to new weather modification concepts and an evaluation of the impact of weather modification on social, economic, legal, and ecological aspects of society.

In the trace contaminants program, research emphasis is on heavy metals, such as mercury and lead. The basic objective is to understand the sources, routes, and targets of trace contaminants in the environment and to develop methods for their control and removal. There have been a number of celebrated cases of mercury and lead poisoning in the world, for example the outbreak of mercury poisoning in the Middle East in 1971-1972, which was investigated by a team from the United States under RANN Program sponsorship. The results of this research should benefit developing countries by helping them to avoid some of the consequences of industrialization in the advanced countries.

A number of the studies are cited in the Appendix for this reason, (40)-(48). Three should be of particular interest because of their approach to the construction of national environmental models. "Ecosystem Design and Management" (41) aims to develop a comprehensive ecological model, viewing the environment as an energy transformation and transmission process. "National Environmental Models of Agricultural Policy, Land Use and Water Quality" (46) deals with land use and water quality problems in the agricultural sector, incorporating such variables as population, markets, and technology.

"National Economic Models of Industrial Water Use and Waste Treatment" (47) proposes to develop models of the five major water-using industries: chemicals, pulp and paper, primary metals, petroleum refining, and electric power generation. These models should prove useful in the planning of long-term preventative solutions to some of the environmental problems of industrialization, as opposed to the short-term solutions possible through the use of existing technology for better treatment of waste and more judicious use of toxic chemicals.

III. CONCLUSIONS

RANN projects are addressed to the scientific and technological problems of urgent national importance in the United States. However, with the exception of those projects concerned with special regional or societal problems of the country, project results shoul have world-wide significance and applicability. The transferability of benefits to the developing countries is limited mainly by their state of development and order of national priorities. Developing countries differ in degrees of readiness to assimilate these benefits. Those ranking high on the industrialization scale may have the technological capability to adapt to their circumstances a significant portion of the results of RANN research. Those ranking lower on the scale may benefit by being made generally aware of some of the most important technological trends of our time, as reflected by the RANN Program, and by initiating steps to develop manpower and facilities in line with these trends.

Knowledge from RANN programs could benefit developing countries in a number of ways:

a) In developing countries, the problems of technology transfer are of high national concern. Scarce resources are being committed to find ways of enhancing the transfer effectiveness at the receiving end. Thus far, private industry has been the primary conduit for technology transfer, with multinational corporations playing a dominant role. While universities generally have not been active in technology transfer, RANN programs could provide the mechanism for a project-by-project approach to scientific and technological assistance to developing countries involving the universities, with related educational and training benefits.

b) Developing countries need not repeat the mistakes of the industrialized nations. They should benefit from all that is known today and selectively short-cut historical stages of technological advance and avoid many of the negative environmental impacts of industrialization. The issues highlighted by RANN programs could provide valuable guidance to these countries in charting their development course.

c) Methodologies and models are being developed under RANN programs to tackle complex economic and technological issues in a systematic way. These could be valuable tools to the planners in developing countries. In view of the critical need for planning know-how in these countries and the relatively simple transferability of this body of knowledge, research results of this kind could well emerge as the first spin-off benefits for development from RANN programs.

d) A not-often recognized but very important need of industries and R & D laboratories in developing countries is access to information on current technological trends. A number of RANN projects are information-oriented. They attempt through conferences, workshops, and information services to develop the best available knowledge on the state-of-the-art and research needs and opportunities of selected technologies of major concern. The information generated could be useful in many developing countries.

More specifically, developing countries might benefit from RANN research by considering these possibilities:

-- adapting U.S. energy models to local energy situations;

-- coupling RANN studies to local solar energy programs;

-- by-passing an internal combustion engine stage in planning to establish local automotive industries;

-- collaborative field work on tsunami warning systems, and utilization of information services on advances in earthquake engineering;

-- establishing programs to meet flammability standards of fabrics;

-- adapting process optimization techniques in metallurgical operations for steel mills;

-- collaboration on site search in tropical waters for power generation utilizing ocean thermal gradients;

-- adapting forest fire simulation models to fire control programs;

-- initiating research on enzyme applications, in anticipation of the impact of current advances in enzyme technology on chemical, food-processing, and pharmaceutical industries;

-- adapting national environmental models on trace contaminants to long-term preventive solutions for environmental pollution.

-- further research related to:

biological conversion of solar energy to fuel gas using local species of algae;

environmental consequences of heat rejected from power plants;

flame propagation in liquid fuels; and

earthquake induced loadings on earth dams.

APPENDIX

LIST OF RANN PROJECTS

1.	Title:	Dynamics of Energy Systems
	Identification:	David C. White Department of Electrical Engineering Massachusetts Institute of Technology Cambridge, Massachusetts 02139 Phone: (617) 864-6900
	Illustrative benefit:	Possibility of adapting energy models to local situations.
2.	Title:	Analytical Tools and Modeling Studies for the Gas Industry
	Identification:	David C. White Department of Electrical Engineering Massachusetts Institute of Technology Cambridge, Massachusetts 02139 Phone: (617) 864-6900
	Illustrative benefit:	Possibility of adapting energy models to local situations.
3.	Title:	Power Plant Siting
	Identification:	William C. Ackermann National Academy of Engineering Committee on Engineering Aspects of Environmental Quality Washington, D.C. 20418 Phone: (202) 961-1658
	Illustrative benefit:	Important reference on environmental issues for power industry.

4. Title: Management of Heat Rejected from Large Power Plants

Identification: George J. Trezek/Virgil E. Schrock
Department of Mechanical Engineering
University of California
Berkeley, California 94720
Phone: (415) 642-6000

Illustrative benefit: Research opportunity for energy specialists to work on a significant industrial research problem.

5. Title: Ocean Sited Power Plant

Identification: William E. Heronemus
Department of Civil Engineering
University of Massachusetts
Amherst, Massachusetts 01002
Phone: (413) 545-0215

Illustrative benefit: Possible research participation in site search.

6. Title: Electrical Energy and Its Environmental Impact

Identification: J.L. Liberman
Department of Environmental Sciences
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37830

Illustrative benefit: Important reference on environmental issues for power industry.

7. Title: Research and Development on Lithium/Sulfur Secondary Batteries

Identification: Elton J. Cairns
Argonne National Laboratory
Chemical Engineering Division
9700 South Case Avenue
Argonne, Illinois 60439

Illustrative benefit:	Possible major impact on development pattern of auto industry.
8. Title:	Thermal Conversion of Solar Energy for Electric Power Production
Identification:	Aden B. Meinel Optical Sciences Center University of Arizona Tucson, Arizona 85721 Phone: (602) 884-2974
Illustrative benefit:	Possible research collaboration in solar power development.
9. Title:	Research Applied to Solar-Thermal Power Systems
Identification:	R.C. Jordan Department of Mechanical Engineering University of Minnesota Minneapolis, Minnesota 55455
Illustrative benefit:	Possible research collaboration in solar power development.
10. Title:	Computer Modeling and Simulation of Solar Heating and Cooling Systems
Identification:	J.A.Duffie Department of Chemical Engineering University of Wisconsin Madison, Wisconsin 53706 Phone: (608) 262-3481
Illustrative benefit:	Design information potentially useful for development of solar heaters and refrigerators.

11.	Title:	Technology for the Conversion of Solar Energy to Fuel Gas
	Identification:	Iraj Zandi School of Civil and Mechanical Engineering University of Pennsylvania Philadelphia, Pennsylvania 19104
	Illustrative benefit:	Possibility of adapting technology, particularly in conjunction with research on local algae species.
12.	Title:	Hydrogen Production by Photosynthesis and Hydrogenase Activity--An Energy Source
	Identification:	L. O. Krampitz Department of Microbiology Case Western Reserve University Cleveland, Ohio 44106
	Illustrative benefit:	Possibility of adapting technology, particularly in conjunction with research on local algae species.
13.	Title:	Energy Research Priorities
	Identification:	Donald D. Dunlop United Engineering Trustees New York, New York 10017
	Illustrative benefit:	Important reference information for energy planners.
14.	Title:	Workshop on Energy and the Environment
	Identification:	Thomas M. Lodahl Graduate School of Business and Public Administration Cornell University Ithaca, New York 14850

	Illustrative benefit:	Important reference information for energy planners.
15.	Title:	A Comprehensive 5-Year Research Program in Earthquake Engineering
	Identification:	Donald E. Hudson/ George W. Housner Division of Engineering & Applied Science California Institute of Technology Pasedena, California 91109 Phone: (213) 795-6841
	Illustrative benefit:	Source for current information on advances in earthquake engineering.
16.	Title:	National Information Service for Earthquake Engineering
	Identification:	Donald E. Hudson California Institute of Technology Pasedena, California 91109 Phone: (213) 795-6841
	Illustrative benefit:	Source for current information on advances in earthquake engineering.
17.	Title:	National Information Service for Earthquake Engineering
	Identification:	J. Penzien Earthquake Engineering Research Center University of California Berkeley, California 94720 Phone: (415) 642-0543
	Illustrative benefit:	Source for current information on advances in earthquake engineering.

18. Title: Investigations of the Effects of Earthquake Motions on Reinforced Concrete Buildings

Identification: Mete A. Sozen
Department of Civil Engineering
University of Illinois at Urbana
Urbana, Illinois 61801

Illustrative benefit: Possibility of adapting knowledge to local building practices.

19. Title: An Engineering Feasibility Study of an Ionospheric Technique to Improve Tsunami Warning Systems

Identification: P. C. Yuen
Department of Electrical Engineering
University of Hawaii
Honolulu, Hawaii 96822

Illustrative benefit: Possible collaborative field work on warning system.

20. Title: Earthquake Induced Transient Pore Pressures in Earth Dams

Identification: Victor L. Streeter/
E. Benjamin Wylie
Department of Civil Engineering
University of Michigan
Ann Arbor, Michigan 48104

Illustrative benefit: Research opportunity for hydrodynamicists to work on important real-life problem.

21. Title: Fire Safety of Low Cost Housing

Identification: R. B. Williamson
Department of Civil Engineering
University of California
Berkeley, California 94720
Phone: (415) 642-6611

Illustrative benefit: Important reference for architects and construction industry.

22. Title: Flammability and Burn Potential of Fabrics

Identification: G. C. Williams
Department of Chemical Engineering
assachusetts Institute of Technology
ambridge, Massachusetts 02139
hone: (617) 864-6900

Illustrative benefit: Possible initiation of research and quality control programs in textile industry to meet flammability standards.

23. Title: Flammable Fabrics

Identification: Wolfgang Wulff
School of Mechanical Engineering
Georgia Institute of Technology
Atlanta, Georgia 30332

Illustrative benefit: Possible initiation of research and quality control programs in textile industry to meet flammability standards.

24. Title: Flame Spreading Across Liquid Fuels

Identification: Irvin Glassman
Department of Aerospace & Mechanical Science
Princeton University
Princeton, New Jersey 08540
Phone: (609) 452-5199

Illustrative benefit: Opportunities for industrial research in liquid fuel handling.

25. Title: Flame Spread Over Liquid Fuel

Identification: Kenneth E. Torrance
Department of Thermal Engineering
Cornell University
Ithaca, New York 14850
Phone: (607) 256-4314

Illustrative benefit: Opportunities for industrial research in liquid fuel handling.

26. Title: Forest Fire Statistical Problems

Identification: F. N. David
College of Biological and Agricultural Sciences
University of California
Riverside, California 92502
Phone: (714) 787-3774

Illustrative benefit: Possibility of adapting fire simulation model for forest fire control.

27. Title: A Model for Systems Analysis of Tunnelling and Excavation

Identification: F. J. McGarry
Department of Civil Engineering
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139
Phone: (617) 864-6900

Illustrative benefit:	Model might be difficult to adapt, but information useful reference to city planners.
28. Title:	Tunnel and Tunnel Lining Behavior
Identification:	A. J. Hendron, Jr. Department of Civil Engineering University of Illinois Urbana, Illinois 61801 Phone: (217) 333-6944
Illustrative benefit:	Instrumentation Guide to be published; should help safety planning in underground construction.
29. Title:	Effectiveness of Underground Construction
Identification:	William H. Wisely American Society of Civil Engineers 345 East 47th Street New York, New York 10017
Illustrative benefit:	Information source--review of state-of-the-art in underground construction.
30. Title:	Advisory Conference on Excavation Technology
Identification:	Albert N. Bove U.S. National Committee for Rock Mechanics National Research Council Washington, D. C. 20418
Illustrative benefit:	Information source--research needs and priorities in excavation technology.

31. Title: Studies on Systems for the Non-polluting Disposal and Economic Utilization of Solid Waste

Identification: Elmer L. Gaden/Helmut W. Schulz
Chemical Engineering Department
Columbia University
New York, New York 10027
Phone: (212) 280-4457

Illustrative benefit: Information source--solid waste disposal systems.

32. Title: Enzyme Systems and Their Practical Utilization

Identification: Arthur E. Humphrey/
E. Kendall Pye
School of Chemical Engineering
University of Pennsylvania
Philadelphia, Pennsylvania 19104
Phone: (215) 594-8351

Illustrative benefit: Possibility of establishing research or other appropriate programs in enzyme applications; programs important to chemical, food-processing and pharmaceutical industries.

33. Title: Use of Immobilized Enzymes in Food Processing, Waste Treatment and Pharmaceutical Preparations

Identification:	Wolf Vieth Department of Chemical Engineering Rutgers University New Brunswick, New Jersey 08903
Illustrative benefit:	Possibility of establishing research or other appropriate programs in enzyme applications; programs important to chemical, food-processing and pharmaceutical industries. Opportunity particularly attractive for new plant investment in continuous processes possible with immobilized enzymes, as opposed to less efficient batchwise process used in existing plants (e.g. production of dextrose from starch).
34. Title:	Enzyme Systems and Technology for Large-Scale Synthesis
Identification:	Daniel I.C. Wang Department of Food Science Massachusetts Institute of Technology Cambridge, Massachusetts 02139 Phone: (617) 864-6900
Illustrative benefit:	Possibility of establishing research or other appropriate programs in enzyme applications; programs important to chemical, food-processing and pharmaceutical industries.

35. Title: An Information Exchange in Enzyme Technology

Identification: I. Melville Roberts
New Extensions for Utilizing Scientists
P.O. Box 1365
Santa Monica, California 90406

Illustrative benefit: Information source--advances in enzyme technology.

36. Title: Modelling and Optimization of the Ironmaking-Steelmaking Operational Sequence

Identification: W. Harman Ray/Julian Szekely
Department of Chemical Engineering
State University of New York at Buffalo
Buffalo, New York 14214
Phone: (716) 831-4716

Illustrative benefit: Possibility of adapting metallurgical process model to steel mills.

37. Title A Survey of Instrumentation for Environmental Monitoring

Identification: Dick Mack
Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720
Phone: (415) 642-6000

Illustrative benefit: Information source--pollutant monitoring instruments.

38. Title: Applications of Cryogenic Techniques to Problems in Air Pollution

Identification	Russel J. Donnelly Department of Physics University of Oregon Eugene, Oregon 97403 Phone: (503) 686-4754
Illustrative benefit:	Information source--pollutant monitoring instruments.
39. Title:	Evaluation of the Ecological, Resources and Socio-Economic Impacts of Advanced Automotive Propulsion Systems
Identification:	Herbert N. Berkow Hittman Associates Inc. 9190 Red Branch Road Columbia, Maryland 21043 Phone: (301) 730-7800
Illustrative benefit:	Important reference on factors to be considered in auto sector planning regarding engine options.
40. Title:	A Study of Certain Ecological, Public Health and Economic Consequences of the Use of Inorganic Nitrogen Fertilizer
Identification	Daniel H. Kohl/Barry Commoner Department of Biology Washington University St. Louis, Missouri 63130 Phone: (314) 863-0100
Illustrative benefit:	Important references for control of trace contaminants in environment.

41. Title: Ecosystem Design and Management

Identification: Herman E. Koenig
Department of Electrical Engineering & Systems Science
Michigan State University
East Lansing, Michigan 48823
Phone: (517) 353-3787

Illustrative benefit: Important references for control of trace contaminants in environment; comprehensive environmental model potentially useful in planning long-term preventive solutions to environmental problems of industrialization.

42. Title: Trace Elements in Water: Origin, Fate, and Control of Mercury

Identification: George A. Parks
Department of Mineral Engineering
Stanford University
Stanford, California 94305
Phone: (415) 321-2300

Illustrative benefit: Important references for control of trace contaminants in environment; opportunity for actions to avoid mistakes of industrialization.

43. Title: Ecology and Analysis of Trace Contaminants

Identification: J. L. Liberman
Department of Environmental Sciences
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37830

Illustrative benefit: Important references for control of trace contaminants in environment; opportunity for actions to avoid mistakes of industrialization.

44. Title: An Interdisciplinary Study of Environmental Pollution by Lead and Other Metals

Identification: H. A. Laitinen
Department of Chemistry
University of Illinois
Urbana, Illinois 61801
Phone: (217) 333-0675

Illustrative benefit: Important references for control of trace contaminants in environment; opportunity for actions to avoid mistakes of industrialization.

45. Title: Environmental Pollutants and the Urban Economy

Identification: George S. Tolley
Department of Economics
University of Chicago
5801 South Ellis Avenue
Chicago, Illinois 60637
Phone: (312) 753-4508

Illustrative benefit: Important references for control of trace contaminants in environment; opportunity for actions to avoid mistakes of industrialization.

46. Title: National Environmental Models of Agricultural Policy, Land Use and Water Quality

Identification: Earl O. Heady
Department of Economics
Iowa State University
Ames, Iowa 50010

Illustrative benefit: Environmental models potentially useful in long-term planning in agricultural sector.

47. Title: National Economic Models of Industrial Water Use and Waste Treatment

Identification: Russell G. Thompson
Department of Quantitative Management Science
University of Houston
Houston, Texas 77004

Illustrative benefit: Important references for control of trace contaminants in environment; models potentially useful in planning long-term preventive solutions to environmental problems of industrialization.

48. Title: Workshop/Conference on Research Needs for Planning, Development and Management of Our Physical Environments

Identification:	Harvey S. Perloff School of Architecture and Urban Planning University of California, Los Angeles Los Angeles, California 90024
Illustrative benefit:	Information Source - discusses major issues surrounding control of trace contaminants in environment.