RESEARCH TRIANGLE INSTITUTE
N.C.

RANN UTILIZATION EXPERIENCE

REPORT TO
THE NATIONAL SCIENCE FOUNDATION
Case Studies 22 through 31

Washington, D.C.

August 31, 1976

Compiled by:

R. M. Burger
M. F. Massoglia

Research Triangle Institute
P.O. Box 12194
Research Triangle Park
North Carolina 27709

As a Final Report on:
Contract No. NSF-C76-17165
National Science Foundation
Research Applied to National Needs
1800 G Street, N.W.
Washington, D.C. 20550

BIBLIOGRAPHIC DATA SHEET	1. Report No. NSF/RA-760412	2.	3. Recipient's Accession No.

4. Title and Subtitle
RANN Utilization Experience (Case Studies 22 through 31)

5. Report Date
August 1976

6.

7. Author(s)
R.M. Burger, M.F. Massoglia

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
Research Triangle Institute
P.O. Box 12194
Research Triangle Park, NC 27709

10. Project/Task/Work Unit No.

11. Contract/Grant No.
C7617165

12. Sponsoring Organization Name and Address
Research Applied to National Needs (RANN)
National Science Foundation
Washington, D.C. 20550

13. Type of Report & Period Covered
Final Report

14.

15. Supplementary Notes
Case Studies 1 - 41 are available from NTIS

16. Abstracts This report contains case studies of the utilization of research results of ten Research Applied to National Needs (RANN) projects that were selected as representative of well utilized efforts. The selection was based on data obtained in a sample survey designed to determine the extent of utilization of RANN research projects that were initiated in February 1972 and February 1973. These case studies followed twenty-one that were previously prepared and distributed, and will be followed by additional utilization case studies. Findings and analysis are confined to the individual cases. Subject areas include: (1) Development of x-ray fluorescence analysis and application to atmospheric aerosols; (2) Dredge spoil distribution and estuarine effects; (3) Laboratory cloud simulation to support weather modification research and field programs; (4) Feasibility study: coordination of data collection activities on the nation's building inventory; (5) Biological conversion of organic refuse to methane; (6) Fire and smoke spread in corridors; (7) Computer abuses; (8) Problems and research priorities in the Rocky Mountain region; (9) Development of a plan to maximize the learning from destructive earthquakes; and (10) Research and development of Lithium/Sulfur secondary batteries.

17. Key Words and Document Analysis. 17a. Descriptors

Research
Research Management
Research Projects
X-Ray Fluorescence
Weather
Fires
Organic Wastes
Earthquakes
Aerosols
Estuaries
Computers
Electric Batteries

17b. Identifiers/Open-Ended Terms

Case Studies
Findings
Research Applied to National Needs (RANN)
Research Utilization
Technology Utilization

17c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
NTIS	UNCLASSIFIED	288
	20. Security Class (This Page) UNCLASSIFIED	22. Price

CAPITAL SYSTEMS GROUP, INC.
6110 EXECUTIVE BOULEVARD
SUITE 250
ROCKVILLE, MARYLAND 20852

RANN UTILIZATION EXPERIENCE

REPORT TO
THE NATIONAL SCIENCE FOUNDATION
Case Studies 22 through 31

Washington, D.C.

August 31, 1976

SUMMARY

This report contains case studies of the utilization of research results of ten Research Applied to National Needs (RANN) projects that were selected as representative of well utilized efforts. The selection was based on data obtained in a sample survey designed to determine the extent of utilization of RANN research projects that were initiated in FY'72 and FY'73. These case studies follow twenty-one that were previously prepared and distributed, and will be followed by additional utilization case studies. Findings and analysis are confined to the individual cases. No general findings are given in this report.

Table of Contents

INTRODUCTION

Background

The Research Applied to National Needs (RANN) Program of the National Science Foundation supports research on selected problems of national importance with the objective of contributing to their practical, timely solution. Various studies have been undertaken to assess the prompt utilization of RANN research. One utilization assessment tool is the case study wherein an individual project is examined, its utilization determined, the various factors that apparently affect its utilization are identified, and conclusions are derived relative to its utilization experience.

Research Triangle Institute (RTI) completed an initial group of twenty-one such case studies in 1975.* The projects selected for those case studies were among the better utilized ones as judged by RANN management. In that effort, and in subsequent analyses by NSF/RANN, much has been learned on how to conduct case studies so as to improve their effectiveness both in communicating the experience of the project and in revealing the features of the utilization process in general. This collective experience has been applied, albeit not with complete success, in the preparation of these new case studies.

In this report, ten new case studies are presented. Essential information on these is given in Table 1. Additional case studies are being prepared and will be presented in later reports.

---

*R.M. Burger, RANN Utilization Experience Final Report to the National Science Foundation, Research Triangle Institute, June 16, 1975.

TABLE 1. RANN PROJECTS FOR WHICH CASE STUDIES ARE INCLUDED IN THIS REPORT

	PROJECT	PRINCIPAL INVESTIGATOR(S)	NSF PROGRAM MANAGER	TERM	FUNDING
22	Development of X-Ray Fluorescence Analysis and Application to Atmospheric Aerosols	T. A. Cahill and F.P. Brady University of California, Davis	Loyd Herwig, Richard Bleiden Richard Carrigan	3/72- 8/75	$ 264,400
23	Dredge Spoil Distribution and Estuarine Effects	L. S. Slotta and M.L. Schroeder Oregon State University	Richard Kolf, Edward Bryan	7/72-	$1,146,500
24	Laboratory Cloud Simulation to Support Weather Modification Research and Field Programs	L. O. Grant and M. L. Corvin Colorado State University	Currie Downie	71-	$ 478,000
25	Feasibility Study: Coordination of Data Collection Activities on the Nation's Building Inventory	R. M. Dillon National Academy of Sciences	Charles C. Thiel and J. B. Scalzi	7/73- 2/74	$ 25,000
26	Biological Conversion of Organic Refuse to Methane	J. T. Pfeffer University of Illinois	Roscoe Ward, Richard Bogan Tapan Mckherjee	6/73- 5/76	$ 284,900
27	Fire and Smoke Spread in Corridors	K. T. Yang, J. R. Lloyd, M. E. Doria Notre Dame	Ralph Long	2/73-	$ 132,000
28	Computer Abuses	Dan B. Parker Stanford Research Institute	A. F. Konopka	2/73- 12/73	$ 39,000

TABLE 1. (CONTINUED)

	PROJECT	PRINCIPAL INVESTIGATOR(S)	NSF PROGRAM MANAGER	TERM	FUNDING
29	Problems and Research Priorities in the Rocky Mountain Region	J. M. Newhold Utah State University	Larry W. Tombaugh, Terry R. Sopher	6/73- 3/75	$ 114,800
30	Development of a Plan to Maximize the Learning from Destructive Earthquakes	C. M. Duke, D. F. Morgan Earthquake Engineering Research Institute	Charles Thiel	5/73- 12/75	$ 189,000
31	Research and Development on Lithium/Sulfur Secondary Batteries	F. J. Cavins, P. A. Nelson Argonne National Laboratory	Richard Shoen	2/72- 2/74	$ 1,050,000

An important application of the case studies is their usefulness for comparative analyses. To facilitate this, a degree of necessary uniformity is imposed. However, it must be emphasized that a case study is not constrained to a limited set of questions and answers. Flexibility in the pursuit of information is both desirable and necessary to obtain a valid measure of utilization. The Case Investigator must probe with zeal into the various nooks and crannies of the conceptualization-research-dissemination-utilization process in order to obtain an accurate and complete study.

What constitutes utilization of research results is a difficult question to answer. Measures of utilization that are operationally useful and are broadly applicable have eluded us so far. In the interim, we postulate that for RANN, utilization implies a contribution toward meeting a need of national importance. The research contributions might range from a minor influence to directly attributable important changes, actions, or decisions. In a case study, some or all of the research utilizations are identified; however, when utilization is widespread, the less important categories can only be sampled. The extent of this sampling is determined by the case investigator on the basis of the results obtained and the effort available. Since utilization is frequently either feast or famine, this restriction is less severe than would appear.

These case studies were prepared under Contract NSF-C76-17165 with Research Triangle Institute. The project began on April 1, 1976, and is continuing.

Dr. Robert Burger is Principal Investigator for this study. Dr. Martin Massoglia is a Co-investigator and is administering the effort. These individuals were joined by 9 other professionals at RTI in performing these case

studies. This project team is identified in Table 2. The level of effort is such that, on the average, about 2.5 man-weeks are available to prepare each of the case studies. This necessitates heavy reliance on information supplied by NSF/RANN program managers and on project principal investigators. The procedures employed are described in a following section of this report.

Dr. Samuel J. Raff of the NSF Division of Exploratory Research and Systems Analysis is Program Manager for this effort. He has selected the projects to be studied, assisted in arranging the many required liaisons with NSF staff, and has reviewed each of these case studies. This participation has had an important influence on the accuracy and completeness of the information provided in this report.

Project Selection

NSF made the selection of the projects studied here. The basis for selecting these 10 projects is a survey of RANN utilization conducted by RTI in 1975.* That survey was concerned with a randomly selected sample (stratified in accordance with several criteria) of 100 of the 512 research projects funded by Research Applications Directorate in 1972 and 1973. The survey procedure started by obtaining from the Principal Investigator a list of up to ten people who he thought might be using or were intending to use the results of his research. These people were then interrogated by a questionnaire regarding the details of their use or intended use.

---

*Q.W. Lindsey & J.T. Lessler, Utilization of RANN Research Results: The Program and Its Effects - A Survey of the Research Applied to National Needs Program of the National Science Foundation, Research Triangle Institute, March 30, 1976.

TABLE 2. PROJECT PARTICIPANTS

	PROJECT	CASE INVESTIGATOR	TECHNICAL REVIEWER
22	Development of X-Ray Fluorescence Analysis and Application to Atmospheric Aerosols	J. J. Wortman	R. Gardner (NCSU)
23	Dredge Spoil Distribution and Estuarine Effects	M. F. Massoglia	D. Herron (Duke)
24	Laboratory Cloud Simulation to Support Weather Modification Research and Field Programs	H. L. Hamilton, Jr.	E. Droessler (NCSU)
25	Feasibility Study: Coordination of Data Collection Activities on the Nation's Building Inventory	D. F. Tolman	J. Mirza (NCSU)
26	Biological Conversion of Organic Refuse to Methane	J. W. Harrison	M. Overcash (NCSU)
27	Fire and Smoke Spread in Corridors	S. Plotecia	R. Liepins (RTI)
28	Computer Abuses	P. S. McMullan	J. Vaupel (Duke)
29	Problems and Research Priorities in the Rocky Mountain Region	M. vE. Rullison	F. J. Convery (Duke)
30	Development of a Plan to Maximize the Learning from Destructive Earthquakes	R. Whisnant	D. Stewart (UNC)
31	Research and Development on Lithium/ Sulfur Secondary Batteries	R. D. Alberts	E. Yaeger (Case Western)

A point system was devised for evaluating the degree of utilization indicated by questionnaire responses, e.g., five points were given for the combined statement that the research was in use and had a major impact on the operations of their organization; one point was given for the statement that the research increased the organization's quality of output, etc. The point total of each respondent was accrued to the proper project and the 100 projects were ranked in order of their point totals. The next step in the process of project selection was to form pairs of projects in the same substantive areas and with approximately the same funding level--with one project coming from the top of the ranking and the other from near the bottom. A few of the top projects were omitted because no suitable paired project could be found.

The intention is to perform case studies on both projects in each of the ten pairs, with each pair being studied by a single case investigator so as to obtain the maximum information available from such a comparison. The ten projects for which case studies are presented here constitute one member of each pair--the one near the top of the utilization ranking. Case studies for the lower ranked member of the pairs are now in process.

Procedures

The objective of a case study is to identify and describe the specific utilization of the project in an accurate and comprehensive manner. In meeting this objective, it is necessary to also discuss, to some extent, the nature of the research and the project itself. The Case Investigator, assigned from RTI's staff, obtains all relevant information on the project and prepares the case study.

Every case has a Technical Reviewer. He provides the Case Investigator with additional specialized background knowledge, should that be required. The Technical Reviewer also reviews the case study for technical accuracy and independently derives conclusions on the utilization factors relevant to the project. The Case Investigators and Technical Reviewers for the ten case studies included in this report are identified in Table 2.

The procedures employed in carrying out these utilization case studies were dominated by the schedule. Programmatic requirements of NSF necessitated rapid accomplishment. This in turn required close cooperation with and support from NSF. The procedures employed were as follows:

- Projects for which case studies were to be prepared were selected by the RANN Program Manager, Dr. Raff, in consultation with RANN management, as described in the previous subsection.
- Assignments of case investigators and technical reviewers were made to the individual cases as shown in Table 2, and interviews of NSF program managers were scheduled. In these interviews, the case investigators discussed the cases and asked questions as necessary to acquire information. In each case, the program manager was asked to inform the principal investigator of the project that the utilization study was being made.
- Case investigators provided technical reviewers with information on the case study, discussed with them the perspective of the research, and obtained guidance for the user interviews.

- Each case investigator subsequently contacted the project principal investigator to discuss the utilization study. In each case, first contact was by telephone. In a majority of the case studies, this was followed by a visit to the principal investigators for more intensive discussions. Cooperation of the principal investigators was very good.
- The identified users were contacted, primarily by telephone, but written communications and visits were also employed. Each was requested to provide an evaluation of the project as related to his needs and to relate the uses he had found for the research results.
- Each of the case investigators prepared a case study report, in most cases with the direct participation of the Technical Reviewer. The ten completed reports were reviewed by the Technical Reviewer and subsequently submitted to NSF and to the ten principal investigators for review.
- Burger, Massoglia, Raff, and, when necessary, the Case Investigator discussed the comments obtained from the reviewers. The case investigators prepared the final case studies, which are included in this report.

RESEARCH TRIANGLE INSTITUTE N.C.

RANN UTILIZATION EXPERIENCE

CASE STUDY NO. 22

DEVELOPMENT OF X-RAY FLUORESCENCE ANALYSIS AND APPLICATION TO ATMOSPHERE AEROSOLS

UNIVERSITY OF CALIFORNIA AT DAVIS

Case Investigator:

J. J. Wortman

Research Triangle Institute
P.O. Box 12194
Research Triangle Park
North Carolina 27709

Technical Reviewer:

R. Gardner

Department of Nuclear Engineering
North Carolina State University
Raleigh, North Carolina 27607

Prepared under:

Contract No. NSF-C76-17165
National Science Foundation
Research Applied to National Needs
1800 G Street, N.W.
Washington, D.C. 20550

DEVELOPMENT OF X-RAY FLUORESCENCE ANALYSIS AND APPLICATION TO ATMOSPHERE AEROSOLS

Introduction and Summary

Environmental and energy problems have brought to national attention the critical need for advances in the ability to quantitatively measure and analyze many elements and compounds. Without order of magnitude improvement in sensitivities and costs, it will not be possible to meet these measurement requirements. The purpose of this project has been to develop and evaluate X-ray analytical techniques as applied to quantitative analysis. The program emphasized both the X-ray fluorescence (XRF) and the ion-excited X-ray emission (IEXE) methods of excitation for elemental analysis. These methods are based on the fact that each element has its own unique X-ray emission spectrum which, when excited, can be used for quantitative analysis. Both systems were developed along with sampling techniques for a variety of applications with emphasis on automated schemes to reduce the cost per analysis.

At the University of California at Davis, Professor T. A. Cahill and his colleagues, stimulated by the need for improved analytical capabilities in environmental chemistry, the availability of a suitable accelerator, and research results that indicated the potential for X-ray analysis, proposed this study in 1971. NSF/RANN support was initiated in early 1972 and has continued since. Project information is detailed in table 22-1.

Table 22-1. PROJECT INFORMATION

Project Title Development of X-Ray Fluorescence Analysis and Application to Atmosphere Aerosols	**Grant/Contract No.** GI-32932
RANN Program Manager Lloyd Herwig, Richard Blieden, Richard Carrigan	**RANN Program Area**
Principal Investigator(s) F. P. Brady T. A. Cahill	**Schedule** Start: March 1, 1972 End: June 30, 1976
Institution Crocker Nuclear Laboratory University of California, Davis	**Funding** NSF: $264,400 Other: $ 25,637

Contributors/Collaborators		
Allen W. Knight	Steven Brooks	G. McClelland
J. F. Harrison	E. Cray	S. Murray
Scott K. Perry	John Elder	E. Sassenrath
D. J. Shadoan	G. Fisher	T. Sibley
John C. Young	Larry Immer	P. Stout
M. R. McGie	D. Jolly	D. Viglierccchio
	D. McKenna	

User Advisory Committee

None.

Precursor Activities

A concurrent study was funded by California Air Resources Board through the University of California's Project Clean Air: "Cyclotron Analysis of Atmospheric Contaminants," PCA 238 (ARB 3-038-1), Thomas A. Cahill, University of California, Davis ($25,637) 7/1/71 to 6/30/72.

Several products are readily identifiable as a result of this program:

- A vastly improved ion-excited X-ray analysis system,
- An automated X-ray fluorescence system,
- Computer codes for automated sample analysis,
- Alpha particle scattering techniques for light elements, and
- Improved sampling techniques.

Several indirect products including data filtering techniques, beam pulsing techniques, and the demonstration of X-ray analysis as a valuable tool for high volume analytical applications, have proven valuable.

Based on the systems developed during this effort, a series of other systems to fulfill the national need for such analysis (at least eight known IEXE systems are now in operation) has been set up. The computer codes developed have been made available to all interested parties. Major environmental monitoring programs now utilize systems of this type.

Factors that have influenced the utilization of the products of this research include the critical national need for such analyses as provided by the X-ray systems, the coupling of the development work with actual monitoring programs, and the willingness, motivation and time devoted by the research team in making information available to interested people.

From a utilization viewpoint, this research effort is indeed a success. It demonstrated that problems can be overcome when there is a need and a motivated research team willing to work on them.

At least ten facilities have been, or are, in the process of being created for performing analyses that utilize the hardware, techniques, and software similar to that developed by the Davis team; and already a variety of analytical needs are being met by these facilities. Notable is the

Florida State University system, which is being used for a study in Florida which is the second largest sulfate study in the nation to date.

Probably the most notable use of the results of this RANN sponsored research is the work being done by Dr. Cahill and his colleagues lending to the possible discovery of new super heavy elements.

Research Description

This research effort had its beginning in mid-1970 when several interested staff and students at the Crocker Nuclear Laboratory, University of California at Davis, initiated preliminary work on the use of accelerators for the analysis of water and soil samples. Shortly after (and unrelated to this effort), the University of California formed "Project Clean Air," a coordinated effort on air pollution throughout the many University of California campuses. In the latter part of 1970, a Swedish paper was published that demonstrated promise for the IEXE method of analysis. Also at that time, the investigators in this program submitted a proposal to "Project Clean Air" to develop the IEXE method based on the earlier results. The Davis team in February 1971 wrote a proposal to NSF/RANN entitled "West Coast Aerosol Study." In mid-1971, NSF/RANN rejected the original proposal and suggested a major revision which was to become the subject of the present study. A substitute proposal was submitted, and funding of $121,200 was initiated in March 1972.

This research program is concerned with the development of photon excitation and ion excitation methods for the X-ray fluorescence elemental analysis of multi-element samples. The ion exciation method (IEXE) was primarily concerned with the adaptation of an existing ion accelerator

facility at the University of California at Davis. A secondary, subsequent objective was the adaptation of the ion accelerator to alpha-particle scattering analysis which allowed the measurement of low atomic number elements. The investigators attempted to either apply existing state-of-the-art techniques or adapt them to effect the optimum and most efficient use of these elemental analysis methods.

In the past few years, the development of high-resolution semiconductor detectors* has revolutionized the technique of trace element analysis and added to it a new dimension. A paper on smog analysis** provides a good review of the method, which is sometimes called energy-dispersive, to distinguish it from the wavelength-dispersive method of X-ray energy measurement. Very briefly, this analytical method is based on the use of an x-ray beam (XRF) or charged particle beam (IEXE) to excite atoms in a sample target. In this process, electrons are removed from inner atomic shells (I, L, etc.); and X-rays (K, L, etc.) are emitted when electrons from outer atomic shells fill the inner shells. The energies of these X-rays are characteristic of each element; hence, they provide a signature of the elemental composition of the sample target.

From a given specimen or sample, a spectrum of X-ray energies of various intensities is obtained. (Figure 22-1 shows an idealized XRF spectrum.) The useful energy spectrum is limited at higher energies due to

*T. A. Cahill, Cyclotron Analysis of Atmospheric Contaminants, Final Report, Project Clean Air, Contract PCS-038, University of California, Davis, October 31, 1972.

**T. A. Cahill et al., "Elemental Analysis of Smog by Charged Particle Beams: Elastic Scattering and X-Ray Fluorescence," Nuclear Methods in Environmental Research, American Nuclear Society, Columbia, Mo. (1971).

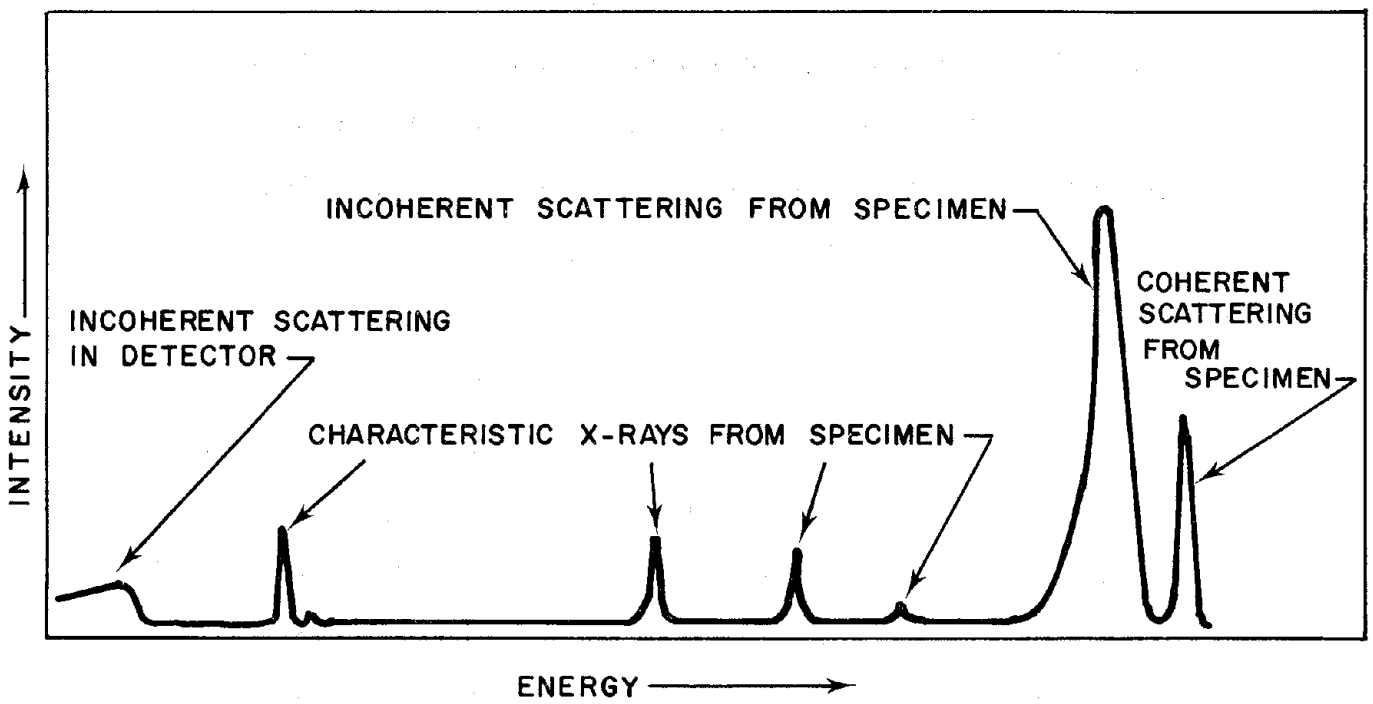

Figure 22-1. XRF spectrum.

coherent (Rayleigh) and Compton scattering. The detection limits for elemental determinations are in general governed by the intense incoherent "scatter-peaks" that limit the counting rate of the system and produce a background for the characteristic peaks. Interference among peaks can also be a limiting factor.

A schematic representation of the IEXE system is given in figure 22-2. The cyclotron beam, generally 30 MeV alpha particles, is focused by a quadrupole lens about 8 meters upstream of the target onto a set of diffuser slits. For use as an IEXE source, the beam is defocused to obtain a somewhat uniform beam spot on the sample and is then collected by the Faraday cup, which provides absolute calibration of beam current. X-rays generated in the sample by ion bombardment are passed through an optional attenuator or filter to the detector (Si Li) and the signal from the preamplifier is

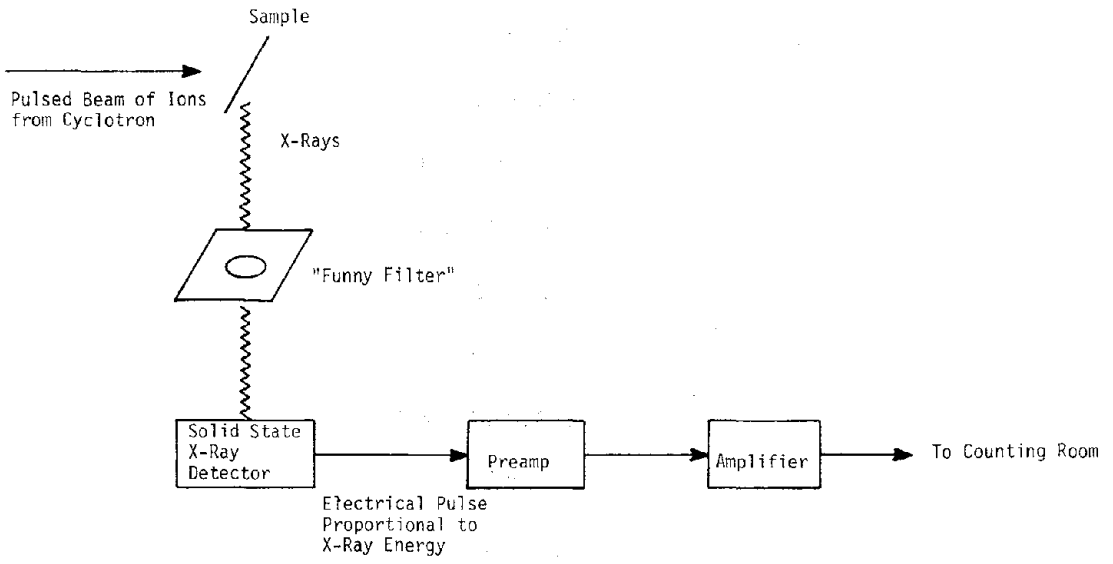

Figure 22-2. Schematic Representation of Ion-Excited X-Ray Emission Analyses System.

transmitted to a counting room. After the signal is processed, it is directed for analysis to an analog to digital converter associated with Crocker Nuclear Laboratory's PDP 15/40 computer.

The significance of this work lies largely in the adaptation of an existing ion accelerator facility to XRF elemental analysis. This facility represents a significant investment and was apparently no longer needed as much (or at least no longer funded as much) for the original intended purpose of research in particle physics. A number of facilities of this type exists around the country, and many are in the same situation. The present work developed and demonstrated an alternate purpose for these facilities so that they can continue to be useful even if they are no longer required for their original intended purpose.

The significance of this effort is that now at least ten facilities (Florida State University, Virginia Associated Research, University of

Florida, Brigham Young University, Purdue University, Duke University, California Institute of Technology, International Business Machines, Bell Telephone Laboratories and Sandia Corporation) are available, or are under development, to provide services that are cost-effective. The work at Davis certainly influenced some of these efforts. The IEXE system requires only a small amount of mass (on the order of a few hundred $\mu g/cm^3$) and gives the widest atomic weight range of any existing system.

An interesting technique for filtering the X-rays coming from the target is called a "funny filter." It was developed to reduce the large differences in count rates for hard and soft X-rays and consists of a thin metal sheet of a preselected thickness pierced by a hole or holes, the diameters of which are chosen to allow a selected fraction of light element X-rays to penetrate to the detector. This technique allows detection of light elements (Na through Ca) at the same time as detection of heavy elements (Ca through U) without double runs.

Beam pulsing was introduced as a method for reducing electrical noise in the system. In this scheme, which is common in electronics, the source is pulsed and consequently does not interfere with the electronic signal processing during that phase of the detection cycle. Although the beam pulsing idea was not generated at Davis (it was suggested by a group at Berkeley), it was the Davis team who proved its effectiveness. A number of contributions was also made to the IEXE system in the electronic processing area. For example, a technique was developed that included count-rate and dead-time corrections.

Successful application of the IEXE system to real analysis was assured by constant attention to the sampling problem. For example, in the study of

air pollutants, such as particulates, one must collect the sample onto some suitable collector or substrate. As a part of the RANN study, the investigators developed a technique for collecting particulates onto a mylar film for use in the IEXE system. This technique utilizes a mini Anderson sampler (a small version of the standard impactor for sample collection). Significant work was also directed to the problem of "bounce off" (the rebounding of particulates from the collecting sampling substrate).

The two major objectives of this research program have been to:

- Demonstrate and provide a new, unique analytical capability to industries and agencies interested in rapid, multi-sample, multi-element analysis; and
- Provide fundamental research and development information on the application of photon excitation and ion excitation (IEXE) methods to XRF analysis.

The first objective was met early in the study and has resulted in a technique routinely used in a number of analytical studies, particularly in the air pollution field.

The second objective has been accomplished by development of:

- Automation techniques for IEXE systems,
- Computer codes for the control and analysis of sample data,
- Improved sample preparation techniques,
- Accelerator pulsing techniques for reducing background noise and enhancing sensitivity, and
- Filtering techniques for improvement in the range and sensitivity of the IEXE method.

Utilization Objectives

The users of the research products from this effort are in two general categories: (1) those who have a need for the analytical services (both XRF and IEXE) as developed under the effort, and (2) those who wish to duplicate or develop a similar analytical capability for their own use or can apply the techniques and data developed to their existing or future work. The research products have varied in application from direct--such as the analysis of tens of thousands of samples, to indirect--in which system performance data are used to aid in the design of new systems. Both the user and the application, therefore, range from basic research to routine analysis.

The investigators, through previous involvement with the user community, were keenly aware of the need for the development and demonstration of the analytical techniques investigated under this effort. As a consequence, they worked closely with a number of users. For example, they were supported by the California Air Resources Board for analytical work during the NSF/RANN study. The magnitude of user involvement is readily apparent by looking at the first annual report in which some 21 different users of the Davis facility were identified. Their involvement included such areas as pollution (air and water), radiobiology, entomology, soil sciences, nematology, medicine, oceanography, and geology.

An active effort was carried out during the study to make the instrumentation practical and to demonstrate the techniques on real problems. This involved regular communication and interaction between the physical scientists and the users of the analytical data to develop the credibility needed for acceptance by both communities. The investigators actively assisted in helping other institutions develop similar capabilities for analytical services and research.

The dissemination techniques used were direct, personal contact at the investigators' laboratories and the users' laboratories and sampling sites, workshops, professional meetings, and user program reviews and meetings. These direct contacts included the training of individuals in the investigators' laboratories. In addition to the direct contacts, there was considerable communication by telephone and letter between users and the investigators. The investigators also employed the usual professional avenues such as papers and talks to communicate their results--for example, to date there have been over 25 publications, reports, and papers resulting from this effort (see Appendix). The participation by the Davis team in active analytical programs was also significant in disseminating the research products. In short, it was the objective of the investigators to prove that X-ray analysis (both XRF and IEXE) could competitively fill a national need.

Utilization Obtained

As discussed in the previous sections, the users of this research fall into two classes: (1) those who need analytical services and (2) those who are duplicating or developing a similar analytical system.

Analytical Services Users

In the first category, the investigator's institution has contracted to provide analytical data to at least ten institutions--e.g., the California Air Resources Board, the U.S. Environmental Protection Agency, the Illinois Water Survey, and Meteorological Research, Inc. The California Air Resources Board has paid for about 30,000 analyses at $6 per analysis. The following is a sampling of some of these users.

Dr. David Ensor, a research scientist with Meteorology and Research, Inc. (MRI), in Altadena, California stated that his company utilizes the service developed in the NSF/RANN study to support their work in scrubber chemistry. Dr. Ensor not only uses the analytical services, but also has used some of the sampling techniques developed by the Davis group. MRI learned about the Davis work through their joint participation in experiments and field studies. They have found the Davis team to be very willing and eager to work new problems, participate in total experiments, and not limit their efforts to the analysis only. The major problems they have encountered in using IEXE have been associated with sampling techniques that are unique to specific work areas. Dr. Ensor recommended that NSF/RANN consider making collaborative testing a required part of projects of this type.

Dr. Jerome Wesolowski, Director of the Air and Industrial Hygiene Laboratory, California State Department of Health, has utilized the analytical capabilities of Davis in the evaluation of monitoring techniques. Both XRF and IEXE techniques were used. The major problem encountered was the error due to particle "bounce off" on the substrates in the sampling system. Dr. Wesolowski suggested that NSF/RANN should put more emphasis on technique

development and less on analytical services support. He emphasized the critical need in programs of this type to provide for a quality assurance program to validate developed techniques.

Another analytical user, Mr. Michael Chan, Manager of Air Quality Studies at Aerovironment, Inc., Pasadena, California, utilized the IEXE and alpha-scattering systems for analysis. His program was concerned with a baseline study of air quality in Utah in relation to shale oil recovery. Dr. Chan was referred to the Davis group by associates.

Dr. Jack Suder, Air Pollution Research Specialist at the California Air Resources Board (ARB) in Sacramento, was another user contacted. ARB, for which a large volume of analyses was performed, was an early sponsor of the Davis team, as mentioned earlier. A low-cost, high-speed analytical system was needed for particulate analysis. ARB sponsored the Davis team throughout the duration of the NSF/RANN study and used the analytical services as they were developed. The IEXE technique was found to (1) offer the widest range of elemental analyses, (2) be quantitative, (3) be capable of detecting monolayers, and (4) be the most cost effective. This funding has been renewed several times.

Users Developing Analytical Systems

The second category of users, those concerned with the development of their own analytical systems, is surprisingly large in number considering the necessity for an expensive accelerator in the IEXE system and the need for significant computer capability in both the XRF and the IEXE systems. The fact that several of such systems are either now in operation or are being developed is indicative of the critical need for such analytical

systems. To date, these users ordinarily have, or have access to, an accelerator similar to that of the Crocker Nuclear Laboratory. Typically, these accelerators are not dedicated to the analytical work, but are shared with other efforts. At Davis, only approximately 25 percent of the available time is used for IEXE studies.

One such user of this type is Dr. R. K. Jolly, a Senior Research Scientist at the Virginia Associated Research Campus of the College of William and Mary in Newport News, Virginia. The Environmental Sciences Laboratory of that organization is utilizing an IEXE system to support environmental and health studies. Four specific products of the research are being utilized or are planned for future use: (1) the detection geometry and the "funny filter," (2) the sample collection technique using mylar films, (3) the beam pulsing technique, and (4) the alpha-scattering technique. These research products were obtained by personal contact with the Davis investigators and through publications in the technical literature. Dr. Jolly was not aware of any specific problems in utilizing the research results. He suggested that NSF/RANN consider setting up some type of central repository for information developed in major fields such as this to speed dissemination of new results and avoid delays in utilization.

Another user in this category is a team in the Physics Department of Florida State University at Tallahassee. Dr. J. William Nelson, an Associate Professor in that department, related that they are using techniques developed at Davis in their analytical system, which was developed during the same period as that of the Crocker Nuclear Laboratory. Their system uses an accelerator and is applied primarily to the analysis of particulate

matter. (One such project is a sulfate study in Florida which is the second largest such program in the nation.) Specifically they use the beam diffraction technique and the filter system developed by the Davis team. They also use a similar technique for the removal of background noise.

The Chemistry Department at Brigham Young University in Provo, Utah, has developed an IEXE analysis system. Their system, unlike the two previously mentioned, does not use a major accelerator. Instead, they have a 2-MeV Van der Graff to supply the needed proton beam. Dr. Nolan Mangelson, an Associate Professor at Brigham Young, said that a number of the Davis concepts and techniques are being applied in their system. He cited an adaptation of the Davis computer code, the sample changer, mylar-coated substrates, and the mini Anderson impactor as being specific products that they use. He also said that there are plans for using beam pulsing and the Davis "funny filter". The effort at Brigham Young is concerned primarily with biological samples related to environmental concerns of power companies. Their system is currently being used for 10- to 15-element analysis only. The Davis research results being used in this laboratory were obtained by personal contact (at meetings and laboratory visits), correspondence (letter and telephone), and from the technical literature. They also sent two undergraduate students to the Crocker Nuclear Laboratory to work with the Davis team. Specific problems that Dr. Mangelson mentioned included the difficulty encountered by small users in adapting computer codes to their systems. Small labs cannot afford the development and adaptation costs. He recommended that NSF/RANN add additional funds to programs of this type to aid in the solution of this problem and encourage the investigators to write detailed descriptions and drawings to aid those who wish to reproduce

the systems. In this case, Dr. Cahill made drawings available to Brigham Young personnel for their use.

Duke University, Durham, North Carolina, is another institution that has developed an IEXE system for analytical analysis, primarily in the biological field. Dr. Richard L. Walter of the Physics Department has been the key individual in Duke's effort. Dr. Walter was very quick to recognize the great value of the Davis work in setting up their system. He listed the following research products from the Davis study which he felt were significant to Duke:

- The "funny filter" technique,
- Parts of the analysis computer code,
- The procedure for detection of lighter elements,
- Sampling techniques for, and philosophy of, data handling, and
- Beam pulsing.

Dr. Walter pointed out that the size of the Davis effort and its timeliness were very significant in that they allowed for rapid progress and kept others from making similar mistakes at a later date.

The Davis results were disseminated to the Duke investigators primarily through personal contact at professional meetings and NSF sponsored workshops at Seattle and Tallahassee. Information was also obtained through the professional literature. Dr. Walter was quick to point out that the latter avenue, although important, often was not timely and was not sufficient for development efforts. There was also direct correspondence between these investigators during the time of the NSF/RANN study.

The Duke interests have been primarily bio-environmental in nature and have resulted in the setting up of equipment similar to that at Crocker Nuclear Laboratory. The problems encountered in utilizing the Davis results

were those due to differences in accelerator types and computers. Dr. Walter strongly recommended that NSF/RANN hold frequent workshops on programs of this nature to foster rapid exchange of information and develop rapport between investigators and institutions.

The most notable use of the research products from this RANN program has been an application by Dr. Cahill himself in which he and a group of physicists utilized the knowledge gained in the IEXE system to perform elemental analysis of monazite crystals.* This work led to the possible discovery of a number of superheavy elements in the atomic number range of 116 to 127. An IEXE system in which a 5 Mev proton beam was used played a unique role and provided an independent measurement that could easily be correlated with known and theoretical estimates. Needless to say, this discovery--if substantiated, will be of much importance to nuclear physics and will open up new fields of scientific inquiry.

Features

The factors that go into the making of a successful research effort are almost by definition unique to the investigators, the particular research problem, and the need for the research. In this particular case, some of the unique features are:

- An accelerator was available and, further, was in danger of being closed should a need for its existence not continue.
- A team of highly motivated, highly creative professionals was not

*Physical Review Letters, Vol. 37, No. 1, July 5, 1976

only available to work on the problem, but also was interested in the interpretation of the results obtained from the application of the analytical systems.

- The technology, science, and hardware were available and needed only to be pulled together.
- Recognition of the critical national need for the research product.

In rating contributions to product use, the influence of the investigators in promoting the utilization of the research is exceeded only by that of the need for low-cost analytical systems. The efforts of one of the investigators, Dr. Thomas Cahill, were mentioned by every user contacted. One user states that: "I was impressed by Dr. Cahill's enthusiasm for the technique and progress made in demonstrating the IEXE method in the first year of the NSF study. Because of this, I entered into this phase of work, which has been a success and a source of pride."

It is significant that the Davis team, oriented and trained in the particle physics area, did not limit their study to the physics and engineering of an analytical system. They in fact have developed into participating members of environmental study teams in which they play a role in the interpretation of the data. The investigators apparently took every opportunity to attend professional and project meetings and workshops and to participate in interlaboratory studies. Also, the investigators apparently spent much time and effort in helping others solve sampling problems and developing similar capabilities. This is evidenced by the large volume of material such as computer codes and drawings supplied to other workers. The performing organization had to at least permit this type of interaction;

otherwise, they would not have been as successful as they were. For example, mechanisms were available to the investigators for participation in interdisciplinary efforts and accommodating visiting researchers.

NSF management and funding cannot be neglected in evaluating the success of the effort. The farsightedness of the original Program Manager is significant. There was considerable resistance to be overcome in investigating the use and value of big, expensive accelerators for simple X-ray analysis. For example, as late as 1973, in the Annual Review of Nuclear Science, the concluding sentence in a chapter dealing with photon-excited energy dispersive X-ray fluorescence analysis for trace elements is:

> "On the whole, there seems little point to the use of charged particles produced by accelerators for trace element analysis. The high cost of accelerator facilities could only be justified if sensitivities better than photon excitation could be achieved. This appears not to be the case."

The timely funding of an effort large enough to prove the worthiness of the X-ray analysis systems for meeting an existing critical need is significant.

The role of the user in the utilization of the research products has been major in this project. The users of the analytical services were there before the study started and have increased in number as the results were obtained. The fact that the location of the performing organization was in an area in which the need existed was important. Also, those interested in developing their own systems worked in close communication with the Davis team. Dissemination efforts were not organized, but were very much in evidence at all times. Often these efforts must have consisted of the active defense of results from critics and of collaborative work with others who were applying the analytical procedures.

The quality of the analytical analysis during the effort obviously improved with time as the system was improved. Like most analytical efforts, the quality of the results is no better than that of the sampling procedures, which often are not under the control of the analysis team. Some effort under this RANN study went into the improvement of sampling techniques for specific applications. The results of this effort, like most sampling work, are unique to the specific problems. The nature of the XRF and IEXE procedures requires that the sample be taken to an off-site location for analysis; however, the cost effectiveness, accuracy, elemental range, and low mass requirements have made these procedures very viable, competitive analysis tools for certain types of studies. The major objective of this total effort was to demonstrate this cost effective aspect of the techniques.

There were and still remain some barriers to the utilization of the research results. For example, in the IEXE system requires an accelerator of some type; however, not necessarily the large machines that were used to demonstrate the viability of the system. It also requires significant computer capability when large numbers of elemental analyses are desired. These two factors and the fact that it is a new technique will limit its utilization. Other negative features are that it is an elemental analysis system, not a chemical compound analysis system; and the IEXE system requires a thin sample. The requirement of a thin sample is an asset in some applications such as for analysis of thin layers of particulates collected on thin substrates.

The strength of the program in terms of utilization is the cost effectiveness of the product. The fact that the techniques met a need in a

timely fashion was certainly an important factor in the high utilization of the research. A good research product is useless unless the users know that it exists; hence the role of the investigator in the dissemination of the results was also very significant.

Conclusions

This particular research effort resulted in a number of definite research products that found immediate application to national problems. A high level of utilization has resulted already and will continue to grow with time as new facilities of the types demonstrated go into operation.

Like all other analytical techniques, the systems demonstrated in this research do not solve all the world's problems. The X-ray analysis techniques developed here, however, are applicable to broad fields of application such as environment, energy, health, geoscience, agriculture, and scientific research. They are capable of providing, on a quantitative basis, physical measurements (no chemical extraction or concentrating is necessary) of all elements in the periodic table from hydrogen to uranium. An IEXE system has been used as a primary tool in providing evidence for primordial superheavy elements.

X-ray analysis is particularily well suited to problems related to field surveys in which there is a need to establish baseline information such as pollution and hazardous element backgrounds. The X-ray fluorescence (XRF) system is particularly useful when the element in question is dispersed through a small sample, while the ion beam system (IEXE) is valuable when thin layers of elements are on the surface of a sample. The alpha

scatter system, of course, is limited to the analysis of elements with low atomic numbers and complements the IEXE and XRF approaches.

The motivation and enthusiasm of the Davis team, and particularly Dr. Cahill, resulted in a dissemination effort that was highly successful. This, coupled with the critical need for the products and the state-of-the-art in the field, led to the high utilization of these research products.

NSF management clearly saw the potential at the onset of this effort. It appears there was a tendency on their part later in the project to emphasize that the analytical services of the Davis facility were most important. It is this author's belief that the timely demonstration of cost competitive analytical systems was by far the most valuable research product. This allowed other organizations to move quickly in response to the need and make these services available on a national scale. The fact that the investigators were aggressive in working with other laboratories and participating in actual sampling programs provided the credibility needed to launch these techniques into practical use. Had the Davis team not worked hard outside the support of NSF, this would not have resulted in the immediate success that was realized.

Although education is not the function of RANN programs, it appears that at least one team of physicists is now able to work very successfully in a field that chemists have dominated for years. This team was able to apply the practical analytical tool developed to the identification of what appear to be super heavy elements in monazite crystals. Based on the total success of the program, the instrumentation is now being duplicated in probably a dozen other institutions with the result that each institution will apply the technique to other problem areas. Several expensive, but surplus accelerators paid for with public funds are now being utilized to solve a critical need.

Appendix

REPORTS, PUBLICATIONS AND PAPERS

1. F. P. Brady and T. A. Cahill, Development of X-Ray Fluorescence Analysis and Application, Report to the National Science Foundation-Research Applied to National Needs, UCD/CNL 166, April 30, 1973.

2. T. A. Cahill and P. J. Feeney, Contribution of Freeway Traffic to Airborne Particulate Matter, Report to the California Air Resources Board, UCD/CNL 169, June 15, 1973.

3. T. A. Cahill and R. G. Flocchini, Regional Monitoring of Smog Aerosols, Report to the California Air Resources Board, UCD/CNL 184, November 1, 1973.

Publications of work performed on the UCD/ARB Aerosol Analysis System

4. T. A. Cahill, et al., "Elemental Analysis of Smog by Charged Particle Beams: Elastic Scattering and X-Ray Fluorescence," Nuclear Methods in Environmental Research, American Nuclear Society, Columbia, Mo., 1971.

5. R. G. Flocchini, et al., "Sensitivity Versus Target Backing for Elemental Analysis by Alpha Excited X-Ray Emission," Nuclear Instr.and Methods, Vol. 100, pp. 397-402 (1972).

6. S. Murray, et al., "Application of X-Ray Analysis in Plant Nutrition Studies," Amer. Journal of Botany, Vol. 59, p. 6 (1972).

7. H. Thibeau, et al., "On-Demand Beam Pulsing for an Accelerator," Nuclear Instr. and Methods, Vol. 111, p. 615 (1973).

8. R. K. Wyrick, et al., "L X-Ray Intensity Ratios of U, Th, Pb, Ta and Lu by Alpha Particle Induced Emission," Physical Review, Vol. A8, p. 2288 (1973).

9. S. K. Perry and F. P. Brady, "A Comparative Study of Alpha and X-Ray Induced Emission for Elemental Analysis," Nuclear Instr. and Methods, Vol. 108, p. 389 (1973).

10. G.A.H. McClelland, et al., "New Approaches to Mark-Release-Recapture Studies of Biting Insects," Proc. Biting Fly Control and Environmental Quality, Alberta, Canda (1973).

11. T. A. Cahill, et al., "Uses of Isotopes and Accelerator Sources in X-Ray Spectroscopy: Alpha Particle Excitation Using Cyclotrons," American Nuclear Society, TANSAO, Vol. 17, p. 102 (1973).

12. J. Harrison and R. A. Eldred, "Data Acquisition and Reduction for Elemental Analysis of Aerosol Samples," Advances in X-Ray Analysis, Vol. 17, p. 560, Pergamon Press, Elmsford, N.Y. (1973).

13. J. Azevedo, et al., "Elemental Composition of Particulates near a Beef Cattle Feedlot," Journal of Environmental Quality, Vol. 3, No. 2 (1974).

14. T. A. Cahill, et al., "Monitoring of Smog Aerosols with Elemental Analysis by Accelerator Beams" (to be published in the Proceedings of the Fourth Materials Research Symposium).

15. T. A. Cahill, et al., "Use of Ion Beams for Monitoring California's Aerosols" (to be published in the Proceedings of the Second Annual NSF/RANN Trace Contaminants Conference).

Submitted for Publication

16. P. J. Feeney, et al., "Effect of Roadbed Configuration on Traffic-Derived Aerosols" (submitted to the Journal of the Air Pollution Control Association).

17. R. G. Flocchini, et al., "Monitoring Aerosols by Size and Composition, Part I: Analytical Techniques" (to be submitted in Environmental Science and Technology).

Invited Papers

18. P. K. Mueller, et al., "Elemental Composition by Alpha-Excited X-Ray Fluorescence," American Chemical Society Meeting for the Division of Colloid and Surface Chemistry, March 1971.

19. T. A. Cahill, "Alpha Excitation for Monitoring Aerosols in California," Third Conference on Application of Small Accelerators, Denton, Texas, October 1974.

Extracts of Talks Given at Professional Socieities

20. T. A. Cahill, et al., "Trace Element Analysis with Alpha-Excited X-Rays and Commercial Thin Plastic Backing," Bulletin of the American Physical Society, Vol. 16 (1971) (delivered at American Physical Society meeting, April 26-29, 1971, Washington, D.C.).

21. R. G. Flocchini, et al., "Charged Particle Induced X-Ray Excitation by 15.0-30 MeV Beams," Bulletin of the American Physical Society, Vol. 17, p. 88 (1972) (delivered at American Physical Society meeting, Jan. 31-Feb. 3, 1972, San Francisco).

22. S. Perry, et al., "A Comparative Study of Charged Particles and X-Ray Induced X-Ray Excitation for Elemental Analysis," Bulletin of the American Physical Society, Vol. 17, p. 120 (1972) (delivered at American Physical Society meeting, January 31-Feb. 3, 1972, San Francisco).

23. S. A. Murray and T. A. Cahill, "Analysis of Light Elements in Plants by Elastic Scattering of a-Particles," Plant Physiology, Vol. 49 (Supplement), July 1972.

RESEARCH TRIANGLE INSTITUTE N.C.

RANN UTILIZATION EXPERIENCE

CASE STUDY NO. 23

DREDGE SPOIL DISTRIBUTION AND ESTUARINE EFFECTS

OREGON STATE UNIVERSITY

Case Investigator:

M. Massoglia

Research Triangle Institute
P.O. Box 12194
Research Triangle Park
North Carolina 27709

Technical Reviewer:

D. Heron

Department of Geology
Duke University
Durham, North Carolina 27706

Prepared under:

Contract No. NSF-C76-17165
National Science Foundation
Research Applied to National Needs
1800 G Street, N.W.
Washington, D.C. 20550

DREDGE SPOIL DISTRIBUTION AND ESTUARINE EFFECTS

Introduction and Summary

The importance of dredging in the evolutionary industrialization of estuaries is commonly acknowledged. Development of protected anchorage and ship facilities usually requires dredging and the construction of jetties in a pristine estuary. Industrial growth then takes place creating additional needs for channel dredging and port development. These activities may cause additional sediment transport requiring periodic maintenance dredging. Environmental quality degrades as a result of these activities, notably as a decrease in water quality and an irreversible loss of some animal habitats.

The National Environmental Protection Act of 1969 (NEPA) has as one of its objectives the reduction of environmental degradation by public work projects. Environmental Protection Agency (EPA) guidelines also require the assessment of the environmental impacts of dredging and other estuary operations. Many court actions have clarified and emphasized the requirement for the preparation of Environmental Impact Statements (EIS) for dredging projects. EIS preparation requires description of the potential effects of the project and a list of possible alternatives; addressing of comments from other agencies and the public; and incorporation of methods that ensure that unquantifiable environmental and ecological information is included in the planning processes and selection of alternatives.

Even in the absence of legal and regulatory requirements, rational management of estuarine systems would require that consideration be given to potential physical and biological impacts of dredging. Interactions within estuaries can be highly complex and involve geological, hydraulic, chemical, social, economic, and political factors and could result in undesired consequences.

The research discussed in this case study provides guidance for planning the utilization of estuarine systems, for developing and operating systems, and for evaluation of the environmental impacts of development and operations. It is being conducted by an interdisciplinary team from Oregon State University and is directed toward determination of the effects of dredging and related marine activities on estuarine ecosystems and assessment of their significance.

This research complements research by the U. S. Army Corps of Engineers on dredging operations in estuaries, and will be useful to planners, environmen-talists, and engineers.

The tangible results from the three-year study will be a series of specific guidelines for the assessment of dredging impacts on estuarine ecosystems. These guidelines will be issued in three manuals entitled:

- Guidelines for Implementation of NEPA for Dredging in Estuaries.
- Impact Identification Guidelines.
- Execution Guidelines: Incorporation of NEPA Goals by the U.S. Army Corps of Engineers.

Several secondary products of the research have already been developed. These include improved sampling methods, a model for the sulfide-sulfate reactions in estuarine sediments, and an analysis of the problems associated with the planning and management of interdisciplinary research projects.

Utilization of this ongoing research has been significant in the Pacific Coast States where it is being conducted. Dr. Slotta and his project team have been heavily involved in estuarine and dredging research sponsored by other agencies. This involvement has served as a dissemination mechanism for this RANN sponsored project as well as for other research. This has been obtained through heavy involvement of the user community in the project, by active dissemination efforts of the project personnel, and through education and training activities. Although dissemination by publication and conference participation has extended beyond the region, utilization for estuarine activities beyond the region will not reach a significant level until the set of final guideline documents is issued, distributed, and accepted.

One of the culminating activities in the final phase of the research will be a workshop in Washington, D.C. during March 1977. This workshop will provide for a wider dissemination of the research results, provided the attendance at the workshop is properly developed.

The effectiveness of graduate students, studying under the Principal Investigator and his staff, as a dissemination technique is demonstrated in this project.

The research appears to be progressing as planned and should attain the program objectives. There appears to be no barriers to preparing the guidelines, operationalizing the technical and scientific information into a form usable by persons involved in planning, managing, regulating, and controlling dredging and other estuarine operations. While there have been interactions at the local level between the research team and regulatory agencies, continued coordination, especially at the national level, is deemed necessary for eventual consideration and acceptance of the guidelines by the concerned

regulatory agencies. It is not apparent that this coordination at the local level has been adequate to result in ultimate acceptance of the methodologies developed during the research. Such acceptance is essential to ensure that all concerned are "reading from the same sheet of music."

Dr. Larry S. Slotta, Director of Ocean Engineering Programs, is the Principal Investigator for the research; Dr. W. Lee Schroeder, Assistant Dean of Engineering Research and Graduate Studies at Oregon State, will assume this role for the final project period. Dr. Edward H. Bryan is the NSF/RANN Program Manager, having assumed that responsibility upon the departure of Dr. Kolf in 1974. Further project data are presented in table 23-1.

The information upon which this case study is based was obtained from several sources. These included project reports, NSF/RANN documents, and personal conversations with the RANN Program Manager and the Principal Investigator. Telephone contacts were made with 31 potential users of the research results. Summaries of 25 of these contacts are included in this report. Contacts with the remaining six, not summarized herein, were for the purpose of identifying specific users and user groups.

Research Description

An interdisciplinary group of faculty members, research associates, and research assistants was assembled at Oregon State University (OSU) during the Spring of 1971 with the objective of identifying, assessing, and proposing techniques to minimize the environmental impacts of dredging. A preliminary proposal submitted to NSF/RANN evolved into a final proposal in February 1972 to the Division of Environmental Systems and Resources of NSF. An Exploratory and Planning Grant, funded for 18 months ($269,600), was awarded to OSU under the

Table 23-1. PROJECT INFORMATION

Project Title:

(1) Dredge Spoil Distribution and Estuarine Effects
(2) (3) An Examination of Some Physical and Biological Impacts of Dredging in Estuaries
(4) Guidelines for Impact Assessment for Dredging in Estuaries.

Grant/Contract No.

(1) GI 34346
(2) (3) A & M 71-0198
(4)

RANN Program Managers:

(1) Dr. Richard Kolf
(2) (3) (4) Dr. Edward Bryan

RANN Program Area:

Advanced Environmental Research and Technology

Principal Investigators:

(1) (2) (3) Dr. Larry S. Slotta
Director, Ocean Engineering Program
(4) Dr. W. Lee Schroeder
Assistant Dean of Engineering

Schedule:

	Start	Finish
(1)	1 Jul 72	1 Dec 73
(2)	1 Feb 74	30 Jun 75
(3)	1 Jul 75	30 Jun 76
(4)	1 Jul 76	31 Dec 76

Institution:

Oregon State University
Corvallis, Oregon 97331

Funding:

NSF	(1)	$296,600
	(2)	$450,900
	(3)	$276,000
	(4)	$123,000

Other: See note

Contributors/Collaborators Co-Principal Investigators:

Dr. David Bella, Strategic Aspects of Estuarine Management
Dr. Danil Hancock, Biology
Dr. James McCauley, Biological Oceanography
Dr. Charles Sollitt, Hydrodynamics
Dr. Kenneth Williamson, EIS Implementation
Mr. Jeffrey Stander, Extension Specialist in Estuarine Resources Management

User Advisory Committee:

David R. Basco, Associate Professor, Department of Civil Engineering, Texas A & M, College Station, Texas.
John F. Sustar, Navigation Division, U.S. Army Corps of Engineers, San Francisco, California
Charles Walters, Water Resources Specialist, Fish Commission of Oregon
Robert Moulton, Environmental Branch, U.S. Army Corps of Engineers, Portland, Oregon
Mort Richardson, Executive Secretary and Director, World Dredging Association
Mike Giari, Maritime Administration, U.S. Department of Commerce, San Francisco, California
H.V. Kibby, Biologist, Environmental Research Laboratory, EPA, Corvallis, Oregon

Precursor Acitivities:

(1) None
(2) (3) Exploration and Planning Grant, GE 34346
Grant A & M 71-0198

Note: Funding for related projects conducted at Oregon State University is significant, but no total is available.

RANN Environmental Systems and Resources Program. This initial grant covered three general areas:

- Nature of benthic systems and impact of dredging operations,
- Impact of dredging operations on water quality, and
- Dredge spoil distribution and transport mechanics.

The objectives of this exploratory study were to:

- Develop and evaluate methods suitable for measuring and evaluating ecological changes resulting from estuarine dredging operations
- Examine existing records to estimate the possible long-term effects related to past dredging, and
- Develop plans for a long-term research program utilizing established methods for recommending environmental guidelines concerning dredging operations.

Primary technical accomplishments of the initial program were:

- Development of a system of classification indices,
- Preliminary development of several rapid survey methods, and
- Development of strong user interest.

The research was continued for 18 months beginning February 1, 1974 ($450,900), and for a subsequent 12-month period beginning July 1, 1975 ($276,000) to provide recommended criteria and guidelines for minimizing estuarine impacts of dredging. Specific objectives of the continuations were to:

- Identify important systems properties of estuarine benthic deposits,
- Develop methods of assessing dredging and dredging-related impacts,
- Identify methodologies to incorporate results into decision-making processes, and

- Develop concepts and techniques for monitoring of dredging and other alterations to estuaries.

Of particular interest is the conceptual model that was used. This model allows the systematic analysis of the complex benthic system by plots of sediment organic content and the rate of sediment turnover. The plots, termed "cutting plane algorithms" by the project team, depict in a two-dimensional manner the three-dimensional relationship between the unifying parameters--organic content and turnover--and selected variables such as sediment particle size, porosity, sulfide content, and faunal constitutents in the area under study. Examples of these are shown in figure 23-1. Alterations in estuarine systems due to dredging can be described as changes in positions in these planes. For example, the construction of a dike that partially encloses a tidal flat area will reduce sediment turnover rate and increase the organic carbon content of the sediment, thereby shifting the area into the upper left hand corner of the planes shown in figure 23-1. Changes in the system by tidal flushing, marine traffic, dredging, and other natural and artificial actions can be studied through their influence on the sediment and its components. This model is expected to permit prediction of conditions that follow such perturbations of the sediment, and the physical and biological impacts on estuarine benthic systems.

It should be noted that the scope of the research has been expanded over that of the initial grant by the inclusion of other estuarine disturbances, e.g., shipping, in addition to dredging.

The research under the second continuation grant has essentially the same objectives as that under the first. However, tasks performed during this period are directed toward gathering more specific data and refining

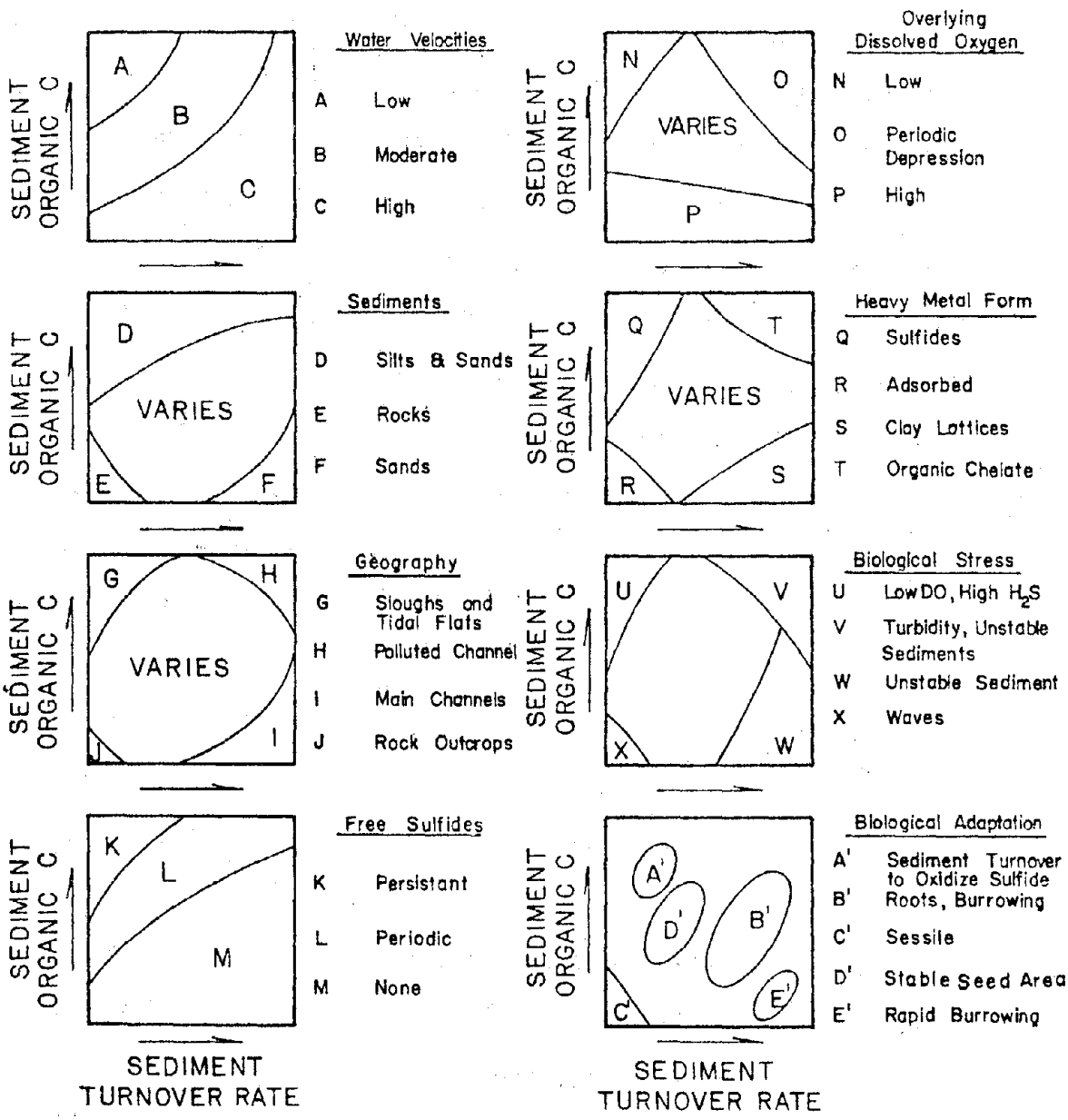

Figure 23-1. Example Images on an Estuarine Dissection Plane

the results of previous research. Principal tasks of this research were:

- Refinement of the characterization of sediments at ten Coos Bay (the test site) stations by seasonal sampling of sediment physical properties;
- Quantitative adjustment of the existing disturbance-sediment model for dependent physical responses;
- Seasonal sampling of sub-tidal biological seed areas to characterize biologically preferred physical estuarine characteristics;
- Sampling of estuaries under various stages of development using broad perspective, low detail methods to map characteristic physical properties for assessment of chronic impacts; and
- Synthesis of results that will permit advising potential users how research results can be utilized in considering alternatives for management of estuarine environments.

It should be noted that the focus of research has been again broadened by the consideration of long-term chronic results of perturbations of the estuarine environment.

Field research being conducted at Coos Bay, Oregon during the current phase of the research includes studies on sulfate-reduction processes in sediments, pyrite formation, and the rate of ferrous sulfide oxidation in overturned sediments. Investigations were directed toward the possibility of using subtidal hardshell clam beds for seeding exploited intertidal clam populations. The estuarine sediment model is being used to analyze the bacterial degradation of iron, sulfur, and carbon.

A proposal for a third and final continuation of the research was submitted and has been funded for $122,953. The objective of this final

research phase is the compilation of the results of previous research into specific guidelines for the assessment of dredging impacts on estuarine ecosystems and specific utilization activities including the three manuals described in the introduction and a workshop scheduled for March 1977 in Washington, D. C. The symposium, which will be open to scientists, engineers, and resource managers, will serve to familiarize the various user groups with the research results and their application.

To date, the grants covering the research have provided educational support to 23 graduate students. A listing of these along with areas of study appears in Appendix A.

Principle products of the research, to date, have been reported in a formal interim progress report published in December 1974, an interim progress report published in January 1976, and numerous publications in professional and scientific journals. Appendix B contains a list of articles written by the research team.

Examples of accomplishments to date include:

- Preliminary findings indicate that the chronic impacts of dredging could be studied by establishing a classification based on the disturbance frequency and organic content of the sediments.
- Seasonal biological data from Coos Bay have been collected and are undergoing multivariate analysis.
- Preliminary findings suggest that sub-tidal hardshell clam populations may be used as seed stock for intertidal clam beds. A computer simulation model of the sub-tidal clam population has reached the stage of multilevel interaction matrixes.
- Determination that ecosystems in the Coos Bay area under stress recover more rapidly from additional stress than unstressed systems.

- Kinetics of oxidation reactions and stoichiometry of ferrous sulfides in sediments were found to be strongly dependent on both the concentrations of ferrous sulfide and dissolved oxygen.
- A computer model of the iron and sulfur cycle in estuarine sediments has been developed. It incorporates rates of FeS and FeS_2 formation, the oxidation rates of FeS, diffusion of soluble species, and turnover rates.
- A pneumatically driven core penetrometer that measures penetration resistance and water content as a function of sediment depth has been constructed.
- An improved vibra-core device has been designed.
- Hydrodynamic models for determining disturbance frequency of sediments have been developed.
- Graphic information regarding channel disturbances associated with marine traffic and dredging have been obtained using side scan sonar.
- Interpretation of the side scan records have been confirmed by SCUBA surveys.
- Instrumentation for measurement of exchanges between the overlying water and interstitial fluid in estuarine sediment has been designed and tested in the laboratory.
- Qualitative and quantitative information on the rate of sediment turnover and horizontal dispersion of sediments has been collected from dyed sand experiments.
- Extension activities included two workshops for the general public on estuarine processes.

Utilization Objectives

Emphasis on utilization has, from the start, been part of the research program. The primary users of the research were identified as planners and managers of estuarine systems, and Federal and state regulatory agencies.

The culminating guidelines scheduled for preparation during the final research phase will have use in the preparation and review of EIS's for estuarine systems, and in the planning and management of dredging operations. Specifically the final products will be useful for:

- State and regional land use planners for determination of immediate and long-range impacts of dredging and other estuarine operations;
- Planners involved in the preparation of environmental impact statements in conjunction with estuarine operations;
- U. S. Army Corps of Engineers and EPA in reviewing environmental impact statements; and
- U. S. Army Corps of Engineers and private industry in planning and managing dredging operations.

The ultimate research results in the form of the guidelines will be published upon completion of the research. There appears to be a need for a procedure to assure adequate consideration of the guidelines by the regulatory agencies. The culminating workshop scheduled for March 1977 is intended to serve this purpose.

User participation in the research has been accomplished primarily through personal contacts by the project staff, publication in scientific journals (see Appendix B for a listing), and conferences and workshops. A listing of conferences, seminars, and symposia in which the members of the research team participated in 1975 is presented in Appendix C.

In addition, an extension specialist added to the project staff after completion of the exploratory and planning phase has conducted mini-workshops, seminars, and conferences on coastal and estuarine management.

An Advisory Committee consisting of the following individuals was formed upon initiation of the research:

- Norbert A. Jaworski, Pacific Northwest Regional Lab, U.S. EPA;
- David R. Busco, Texas A&M, Department of Civil Engineering;
- Mortimer J. Richardson, President, Symcon Marine Corporation and Executive Secretary, World Dredging Association;
- John F. Sustar, U.S. Army Corps of Engineers, Sam Francisco District;
- Charles Walters, State of Oregon Fish Commission;
- Paul Rudy, State of Oregon Land Conservation and Development Commission;
- William Wick, Director, Sea Grant Program, Oregon State University; and
- Paul Winnicki, California Regional Water Quality Control Board.

Information provided by the OSU project team indicate that the Advisory Committee did not meet formally. Frequent contact has been maintained, however, and many ad hoc discussions have been held with all or part of the group. The Advisory Committee for the final project period is shown in table 23-1 supra.

Utilization Obtained

Ultimate utilization of the research results cannot be assessed until the culminating guideline documents are published. Acceptance and adoption of

the guideline documents and their use in planning and managing use of estuarine areas will be indications of utilization. Three general audiences for the final documents can be identified: (1) planners; (2) estuarine managers; and (3) regulatory agencies. Discussions with representatives of these sectors indicate that the guidelines will satisfy a long recognized need. However, they must first be accepted by all three of the user sectors before their full value can be realized.

Interim research results and procedures developed during the research have been used. Results of individual studies have been applied by the user community in their day-to-day operations. The active participation of the project team in scientific and professional meetings, and in personal contacts with the user community has been the principal channel through which utilization of interim research has resulted.

In some cases it has been difficult to directly attribute the reported utilization of interim research results to the project itself. Dr. Slotta and his project team are heavily involved in estuarine and dredging research sponsored by other agencies, e.g., U.S Army Corps of Engineers, State of Oregon. Most of the users contacted during the development of this case study veiwed all of the project team's efforts as an entity. Thus the audit trail of utilization due to the NSF/RANN project was, at times, somewhat vague.

The participation of the project team in multiple research projects served, in itself, as a means for dissemination of the research results. For example, the information developed by the research team assisted materially, according to Dr. Slotta, in a study performed for the Corps of Engineers in Tillamook Bay, Oregon [ref. 1].

The educational component of the research (Appendix A) serves as a utilization mechanism (for example, see report of contact with Mr. Hartman, p. 23-18). Dr. Slotta reports that other graduate students are utilizing the education and training gained while participating in the program. B. H. Choi is currently a member of the Korean Oceanographic Research and Development Institute, Seoul, Korea; R. Downs has a position with a consulting firm in the Northwest dealing with work similar to that of the OSU project; and M. Utt is employed by Union Oil in studying the effects of ice on oil structures.

Reactions of reported and potential users of the research results are presented below:

U.S. Army Corps of Engineers

Mr. John Sustar, Chief, Regional Navigation Planning Section, U. S. Army Engineer District, San Francisco, has used the results of the research in evaluating environmental impacts from dredging operations. Mr. Sustar, a member of the project advisory committee, considers the approach to describing estuarine systems as the most significant feature of the research. According to Sustar, this is a "unique" approach. The data developed to date on sediment transport fill a void in the data base. However, Mr. Sustar cautions that the data cannot be transferred directly to his work, but must be evaluated in the light of how they were collected and the uses to be made of them. Mr. Sustar expressed the opinion that the public relations component of the research-use of an extension specialist to communicate research results to the field has been instrumental in bringing the research results to state and local planners who can use the data in their planning processes.

Mr. Robert G. Moulton, Chief, Coastal Section, U. S. Army Engineer District, Portland, has used the estuarine system description in his research and planning activities, especially in the preparation of the Environmental Impact Statement for the Corps' project to deepen the Newark Channel and for maintenance dredging of the channel. Mr. Moulton has used project data on benthic organisms as input to some ot his studies. He reports that the Corps of Engineers has initiated a project to verify and/or refine the data developed on the recovery of ecosystems under stress. Data developed by the project represent the first reports of recovery times in quantitative terms. The description of impact of dredging during different seasons of the year has been used by the Portland Engineer District to schedule dredging operations in seasons when the least environmental impact will occur. Mr. Moulton is a member of the NSF/RANN panel that reviewed OSU's proposals.

Mr. Gregg Hartman, Chief, Dredging Operations, U. S. Army Engineer District, Portland, has recently completed a year of study under Dr. Slotta. His studies, funded by the Corps of Engineers, led to an M.S. degree. As a graduate student under Dr. Slotta, Mr. Hartman became familiar with the research and now serves as a focal point for further dissemition of the study results within the Portland Engineer District Office. He has used the interim results of the RANN sponsored research to temporally and spatially schedule dredging operations for the Portland District so as to minimize environmental impact. Mr. Hartman feels that the concept of a cutting plane algorithm, currently under study by the OSU team, shows promise of high use in that it will provide a body of knowledge that will permit more informed decisions. He could not identify this concept specifically with the RANN research on dredging operations. According to Mr. Hartman, it is difficult for users to become actively involved in the

research because of its interdisciplinary nature and the manner in which the project is being carried out.

Mr. Robert Hopman, Chief, Waterways Maintenance Branch, U. S. Army Engineer District, Portland, has used the information and concepts developed by the OSU team in a hopper dredging project in Coos Bay. He feels that the Corps' investment in funding Mr. Hartman's studies at OSU has and will continue to pay dividends. (Mr. Hopman is Mr. Hartman's supervisor.)

Mr. Adam Heineman, Chief, Navigation Division, U. S. Army Engineer District, Portland, has not directly used the research results. He has referred to the discussions of the impact of dredging on the environment as background information for the dredging permit system. He feels that the research supports the Corps of Engineers' judgment about the impact of dredging on the environment.

Dr. Robert Engler, Manager, Environmental Impacts Criteria Development Project, Waterways Experiment Station (WES), is familiar with the OSU work, having served as a member of the NSF panel reviewing the December 1974 Interim Progress Report. His primary interest is in sediment chemistry. Dr. Engler feels that the research does not directly relate to what WES is doing in the field. In Dr. Engler's opinion, the chemical work (as of December 1974) especially concerning the sulfide-sulfate process was too narrow in scope, e.g., applicable only to the Coos Bay test site, to be of use by his organization.

Dr. Paul Becker, Research Biologist, Waterways Experiment Station, was also a member of the panel that reviewed the 1974 Interim Progress Report. His comments were based on that review.

Dr. Becker felt that the biological data that had been collected and reported would be of more value and use by researchers if accompanied by a measure of the statistical variation. The data as presented in the interim

progress report gave the impression that the collection and analysis plan lacked a real strong statistical design. Dr. Becker remarked that the biological seeding studies had potential for wide application in estuary systems other than those in the Pacific Northwest. His overall evaluation of the research as reported in the Interim Progress Report was that the usefulness of the results was limited because of the narrow scope (limited to Oregon estuaries) and the apparent lack of a strong statistical design.

Mr. Ron Lee, Chief, Ocean Dumping and Construction Permit Section, Environmental Protection Agency Region X, is aware of the research, but has seen only a portion of the interim results. What he has seen, however, provided him with insight into the environmental problems associated with dredging. The data as being developed show promise of enabling him to make a better review of the Corps of Engineers project and permit actions.

Other Federal Agencies

Dr. Richard H. Burroughs, Environmental Studies Forces, National Research Council, is primarily interested in studies of the application of scientific and technical data to public policy. The outputs of the research to date do not fall into this category. However, he believes the guideline series to be prepared during the final phase of the research will have application for this purpose.

Mr. Michael Giari, Port Development Representative, Western Region, U. S. Maritime Administration, was made aware of the research through attendance at professional and scientific meetings at which members of the OSU project team made presentations. Much of the data he has seen to date are far too technical for port development activities and the regulatory aspects of port

development projects. The publication of the culminating guidelines should ranslate the highly technical data into information useful to him and port development personnel. Mr. Giari made specific comments on the discussions of interdisciplinary research which appear in the December 1974 Interim Progress Report. He has applied the approach discussed by the research team to the complex subject of port operation and dredging. Mr. Giari used a portion of the report as input to a report on dredging operations he prepared for the Maritime Administration.

Mr. Kenneth Randall, Project Manager, Environmental and Resource Planning, U. S. Maritime Administration, has heard of the project but had not seen the results. However, based on this limited exposure, he is now negotiating with OSU for a study of the impact of port operations on water quality. Mr. Randall feels that the systems approach developed by the OSU project team has application to this study.

Mr. Charles K. Walters, Regional Coastal Zone Management Representative, Northwest Region, National Marine Fisheries Service (NMFS), is currently using the concepts developed by the OSU research team for evaluation of the Corps of Engineers proposal for improving the present channel and dredging a new one in Gray's Harbor, Washington. The OSU estuarine model is applicable to the evalu ation of dredging impacts. Prior to joining NMFS, Mr. Walters was a Water Resources Specialist with the Oregon Fish Commission where he also used the OSU estuarine model. Mr. Walters has conferred with the research project team who assisted him in interpreting the problems associated with estuarine activities so that they would be readily understandable by lay persons. He is of the opinion that the culminating guidelines will be valuable to State and Federal agencies engaged in estuary management. Mr. Walters views the OSU project

team as providing much needed and previously unavailable leadership in obtaining and generating data on estuarine systems. The research results show promise of being applicable to estuary systems elsewhere in the United States.

Ms. Nancy Ellifret, U. S. Fish and Wildlife Service, Pacific Northwest, while aware of the research, has not used the results directly. She feels that the data generated from OSU studies on the Coos and Tillamook Bays fill data needs necessary for the evaluation of dredging on areas in which the Fish and Wildlife Service has a concern.

State Agencies

Mr. James A. Lichtowich, Program Director, Rouge Basin Evaluation Program, Oregon Department of Fish and Wildlife, plans to use data and concepts developed by the OSU team in a study of the Rouge River he is currently undertaking.

Dr. Edward LaRoe, Coastal Specialist, Oregon Land Conservation Development Commission, (a position he is occupying during a year's leave of absence from his position as Chief Scientist, Office of Coastal Zone Management, Washington, D. C.), has referred to the research in his work on the effects of dredging on land use planning in coastal zone management areas. He found the research results to date useful as general background. The work has immediate value in that it relates directly to West Coast estuaries and has filled gaps in the data base for these areas. He expressed the opinion that the OSU estuarine model should prove most useful in identifying similarities and differences between western and eastern estuaries. This will enhance transfer of knowledge and information from one estuary to another.

Mr. Rollie Rosseau, Chief Biologist, Environmental Management Section, Oregon Department of Fish and Wildlife, has used the OSU developed estuarine

model to interpret the impacts of perturbations of bottom sediments on biological communities.

Industry

Mr. Mort Richardson, Executive Secretary, World Dredging Association, reported that he served on the project advisory board. As such, his primary contribution has been to serve as an interface and communication channel between the research community and the dredging industry. The Ecology Committee of the Association has made known its research requirements to the OSU team. Mr. Richardson stated that the estuarine description, and the analysis of the impact of dredging activities and concomitant sediment perturbation being developed in the research, serve to put the environmental impacts of dredging in the proper perspective. The civil engineering components of the research, according to Mr. Richardson, will be of more value to the dredging industry than the marine biology studies.

Mr. Robert Lofgren, President, Western Pacific Dredging Company, is aware of the research through personal contacts with Dr. Slotta and through the World Dredging Association. In his opinion, the research has not advanced enough to be of value to his organization.

Mr. Michael Cheney, Consulting Engineer, California Marine Affairs Conference, reported that his organization has not used the results of the OSU research. He has seen excerpts of the results, but not a complete report of the research. Mr. Cheney would prefer that more attention be given to regulatory aspects. He was not aware of the guidelines that are to be prepared during the final research efforts. After they were described to him, he expressed the opinion that if developed as outlined, the guidelines would be of

value and use. He did caution, however, that the guidelines must be accepted and used by the regulatory agencies in reviewing and acting on permits. Mr. Cheney reemphasized the need for a decisionmaking model based on facts readily understandable by the nonscientific members of the dredging community.

Research Community

Dr. Ted Chamberlain, Head, Department of Earth Resources, Colorado State University, participated in an OSU sponsored Estuarine System Symposium at Mount Angel Abbey, Oregon in November 1974. At that time, he was associated with the Johns Hopkins Chesapeake Bay Consortium, Inc. He has not used the research results at this writing because, in his opinion, the effort was more in the applied research area and, as such, more usable by State and Federal regulatory agencies.

Ms. Sharon Saari, Technical Staff, MITRE Corporation, attended the Mount Angel Conference and became familiar with the OSU research. She has used a variety of the research results in the preparation of EIS under contract to the Corps of Engineers. The results of the research have given her a better insight into the environmental problems in estuarine systems. Of particular interest to her is the demonstrated conclusion that ecosystems under stress recover more rapidly from additional stress than do unstressed systems. The times for recovery developed by the project have been most helpful and, insofar as Ms. Saari is aware, constitute the first quantification of recovery times. Ms. Saari reported that the data developed by the research team relative to biological species abundance and recovery are transferable to other estuarine systems for those species having an ubiquitous distribution. She was quite complimentary about the Mount Angel symposium as a vehicle for

disseminating research results and providing an opportunity for interaction with other persons with similar interests.

Dr. Peter K. Weyl, State University of New York at Stony Brook, a participant in the Mount Angel Symposium, reported that he had not used any part of the research. He declined to give any reasons.

Dr. Robert Holton, Research Associate, School of Oceanography, Oregon State University, has used general approach and general systems description described during the research results in the formulation and design of dredging operations off the mouth of the Columbia River.

Dr. John Fisher, Department of Environmental Sciences, University of Virginia, has followed the progress of the research through personal contact with members of the project team. While he has not used any of the research results, Dr. Fisher is of the opinion that the research would be useful in work on the Atlantic Coast barrier islands. Of particular relevance are the data on the movement of lighter bottom sediment fractions by strong and weak currents.

Dr. M. Grant Gross, Director, Chesapeake Bay Institute, Johns Hopkins University, is not aware of the current status of the project. His knowledge is on methodology rather than project content. He has requested one paper that he feels might be helpful in some consulting work he is doing for the State of Maryland. Dr. Gross, based on his limited knowledge of the research results, feels that the research could be useful in planning the use of estuarine systems.

Features

Extensive involvement of the project team in conferences, symposia, workshops, and professional meetings has been instrumental in making the project and the research results to date known to the scientific, public and private communities of which potential users are members. In addition, a large number of articles have been published or submitted for publication in professional journals. This latter activity, however, provides exposure only to the scientific research community.

The inclusion of an extension specialist as a member of the project team at NSF/RANN's behest has resulted in bringing information about the projects and environmental problems associated with estuarine and coastal development to a wide audience in Oregon.

The Principal Investigator, Dr. Larry Slotta, and his project team of co-principal investigators are held in high regard by the estuarine management and dredging community, especially in the Pacific Coast area. In 1975, members of the project team served as consultants for 33 Federal, State and local governmental agencies and for 16 private companies. The professional esteem in which the researchers are held certainly makes their research credible to the user communities. NSF funding appears to have been adequate.

Potential users have had some input into the research through formal and informal contacts with the OSU team. The U.S. Army Corps of Engineers is collaborating with the project in that much of the field test data have been and are being gathered in conjunction with the Corps' dredging operations.

The OSU research team is heavily involved in estuarine and dredging research. Such an involvement provides an excellent opportunity for transfer of

results from one project to another. It did, however in some cases, make the audit trail for utilization vague. Many of the users contacted during the preparation of this case study had a tendency to view the estuarine and dredging research being conducted at OSU as a complete package. These users were aware of the scope of the overall research, but found it difficult to ascribe results of utilization to a specific program.

The highly technical nature of the research performed to date has caused some of the potential users to gradually cease using the research results. A definite need was identified for the translation of the highly technical data into terms that could be used by nonscientific personnel in estuarine planning and management. The culminating guidelines to be prepared during the last six months of this year should provide this bridge.

The research team has demonstrated flexibility in changing the focus of the research to incorporate additional objectives that were identified during the conduct of the research. The initial concept focused on dredge spoil disposal. Subsequently, bottom perturbations from non-dredging activities were included in the study, as well as consideration of chronic long-term effects of dredging and other estuarine operations. Focus has also shifted away from dredge spoil disposal to the environmental impacts of operations in estuarine areas. This latter change is most likely the result of the initiation of a $30 million program by the Waterways Experiment Station, U. S. Army Corps of Engineers for Dredged Material Research Program (DMRP). Generally the DMRP focuses on development of a set of guidelines that can be utilized by an Engineer District to evaluate the environmental aspects of dredging and dredged material disposal [ref. 2]. This change in research focus tends to eliminate duplicative efforts and makes the OSU research complementary to the DRMP.

Of particular interest is the philosophical discussion of and paradigm for the planning and management of interdisciplinary research models [ref. 3]. The discussion of risks involved in this type of research, potential conflicts that could arise, and appropriate milestones provide considerable insight that should assist in the planning and management of interdisciplinary research projects.

Conclusions

The research is progressing as planned. The research to date has generated data and test procedures that have been adapted for use by other researchers in dredging and estuarine systems.

Translating the technical data generated by the research into guidelines providing uniform standards and procedures based on state of the art technology for implementing NEPA in the preparation and review of Environmental Impact Statements (EIS) for dredging in estuarines should make the research useful to scientific and nonscientific personnel engaged in planning, management, permitting, and control of dredging and other estuarine operations.

The guidelines also show potential for use by the U.S. Maritime Administration in port development activities.

The culminating workshop, scheduled for March 1977, will serve to acquaint the user community with the research results and serve as an additional mechanism for consideration of the guidelines by the regulatory agencies.

The educational support provided by the project appears to be an effective dissemination medium for the expertise and results generated by the research.

The inclusion of an extension specialist as an integral part of the research team has facilitated dissemination of estuarine problems to the public sectors. Further study of the effectiveness of this medium is indicated.

Evaluation of utilization of the final products of this RANN sponsored research must await publication and subsequent acceptance of the guidelines. There has been significant dissemination and high utilization of the results of the research produced to date.

Knowledge of the research and utilization of the results to date, however, appear to be concentrated in the Pacific Coast area. Special effort should be made to acquaint other areas of the country with the research and its results. The culminating conference scheduled for March 1977 in Washington, D.C. appears to be a primary method for accomplishing this.

References

1. L.S. Slotta et al., "Effects of shoal removal by propeller wash, December 1973, Tillamook Bay, Oregon," report on contract 57-74-C-0087 by Schools of Engineering and Oceanography, Corvallis: Oregon State University, July 1974, Sponsored by U.S. Army Engineer District, Portland.

2. G. Fred Lee, "Dredged material research problems and progress," Environmental Science and Technology, Vol. 10, No. 4 (April 1976), pp. 334-338.

3. L.S. Slotta et al., "An examination of some physical and biological impacts of dredging in estuaries," Interim Progress Report, Corvallis: Oregon State University, December 1974.

Appendix A

EDUCATIONAL SUPPORT RELATED TO NSF/RANN PROJECT

Student Name	Type of Support	Supporting Agency	Degree (Sought or Obtained)	Major Professor	Date	Thesis Title - Area of Interest
R. Naef	Wages	NSF/RANN	MS/CE	Williamson	6/74	"Effect of Dredging on Siuslaw Estuary, 1973"
H.S. Shieh	Wages	NSF/RANN	MS/CE	Williamson	4/75	Sulfur Cycle in Estuarine Sediment
D. Miller	Wages	NSF/RANN	MS/CE	Williamson	6/75	Chemistry of Coos Bay Sediments
K. Hood	Traineeship	EPA	MS/CE	Williamson	----	Sulfate Reduction Stoichiometry
J. Minor	Traineeship	EPA	MS/CE	Williamson	12/75	Tidal Induced Sediment Transport
G. Ott	Traineeship	EPA	MS/CE	Williamson	----	Ferric Hydroxide in Estuarine Sediments
F. Dudek	Traineeship	EPA	MS/CE	Williamson	1/76	Chemical Characteristics of Gaper Clam Beds
L. Jellison	Traineeship	EPA	MS/CE	Williamson	1/76	Computer Model of Pyrite Formation
S. Delphy	Wages	NSF/RANN	MS/CE	Williamson	----	Heavy Metal Research from Oxidize Sediments
B. Boese	Self	Self	MS/Ocean.	McCauley	1/75	Behavior of an Intertidal Limpet
A. King	Self	GI Bill	MS/Ocean.	McCauley	9/75	Behavior of Benthic Organism Under Dredge Spoils Impact
K. Jefferts	RA	NSF/RANN	MS/Ocean.	McCauley	6/76	Benthic Biology of Channel
F. Ratti	RA	NSF/RANN	MS/Ocean.	McCauley	6/76	Clam Populations in Netarts Bay
R. Parr	---	Self	MS/Ocean.	McCauley	9/73	"Harbor Dredging and Benthic Infauna, a Case Study"

EDUCATIONAL SUPPORT RELATED TO NSF/RANN PROJECT (Continued)

Student Name	Type Support	Supporting Agency	Degree (Sought or Obtained)	Major Professor	Date	Thesis Title - Area of Interest
R. Wells	NSF Traineeship	NSF	Ph.D/CE	Bella	----	Estuarine Benthic Systems
R. Baliga	RA	NSF/RANN	M.O.E.	Hudspeth	----	Stoichastic Analysis of Sand Waves
B. Higgins	---	---	MS/CE	Sollitt	5/74	"Airphoto Analysis of Estuarine Circulation"
R. Arneson	RA	Sea Grant	M.Oc.E.	Slotta	6/75	"Seasonal Variations in Tidal Dynamics Water Quality, and Sediments in the Coos Bay Estuary"
A. Boyce	RA	Sea Grant	M.Oc.E.	Slotta	6/75	Sediment Physics
B.H. Choi	RA	Sea Grant	M.Oc.E	Slotta	6/75	"Pollution and Tidal Flushing Predictions for Oregon's Estuaries"
J. McGinnis	Student Wages, Tech.	Work Study	BS/CE	---	6/76	---
G. Hartman	Corps of Engineers Academic Leave	A.C.E.	M.Oc.E.	Slotta	8/75	"Analysis of Estuarine Channel Conditions at Coos Bay, Oregon using Side Scan Sonar"
B. Higgins	RA	NSF/RANN	M.Oc.E.	Slotta	6/75	Operations of the Dredge SANDWICK
R. Downs	RA	NSF/RANN	M.Oc.E.	Slotta	8/75	Effect of Ship Traffic on Bottom Sediments
M. Utt	RA	Sea Grant	M.Oc.E.	Slotta	5/74	"Seasonal Variations in Tidal Dynamics, Water Quality and Sediments in the Siuslaw Estuary"

EDUCATIONAL SUPPORT RELATED TO NSF/RANN PROJECT (Continued)

Student Name	Type of Support	Supporting Agency	Degree (Sought or Obtained)	Major Professor	Date	Thesis Title - Area of Interest
S. Tang	RA	Sea Grant	M.Oc.E.	Slotta	---	Tidal Flushing of Brookings Marina
D. Askren	RA	Sea Grant	M.Oc.E.	Slotta	----	Numerical Modeling of Estuarine Sediment Flow
S. Noble	Traineeship	EPA	M.Oc.E.	Slotta	----	Chemical Characteristics of Marina Muds

Appendix B

REPORTS AND PUBLICATIONS

D.A. Bella and P.C. Klingeman, "General planning methodology for Oregon's estuarine natural resources," Water Resources Research Institute Report WRRI 18-1, Corvallis: Oregon State University, 1973. 113 pp.

D.A. Bella and R. Wells, 1973. "Analytical procedures--methods developed for measuring and evaluating ecological changes in benthic materials and estuarine waters," in NSF/RANN Grant GI 34346 Progress Report to Division of Environmental Systems and Resources, Research Applications Directorate, National Science Foundation, submitted by Oregon State University, Corvallis, 1973. 38 pp.

E. Condon, "Compilation of studies in dredging, dredge spoil usage and disposal," Oregon State University Marine Advisory Extension paper, Corvallis, 1973. 7 pp.

R. Naef, "Effects of dredging on Siuslaw Estuary," Master's Thesis, Oregon State University, Corvallis, 1973.

R.A. Parr, "Harbor dredging and benthic infauna: a case study," Master's Thesis, Oregon State University, Corvallis, 1973. 114 pp.

K.L. Percy et al., "Descriptions and information sources for Oregon estuaries," Water Resources Research Institute Publication 19-1, Oregon State University, Corvallis, 1973. 190 pp.

J. Seaders and R. Spencer, "Aerial photogrammetric methods concerning dispersion and diffusion," in NSF/RANN Grant GI 34346 Progress Report to Division of Environmental Systems and Resources, Research Applications Directorate, National Science Foundation, submitted by Oregon State University, Corvallis, 1973. 6 pp.

L.S. Slotta (ed.), "Integrated approaches to examine dredging needs and future consequences," Proceedings of Pacific Chapter, World Dredging Association, Portland, Oregon (1972), Ocean Engineering Miscellaneous Publication, Oregon State University, Corvallis. 31 pp.

L.S. Slotta et al., "Effects of hopper dredging and in-channel spoiling (October 4, 1972) in Coos Bay, Oregon." Oregon State University Interdisciplinary Study report to Navigation Division, Department of the Army, Portland District, Corps of Engineers and Division of Environmental Systems and Resources, Research Applications Directorate, National Science Foundation, 1973. 133 pp.

L.S. Slotta and K.J. Williamson, "Monitoring dredge spoils," presented at the Environmental Protection Agency Symposium on Methodology for Monitoring the Marine Environment, Seattle. 1973.

L.S. Slotta and K.J. Williamson, "Dredging problems and complications," in Oregon State University's Water Resources Research Institute's Seminar Proceedings, Fall 1973 on Coastal Zone Management Problems, 1974. 14 pp.

L.S. Slotta and K.J. Williamson, "Estuarine impacts related to dredge spoiling," presented at the Sixth Dredging Seminar at Texas A&M University, College Station, 1974.

M. Utt, "Seasonal variations in tidal dynamics, water quality, and sediment in the Siuslaw Estuary." Master's Thesis, Oregon State University, Corvallis, 1974.

H.G. Weise, "Airphoto analysis of estuarine circulation." Master's Thesis, Oregon State University, Corvallis, 1973. 98 pp.

K.J. Williamson, et al., "Effects of dredging on water quality (Siuslaw Estuary) maintenance dredging, 1972." In NSF/RANN Grant GI 34346 Progress Report to Division of Environmental Systems and Resources Research Application Directorate, National Science Foundation, submitted by Oregon State University, Corvallis, 1973. 62 pp.

In addition, the following papers have been submitted for publication or presentation at scientific meetings:

B.H. Choi, Master's Thesis, "Pollution and tidal flushing predictions for Oregon's estuaries." 1975.

R. Downs, Master's Thesis preparation, "Effect of ship traffic on bottom sediments," 1976.

G.L. Hartman and L.S. Slotta, "Estuarine benthic topographic conditions interpreted from side scan sonar records," presented to the Seventh World Dredging Conference, San Francisco, July 9-13, 1976.

K. Jefferts and D.R. Hancock, "A diver-operated air lift corer for sampling unconsolidated sediments," Western Society of Naturalists, San Francisco, December, 1975.

J.E. McCauley, D.R. Hancock and R.A. Parr, "Effects of dredging and in-bay spoiling in northwest estuaries," National ASCE Meeting, San Diego, April, 1976.

J.E. McCauley, R.A. Parr and D.R. Hancock, "Benthic infauna and harbor dredging: a case study," Water Research.

J.E. McCauley, D.R. Hancock and R.A. Parr, "Maintenance dredging and four polychaete species," ASCE Specialty Conference, Mobile, January 1976.

J. Miner, K.J. Williamson and C.K. Sollitt, "Resuspension of estuarine sediments," to be submitted to Harbors and Coastal Engineering Division ASCE.

L.S. Slotta, "State of the art: environmental dredging research," presented to the Vereinigung der Nassbaggerunternehmungen eV (Association of German Contractors), Hamburg, Germany, December 5, 1975.

L.S. Slotta and R.T. Hudspeth, "Estuarine tides" (Theory of damped co-oscillating tides with dampened reflection), 7th Belle W. Baruch Symposium proceedings on "Transport processes in estuarine environments," University of South Carolina, Columbia. May 19-22, 1976.

L.S. Slotta, "Side scan sonar views of channel disturbances associated with marine traffic and dredging," presented to the Vereinigung der Nassbaggerunternehmungen eV (Association of German Contractors), Hamburg, Germany, December 5, 1975.

L.S. Slotta, "Side scan sonar views of channel disturbances associated with marine traffic and dredging," presented to the ASCE Specialty Conference on Hydraulics, Mobile, January 26-29, 1976.

B.K. Sullivan and D.R. Hancock, "Zooplankton and dredging: research perspectives from a critical review," Environmental Pollution.

A. Todd and K.J. Williamson, "Oxidation of ferrous sulfides in estuarine sediments," presented at Fifth Technical Conference on Estuaries in the Pacific Northwest, Corvallis, April, 1976.

K.J. Williamson and D.A. Bella, "Pyrite formation and free sulfide generation in estuarine sediments," to be submitted to Water Research.

K.J. Williamson and D.A. Bella, "Strategic planning for ocean dumping," presented at National ASCE Conference, San Diego, April 1976.

K.J. Williamson and D.A. Bella, "The sulfur cycle in estuarine benthic deposits," presented at National ASCE Conference, San Diego, April 1976.

Appendix C

UTILIZATION ACTIVITY-CONFERENCES, SEMINARS AND WORKSHOPS

PRESENTATION	SPONSOR	P.I.	DATE
Comprehensive Environmental Planning (audience: about 30 students)	OSU-Dept. of Geography	Bella, D.A.	Spring, 1975
Conflicts in the Coastal Area	WAVES (Western Assoc. for the Valuation of Ecosystems)	Bella, D.A.	Sept., 1975
Ocean Dumping	FAO-Oregon State Univ.	Hancock, D.R.	1975
Oregon's Subtidal Clams	NOAA-Sea Grant Sem.	Hancock, D.R.	Jan., 1975
"The World's Sewer"	OSU World Population and Resources Program	Hancock, D.R.	Feb. 1975
Benthic Systems as a Function of Resource Management	NSF/RANN	Hancock, D.R.	May, 1975
Estuaries in Action-4-H Workshop	Short Course Sea Grant	Hancock, D.R.	June, 1975
Dissection Planes, Catastrophism and Subtidal Clams	NSF/RANN	Hancock, D.R.	Oct., 1975
Miniworkshops to Resource Agencies	Corps of Engineers	Slotta, L.S.	Jan.27, 1975
CE 572-Marine Water Quality Dynamics, a course on water quality control & waste disposal in estuaries and near-shore areas; principles of diffusion and dispersion of dissolved and particulate matters in marine waters; fate of pollutants; interrelationships of physical, hydraulic, chemical, and biological factors.	OSU	Slotta, L.S.	Spring, 1975 3 hrs/week
CE 503-Seminar on NSF/RANN Research-"Hydrodynamics and Rate of Sediment Turnover"	OSU	Slotta, L.S.	Spring, 1975 2 hr/week

UTILIZATION ACTIVITY-CONFERENCES, SEMINARS AND WORKSHOPS (CONTINUED)

PRESENTATION	SPONSOR	P.I.	DATE
CE 579-Seminar on Coastal Zone Management-developed program with WRRI during Summer 1975	OSU	Slotta, L.S.	Fall, 1975 2 hr/week
"State of the Art-National Science Foundation-RANN Dredging Research"	California Marine Affairs & Navigation Conference-San Fran.	Slotta, L.S.	Feb.20-21,1975
"Energy from the Sea"	OSU-World Population and Resources Program	Slotta, L.S.	Feb.26, 1975
"Dredging by Means of Water Jets"	ASCE National Conv. New Orleans, LA	Slotta, L.S.	April 14-18, 1975
"Ambient Current Effects on Vertical Selective Withdrawal in a Two Layer System"	IAHR Conf.-Sao Paulo, Brazil	Slotta, L.S.	July 25-Aug.8, 1975
"Hydraulic Characteristics of Several Oregon Estuaries"	ASCE Hydraulics Div. Specialty Conference Seattle, WA	Slotta, L.S.	Aug. 7-8, 1975
"Changes in Tidal Dynamics and Filling of Tidal Areas at Coos Bay, Oregon"	3rd Int'l. Conf. on Estuaries-Galveston, Texas	Slotta, L.S.	Oct.7-9, 1975
"Side Scan Sonar Views of Channel Disturbances Assoc. with Marine Traffic & Dredging"	Dredging Contractors	Slotta, L.S.	Dec. 5, 1975
"State of the Art: Environmental Dredging Research"	Dredging Contractors Conf-Hamburg, Germany	Slotta, L.S.	Dec.5, 1975
"State of the Art: Environmental Dredging Research"	University of Karlsruhe Germany	Slotta, L.S.	Dec. 10, 1975
Workshop on problems and environmental mgmt. of Oregon's estuaries (involved people from state agencies, OSU, public and COE)	RANN Team	Stander, J.M.	Jan., 1975
"Economics and Coastal Planning" (participated in workshop on economics of the coastal zone)	Extension Serv.-OSU	Stander, J.M.	Sept., 1975

UTILIZATION ACTIVITY-CONFERENCES, SEMINARS AND WORKSHOPS (CONTINUED)

PRESENTATION	SPONSOR	P.I.	DATE
"Long-Range Environmental Planning" (given to members of an engineering class)	Civil Engineering	Stander, J.M.	Nov., 1975

RESEARCH TRIANGLE INSTITUTE N.C.

RANN UTILIZATION EXPERIENCE

CASE STUDY NO. 24

LABORATORY CLOUD SIMULATION TO SUPPORT WEATHER MODIFICATION RESEARCH AND FIELD PROGRAMS

COLORADO STATE UNIVERSITY

Case Investigator:

H. L. Hamilton

Research Triangle Institute
P.O. Box 12194
Research Triangle Park
North Carolina 27709

Technical Reviewer:

E. Droessler

Department of Geosciences
North Carolina State University
Raleigh, North Carolina 27607

Prepared under:

Contract No. NSF-C76-17165
National Science Foundation
Research Applied to National Needs
1800 G Street, N.W.
Washington, D.C. 20550

LABORATORY CLOUD SIMULATION TO SUPPORT WEATHER MODIFICATION RESEARCH AND FIELD PROGRAMS

Introduction and Summary

The development of the capability to beneficially modify several scales of meteorological systems--generally referred to as weather modification--has been a goal of researchers for many years. The beneficial modification may result in an increase in the amount of precipitation, the reduction in the size and/or quality of hail, the alleviation of the damaging effects of severe storms, or the dissipation of fog.

Since 1946, experimental evidence has been available to show that certain substances introduced into liquid water clouds at temperatures below freezing will act as freezing nuclei and cause a growth of ice crystals within the cloud. In such clouds, ice crystal formation is considered a necessary prelude to the development of cloud particles large enough to precipitate. Experimental work in the late 1940's indicated that silver iodide (AgI) was perhaps the most effective with regard to acting as a nucleus for the formation of ice crystals.

While the superiority of AgI as a seeding agent was generally accepted, its preparation into the very small aerosol required in weather modification was uncertain, and quantitative techniques for evaluating this and other agents were crude. In a search for a standardized and generally acceptable procedure to use in support of weather modification field research programs, the development of an Isothermal Cloud Simulation Chamber was undertaken at Colorado State University

(CSU). The CSU field research programs then underway on western slopes of the Rocky Mountains were designed to evaluate the rainfall augmentation potential from seeding orographic clouds* and involved a "systems" approach to explore all aspects of the seeding process.

The Isothermal Cloud Simulation Chamber is an outgrowth of efforts to describe the nucleating efficiency of the seeding materials to be used in the weather modification field experiments. Earlier work clearly showed that a wide range of production efficiencies and nucleating characteristics can occur with silver iodide smokes. Variations of four orders of magnitude in the numbers of ice nuclei formed at a given temperature can be exhibited by various generators. Variations nearly as great were observed for some individual types of generators as a function of their operational adjustments.

Since 1971, the operation of the facility has been supported by the National Science Foundation Research Applied to National Needs (NSF/RANN) program, with RANN receiving funds through interagency agreements from the Department of Defense, the Department of Commerce, and the Department of Interior. Project information is detailed in table 24-1.

The requests for the testing of seeding materials and devices have continued. Several university and governmental groups have established regular schedules for the calibration of their seeding devices. University, government, and private groups working on improved seeding materials and devices are having these tested at various stages of their development. The use of the chambers for evaluating

*Orographic clouds are those formed in air being lifted as it flows over rising terrain. Such clouds may have limited areal extent and usually show little movement. Air flowing through the cloud continually replenishes the supply of water which forms the cloud particles.

Table 24-1. PROJECT INFORMATION

Project Title	Grant/Contract No.
Laboratory Cloud Simulation to Support Weather Modification Research and Field Programs	GI 32894X
RANN Program Manager Currie Downie	**RANN Program Area** Weather Modification
Principal Investigator(s) Lewis O. Grant Myron L. Corrin	**Schedule** Start: 1971 End: --
Institution Colorado State University Department of Atmospheric Sciences	**Funding*** FY 1971 - $94,300** FY 1972 - $106,800** FY 1973 - $112,600** FY 1974 - $55,000† FY 1975 - $55,000† FY 1976 - $55,000†

Contributors/Collaborators

Dennis Garvey - Director, Aerosol and Cloud Simulation Laboratory, Colorado State University

User Advisory Committee

Precursor Activities

Precursor Activities
NSF, Navy, ESSA support for the development, construction and operation of the simulation facility from 1965 to 1971.

Funding Notes

* NSF/RANN support has been provided by funds transferred to NSF/RANN by Department of Defense, Department of Commerce, and Department of Interior as well as by NSF/RANN funds. For example, in 1975, the Departments of Defense and Commerce each furnished $10,000; Department of Interior, $25,000; and NSF/RANN, $8,000. Grants to CSU have been administered by NSF/RANN.

** Approximately one-half for research and one-half for facility support.

† Facility support only.

nucleus counters, for testing other cloud physics equipment and techniques, and for specific cloud physics research is continuing.

The utilization of the testing or "calibration" services that can be provided by CSU has been strongly influenced by the uniqueness of the facility. There is one comparable facility in the United States and one in Zurich, Switzerland. Confidence on the part of the users that the test program will adhere to standardized procedures, and that the test results will be reliable and comparable with data obtained on other tests made in the CSU facility, and the prompt response and cooperative attitude exhibited by the facility staff, have also enhanced utilization.

This RANN project has fulfilled a requirement of the community of people concerned with all aspects of weather modification for an accepted standard procedure by which various types of nucleating agents and devices can be compared. The requirement for such a standard procedure arises from legal, environmental, and commercial considerations as well as from scientific priorities.

Research Description

The augmentation of the water supply for cropland irrigation and electric power production, and the modification of local weather systems to suppress the occurrence of hail, prevent the development of strong winds, or enhance precipitation, are some of the desirable goals of weather modification research and operations.

Following the demonstration by Vincent Schaefer in 1946 that solid carbon dioxide would convert a cloud of supercooled water droplets to ice crystals,*

*A necessary precurssor event to the formation of rain in sub-tropical connective clouds.

and the discovery by Bernard Vonnegut that silver iodide would produce similar effects, many operational and numerous experimental programs in cloud modification and precipitation augmentation were undertaken. In 1957, the President's Advisory Committee on Weather Control concluded, on the basis of statistical evaluations, that cloud seeding in mountainous areas of the western United States "produced an average increase of 10 to 15 percent...with a satisfactory degree of probability that the increase was not the result of the natural variations in the amount of precipitation." While this conclusion was not universally accepted as valid because the data were not produced by randomized experiments, Congress, on the basis of the Committee's report, charged NSF to support studies needed to provide a broad scientific base for weather modification (PL 85-510). NSF accepted this responsibility and, through grants to other agencies, supported projects such as SKYFIRE (Forest Service), STORMFURY (Navy-National Weather Service), and many research and manpower development projects at universities.

With its reorganization in the mid 1960's, the special responsibilities of NSF under PL 85-510 were eliminated and, to date, these responsibilities have not been re-assigned to NSF or any other agency.

Throughout the last 30 years, periodic assessments of the state of knowledge and of technology of weather modification have been made. The previously mentioned report of the President's Advisory Committee on Weather Control, 1957; the 1966 Final Report of the Panel on Weather and Climate Modification to the Committee on Atmospheric Sciences, National Academy of Sciences, National Research Council (NRC); the 1971 report, The Atmospheric Sciences and Man's Needs, Priorities for the Future, by the NAS-NRC Committee on Atmopheric Sciences; and the NAS-NRC 1973 report, Weather and Climate Modification, assessing programs in

weather modification since the 1966 report of the same title, have all discussed the then current state-of-the-art, the requirements for additional research, and the institutional and legal implications of weather modification activities.

In particular, the NAS-NRC 1966 report, in its enumeration of the "Special Problem Areas in Weather Modification," cites the lack of detailed knowledge of the processes taking place in the devices used to generate nucleating agents for cloud seeding, and the absence of a "quality-control program of regular testing of the output of generators used in operational seeding."

The NSF/RANN project, "Laboratory Cloud Simulation to Support Weather Modification Research and Field Programs," at CSU has addressed itself to the second of these problems areas. This facility, under the direction of Dr. Lewis O. Grant, Professor of Atmospheric Sciences, was established in 1966 (with NSF grants) for the purposes of conducting cloud physics research and calibrating or empirically measuring the output of nucleating agent generators.

There are two other facilities of this type in existence. The one in the United States, at the South Dakota School of Mines and Technology, features a horizontal wind tunnel for dilution of the nucleant generator output and five temperature-controlled, but not pressure (altitude) controlled, cloud chambers for the measurement of five simultaneous samples from the dilution tunnel. The facility in Switzerland is in the Laboratory for Atmospheric Physics and Research of the Federal Institute of Technology. While designed for research on the growth rates and characterizations of hail, it has been used for investigation of the nucleation of ice crystals.

Prior to 1965, calibrations at CSU were made using a large horizontal wind tunnel for the dilution of generator output, and a chest-type home freezer for

activating the samples. The number of nuclei generated was approximated from the number of ice crystals that precipitated onto a glass microscope slide in the freezer, using the volume, the sample injected into the freezer, and the freezer volume as additional terms in the relationship. The greatest deficiencies in this procedure were the large temperature and supersaturation variations in the freezer. The temperature variations in such units, as great as 4 to 8 Celsius degrees, are much too large since ice activation of most agents can increase by a factor of 10 within a temperature interval of 4 Celsius degrees. Other problems occurred due to contamination of the facility by material exhausted from the horizontal dilution tunnel.

Despite these deficiencies, useful results were obtained, and other research groups began to request that their seeding materials and devices be calibrated in the existing facilities. The limitations of the facilities were obvious and, in 1963 planning was initiated to build a facility that would provide the requisite capacity. Emphasis was placed on (1) development of a relatively large cloud chamber in which the temperature would be extremely uniform throughout, and (2) construction of a large, vertically oriented dilution tunnel that would reduce sample contamination by discharging the source materials outside the test building. With support from the Atmospheric Science Section of the National Science Foundation, an isothermal cloud chamber, designed by Roger Steele of the Mechanical Engineering Department at Colorado State University, became operational during the spring of 1965.

At present, the CSU facility comprises three primary units of equipment: a 1 m^3 isothermal cloud chamber; a 1 m^3 controlled, slow-expansion cloud chamber, and, an 84-ft. variable-flow, vertical dilution tunnel. The cloud chambers are

inside a specially constructed building (approximately 10,000 sq ft) that can be maintained at a slight overpressure to help avoid contamination from nucleating agents introduced into the tunnel for dilution. The tunnel is outside the main structure. The isothermal cloud chamber has the capability of providing supercooled clouds with temperatures within $\pm 0.3^{o}$ Celsius at all locations within the chamber. Air flow through the tunnel can be induced by a fan at speeds up to approximately 50m sec^{-1} (100 kts) to simulate operational conditions for aircraft-mounted generators, or by natural ventilation to approximate conditions for ground-based generators. A sample of the aerosol being tested is collected downstream from the generator, diluted with dry air, and injected into the isothermal cloud chamber. The ice crystals that develop in the chamber on the introduced nuclei settle and deposit on microscope slides that are pulled from the bottom of the chamber for counting. The effectiveness of the nucleating agent is calculated as the ratio of the number of crystals to the maxx of nucleating material in the diluted sample.

The controlled slow-expansion cloud chamber, still under development, is designed to more closely reproduce conditions within cumulus clouds by simulating ascent of an air parcel (after the introduction of a sample of nucleating agent). The ascent rates--up to 15m sec^{-1}--are simulated by controlled evacuation of the chamber with a corresponding lowering of the chamber temperature.

It was immediately apparent that the unit provided a basis for a substantially improved calibration capability. Among the first generators tested at the improved facility were those used by CSU scientists in the Climax randomized seeding experiments. The number of requests from outside groups for testing seeding materials and devices increased. The requests were originally filled as

a cooperative research effort. In 1965, however, these requests became so numerous and time-consuming that specific financial support for the calibration of seeding materials and devices was requested. The support was initially provided by NSF and the U.S. Naval Ordinance Station at China Lake, California. Since 1967, the basic support for the testing and calibration, and for research into the improvement of the simulation procedures, has been provided by the National Science Foundation. The funds for the construction of the present specifically designed building for this testing program were made available by Colorado State University in 1966 and 1967. Environmental Sciences Services Administration (ESSA) provided the primary support for the construction of a vertical dilution tunnel in the new structure. Substantial parts of the support instrumentation were obtained through the support from the Bureau of Reclamation.

The development of the facility has continued along with the calibration service provided to outside users, and cloud physics research utilizing simulated clouds has increased as the simulation capability expanded.

The facility served as a base for the Second International Workshop on Condensation and Ice Nuclei in 1970. A mini-workshop was held in the spring of 1973 for the simultaneous comparison of nearly all types of ice nucleus counters that had been in use in 1970. With support from NSF, important improvements in the building were made during preparation for the 1970 Workshop. Subsequent to the workshop, substantial improvements were made in the control of the isothermal cloud chamber (primarily in the production and introduction of the cloud to the chamber) and in the control and calibration of the dilution procedures.

RANN assumed the responsibility for CSU "Laboratory Cloud Simulation to Support Weather Modification Research and Field Programs" in 1971. During 1965-1970, it had been supported by the NSF Atmospheric Sciences Section. Until 1974,

funds awarded by RANN to CSU were divided evenly between testing facility support and cloud physics research. Since 1974, grants have been awarded only for the testing of devices for generating nucleants, i.e., for facility support, not for research.

Throughout the period of support by RANN, some funds have been obtained from the Department of Commerce, Department of Defense, Department of the Interior, as well as from NSF/RANN, with RANN administering the grant. Beginning in fiscal year 1976, CSU considered instituting a nominal charge for testing nucleant generators for non-research organizations. However, investigation by the University indicated that the costs of billing and accounting would be greater than the money collected. So far, no charges for testing have been levied.

The NSF/RANN support to CSU has permitted the development of a facility that can evaluate devices for the generation of materials for the artificial nucleation of clouds in terms of the number of nuclei produced under a set of standard conditions and procedures. Having availed themselves of the services of this facility, the designers/users have a basis for planning the remaining steps of their weather modification experiment/operation, or for further development to improve their device performance.

Utilization Objectives

The objective, in terms of the use to which the facility supported by this RANN grant was to be applied, was to furnish government agencies and their contractors a standard calibration--or effectiveness rating--for nucleating agent generating materials or devices. These calibrations, essential for the scientific evaluation of weather modification experiments and/or operations, are

expressed as the number of effective ice nuclei generated per unit mass of feed material to the generating device. All the government agencies* providing support through NSF/RANN have substantial interest in weather modification/cloud physics activities and have used the facility directly.

The facility was planned to serve the needs of the user and is capable of handling nucleant generating devices of various types--e.g., ground based pyrotechnic, or airplane-mounted--and can provide a simulated cloud having a temperature corresponding to the anticipated conditions in the cloud(s) to be modified.

In addition to being designed as a calibration facility, the isothermal chamber was intended to provide a facility for basic research in cloud physics.** No specific plan was developed initially to promote the utilization of this facility by others in addition to the CSU personnel in support of their ongoing precipitation augmentation research. However, the contributions to the funding of the RANN grant by the several government agencies in recent years have assured availability of the facility for Federally sponsored or operated programs requiring nucleating device calibration.

The worldwide community of scientists involved in cloud physics, precipitation augmentation, hail suppression, severe storm abatement, or other forms of weather modification research and of scientists and operators engaged in commercial weather modification activities is small; its members are well known to one another, and are reasonably prolific in the publication of research results.

---

*National Oceanic and Atmospheric Agency, Dept. of Commerce; Naval Weapons Center (China Lake, Ca.), Dept. of the Navy, Bureau of Reclamation, Dept. of Interior; National Center for Atmospheric Research (NSF)

**The research activities using this facility have not been funded by NSF/RANN since 1973.

Direct discussion with other researchers, publication of technical papers, and participation in symposia and conferences contributed the primary mode of dissemination of reports of activities and results under this program.

Utilization Obtained

The utilization of the facility supported by this grant has been very impressive. Dr. Lewis O. Grant, the Principal Investigator, estimates that approximately 95 percent of the artificial nucleating agent generating devices in use in the United States, and a large percentage of those in use in the remaining western bloc nations, have been calibrated in the CSU isothermal cloud simulation facility to determine the number of nuclei generated per unit period of time under specified operating conditions. Testing has included both devices and materials for U.S. Federal and local government agencies, foreign government agencies, domestic and foreign universities, and commercial operators.

Table 24-2 gives a listing by number of tests conducted in the facility for Federal government agencies, their contractors, and others (including CSU) during the years 1971-1974. Detailed tabulations of the number of tests by Federal users have not yet been developed for 1975 and 1976.

Table 24-3 is a selected list of some of the non-Federal government users of the services of the facility through the years of RANN support. In addition to its primary use for calibration of cloud seeding nucleating agent generating devices and materials, the isothermal cloud simulation facility has been used for evaluating other devices used in cloud physics studies. For example, several sets of tests have been conducted comparing the performance of ice nucleus counting instruments.

Table 24-2. Number of Tests Conducted for Federal Agencies or Their Contractors, 1971-1974.

Year	Dept. of Defense	NOAA	Bureau of Reclamation	NSF	Other	Total
1971	14	0	410	0	257	681
1972	254	0	450	45	70	819
1973	0	118	105	151	232	606
1974	162	29	66	84	231	572
Total	430	147	1031	280	790	2678

A group of users of the isothermal cloud simulation facility during 1975-1976 was selected to provide a cross section of researchers and operators, i.e., governmental, university, and commercial. Comments by each of these users indicating their assessment of the value of the calibration services available from the CSU facility are discussed below.

Federal Agencies

Atmospheric Physics and Chemistry Laboratory, National Oceanic and Atmospheric Administration (NOAA), Boulder, Colorado. A Research Associate, Mr. Russell Schnell, is conducting basic research to determine the effectiveness of natural biologic materials (such as decayed vegetation, or bacteria) as ice crystal nucleants. He characterized the CSU facility as unique and as providing standard repeatable conditions essential to agent or device evaluation.

National Hurricane and Experimental Meteorology Laboratory NOAA, Coral

Table 24-3. Numbers of Tests Conducted For Non-Federal Groups, 1971-1974 (Selected List)

User	Number of Tests
Societa Ricerche Experienze Meteorologiche (Italy)	4
Rhodesian Department of Meteorological Services	44
South Dakota School of Mines & Technology	14
EG&G	297
Olin Corporation	258
Water Resources Development Corporation	68
Santa Clara Valley Water District	49
Hebrew University, Israel	48
University of Wyoming	74
Sacramento Municipal Utility District	52
Atmospherics, Inc.	23
Sierra Research	64
New Mexico State University	142
Montana State University	45
Fresno State University	216
3M Company	3
Calspan	49

Gables, Florida. Dr. William L. Woodley, the Principal Investigator for cumulus cloud experimentation at this laboratory, expressed complete satisfaction with the services furnished by the CSU facility. The availability of a facility with established procedures and repeatable conditions was invaluable in his research. Tests prior to his 1975 operating season resulted in a change in the supplier of the pyrotechnic agent delivery devices used.

Naval Weapons Center, China Lake, California. Mr. John Carroz reports that work on the development of pyrotechnic seeding devices performed by this laboratory has been for another Federal agency and that calibration or test data must be provided. The CSU facility has been used to obtain data to permit the maximizing of the effectiveness of the agent used and the delivery device as a system. Again, the availability of a facility that provides repeatable conditions and standardized procedures was emphasized as invaluable. In this case, the investigator emphasized that the calibration values (i.e., the number of ice nuclei generated by a pyrotechnic device) obtained in the cloud simulation chamber probably are not absolute, but from test to test, the values can be compared.

State and Local Agencies

San Bernardino Municipal Water District, California. Mr. Larry Rowe stated that this local governmental unit conducts its own cold weather orographic cloud precipitation augmentation program. Calibration of their nuclei generators at the CSU facility has shown that the efficiency--in terms of number of ice crystal nuclei produced per gram of silver iodide consumed--was greater than previously thought. This has enabled the seeding operations to be conducted with fewer generators with a consequent savings of both dollars and manpower. In addition, the data provided by CSU on the relative efficiency of the ice crystal nuclei produced by the generators at various temperatures have enabled the selection of the most appropriate meteorological opportunities for seeding operations. This selection of opportunities has made for more effective operations.

The water district is developing a new automated ice crystal nucleating agent generator, and plans to have this device tested at CSU. It is significant

to the utilization pattern for the CSU calibration facility that weather modification operations, which previously have been exempt, are now required to submit Environmental Impact Statements to the State of California (and in other states as well). These statements must include, among other data, details on the seeding agents to be used and the number of nuclei expected to be generated. This requirement can be expected to increase the need for calibration.

University of Wyoming Microbiology Department. Dr. Leroy Mackey is investigating the effectiveness of bacteria as nucleating agents and finds the capabilities of the CSU isothermal cloud simulation chamber essential to his work. He believes that the close approximation to real cloud conditions available in the chamber provides him with much more useful data than could be obtained in cold boxes and similar laboratory devices.

Private Firms and Individuals

Mr. Richard A. Marten, California. Mr. Marten has been engaged in developing more effective ice crystal nucleating agents which he hopes will be patentable. He considers the CSU facility as the only source of data required to improve his product. Modifications have been made in his formulations on the basis of the reports from tests conducted in the isothermal cloud simulation chamber. He made special mention of the excellent response received from the facility.

Colorado International Corporation, Boulder, Colorado. Mr. Robert T. Beaumont and Mr. Ralph Papania indicate that this company, which conducts operations in several countries, has used the CSU facility for the calibration of devices and agents and also has used facilities in Zurich, Switzerland. Results have been comparable although some discrepancies have occurred. Again,

the excellent response of the CSU facility to the user's needs was mentioned. Nucleating agents produced by competitors have also been submitted by this company to the CSU facility for evaluation.

Convergence Systems, Inc., Ft. Collins, Colorado. James Swenson reports that this organization has used the facility to evaluate the relative performance of airborne ice crystal counting instruments under development. Due to pressure of contractual commitments, the company was unable to have as many tests conducted as it desired, but was pleased with the data obtained and the cooperation received at CSU.

Atmospherics, Inc., Fresno, California. According to Mr. Tommy Henderson, this company has been required by customers to provide calibration data for nuclei dissemination devices used, but has not yet modified its operating devices, techniques, or procedures as a result of data obtained from tests made at the CSU facility. The availability of the repeatable conditions and standard procedures at CSU and the cooperation received from the staff were stressed.

Olin Corporation, Illinois. Mr. Clark Vineyard reports that this supplier of pyrotechnic ice crystal nucleating devices is usually required by customers to provide data on device nucleating efficiency. The CSU facility has been the source of these data and this firm has never considered an alternative method of calibration. The service provided by CSU, and the information furnished, completely fills the company's requirements.

Western Weather Consultants, Durango, Colorado. Mr. Larry Hjermstad, a principal of this newly formed company, has previously worked for another Colorado commercial operator and has modified operating procedures for seeding cold orographic clouds on the basis of data received from generator tests at CSU.

He expressed confidence in the data provided by the CSU facility and anticipates continued use of the services.

Weather Modification, Inc., Bowman, North Dakota. Mr. Lynn Rose provided the only negative comments. His company's operations are conducted using an airborne nucleating agent generator of their own design. This device depends on ram pressure for operation rather than an externally provided pressurization. The vertical configuration of the wind tunnel at CSU requires that this generator be oriented in an abnormal position while in operation for test purposes, adversely affecting operating efficiency. The validity of the sample of nuclei collected in the vertical wind tunnel was also questioned.* This company has also used the facility at South Dakota School of Mines and Technology and has received data from that facility that appear more reasonable. This operator is usually required to provide test or calibration data to his customers in submitting quotations on solicited modification programs, and feels at a disadvantage if required to have tests conducted at CSU.

Features

The stature of the Principal Investigator, Dr. Lewis O. Grant, in the fields of cloud physics and weather modification and the active role that Colorado State University's Department of Atmospheric Science has played in the training of scientists in these fields, have been important features in the utilization pattern of the isothermal cloud simulation chamber. Many of the

*This question has been discussed by CSU personnel in the literature. See "Testing of Cloud Seeding Materials at the Cloud Simulation and Aerosol Laboratory, 1971-1973" by Dennis M. Garvey, J. Appl. Met. 14, 5, pp. 883-890 (August 1974).

present day users became acquainted with the facility during their academic careers.

During the period of development and in trial operation of the simulation facility, the funding through NSF was apparently adequate. With the decision in 1973 by NSF/RANN (and the other Federal agency co-sponsors) to reduce funding to 50 percent of the prior level, the facility could be considered fully supported. This caused personnel management difficulties in the CSU Cloud Simulation and Aerosol Laboratory because the skilled and experienced individuals required to operate the facility can be assigned only part-time to this operation. Lack of full support to the facility may be a problem of increasing concern because the demand for services can be expected to increase with the state requirements for test data in Environmental Impact Statements required for weather modification experiments or operations.

The users of the CSU facilility are relatively few in number, but even that small group can be readily divided into researchers (Federal or university laboratories, with a few individuals and product manufacturers) and commercial operators. The researchers need the facility to assess the results of their development or theoretical work, and the operators need the facility to obtain information for the design of effective programs.

At the time the isothermal cloud simulation facility was developed, CSU was actively engaged in a research program involving long-term field operations of nucleant generators. One user (CSU) was actively involved in determining the required performance characteristics of the facility. In conducting tests at the facility under its present mode of operation, scientists or technicians from the user organization are frequently present to assist in the program.

This is sometimes essential to assure the optimum operation of a device being tested, but also helps to provide for exchange of information between users and test facility operators.

The existence of the facility at CSU has been well-publicized through staff participation in national and international conferences on weather modification sponsored by the American Meteorological Society and the World Meteorological Organization, and by articles in appropriate technical journals.

An almost coercive factor in promoting the utilization of the CSU facility has been the requirement by government agencies requesting proposals for weather modification projects, that the respondent organization provide results of tests on the nucleating efficiency of devices and materials to be used. In some cases, because the agency involved is among the co-sponsors of the CSU facility, that facility is designated to be the source of the test data. This requirement for substantiated test data is becoming more common with, as was mentioned earlier, the imposition of the requirement for environmental impact statements for weather modification projects.

The time frame in which the isothermal cloud simulation chamber was developed, and has become fully operational as a test and calibration facility, has been very appropriate, and the need for the facility in coming years seems to be assured. Drought alleviation, water supply augmentation, hail suppression, and severe storm modification are all objectives of national concern that can be approached through cloud physics and weather modification studies. To provide adequate control of the materials and devices to be used in field experiments supporting these studies, standardized testing and calibration are required.

Particular mention was made by almost all users interviewed of the excellent cooperation received from facility personnel and of the timely response received when tests are required. The small annual funding now being provided by the Federal government through NSF/RANN for the annual operation of this essential facility makes it a very cost-effective project. The data provided by the facility are directly applied to research and operations intended to satisfy national needs in weather modification, particularly toward precipitation augmentation in the western states that is so essential at present for hydroelectric power generation and for agricultural activities. The fact that the facility has, and is being used as an adjunct to academic training in cloud physics and weather modification at CSU can be considered a bonus.

At present there seem to be few barriers to the utilization of the CSU facility. In fact, the requirements for test data being imposed by environmental concern in all probability will increase the utilization. Past records show that the facility has been used by Federal and local government units, private individuals, material and device manufacturers, and by commercial weather modification operators. This pattern should continue.

Withdrawal or reduction of NSF/RANN or other Federal support would require a re-evaluation of the CSU position with regard to the continued operation of the facility. Attempting to put the facility on a truly self-supporting basis might not be practicable since fees required might be so large that the use of the facility for the numerous tests required for nucleating device research and development would be discouraged. Organizations operating under government contracts could, of course, include fees for tests in their budget, but the actual cost per test to the government might prove to be higher than experienced

when the CSU facility receives direct support.

From a technical standpoint, the facility fulfills its intended purpose in most respects. To make it truly capable of handling all types of nucleating agent dissemination, a horizontal wind tunnel for sampling the output from certain type airborne generators might be a useful addition to the facility.

Conclusions

The NSF and NSF/RANN (with co-sponsors) support of the development and operation of the CSU Isothermal Cloud Simulation Chamber and ancillary fixtures has permitted the establishment and operation of a standardized calibration service for the evaluation of the relative effectiveness of artificial cloud nucleating agents and delivery devices, and of cloud physics research instrumentation. The services of the facility have been made available to all classes of users. The cooperation of a facility personnel and the response to users' needs, including timely performance of calibrations, have been considered exemplary by the majority of users interviewed. All but one of the twelve users interviewed expressed satisfaction with the services rendered.

The stature of Dr. Lewis O. Grant in the field of weather modification and cloud physics, and the need for a test facility arising from CSU involvement in a long-term experimental weather modification program at the time of the development of the facility, contributed to superior management and the creation of a practical and versatile design.

The facility has been in existence for approximately 10 years and knowledge of it is universal among the relatively small worldwide community of weather modification and cloud physics research scientists and commercial

operators. Participation by Dr. Grant, his colleagues, and students in national and international conferences on weather modification and cloud physics and publication of articles in technical journals, have aided in the dissemination of information concerning the existence and capabilities of the facility.

Many Federal and local government procurements, including interagency agreements concerned with cloud or weather modification, are now requiring effectiveness data or calibration data for nucleating agents or devices to be provided prior to contract award. To a large extent, these data are required for environmental impact statements evaluating the possible effects of planned operations. Such requirements will provide a continuing demand for the services of the CSU facility.

RANN UTILIZATION EXPERIENCE

CASE STUDY NO. 25

FEASIBILITY STUDY:
COORDINATION OF DATA COLLECTION ACTIVIES ON THE NATION'S BUILDING INVENTORY

NATIONAL ACADEMY OF SCIENCES

Case Investigator:

D. F. Tolman

Research Triangle Institute
P.O. Box 12194
Research Triangle Park
North Carolina 27709

Technical Reviewer:

J. Mirza

Department of Civil Engineering
North Carolina State University
Raleigh, North Carolina 27607

Prepared under:

Contract No. NSF-C76-17165
National Science Foundation
Research Applied to National Needs
1800 G Street, N.W.
Washington, D.C. 20550

FEASIBILITY STUDY:
COORDINATION OF DATA COLLECTION ACTIVITIES
ON THE NATION'S BUILDING INVENTORY

Introduction and Summary

The national inventory of buildings is an enormous investment estimated to represent more than half the nation's physical wealth. This resource is continually growing and changing and requires major additional resources for operation and maintenance. It is somewhat surprising that less is known about this resource--its size, changes, input requirements and composition--than is known about other types of physical wealth, e.g., farmlands, minerals, highways or automobiles.

Most building-related statistics focus on new construction, thus obscuring the importance of existing structures. Largely due to the lack of data, there are no official comprehensive estimates nor statistical information about existing buildings. The only exception is the census of residential real estate. Thus, there are no effective measures that describe the characteristics of the building inventory, indicate how the inventory is changing, or that can be used to define future resource requirements. The lack of a building inventory is a national problem inhibiting effective utilization and management of this, the largest national resource.

To provide data for identifying problems related to the broadly defined area of buildings and structures, the Building Research Advisory Board (BRAB) of the National Research Council undertook a study of the subject in 1971.

During initial discussion with interested Federal agencies, BRAB staff discerned a growing concern on the part of Federal agencies, as well as in Congress, about the difficulty of measuring the potential impact of natural and manmade disasters on buildings, and gathering the relevant data needed to develop hazard mitigation plans. However, BRAB believed it necessary to continue to address the broader issue, i.e., the data needs of the building community (public and private) involved in planning, design, construction, operation, maintenance, replacement, ownership, finance, insurance, regulation, taxation, law enforcement, policy determination, and disaster mitigation.

In September 1972, BRAB informally surveyed several Federal agencies to determine what building inventory data collection activities were being carried out and the type of data the agencies would be interested in obtaining. After being briefed on the results of this effort, representatives of the cooperating agencies urged the Board to develop a formal program. BRAB staff acted upon this recommendation. The program, as proposed, was for a feasibility study for a national building inventory. It received funding from the National Science Foundation and the Defense Civil Preparedness Agency (DCPA) in 1973. Relevant project information is given in table 25-1.

The objective of this project was to determine the feasibility of coordinating data collection activities and survey procedures relating to establishing the characteristics of the nation's housing, buildings, and related facilities. If research efforts indicated the feasibility of such a program, a framework for follow-on efforts was to be recommended and guidelines formulated for a data collection and survey procedures coordination program, national in scope, that could be exposed to a large audience for review and then set forth

Table 25-1. PROJECT INFORMATION

Project Title	Grant/Contract No.
Feasibility Study of Building Inventory Survey	P313303/C310-266-000
RANN Program Manager C. C. Thiel J. B. Scalzi	**RANN Program Area** Building Research
Principal Investigator(s) Robert M. Dillon Executive Director Building Research Advisory Board (BRAB) National Research Council	**Schedule** Start: July 1973 End: February 1974
Institution National Academy of Sciences 2101 Constitution Avenue, N.W. Washington, D.C. 20037	**Funding** NSF: $25,000 Other: DCPA-$25,000 (CAHC 20-73-0273)

Contributors/Collaborators

Joan D. Finch, Staff Officer (BRAB)
Samuel Dennis, Consultant
Marika Sumichrast, Research Associate

User Advisory Committee

The BRAB committee under whose direction this study was conducted was representative of government, academia, and the private sector, and includes individuals possessing expertise in the various disciplines and fields of knowledge and experience involved. (See Appendix A).

Precursor Activities

BRAB activities leading up to the subject research.

as a proposed plan of action. These guidelines, if approved, would be a plan of action for the program.

This project was limited to the gathering of data and information by Mr. Dillon, the Principal Investigator; the convening of three workshops in which the data provided a basis for studies and analysis; a committee consideration of the results and conclusions; and preparation of a draft report.

The products of the feasibility study consisted of conclusions pertinent to a building inventory, recommendations for further study, and the stimulation of cooperation among organizations that participated in the study so as to cause them to share current building inventory data. Ultimate utilization was to occur after the proposed follow-on research had been completed and a successful national building inventory program became a reality.

Because of funding limitations--actual funding was only half of that requested--the study results have not been presented in a final report. This has limited utilization to those who participated in the study or who have had access to the draft report. Although relatively little utilization of this feasibility study has occurred, implementation of its recommendations as a national building inventory program could provide major utilization. Those who have been exposed to and utilized this project do not find fault with it as far as it goes. However, they are not generally supportive of a national inventory of buildings because of the associated costs, as revealed in the study, and an uncertain assessment of the benefits which would be contingent upon the results of the proposed follow-on study.

Research Description

Accurate and detailed information on the nation's building inventory has long been a need of many public and private organizations. Data on the status of existing facilities are essential prerequisites to the establishment of sound planning and development goals and the development of criteria and standards for the design, construction, operation, maintenance, repair, rehabilitation, and replacement of such facilities. To date, only isolated and special purpose surveys have been conducted to collect such data.

For many years BRAB has focused on the need for building information. However, the scope of the overall task and limited resources permitted satisfying only a small part of the information requirements. Many factors, such as the performance concept in building management and life-cycle costing techniques, have sharpened the building community's interest in the accumulation and utilization of detailed building inventory data. Needs for these data are being felt in the desire for improved quality and lower costs; in planning for mitigation of the impacts of natural disasters; and in energy and natural resources conservation programs.

These and other factors rekindled BRAB's efforts to launch a program to develop a comprehensive building inventory. Impetus was added in late 1971 by the Defense Civil Preparedness Agency (DCPA--then the Office of Civil Defense) request to BRAB for guidance on how to more effectively relate DCPA's training programs to on-going building construction. At that time, BRAB initiated an informal survey to define the nature and extent of building inventory data available in 40 government agencies. After discussing the survey results with

the participating agencies, BRAB submitted a proposal to NSF/RANN that led to the contract for a feasibility study.

The research effort focused on:

- Identification and documentation of existing data collection efforts to include types of information obtained and uses for both the public and private sector.
- Description of data requirements for existing facilities.
- Preparation of conclusions and recommendations relative to the feasibility of conducting a national building survey.

Tasks performed during the course of the study include:

- A survey of Federal, State and local governments, and of private organizations to determine representative data collection activities and data needs.
- Three exploratory workshop/discussion sessions with participation from the Committee and representatives of the organizations surveyed.
- Review and assessment of the results by the Committee.
- Preparation, review, and approval of the Committee's report.

During the course of the study, representatives from relevant fields met in three workshop/discussion sessions to identify and describe potential data sources, identify potential users, and develop draft recommendations for the proposed follow-on study to generate the building inventory. As a result of the workshops and the survey of existing data and data collection activities on the building inventory, the draft study report discusses in general terms:

- The significance of a building inventory,
- Needs for building inventory data,

- Scope of required data collection activities,
- Nature of available data,
- Relations of needs to collected data,
- Costs in relation to benefits, and
- Feasibility of coordinating data collection activities.

It was concluded that it would be desirable to coordinate data collection activities on the nation's building inventory among the many organizations involved. However, because of the complexity and scope of the data needs and magnitude of the problem, the degree of coordination that actually would be feasible requires further study.

The research was completed in February 1974 and a draft report subsequently prepared.

The BRAB study has also indicated that, on a preliminary basis, sources of data are available for use in compiling a nationwide building inventory. As a part of the project, BRAB has developed both a sample frame for more detailed data collection, and comparability and compatibility standards for on-going building census activities. A significant project result is the demonstration that collaboration can take place among the various Federal, State, local and private agencies in the collection and sharing of building data. Appendix B lists the agencies and private concerns that cooperated with the BRAB study proposal.

Utilization Objectives

This project, being a feasibility study, has a limited set of users: those organizations that are potential initiators, performers, or participants in the building inventory coordination activity that might ensue. Utilization is restricted to the use of the study results in reaching a decision on whether to initiate coordination of a national building inventory survey. Because of the limited number of users involved in this decision process, a report on the research was considered adequate for disseminating. During the course of the research, both the results gained and the workshops provided effective dissemination mechanisms.

Other types of utilization were not anticipated until after follow-on research and implementation was completed.

Utilization Obtained

This project is different from many RANN research projects in that it is an initial feasibility study that is incomplete and for which no final report has been distributed. Before anticipated utilization can be realized, the report must be issued. Ultimately, utilization depends on instituting the building inventory.

Project utilization to date is limited to the stimulation of cooperation among the many organizations that participated in the study and the information provided to the workshop participants and readers of the draft report that aids them in decisions on the building inventory. Discussion, therefore, is also

directed toward potential utilization after the proposed follow-on research has been completed and a successful national program becomes a reality. Outlooks for this have been influenced by the feasibility study.

Many of the potential users contacted are also potential participants. Some were involved in the formative stages of this research. User comments would have been more meaningful if all individuals interviewed had read the draft report. Appendix B lists Federal, State, local and regional governmental agencies and private companies that cooperated in the initial research.

Federal Agencies

Dr. Theodore H. Levin, Chief Economist, Federal Insurance Administration, Department of Housing and Urban Development is a potential user. His major responsibility is for flood and disaster insurance. Dr. Levin is very familiar with, and interested in, the housing inventory research. He participated in early BRAB meetings both to help determine how the research results might be utilized effectively, and to identify typical users. Although he has not seen the draft report, he believes that RANN programs, and this project in particular, are an excellent means of helping working level agency staff. His major interest is in construction data on industrial and commercial buildings and in disaster economics. Dr. Levin believes the proposed follow-on research is urgently needed. He thinks that for states and communities to benefit from revenue sharing, they should have certain reporting requirements based on consistent building and land use codes. He says his organization would be a major user of the resultant inventory.

Mr. Arthur F. Young, Chief, Housing Division, Bureau of Census, is familiar with and participated in formulating the initial research. He points

out that in addition to being a potential user of the inventory, his agency would be a major contributor for residential building data. While he believes that the research is important and worthwhile, he suggests that it may be "ahead of its time." Until the land use planning bill (Jackson Bill) is revived in Congress and eventually becomes law, not much will happen. Then all data should be collected using land units as a common denominator. Mr. Young thinks potential users have trouble conceptualizing how the data could be used. He also suggested that a geographically limited demonstration or pilot project be used to generate statistical tables that would demonstrate the value of the data to users.

Mr. James Roembke, Deputy Assistant Director, Engineering Support Division, Defense Civil Preparedness Agency, is another potential user. Because the Defense Civil Preparedness Agency (DCPA) co-sponsored the research with NSF, Mr. Roembke is well aware of the project and the potential benefit to DCPA if a successful national program results. However, because his agency is primarily interested in physical building characteristics, he believes that the BRAB study committee was far from the optimum mix in that it lacked sufficient engineering or technical representation. He sees a tremendous effort required to educate the Congress regarding the national need and a requirement for an Executive Order for budget consolidation on data collection among Federal agencies. He is concerned that sponsorship or funding to implement the program will not be obtained and that much of the early study momentum and enthusiasm has already been lost. He believes that the study was underfunded after the Office of Emergency Preparedness, now the Federal Preparedness Agency, and HUD declined to provide support.

Mr. Melvin Martin, Research and Development Office, Chief of Engineers, U.S. Army Corps of Engineers, is familiar with the research and attended two of the BRAB meetings in the early stages of the project. He indicated that the Corps of Engineers (COE) was interested as a potential user, as well as a contributor. However, he thought that the project was much too broad in scope, and that the term "data" was too loose and vague. He suggested, as he had done earlier in BRAB meetings, that the initial effort could be limited to "life-cycle costing" of buildings--perhaps operations and maintenance information. He explained that COE had good information on maintenance and operation of heating and air conditioning units, for example. He has not seen the draft final report.

Mr. Ugo Morelli, Program Officer, Federal Disaster Assistance Administration (FDAA), Department of Housing and Urban Development, attended some of the earlier RANN meetings and assisted in the initial definition of the research. At that time he was with the Office of Emergency Preparedness which was disbanded in July 1973. Its mission was reoriented toward hazard mitigation and became FDAA(HUD) with a change in priorities. It is unlikely now that Mr. Morelli, in his present position, would be a user. He suggests, however, that major potential users would be State and local agencies.

Mr. Robert Crist, Chief, Structures Section, National Bureau of Standards, has responsibility in the area of structural research over a broad range of building types. He has heard of the research but has not been involved, nor has he seen the draft report. As the project was described to him, he felt that the results would probably be peripheral to his interests although he might be a future user.

State and Local Agencies

Mr. John Cook, Metropolitan Development Department, City and County of Indianapolis, is familiar with the research, but has not seen the draft report. Until May 1974, he was Deputy Commissioner of Buildings, New York City and had worked closely with the New York State Urban Development Corporation which is a public benefit agency involved with the development of civic and residential housing. Building inventory data would have been of much value in the persuance of housing developments by the Urban Development Corporation. That agency, however, will be dissolved or severely cut back by July 1977. A moratorium has already been placed on new projects. Under the present circumstances, Mr. Cook does not foresee his present department agency as a user. However, he believes that his successor in New York, Mr. Andrew Jenkins, the current Deputy Commissioner of Buildings, as well as his counterparts throughout the country, are potential users.

Mr. Victor E. Hagen, Acting Director, Public Facilities Department, City of Boston, whose department is responsible for planning, design, and construction in the city of Boston, has been active in the formation of the Construction Research Council, initiated by the Building Research Advisory Board, and now an independent non-profit organization. During frequent visits to Washington, D.C., he became acquainted with his project in its early stages. He believes that the building inventory is too ambitious and broad in scope and would take years for useful development. He has no clear understanding of what the ultimate results could or should be. Nevertheless, he feels that building data could be potentially very useful to him and his counterparts throughout

the country as well as others involved in city planning, in capital improvements, and in optimizing the use of municipal resources. He strongly stressed the importance of standardization of data. Mr. Hagen also points out that cities in this country are now very parochial with little interplay of information or ideas.

Mr. Calvin Hamilton, Director of Planning, Department of City Planning, Los Angeles, is also a potential user. As a BRAB member, Mr. Hamilton assisted in the initial formulation of the research. He definitely believes that the project is feasible and that the implemented program would be invaluable, not only to him, but to a wide audience of potential users--particularly local, regional, and State planning agencies. He recommends using existing governmental channels for program implementation. For example, he suggests using the county assessors' regular function of data collection. By providing instruction, training, and assistance to them, the desired data base could be gradually expanded to meet user requirements.

Private Organizations

Mr. Maurice H. Gardner, Manager, Project Operations, General Electric Company, is Vice Chairman of the Planning and Design Resource Council of BRAB's Technology Assessment and Utilization Forum. Mr. Gardner is familiar with the project and has read the draft report. He is overwhelmed by the immensity of the project and feels that unless the broad scope is limited in some way, implementation would be very difficult, if not impossible. In his position, he is particularly interested in one facet--industrial buildings and manufacturing facilities that are available for purchase. He finds it difficult even within G.E. to keep up with the building inventory and find space

for people as required. Others within G.E., such as marketing people, are potential users. He feels that basic building inventory items must be isolated in order to be used. The outcome and format of the research will determine its usefulness to him.

Dr. Donald T. Lyon, Engineering Manager, Engineering, Building, Planning and Designs, American Telephone and Telegraph Company, is responsible for policy on building, planning and design for the Bell System. He is familiar with the research although he has not seen the draft report. He indicated that he might be a user if and when the program is implemented.

Features

The overriding features of this Feasibility Study: Coordination of Data Collection Activities on the Nation's Building Inventory, are (1) the project was not completely funded, (2) the final report has not been issued, (3) definitive results have not been obtained, and (4) as a feasibility study, only limited utilization was to be expected. In the light of these conditions, the utilization of the study results is good. The limited community of users targeted by the study, i.e., those individuals in a position to act on or influence follow-on recommendations, know about the study and its findings.

To some extent, the feasibility study appears successful in that an increased number of individuals seems to be cognizant of the possibility of a building inventory survey and its value to many activities. However, because the follow-on recommendations have not been acted upon, funding for continued study is not available, and the final report has not been issued two years after completion of the study. It appears that the results have, as yet, not been sufficiently convincing.

The study itself appears to have been partially accomplished by committees with the principal investigator as its executive arm. Funding, as pointed out, was 50 percent of that for which the study was planned--an indication of the difficulties in attempting to coordinate a multi-agency effort. The study itself, involving input as it did from a number of the potential users, was competent and well planned.

Although the time delay in reporting and acting on the feasibility study has been criticized, it may be that a building inventory survey is a sufficiently formidable task so as to require considerable incubation before it can be accepted. When the report is issued and receives exposure, perhaps support will build until, at a fortuitous time, action will be taken. However, this is conjecture--there is little evidence to indicate that it will occur.

The most significant barrier to final utilization of the results is clearly the apparent high cost of the building inventory survey and an inadequate compilation of benefits.

Conclusions

The draft report is broad in scope and coverage. Considerable effort has been expended. However, the question of feasibility has not been explicitly answered and perhaps it really can't be answered without the recommended follow-on program aimed at developing specific quidelines for creating a data collection mechanism that can be submitted to a large audience for review and subsequent refinement and recommendation for action.

The following obstacles to the recommended follow-on program, supported by potential user opinion, are summarized:

- A final report on the initial research has not been distributed.
- The delay in follow-on research has reduced the study momentum and enthusiasm.
- Potential users have difficulty in understanding what the results of the data would or could mean to them.
- The proposed program may be too broad and ambitious.
- A tremendous effort is required to educate Congress and an Executive Order for budget consolidation on data collection among federal agencies may be required.

An inevitable conclusion of this case study is that the record is incomplete and the utilization of incomplete feasibility studies is bound to be questionable. This, however, should not be interpreted as being critical of feasibility studies. Such studies with limited funding are necessary in order to intelligently carry out large complex research programs, e.g., RANN.

This study, for good reason, has limited utilization. Its users are found in a small community of individuals--mostly Federal officials, with interests in buildings. In a broad sense, these users have been influenced by the study, but not to the extent that changes have resulted.

There remains a potential for utilization that, if it results in a building inventory survey, could have far-reaching and profound effects in many activities.

Appendix A

NATIONAL RESEARCH COUNCIL

BUILDING RESEARCH ADVISORY BOARD

COMMITTEE ON

A FEASIBILITY STUDY ON COORDINATION DATA COLLECTION

ACTIVITIES ON THE NATION'S BUILDING INVENTORY

Chairman

ROBERT M. FISHER, Chief, Mortgage, Agriculture and Consumer Finance Section, Federal Reserve Board, Washington, D.C.

Members

FREDERICK M. BABCOCK, Frederick M. Babcock & Co., Chevy Chase, Maryland

ROBERT B. BARROWS, Senior Vice President-Investment, Northwestern Mutual Life Insurance Co., Milwaukee, Wisconsin

JOHN J. CALLAHAN, Senior Analyst, Advisory Commission on Intergovernmental Relations, Washington, D.C.

MARION CLAWSON, Director, Land Use and Management Program, Resources for the Future, Inc., Washington, D.C.

CHARLES M. HARR, Louis D. Brandeis Professor of Law, Harvard University, Law School, Cambridge, Massachusetts

OLIVER H. JONES, Executive Vice President, Mortgage Bankers Association of America, Washington, D.C.

EDWARD A. KAEGI, Bloomfield Hills, Michigan

FRANK S. KRISTOF, Director, Division of Economics and Housing, New York State Urban Development Corporation, New York, New York

KATHERINE MARTINI, Director of Research, National Association of Realtors, Washington, D.C.

JOSEPH E. MINOR, Research Associate and Lecturer in Civil Engineering Texas Tech University, Lubbock, Texas

WILLIAM H. SCHEICK, FAIA, Silver Spring, Maryland

JOHN H. WIGGINS, JR., President, J. H. Wiggins Company, Redondo Beach, California

Staff

JOAN D. FINCH, Staff Officer

SAMUEL DENNIS, Consultant

MARIKA SUMICHRAST, Research Associate

Appendix B

ORGANIZATIONS COOPERATING IN THE BRAB
BUILDING INVENTORY SURVEY FEASIBILITY STUDY

Federal Government

ATOMIC ENERGY COMMISSION (AEC)
Division of Construction

DEPARTMENT OF AGRICULTURE (USDA)
Economic Research Service
Farmers Home Administration
Forest Service
Real Property Management
Rural Electrification Administration

DEPARTMENT OF COMMERCE (DOC)
Bureau of the Census
  Construction Statistics Division
  Housing Division
National Bureau of Domestic Commerce
  Construction and Building Materials Program
National Oceanic and Atmospheric Administration

DEPARTMENT OF DEFENSE (DOD)
Department of the Air Force
U.S. Army Corps of Engineers
  Civil Work, Engineering Management Branch
  Civil Work, Planning Division
  Civil Work, Structures and Engineering
  Military Construction and Real Estate
  Program Planning, Construction and Planning Division
Defense Civil Preparedness Agency
  Research and Engineering, Engineering Support Division
Naval Facilities Engineering Command
  DCPA Support Program
  Engineering and Design
  Facilities Assets
  Facilities Planning and Real Estate
  Housing Planning and Acquisition Division
  Research and Development, Cold Regions

DEPARTMENT OF HEALTH EDUCATION AND WELFARE (HEW)
Office of Facilities and Property Management

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT (HUD)
Community Planning and Development
Federal Disaster Assistance Administration
Federal Insurance Administration
Housing Management
Housing Production and Mortgage Credit
Policy Development and Research

DEPARTMENT OF THE INTERIOR (DOI)
Bureau of Land Management
Bureau of Mines
Bureau of Reclamation
National Park Service
U.S. Geological Survey

DEPARTMENT OF LABOR (DOL)
Bureau of Labor Statistics

DEPARTMENT OF TRANSPORTATION (DOT)
Federal Highway Administration

ENVIRONMENTAL PROTECTION AGENCY (EPA)

GENERAL SERVICES ADMINISTRATION (GSA)
Public Building Service
  Building Management
  Design and Construction
  Federal Protection Service Management
  Office of Real Property
  Space Management
Automated and Telecommunications Service
Office of Federal Management Policy
Office of Preparedness

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)
Programs and Engineering Division

NATIONAL SCIENCE FOUNDATION (NSF)
Advanced Technology Application Division/RANN

OFFICE OF MANAGEMENT AND BUDGET (OMB)

U.S. POSTAL SERVICE (USPS)
Real Estate and Building Department

VETERANS ADMINISTRATION (VA)
Office of Construction

Local and State Governments

CITY OF BOSTON
Public Facilities Department

CITY AND COUNTY OF INDIANAPOLIS
Metropolitan Development Department

CITY OF LOS ANGELES
Department of City Planning

CITY OF NEW YORK
Department of Building
Department of City Planning

STATE OF INDIANA
Administrator's Building Council (Indianapolis)

STATE OF NEW YORK
Urban Development Corporation (New York City)

Regional Agencies

NORTHWESTERN INDIANA REGIONAL PLANNING COMMISSION (Highland)

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION (Waukesha)

TRI-STATE PLANNING COMMISSION (New York, New York)

Private Sector

AMERICAN TELEPHONE AND TELEGRAPH COMPANY
Engineering Buildings (New York, New York)

BUILDING OWNERS AND USERS, INTERNATIONAL (Chicago, Illinois)

FEDERAL STATISTICS USERS' CONFERENCE (Washington, D.C.)

INSURANCE SERVICES OFFICE (New York, New York)

McGRAW-HILL
Dodge Division (New York, New York)

NATIONAL ASSOCIATION OF HOME BUILDERS
Department of Economics and Statistics (Washington, D.C.)

NATIONAL ASSOCIATION OF REALTORS
The Department of Economics and Research (Washington, D.C.)

PRODUCERS COUNCIL, INC. (Washington, D.C.)

SANBORN MAP COMPANY, INC. (Pelham, New York)

URBAN LAND INSTITUTE (Washington, D.C.)

WILLIS AND ASSOCIATES, INC.
Environmental Planners (San Francisco, California)

RANN UTILIZATION EXPERIENCE

CASE STUDY NO. 26

BIOLOGICAL CONVERSION OF ORGANIC REFUSE TO METHANE

UNIVERSITY OF ILLINOIS

Case Investigator:

J. W. Harrison

Research Triangle Institute
P.O. Box 12194
Research Triangle Park
North Carolina 27709

Technical Reviewer:

M. Overcash

Department of Agricultural and Biological Engineering
North Carolina State University
Raleigh, North Carolina 27607

Prepared under:

Contract No. NSF-C76-17165
National Science Foundation
Research Applied to National Needs
1800 G Street, N.W.
Washington, D.C. 20550

BIOLOGICAL CONVERSION OF ORGANIC REFUSE TO METHANE

Introduction and Summary

The research described in this case study was directed toward two national needs: a need for an economic and environmentally safe means of disposal of urban refuse and a need for an alternative energy source as a supplement to fossil fuels. Urban solid wastes are currently generated at the rate of almost 50 million tons per year. Incineration and landfill, the present disposal practices, are subject to several drawbacks. Incineration requires auxiliary energy input and generates pollutants that must be controlled by additional capital and energy investment. Use of biological unstabilized refuse in land fills can result in uncontrolled generation of gases as decomposition occurs with subsequent possible settling of the fill area, making it unsuitable as a building site.

In another study* an economic comparison was made of four principal processes for the recovery of energy from municipal solid waste. These are: incineration with energy recovery; production of a solid, refuse-derived fuel for co-combustion in a utility or industrial boiler; pyrolysis of organic components to produce a fuel gas or combustible liquid; and anaerobic digestion of the organic fraction of refuse to produce methane. The cited study indicates that, at present, the latter method is the most costly in terms of dollars per ton of refuse.

---

*H. W. Schulz, "Energy from Municipal Refuse: A Comparison of Ten Processes," Professional Engineer, pp. 20-24, November 1975.

This RANN supported research performed at the University of Illinois, focused on that latter method. It included: (1) an evaluation of the potential for economic production of methane gas by biological fermentation of urban refuse; (2) the generation of process data to facilitate design of large-scale systems; and (3) the development and validation of a mathematical process simulator that would permit evaluation of various unit process combinations under various operating conditions. Digestion by anaerobic bacteria has been used for many years for wastewater treatment to reduce organic sludges and obtain more stable, easily dewatered residues.

Prior studies by the Principal Investigator, Dr. John T. Pfeffer, had established that garbage can be anaerobically decomposed if suitable conditions of temperature, pH, absence of oxygen, and toxicants are maintained and the supply of nutrients is adequate. As decomposition takes place, methane, along with carbon dioxide, is generated. This precursor research provided an analytical and theoretical base for the NSF/RANN study. Project information is given in table 26-1.

In this research, laboratory studies were used to develop reliable design parameters for the anaerobic fermentation system, to evaluate the dewatering characteristics of the residue slurry, to determine means of increasing the efficiency of solid to gas conversion, to evaluate alternate means for residue utilization, to investigate the effect of recycling of filtrate back to the fermenter, and to determine the treatability of the filtrate. Concurrently an analytical model was developed for computer simulation of various process configurations and operating conditions to evaluate the economics of the overall process and provide a basis for comparison with other processes.

Table 26-1. PROJECT INFORMATION

Project Title Biological Conversion of Organic Refuse to Methane	**Grant/Contract No.** GI-39191 (AER73-07872 A02)
RANN Program Manager Dr. Roscoe Ward (1973) Dr. Richard Bogan (1974) Dr. Tapan Mukherjee (1975) Transferred technical responsibility to Dr. Ward (ERDA) on December 16, 1975	**RANN Program Area** Energy Research & Technology
Principal Investigator(s) Dr. John T. Pfeffer, Professor of Civil Engineering	**Schedule** Start: June 1, 1973 End: May 31, 1976
Institution Department of Civil Engineering University of Illinois Urbana, Illinois	**Funding** NSF: $284,900 Other:
Contributors/Collaborators Dr. Jon A. Liebman, Professor Systems Engineering Dr. Charles S. Walters, Professor Department of Forestry	
User Advisory Committee See Table 26-2, page 26-11.	
Precursor Activities Grant No. EPA-R-800776, Environmental Protection Agency, Cincinnati, Ohio	

Based on the process improvements generated by the research, the Principal Investigator estimates that for a 42 ton per day unit the operating costs would be about $9.70 per ton. This compares to $13.31 per ton estimated by Schulz in the previously cited article.

In assessing the degree of utilization of this research, 22 individuals representing government, industry, academia, engineering and consulting firms, and research and development firms were contacted and provided useful information.

In summary, the following utilization features and factors stand out:

- The research is generally regarded as well done.
- Considerable efforts have been made by both the Principal Investigator and NSF/RANN to publicize the work, to obtain user involvement, and to maintain coordination with related research efforts.
- Private industry, as well as local government units, are still skeptical of the economic feasibility of the process and are reluctant to invest funds in a "proof of concept" plant to generate engineering and economic data for a large-scale operation.
- The Energy Research and Development Administration (ERDA) is currently undertaking the "proof of concept" experiment for urban waste processing.
- ERDA is also planning to use bioconversion to generate methane from agricultural residues and possibly from crops.
- The Department of Agriculture (USDA) is also evaluating the use of feedlot wastes to generate methane.

With regard to utilization, the research appears to have been well-conceived and well managed by both the Principal Investigator and NSF/RANN.

Research Description

The Principal Investigator for this research is Professor John T. Pfeffer, Department of Civil Engineering, University of Illinois (Champaign-Urbana). Dr. Pfeffer had previously studied anaerobic fermentation of the organic fraction of urban refuse under EPA sponsorship*. This prior work provided an important basis for the NSF/RANN sponsored research. Dr. Pfeffer has overall project coordination responsibility and directly supervises the laboratory process evaluations. The mathematical simulation and economic evaluation analysis were carried out by Professor Jon A. Liebman of the Department of Systems Engineering using data from the experimental work as well as from prior and concurrent work by others. During one phase of the project, Professor Charles S. Walters of the Department of Forestry investigated the use of residues from the digestion process for synthesis of fiber board laminates. This was for the purpose of evaluating residues as building materials.

The project was initiated by NSF/RANN at a funding level of $83,900 for the first year on June 1, 1973. Dr. R. F. Ward was the NSF/RANN Program Manager. In the second year, the funding was increased to $101,000 and Dr. R. H. Bogan became Program Manager. In the third and final year, $100,000 was provided and Dr. T. Mukherjee became Program Manager. On December 16, 1975, the project was transferred from NSF to the Solar Energy Division of ERDA, with Dr. R. F. Ward again assuming technical responsibility.

---

*John T. Pfeffer, "Reclamation of Energy from Organic Refuse," Final Report on EPA Grant No. EPA-R-800776, Department of Civil Engineering, University of Illinois, Urbana, Illinois, April 1973.

Initial experiments on fermentation were carried out with a 400 liter unit to identify process variables. Empirical equations for the mathematical simulation were developed using these variables as well as data from the literature and from prior University of Illinois studies. Subroutines of the model for the fermentation and vacuum filtration dewatering unit operations were also developed during the first year. By the end of the first year's effort, the fermentation unit was being used to obtain sufficient quantities of solid and liquid residue for adequate characterization of reactor output slurry, dewatered residue, and filtrate.

During the second year, the rheological properties of the fermentation output slurry and settling velocity at various solids concentrations were studied. Laboratory filter test leaf procedures were used to evaluate the dewatering properties of the residue. In this procedure, a tube with a 0.1 ft^2 area opening covered with a filter cloth, is immersed in the slurry for a pre-determined period, while a vacuum accumulates a slurry cake on the filter cloth. This sample is withdrawn into the air and vacuum applied for a second pre-determined period to dry the cake. Following this, the accumulated cake is weighed. Pilot scale tests of a horizontal bowl conveyor centrifuge were initiated. Additional subroutines for centrifugation, dewatering, and residue disposal by direct haul of ash and inerts to landfill were added to the mathematical model. A model for the "front end" process (receiving, shredding and separation), determined to be inadequate, was revised to reflect state-of-the-art advancements. These subroutines are used in conjunction with a main program. The main program maintains influent and effluent information for the various subroutines and provides information on mass and energy flows, and on costs for the various processing steps.

At this point in the project, only about 60 percent of the organic fraction of solids was being converted to gas, providing on the average about 5.4 standard cubic feet (scf) of gas per pound of volatile solids added to the fermentation unit with a retention time of 10 days. The resulting effluent, of which approximately half was carbon dioxide, had a heating value of about 500 Btu/scf, about half that of pure methane.

One of the problems suspected was incomplete digestion of cellulosic fibers due to the presence of lignin. By the end of the second year, experiments were underway to determine the effect of adding caustic (sodium hydroxide) at various temperatures to break down the cellulose-lignin bond prior to digestion. It was proposed that this work be carried over into the third year to obtain kinetic data.

Also, during the second year, several types of fiberboard containing varying amounts of phenolic-formaldehyde adhesive were prepared using several different curing times. The mechanical properties were investigated and additional processing variations were recommended for further study during the third and final year of the project. During the review of the third-year proposal, it was recommended that this effort be discontinued because the economic factors for this end-product were marginal.

In the third and final year, the effect of caustic pretreatment was studied. Because this affects the character of digested solids the dewatering properties of the residue and treatability of the filtrate had to be re-evaluated to modify the computer simulation model. Sensitivity analyses were carried out to determine the effect of changes in the many operating variables on the overall cost of operation. The input and output

formats were reconfigured to provide displays that would be more readily comprehensible to a plant designer. As of the preparation of this case study, the work is nearing completion. The final report is being prepared in two volumes. The first volume will contain information and guidelines for process design engineers. The second volume will be a more conventional research report covering the work of three years and will include a complete listing (with documentation) of the computer program for the process simulation.

The products of this research are:

- Experimental data on the kinetics, energy, and mass balances of fermentation and of dewatering and treatment processes suitable for use by other researchers as well as designers;
- A mathematical simulation program that models energy and material flows, provides cost factors for the processing operations, and permits a sensitivity analysis to determine the effect of process variable changes on operating costs.

The significance of this research is that, according to the Principal Investigator, it provides a method of urban waste disposal and permits extraction of energy that may ultimately provide 5 to 10 percent of urban natural gas energy needs. Skepticism about the economic viability of this method on the part of commercial gas utilities has resulted in hesitancy to commit private investment funds for a "proof of concept" plant that would evaluate operational, technological, and economic features. In the absence of private funding, ERDA is now engaged in the "proof of concept" research.

Utilization Objectives

The research results were envisioned to be of interest to four major groups: commercial energy suppliers (gas utilities), industrial energy users (electric utilities, industrial power plants, industrial heating, etc.), public waste management officials, and the private waste management industry. Experimentally derived data on kinetics, mass and energy flows, and balances were expected to provide a basis for large-scale process design. The process analysis and mathematical model were expected to provide additional flexibility in assessing process design variations on operating efficiency and cost.

User involvement was to be obtained through an advisory committee and through active dissemination of information on the research objective and activities. The advisory committee, with membership as shown in table 26-2, was scheduled to meet quarterly, with meeting results subsequently reported to the NSF staff. This committee was to provide guidance both to this project and to one at Dynatech Research and Development Company being sponsored concurrently by NSF/RANN. The Principal Investigators, Dr. Wise of Synatech and Dr. Pfeffer of the University of Illinois, were members of the committee. Participants from NSF/RANN are not listed.

It was planned that dissemination of research information would be accomplished by keeping each of the four major user groups aware of the status and progress of those aspects of the research germane to their interests. This communication was to take place through public information (media releases), personal contact, by telephone or visit, contacts with trade organization representatives and trade journals. These were to be supplemented by the more conventional (but slower) communication by presentation

Table 26-2. Advisory Committee on Biological Conversion of Waste

Name	Organization	Representation
J. W. Sawyer	Resources for the Future	Non-Profit Interest Group
Rolf Skrinde	Reynolds, Smith and Hills	Engineering Consultants
William Morse	Columbia Gas System Service Corp.	Industrial Gas Utility
Ab Flowers	American Gas Association	Gas Industry Trade Organization
Dwain Spencer	Electric Power Research Institute	Non-Profit Electric Utility Research Organization
Howard Scott	Consolidated Natural Gas Services Co.	Industrial Gas Utility
Steven Levy	Solid Waste Mgt. - EPA	Federal Government-Pollution Control
Richard Speece	College of Engineering Drexel University	Academic
Vern Heisel	National Center for Resource Recovery, Inc.	Non-Profit
Donald Wise	Dynatech Research and Development Co.	Private Contract Research
John Pfeffer	Department of Civil Engineering University of Illinois	Academic

of papers at symposia and conferences, publications in technical and scientific journals and periodic formal reports to NSF/RANN. The latter were to be distributed to a specific list of interested individuals and organizations. More general report distribution was to be achieved through NTIS.

Utilization Obtained

To assess the degree of research utilization, 22 people were contacted from the list of 104 names on the NSF report distribution list for this project. These contacts provided the following organizational representation:

- National, state, local government 6
- Industry 6
- University 2
- Engineering and consulting 5
- Research and Development 3

The names and organizations represented are shown in table 26-3. Results are presented in the following paragraphs.

Engineering and Consulting Firms

Representatives from five engineering and consulting firms presented varied and contrasting responses. One firm had received the reports but had not used the information and did not plan to at any time in the foreseeable future. They were "keeping informed." A second firm had consulted with Dr. Pfeffer when it was in the process of preparing a bid to ERDA for a "proof-of-concept" plant. It was not successful on this bid and therefore had not, and did not plan in the foreseeable future, to make use of the research. A third firm was well aware of Dr. Pfeffer's research and was very interested in bioconversion, but disagreed with the approach. This firm claimed to have a pilot plant in operation for a competitive process that would require only about 25 percent of the capital investment required for implementing

Table 26-3. Individuals Contacted and Organizations Represented in User Survey

Name/Title	Organization	Type
Daniel Newman, Director of Process Engineering	Barnard and Burke, Inc.	Engineering and Consulting
John C. Lichter, Design Engineer	Henningson, Durham, and Richardson	Engineering and Consulting
J. Stearns, Manager, Research Center	Chemetron Corporation	Engineering and Consulting
Dr. Rolf Skrinde, Vice-President	Reynolds, Smith and Hill	Engineering and Consulting
Dr. John Snell, President	Snell Environmental Group	Engineering and Consulting
Peter Vardy, Vice-President Environ. Management and Tech. Services	Waste Management, Inc.	Industry
Harlan Hirschy, Director of Technology	Corporate Research Utility	Industry
Robert Foote, Technical Services Manager	Citizens Gas and Coke Utility	Industry
Dr. Richard Carlson, Manager Products and Processes	Advanced Technology Center Allis-Chalmers Corporation	Industry
William Morse, Research Director	Columbia Gas System Service Corporation	Industry
Howard Scott, Research Engineer	Consolidated Gas System	Industry

Table 26-3. Individuals Contacted and Organizations Represented in User Survey (Continued)

Name/Title	Organization	Type
Donald Augenstein, Staff Biochemical Engineer	Dynatech Research and Development Company	R&D
Sylvia Ware, Chief, Division of Science and Technology	Ebon Research Systems	R&D
Dr. Harvey Alter	National Center for Resource Recovery	R&D
Dr. Richard Dague, Professor and Chairman Environmental Engineering Program	University of Iowa	University
Dr. Perry McCarty, Professor	Department of Civil Engineering Stanford University	University
Robert Kihlman, Director of Public Works	Sheboygan, Wisconsin	Government
John Zitnyar, Chief, Bureau of Solid Wastes	Howard County (MD) Department of Public Works	Government
William W. Hellier, Jr.	Department of Environmental Resources, Bureau of State Parks, Commonwealth of Pennsylvania	Government
Dr. R. A. Rhodes, Assistant Director, Northern Regional Research Center	Agricultural Research Service, U.S. Department of Agriculture	Government
Donald Walters	Division of Conservation ERDA	Government
Dr. Roscoe Ward	Division of Solar Energy ERDA	Government

the Pfeffer/Dynatech design. A fourth company representative characterized the Pfeffer research as good and useful. He appreciated Pfeffer's contribution in carrying the process from a laboratory to pilot plant scale.

Although the latter respondent was thoroughly familiar with the research through reading the reports and through personal contacts with Dr. Pfeffer, he had not yet reached the point where an economical engineering design could be worked out with reasonable confidence. This respondent felt that it was NSF's responsibility to either fund a "proof of concept" experiment or advocate its funding by some other agency. He felt that it was incumbent on NSF/RANN, whenever any of its research appeared promising, to carry through this next step.

The fifth engineering and consultant respondent was in a unique position. He had been retained by NSF and subsequently by ERDA as a consultant on this and similar projects. This respondent characterized Pfeffer's work as significant and useful. He considered that it had much potential, perhaps even more for the use of feedlot wastes and agricultural biomass--either wastes or purposefully grown crops--than for urban refuse methane generation. He considered that it possibly would be even more useful in "Third World" countries. At present, however, this respondent is not using this approach in a design for any of his clients.

When asked for recommendations of methods to improve research utilization, only two of these engineering firm respondents made suggestions. One considered an NSF-sponsored workshop, that he had attended, to be particularly useful and suggested that NSF continue such workshops. Another respondent recommended that each NSF/RANN-sponsored project should have a follow-up plan so that if the research appeared to justify further work,

NSF/RANN could maintain continuity through sponsorship of further effort or advocacy with other appropriate agencies.

Industry

Industry representatives also provided mixed responses. One firm has been studying methods to economically use waste wood from industrial processes. This respondent had been visiting universities throughout the country seeking ideas and was visiting the University of Illinois when he first learned of Dr. Pfeffer's research. Visits were exchanged and contact maintained. A brief experiment on waste wood from one plant indicated a low gas yield. The contact has studied the process carefully and doubts its economic feasibility, even for waste conversion, where he considers it marginal at best.

A second respondent has had many contacts with Dr. Pfeffer during the course of the research. He is not using the approach and questions the economic viability of producing methane this way. At present the capital requirements are large, and the gas cost would be high.

A third representative also considers this process for generating methane too costly. He regards the analysis of economic factors to be insufficiently substantiated because the process has not been carried out on a large enough scale. At present it appears to be too marginal for the investment of private capital for a "proof of concept" plant. This individual also estimated that only 1 to 5 percent of natural gas needs can be derived from urban wastes and that, therefore, there must be more flexibility in feedstock for the fermentation process if it is to be regarded as more than a marginal supplement. He had served as an advisor to NSF/RANN

and was familiar with the technical aspects of the research. He considered the research to be well done. To quote him, "There is no question about the quality of the work Pfeffer did."

A fourth industry representative had also served on the NSF/RANN advisory committee and was familiar with the technical and economic aspects of the process. He did not consider the economics of the process, as an alternative source for methane, to be such as to encourage private investment. He thought it more appropriate for municipal use where the relatively large amount of capital required could be financed by low interest bonds.

The fifth industry respondent characterized the research as a well-run program, "one of the better directed," and coming up with usable results. He had contact through visits as well as through reading reports and had used process data from the research, along with other inputs, to determine whether or not his company should undertake a commercial venture.

The sixth industry respondent is a direct user of the research. His company is now under contract to ERDA to design, build and operate for evaluation a "proof of concept" plant capable of handling 50 to 100 tons per day of urban waste from Pompano Beach, Florida. The design is based on the NSF/RANN sponsored research of Dr. Pfeffer, Dynatech R&D, and a study at Mitre. This respondent had maintained contact with the progress of the research through reports, telephone conversations and visits. His company considers the process to be potentially economically attractive for urban waste disposal, particularly if the off-gas can be marketed as a peak load supplement at premium prices, an eventuality which the company considers quite possible in the Northeast.

There was a variety of recommendations from industry respondents for improvements in NSF/RANN sponsored research utilization. One pointed out that for wider applicability to wood wastes, and even crops, more research needed to be done on the problem of pre-processing to break down lignin and crystalline cellulose to make them more readily digestible. Another suggested research to find bacteria requiring a lower retention time than the present 10 days, or to find some method that would provide a higher yield of methane.

Another industry respondent felt the NSF/RANN program managers were overloaded, preventing them from providing adequate supervision of the research. The same respondent noted that some research expanded in scope as it went along rather than being focused on definite objectives. His recommendation was to reduce the program manager's work load to permit more interaction with the Principal Investigator and his staff.

Research and Development Organizations

Only one of the three research and development firms contacted was apparently using Dr. Pfeffer's research results as a basis for further work. That firm has also been under contract to NSF/RANN for directly related research. The representative characterized the work on the digestion process as a "very definitive study," but pointed out that more work must be done to make the process economically acceptable. This requires increasing the fraction of solids converted to methane. Rates and conversion data from Pfeffer's work were used in mathematical simulation programs by this firm. A representative of a second firm had made personal contact with Dr. Pfeffer

and had read and used his reports. This firm disseminates a state-of-the-art process survey on bioconversion of wastes.

Universities

Only two university representatives were contacted. The first is being supported by NSF for research in the same field. He has maintained continuous contact with Dr. Pfeffer and has exchanged reports with him. His research on pretreatment has been used by Dr. Pfeffer and he, in turn, has used experimental data from Pfeffer in his own research. The second university researcher is currently using some of the process and economic data from Dr. Pfeffer's research as part of a course on solid waste management. Previously, this individual worked with a consulting/engineering firm and had used Pfeffer's research data to prepare a proposal to ERDA.

Public Officials

The last category of potential users includes national, local, and municipal officials. The first two city officials were aware of the research but had no plans for use of the results because the relatively small amount of waste generated in their jurisdictions did not justify the required capital investment. A third respondent was interested in waste and sludge disposal in public recreation parks and was only peripherally interested in the Illinois research. A fourth government official is in an area that is funding the construction of a demonstration pilot plant that will use bioconversion of feedlot wastes to produce methane and a residue enriched in nitrogen and proteins. Some of Dr. Pfeffer's research results, particularly the use of higher temperature thermophilic digestion, were used in the design of this plant.

The last two governmental respondents were from ERDA. One, in the Division of Conservation, is currently the Program Manager on a contract with Waste Management, Inc. (Oakbrook, Ill.) to design, build, and evaluate a 50 to 100 tons per day bioconversion "proof of concept" plant in Pompano Beach, Florida. Total cost of this facility is estimated at $2.4 to $3.0 million. The first phase, conceptual design, was based on the NSF/RANN-sponsored work by Pfeffer and Dynatech R&D, and on a background study by the MITRE Corporation. This phase has been completed and the report is under review at ERDA. Work on the second phase will be negotiated later. Presently, the estimated completion date is summer of 1977. This project was initiated in the Division of Solar Energy of ERDA in mid-1975, but was subsequently transferred to the Division of Conservation.

The final government official, Dr. Roscoe Ward, has had a key role in managing research and development on anaerobic digestion of wastes. He was the initial Program Manager when NSF/RANN began supporting Dr. Pfeffer's research. The Pompano Beach "proof of concept" project, now transferred to the Division of Conservation, was initiated by Dr. Ward in the Division of Solar Energy. More follow-on development work using the research of Dr. Pfeffer (as well as Dynatech R & D and others) is planned. An RFP will be issued by ERDA in the near future calling for the design, construction and evaluation of a 50-100 tons per day anaerobic digestion system using agricultural residues. It is estimated that currently some 300 to 600 million tons per year of such residues are available for such processing, i.e., about 6 to 12 times the mass available from urban wastes. Should the process prove economically competitive with other energy sources, crops could be grown specifically to provide biomass raw materials for the process.

Features

Dissemination of information on the research was accomplished as planned. Press releases from the University of Illinois resulted in broad newspaper and television coverage throughout the midwest. National coverage was achieved on a segment on the NBC/TV program, "Today." As a result, in addition to a large number of inquiries from private citizens, Dr. Pfeffer received a considerable number of requests for technical information.

Table 26-4 presents a tabulation of the distribution of these requests by organization type. Many of these requesters were added to the report distribution list, increasing the total to over 100.

In addition to the semi-annual and annual research reports, presentations were made at the following meetings and symposia:

- AIChE/GVC Joint Meeting, Munich, West Germany, September 17-20, 1974,
- Third National Conference on Waste Management Technology and Resource Recovery, San Francisco, November 14-15, 1974,
- Raw Materials for the Chemical and Metallurgical Industries Symposium, Case Western Reserve University, January 20, 1975,
- A Seminar at Cornell University, February 1975,
- Energy from Wastes Symposium, Washington, D. C. March 13-14, 1975,
- ACS Conference, Mexico City, December 1975.

The paper from item 5 above was published in the Journal of Resource Recovery and the paper from item 6 has been accepted for publication in Bioengineering.

In addition to these contacts, numerous visits by consultants and engineers, industrial firms, and governmental officials have been made to Dr. Pfeffer's laboratory to observe and discuss process details. Dr. Pfeffer

Table 26-4. Summary of Requests for Information

Type of Organization	Number
U. S. Business/Industry	22
U. S. Engineering/Consulting	18
U. S. Federal, State and Local Government	27
U. S. Universities	14
U. S. Research and Development	8
U. S. Utility Companies	4
Foreign Business/Ind./Consultants	12
Foreign Central and Municipal Governments	5
Foreign Universities	13
Foreign Research and Development	5
Total	128

has received invitations from many firms and municipalities to discuss the research. He has also served as a consultant on proposals made to the City of Milwaukee and the City of Indianapolis to construct demonstration plants. These bids were not accepted by the municipalities. He is presently consulting with Hamilton-Standard and with Waste Management, Inc., on system designs that are a direct result of the work performed on this project.

Conclusions

The following utilization features and factors stand out:

- The research work is generally regarded as well done.

- Considerable efforts have been made by the Principal Investigator and NSF/RANN to publicize the work, through user involvement and coordination with related research efforts.
- Private industry, municipal and local government units question the economic feasibility of the process and are reluctant to invest funds in a "proof of concept" plant to obtain engineering and economic data from a large scale operation.
- The Federal government, through ERDA, is currently funding a "proof of concept" plant for urban waste processing.
- The Federal government, through ERDA, is planning to apply bioconversion to generate methane from agricultural residues and possibly from crops. Through USDA, the use of feedlot wastes to generate methane is also being evaluated.

From the point of view of planned utilization, the research appears to have been well-conceived and well-managed, both by the Principal Investigator and by NSF/RANN.

Recommendations of some of the research users that pertain generally to NSF/RANN programs include:

- NSF/RANN should sponsor more workshops to bring researchers and users together.
- NSF/RANN projects should be planned for effective follow-on, either by RANN or other agencies, so that when research looks sufficiently promising, it can be propelled into use more quickly.
- NSF/RANN Program Managers should not be overloaded by having to monitor too many research efforts.

- NSF/RANN sponsored research should be focused on well-defined objectives.

Pertaining to the research area of the case study, it was recommended that:

- NSF/RANN sponsored research should be focused on well-defined objectives.

Pertaining to the research area of the case study, it was recommended that:

- NSF/RANN should sponsor basic research into methods of increasing the digestion of wood wastes and other biomass feedstock, which might have high lignin and crystalline cellulose content.
- NSF/RANN should sponsor basic research to find bacteria that would digest feedstock at a higher rate in order to reduce retention time.

The hesitation on the part of industry to invest private capital is apparently based on economic factors as presently perceived. This is particularly true for urban waste disposal as a methane source. Although there are alternative feedstocks being considered, i.e., feedlot wastes and biomass, it is not clear at what point in the future bioconversion would become cost-effective enough to be considered as a viable supplementary gas source.

RANN UTILIZATION EXPERIENCE

CASE STUDY NO. 27

FIRE AND SMOKE SPREAD IN CORRIDORS

UNIVERSITY OF NOTRE DAME

Case Investigator:

S. Plotecia

Research Triangle Institute
P.O. Box 12194
Research Triangle Park
North Carolina 27709

Technical Reviewer:

R. Liepins

Research Triangle Institute
P.O. Box 12194
Research Triangle Park
North Carolina 27709

Prepared under:

Contract No. NSF-C76-17165
National Science Foundation
Research Applied to National Needs
1800 G Street, N.W.
Washington, D.C. 20550

FIRE AND SMOKE SPREAD IN CORRIDORS

Introduction and Summary

The gross behavior and spread of unwanted fire and smoke is an extremely complex and previously only superficially researched problem. Basic studies on the combustion behavior of specific materials have been conducted, but these are insufficient for predicting the behavior and spread of fire and smoke in structures. A general approach that focuses on heat transfer, fluid mechanics and combustion could enable researchers to obtain a better understanding of the processes and analytically model the fire and smoke spread phenomena for predictive purposes. Application of this approach responds to a need for improved methods for combating destructive fires, and alleviating their effects.

This approach was proposed by a team of engineers from the University of Notre Dame under the direction of Principal Investigator Dr. Jerome L. Novotny (since deceased). Pertinent report information is given in table 27-1.

The research is designed to develop improved predictive methods for describing the movement of fire and smoke in an enclosed area. The long-term goal is the development of a numerical code for predicting the fire and smoke spread behavior in rooms and corridors as a function of availability of combustible material, geometry, and properties of lining materials and contents. This is to be accomplished with a finite-difference equation calculation procedure using a set of first-principle differential equations for the unsteady turbulent flow of gases, that include such effects as

Table 27-1. PROJECT INFORMATION

Project Title	Grant/Contract No.
Fire and Smoke Spread in Corridors	AEN 73-07749-A01 AEN 73-07749-A02
RANN Program Manager Dr. Ralph Long (NFPCA)	RANN Program Area Disaster and Natural Hazard
Principal Investigator(s) Coordinator: Dr. K. T. Yang Principal Investigators: J. R. Lloyd M. L. Doria	Schedule Start: 2/1/73 End: Not Complete
Institution University of Notre Dame Department of Aerospace and Mechanical Engineering	Funding NSF: 132,000 NSF: 74,900 University of Notre Dame: Estimated to be in excess of $25,000.
Contributors/Collaborators: Fire Research Center-National Bureau of Standards	
User Advisory Committee: None	
Precursor Activities: None	

strong buoyancy (i.e., lifting forces of hot gases), compressibility, combustion, multiple species of gases, and wall, soot and gaseous radiation. The numerical code, referred to as the University of Notre Dame Smoke and Fire in Enclosures (UNDSAFE) program, is based on experimental studies at the University of Notre Dame and the Center for Fire Research at the National Bureau of Standards (NBS).

Tests are conducted at Notre Dame and the NBS Fire Research Center to check the numerical predictions in realistic experimental situations.

The computer model supported by experimental test results and documented in technical reports is the primary product of this research. The numerical

model is applicable to small- and large-scale phenomena and can also be used to help interpret various hazard and flammability rating tests, thus being ultimately valuable for selection of construction materials, design of escape routes in buildings and optimizing fire fighting procedures.

Utilization to date consists primarily of information exchange and joint validation tests between the Fire Research Group at Notre Dame and the National Bureau of Standards Center for Fire Research. Because the project is still in a highly theoretical and uncompleted stage, the user audience is composed of technical fire researchers and academic theorists concerned with understanding the technical aspects of fire and smoke spread in enclosed areas. Planned uses thus become more significant. A concerted effort to develop a public awareness and education program has recently been initiated by the Fire Research Group to bring their expertise to the attention and perhaps use of the public. Contacts through talks, presentations, and group discussions have been made with local people and organizations having professional interests in the area of fire prevention and control.

Two major factors affect utilization at this time. First, the project is not yet complete. The model, at this juncture, while useful for replicating the behavior of fire and smoke spread in corridors, is still in a simple two-dimensional state and is not yet developed for application to more complex three-dimensional phenomena. While not a theoretical limitation, implementation is complicated by the high cost of computer time for using the model. Each computer run requires over an hour of computer time in a typical computation facility. This makes the model economically unattractive for users who are not getting free computer time as is the Fire Research Group at Notre Dame.

The project appears to be satisfying a national need by contributing to the theoretical understanding of the behavior of fire. This was supported not only by the Program Manager, Dr. Ralph Long (now deceased), but also by Drs. John Rockett and James Quintere of the National Bureau of Standards, and Dr. E. W. Jerger, liaison with the Defense Civil Preparedness Agency. The project has tremendous potential and the project staff is actively working to see that the results of their research come to eventual fruition in terms of utilization. In the short run, however, the project staff, in the opinion of this author, has failed to identify the audience for information dissemination on the theoretical aspects of this study. The project results are being utilized by a small group of colleagues associated with the study. The lack of publication in professional journals limits scientific awareness of their results. These, and similar points, are discussed more fully in other sections of this report.

Research Description

The University of Notre Dame study, "Fire and Smoke Spread in Corridors," was the result of an unsolicited proposal to the Fire Research Program in NSF's Division of Advanced Environmental Research and Technology for which Dr. Ralph Long was program manager. Dr. Jerome L. Novotny was the Principal Investigator and Coordinator of the University's Fire Research Group that was organized to provide a central focus for fire research at Notre Dame. Following Dr. Novotny's death in late 1974, Dr. K. T. Yang, Chairman of the Department of Aerospace and Mechanical Engineering, assumed the role of project coordinator, and Drs. J. R. Lloyd and M. L. Doria, the roles of

co-principal investigators. Names of members of the Fire Research Group and their respective areas of technical specialization are listed in table 27-2. In addition to these individuals, the project also provides financial support for three graduate students and one undergraduate student.

A key feature of the study is the collaboration with the Fire Research Center at NBS. The original proposal from Notre Dame to NSF/RANN, which was reviewed by officials at NBS, included the specific proposition that an ongoing information and data exchange between the two groups be an integral part of the study. The implementation of this relationship is described in the section entitled "Utilization Obtained."

Validation of the basic model through both small- and large-scale burn experiments is a part of this study. Small-scale experiments are being conducted at Notre Dame in facilities jointly funded by the NSF grant and the University. Experiments in this facility are used to confirm the fundamental details of the various models. Full-scale tests are conducted at the NBS Fire Research Center to check the numerical predictions of the overall behavior of fire spread in realistic situations. The full scale experiments also provide insight into simple models for predicting parameters such as energy exchange processes in corridors under varying ventilation and fire conditions.

The computer model, supported by experimental test results and documented in technical reports, is the primary product of this research. The project goals are long-term in nature; therefore, utilization of the model is still not widespread. The model is designed to simulate large-scale fire tests before they are carried out. Its potential use is to design these tests and suggest valid correlations among various tests. Since the numerical

Table 27-2. Personnel of the Fire Research Group, University of Notre Dame

Name/Title	Specialty	Primary Focus
Dr. K. T. Yang Coordinator	Fluid Mechanics Heat Transfer	Project Management Thermal Loading and Radiation Phenomena
Dr. Michael L. Doria Co-investigator	Fluid Mechanics	Development of the Numerical Mode
Dr. John R. Lloyd Co-investigator	Fluid Mechanics Heat Transfer	Experimental Research in Small-scale Facilities for Turbulence and Radiation Studies, Coordinator with NBS
Dr. V. W. Nee	Fluid Mechanics	Development of the Turbulence Model
Dr. A. M. Kanury	Combustion and Fire Research	Combustion and Flammability of Polymers
Dr. A. A. Szewczyk	Fluid Mechanics	Numerical Analysis and Computer Cinematics
Dr. E. W. Jerger Associate Dean of Engineering	Combustion Chemistry	Burning Processes, Liaison with Indiana State Fire Marshal's Office and the Defense Civil Preparedness Agency
Dr. J. P. Kohn	Chemical Engineering	Project Consultant

model is equally applicable to small- and large-scale phenomena, it can provide scaling laws and correlations between small- and large-scale experiments. The computer code can also help interpret various hazard and flammability rating tests, such as the E-84 Tunnel Test and the Radiant Panel Tests. Finally, the numerical model can provide estimates of the development and spread of fire and smoke in enclosures from source ignition to complete room involvement as a function of room geometry, source location and strength, ventilation, and properties of liner and content materials. Such information ultimately will be valuable for the selection of construction materials, for designing escape routes in buildings, and for optimizing fire fighting measures. Additional potential uses are described in more detail elsewhere in this document.

The major research tasks involved are described in table 27-3, as found in the March 1976 semi-annual progress report to NSF/RANN. Six of the research tasks are summarized in the paragraphs that follow, with emphasis on their state of development, significance, and contribution to the final product.

Turbulence Model

A turbulence model has been developed for the purpose of representing realistic interaction among turbulence, buoyancy and shear processes in order to study fire spread with a recirculating flow of the hot gaseous effluents. Experimentation with different values for parameters such as gas velocity, buoyancy and shear are in progress. The work appears technically sound, and the products are of long-term value, but more work is needed.

Table 27-3. Major Task Description

- Development of parabolic model for corridor analysis with through flow including wall and soot radiation
- Full elliptic two dimensional code for enclosures and corridors
- Modeling of turbulent viscosity

  Constant viscosity, mixing length models
  Turbulent viscosity for buoyant, recirculating flows
  Three dimensional turbulent viscosity model

- Development of radiation model

  One dimensional wall and soot radiation
  One dimensional gas radiation
  Volume-volume radiation interchange
  Three dimensional volume-volume interchange

- Development of combustion and species concentration model

  Simulation with heat source
  Combustion and species concentration model

- Development of small scale experimental facilities

  Design and construction of wind tunnel facility
  Instrumentation for velocity, temperature and concentration
  Modification of wind tunnel for stratified flows
  Modification of wind tunnel for smoke injection
  Design and construction of enclosure-corridor test facility
  Instrumentation for transient measurements
  Development of three dimensional enclosure-corridor facility

- Examination and analysis of NBS data

  Full scale data examination
  1/7 scale model data
  In line small-scale corridor data
  E-84 tunnel test
  Continued interaction and support

- Verification of computer code by Notre Dame small scale data

  Steady state enclosure-corridor data
  Transient enclosure-corridor data
  Stratified flow data
  Smoke spread data
  Three dimensional data

- Development of three-dimensional computer code
- Analysis of Harvard-Factory Mutual bedroom test
- Plume interaction studies

  Multiple plumes
  Plume-wall-ceiling interaction

- Cinematics

  Preparation
  Trial runs
  Production runs

- Ventilation studies

Radiation Model

Modeling one-dimensional wall and soot radiation phenomena has been completed and indicates that the presence of wall and soot radiation is critical in explaining differences in velocity profiles of the spread of smoke. A gas radiation model will be incorporated for the purpose of determining the relative roles of the wall, soot, and gas radiation in fire situations. Future activities will include expansion of the radiation analysis to two dimensions with the ultimate goal of deriving a three-dimensional model including all phenomena. This aspect of the work, therefore, is also of long-term value.

Combustion Model

Gas phase combustion resulting from the presence of vaporizable organic materials is modeled using volumetric heat sources, the strengths of which are proportional to the rate of fuel consumption. This model has been refined to take into account the mass addition due to the fuel supply. This research activity serves to enhance the predictive model with potential long-term value.

ASTM E-84 Tunnel Test Analysis

The objective of this analysis is to gain insight into the meaning of the tunnel testing techniques (ASTM E-84) that are currently used for determining comparative flammability characteristics of materials under wind tunnel conditions. Also in question is the ability of the tunnel test to reliably indicate behavior of materials in full-scale fire situations. The predictive model is useful in explaining radiative heat transfer effects. It is also expected to shed light on the effects of prolonged preheating on

flame spread under the tunnel ceiling and on the possibility of spontaneous extinction of an otherwise accelerating flame. These aspects of the tunnel test have never been fully understood.

The work on the E-84 tunnel test appears to be one of the most valuable products of the work. This analysis has the most immediate short-term impact because of its application to better understanding of a test that is currently used to classify materials. Even more importantly, NBS is proposing a test of standards for the flammability of general wearing apparel using the "mushroom apparel flammability tester," a standard flammability testing technique. The Notre Dame Fire Research Group should be able to contribute significantly to the design and understanding of this test.

Plume Interaction Studies

Following a survey of the literature, work has begun on adapting the UNDSAFE computer code to predict fire plume behavior. Interactions between adjacently based plumes and between a plume and a surface are important in resolving questions relevant to the effectiveness with which the fire gases heat the enclosure surfaces and thus contribute to the growth of fire and the generation of smoke and other products. The work is not yet completed, but will have significant impact in the overall understanding of fire and smoke spread behavior.

Experimental Studies

In addition to developing the predictive computer code, UNDSAFE, the Fire Research Group has constructed a small-scale wind tunnel for experiments to check the validity of the models. It is the opinion of the users contacted and the program manager that more effort should be put into this

experimental activity. The work has been of high quality and all data generated in the experimental studies have contributed significantly to the state of knowledge about fire and smoke spread as well as to validation of the computer model.

Utilization Objectives

At the outset, specific emphasis on utilization was not an integral component of this study in the sense that upon completion there would be a specific packaged product to be delivered to a user community. The major emphasis has been on contributing to the understanding of theoretical phenomena that have practical consequences. To this end, a cooperative, collaborative relationship was established between the Fire Research Group and the Fire Research Center at the National Bureau of Standards. For example, the full-scale testing facilities at NBS are useful in providing experimental input to the development of the computer code and permitting validity checks. The user audience, therefore, was identified as other engineers, theoreticians, academicians, and others interested in understanding fire phenomena.

Utilization of the research products was viewed as occurring at several stages of the research activity. The first phase was essentially a contribution to the theory. Second was the use of the theory in explaining fire and smoke spread behavior. The research results were not originally intended to be a design tool, but they may lead to design procedures.

Because applications were not included in the original study objectives, the utilization plan was developed during the course of the research. There was no user advisory committee; the interaction with NBS essentially served

this role. The current continuation proposal includes provision for an advisory panel because the Fire Research Group is tending toward applications. The potential applications as planned or anticipated by the Fire Research Group are shown in table 27-4.

The information dissemination techniques employed in this project are varied in type. The Fire Research Group has produced numerous articles, papers, reports and similar documents during the course of the research activity. These are listed in Appendix A. Technical talks, colloquia, seminars and similar presentations have been given, based on this RANN

Table 27-4. Anticipated Research Applications

Applications in Fire Hazard Tests of Materials
Tunnel Tests
Radiant Panel Tests
Corner Test
Applications in Architectural Design
Structural Fire Integrity
Design of Escape Routes
Fire Detection and Compartmentalization
Fire Fighting Techniques
Building Codes
Application in Training of Fire Fighting Personnel
Fire and Smoke Spread Simulation
Computerized Movies
Applications in Fire Fighting
Building Contents Inventory
Prediction of Fire Involvement
Support to Large Scale Fire Tests in Rooms and Buildings
Pre-Test Simulation
Instrumentation and Data Acquisition
Post-Test Data Reduction and Analysis

supported project, and are listed in Appendix B. Presentations have also been given to various community groups in order to bring the research results to the lay community. These are itemized in Appendix C.

In addition to continuing information dissemination efforts of these types, the Fire Research Group is planning a motion picture presentation of the experimental studies and the computer simulation. The film is intended for use by other theoreticians investigating fire and smoke spread phenomena.

Utilization Obtained

As indicated throughout this report, utilization of the Fire and Smoke Spread project has been obtained primarily through collaboration with the Fire Research Center at NBS. The interaction between the two groups was established at the proposal stage when the Fire Research Group contacted Dr. Irwin Benjamin of NBS. Later direct communication was established with Dr. John Rockett and James R. Quintere, also at NBS. Much of the information reported here is available in a January 1976 report to NSF in which the Fire Research Group provided specific information regarding uilization and information dissemination.

There are few other direct, actual users at this point in the project activity. Dr. Ed Jerger, Associate Dean of the College of Engineering at Notre Dame is one, as is Dr. Ralph Long at the National Fire Prevention and Control Administration.

Fire Research Center, National Bureau of Standards

The cooperative research activity between the Fire Research Group and the NBS Fire Research Center is based upon data exchange, replication of

experimental results, and validation of Notre Dame's model. Contact between Notre Dame and NBS personnel has been maintained throughout the grant periods by mutual site visits, telephone, and correspondence.

Dr. James Quintere at NBS indicates that the past and present interaction has consisted mainly of information exchange and that NBS has not, to date, significantly influenced the direction of the Fire Research Group's work with the possible exception that NBS did suggest several simulation cases to be run on the computer. On the other hand, the theoretical developments of the Fire Research Group have served to modify slightly some NBS activities. For example, NBS has recently redesigned their small-scale burn facility based on inputs from Notre Dame.

The Fire Research Group has also provided theoretical input to inhouse experimental programs at NBS, that would involve burn facilities. To this end, a preliminary version of the numerical computer code has been utilized as a simulation model for the experimental programs. The results are being used to physically interpret the test data as well as suggest improved test programs.

Dr. Quintere has indicated that (1) NBS does not have a total understanding of the Notre Dame computer model and that some NBS researchers question some details of the model. Dr. John Rockett, for example, feels that there are conceptual problems that need to be resolved. First, the model is now directed to explaining essentially two-dimensional phenomena, but fire and smoke spread occurs in three dimensions. The Fire Research Group has chosen to further refine and improve the two-dimensional model at this point in time because there are some basic situations where the flow of fire and smoke is two-dimensional. Second, there are some questions about

the treatment of turbulence and radiation in the model. Dr. Rockett indicates that the attempt to keep the model simple has clouded other theoretical considerations such that the model, while qualitatively correct, could contain a better balance of factors. Dr. Rockett concludes, however, that these are theoretical or academic differences of opinion stated from a peer perspective.

The above objections notwithstanding, the Fire Research Center at NBS has tremendous interest in the Notre Dame work and, according to Dr. Rockett, they are trying to direct the study into more practical areas. According to Dr. Quintere, the Notre Dame study has provided a significant advancement in the state-of-the-art of fire research. He added that the realization of the long-term goal in the project, the completed computer code, will enable researchers at any full-scale fire research facility to utilize the model. Both Drs. Rockett and Quintere counseled that use of the project results as a design tool is still several years in the future. They concluded that the major limitation to utilization of the model at this stage is that computer run time is excessive and, therefore, use of the model is not financially feasible for most other research groups.

Defense Civil Preparedness Agency (DOD-DCPA)

One of the consultants to the project, Dr. E. W. Jerger, Associate Dean of the College of Engineering at Notre Dame, is active in the various DCPA multiprotection design training programs for practicing engineers and architects. One component of these programs is fire protection and control in which Dr. Jerger is an expert. He uses the research findings in his lectures to DCPA groups and sees promise for the long-term use of the results in the training of fire fighters.

Underwriters' Laboratory

According to the project coordinator, Dr. Yang, Mr. William Parker of Underwriters' Laboratories has supplied the Fire Research Group with experimental data from the E-84 Tunnel Test. The Notre Dame computer model is being tested by using it to predict the results of the E-84 Tunnel Tests. Although the work has not yet been completed, the information exchange is improving our understanding of the E-84 Tunnel Test which, in turn, is important in the development of flammability tests and standards for consumer goods and hazardous substances.

The National Fire Prevention and Control Administration (DOC-NFPCA)

Dr. Ralph Long, Research Director of NFPCA, was the original NSF/RANN Program Manager for the Notre Dame fire and smoke spread study. He retained responsibility for managing NSF/RANN fire research projects after joining NFPCA. He indicated that the long-term goal of fire hazard analysis is the understanding of fire development, spread, flashover, and extinguishment capabilities for application to better fire protection design by building engineers. When the Notre Dame predictive model is complete, knowledge may be gained for improved placement of smoke detectors and sprinklers. There is also considerable potential for use by the NFPCA-National Fire Academy in training fire fighters.

Other Users

In addition to the above users, the distribution of technical reports has resulted in inquiries from private companies and U.S. and foreign government agencies. A complete list of these interested parties is included

as Appendix D. It should be noted, however, that the Fire Research Group is admirably reluctant to release preliminary results that could be either misinterpreted or found incorrect in the future. For this reason, the limited information released to these private companies and agencies has found little direct use.

Features

The Fire and Smoke Spread Project contributes to a national need for basic research on the behavior of fire and smoke in enclosures. In spite of changes in project management at Notre Dame and the departure of Dr. Long from NSF/RANN, the project has continued smoothly. The Fire Research Group appears to be a well-ordered, functional unit committed to the work they are doing.

In addition to NSF/RANN support for two grant periods, the Fire Research Group has also benefited from monetary and in-kind support from the University of Notre Dame. The University purchased a gas chromatograph for gas combustion analysis in the project's small-scale combustion tunnel constructed with NSF funds. The University of Notre Dame has also supplied electrical services and computer and personnel time. For example, approximately $15,000 of computer time was contributed in 1975 for overruns of the grant computer budget. Finally, the services of two consultants to the project, Dr. E. W. Jerger and Dr. J. Kohn, were contributed by the University, at an estimated value of $3,000 for 1975 alone. Consequently, in the words of Dr. Ralph Long, NSF-RANN is "getting more for the money."

Similarly, the collaborator-user relationship between the Fire Research Group and the National Bureau of Standards has enhanced the research, both

through validation and contributions to the research and through utilization. NBS can be considered then as a surrogate user advisory board.

Aside from the relationship with NBS and the interactions with Underwriters' Laboratories, the research results thus far have not been highly utilized. Even in terms of information dissemination, the project experience is fairly limited. The Fire Research Group has confined their printed materials so far to in-house technical reports and semi-annual progress reports to NSF-RANN and has not published in professional journals.* Similarly, their technical presentations have been mainly given at NSF-sponsored seminars rather than to professional groups. Consequently, awareness of colleagues in the field is fairly limited. Dr. Yang, project coordinator of the Fire Research Group, moreover, observes that they "should have chosen (their) research outlets more carefully," and submitted articles to both technical and fire related journals. The Fire Research Group has indicated an intention to correct this in their current continuation proposal submitted to NBS.

It is recognized that the user community at the present time and in the near future consists of fire researchers in various government agencies and universities. This is because the project itself is basic with additional effort required to obtain actual application. The computer simulation model is not intended for use in design specifications or by fire fighters, but only by other researchers.

Since the project is not complete, the computer simulation code is not available for use at this time by other researchers in any general way. There are, moreover, two major factors that will limit the use of the computer simulation model by other researchers: the high cost of using the model in

---

*A paper has been accepted for presentation at the 16th International Symposium on Combustion at MIT, and will be published in the Proceedings.

terms of computer run time (this limits the use of the model even by NBS); and the limited availability of both experimental data for verifying the model and facilities capable of generating the data.

On balance, the strength of the project lies in the quality of the research that has been conducted and in the quality of the personnel in the Fire Research Group. Major deficiencies are few, and these have been documented throughout this paper. A major difficulty is in defining the appropriate user community and reaching that audience. While the public awareness efforts with the Kiwanis Club, etc., are admirable, they are perhaps misguided. More effort should probably be put into meeting with professional and trade associations. A similar case can be made for the development of motion pictures at this point.

Conclusions

It is the unanimous opinion of the program manager, users, and those preparing this case study that this project is sound research, satisfying a need, even though incomplete. The emerging results and the satisfaction of the long-term objectives encourage continuation of the work. To force this research endeavor to focus on highly visible, packaged products at this time is premature and would unnecessarily redirect emphasis from useful theore tical contributions to less meaningful and, consquently, less useful activity.

In the words of the Program Manager, Dr. Ralph Long, the project is "reasonably well utilized for the state it's in." In conclusion, it should be noted that this project was originally funded in the embryonic stages of NSF/RANN, when emphasis on immediate application of research results was

not as strong as it is today. Theoretical enrichment of our understanding of the spread of fire and smoke is a long-term objective requiring sound basic research with future, not present, application.

Appendix A

PROJECT PUBLICATIONS

J. L. Novotny, Progress Report to NSF on Grant GI-37191, Fire and Smoke Spread in Corridors, August 1973.

M. L. Doria, "Fire and Smoke Spread in a Corridor: The Preheat Period Analysis, 2-D Parabolic Flows," University of Notre Dame Tech. Report TR-37191-74-1, February 1974. NTIS No. PB244199/LK.

J. L. Novotny, "Formulation of One-Dimensional Radiative Flux for Non-Homogeneous Nongray Gases and Soot," University of Notre Dame Tech. Report TR-37191-74-1, February 1974. NTIS No. PB244199/LK.

J. R. Lloyd, J. V. Golden and P. K. Schroeder, "Design Construction and Evaluation of Small-Scale Fire and Smoke Spread Facility," University of Notre Dame Tech. Report TR-37191-2, February 1974. NTIS No. PB 242235/As.

J. L. Novotny, Progress Report to NSF on Grant GI-37191, Fire and Smoke Spread in Corridors, February 1974.

J. V. Golden, Design, Construction, and Evaluation of a Small-Scale Fire Research Wind Tunnel, M. S. Thesis, Department of Aerospace and Mechanical Engineering, University of Notre Dame, Notre Dame, Indiana, August 1974.

M. L. Doria, "A Numerical Model for the Prediction of Two-Dimensional Unsteady Flows of Multicomponent Gases with Strong Buoyancy Effects and Recirculation," Notre Dame Technical Report TR-37191-74-4, November 1974, NTIS No. PB242240/AS.

M. L. Doria and T. C. Ku, "Some Predictive Results Obtained from the Numerical Model for the Computation of Unsteady Recirculating Flows," Notre Dame Technical Report TR-37191-74-6, November 1974, NTIS No. PB 242239/AS.

K. T. Yang, J. R. Lloyd and M. L. Doria, Progress Report to NSF on Grant GI-37191, ATA 73-07749-A01, Fire and Smoke Spread, November 1, 1974.

P. K. Schroeder, Species Measurements of Methane Flames in a Wind Tunnel Boundary Layer Flow, M. S. Thesis, Department of Aerospace and Mechanical Engineering, University of Notre Dame, Notre Dame, Indiana, August 1975.

K. T. Yang, J. R. Lloyd and M. L. Doria, Progress Report to NSF on Grant GI-37191, ATA73-07749-A01, Fire and Smoke Spread, May 10, 1975.

K. T. Yang, J. R. Lloyd and M. L. Doria, Progress Report to NSF on Grant GI-37191, ATA73-07749-A01, Notre Dame Technical Report ND-PR-07749-5, October 8, 1975.

J. V. Golden, J. R. Lloyd, and J. L. Novotny, "Design, Construction and Evaluation of a Small-Scale Fire Research Wind Tunnel," University of Notre Dame Tech. Report TR-37191-74-5, November 1975, NTIS No. PB242236/LK.

T. C. Ku, A Numerical Model for the Prediction of Unsteady Buoyant Flows with Application to a Heated Room Corridor, Ph. D. Dissertation, Department of Aerospace and Mechanical Engineering, University of Notre Dame, Notre Dame, Indiana, January 1976.

Note: All of the above reports are available from the Department of Aerospace and Mechanical Engineering, University of Notre Dame, Notre Dame, Indiana.

Appendix B

TECHNICAL PRESENTATIONS

J. L. Novotny, "Fire Research at Notre Dame," Fire Research Group May 22, 1973, University of California at Berkeley; Faculty and Graduate Students in the Berkeley Fire Research Group; Sponsored by NSF RANN and Berkeley; Technical Presentation of Notre Dame RANN Fire Research Project.

J. L. Novotny, "Fire and Smoke Spread in Corridors," Conference on Fire Safety for Buildings, July 18-20, 1973, Airlie House, Airlie, Virginia, Sponsored by GSA, HUD, NBS, NSF; Representatives from NSF RANN Fire Research Grantee Institutions, Practicing Fire Protection Engineers, NBS, HUD and GSA Fire Control Technical Personnel; Progress Report Presentation on Project Initiated in February of 1973.

J. L. Novotny, "Fire Research at Notre Dame," Mechanical Engineering Seminar, October 12, 1973, University of Kentucky; Faculty and Graduate Students in Mechanical Engineering; Sponsored by Kentucky; Technical Presentation of Notre Dame RANN Fire Research Project.

J. R. Lloyd and J. L. Novotny, "Fire and Smoke Spread in Corridors," Fire Research Seminar, December 12, 1973, NBS; Technical Personnel in the Center for Fire Research, NBS; Sponsored by NSF RANN; Progress Report Presentation.

J. R. Lloyd, "Fire and Smoke Spread in Corridors," NSF/RANN Conference on Fire Research, May 28, 29, 1974, Georgia Tech., Atlanta, Georgia; Sponsored by NSF RANN; Representatives from NSF RANN Fire Research Grantee Institutions and from various Government Agencies; Progress Report Presentation.

M. L. Doria, "Fire and Smoke Spread in Corridors," Polymer Conference Series, July 10-12, 1974, University of Utah; Conference Attendees and Representatives from Government, Industry, and Universities, Sponsored by NSF and University of Utah; Invited Presentation of the Notre Dame NSF RANN Fire Research Program.

K. T. Yang, "Fire Research at Notre Dame, "Fire Research Seminar, September 7, 1974, Fire Research Institute, Tokyo, Japan; Technical Personnel at the Fire Research Institute; Sponsored by the Fire Research Institute; Progress Report Presentation.

M. L. Doria and J. R. Lloyd, "Fire and Smoke Spread in Corridors," Fire Research Seminar, October 28, 1974, NBS; Technical Personnel in the Center for Fire Research, NBS; Sponsored by NSF RANN; Progress Report Presentation.

E. W. Jerger, "Multi-Disaster Mitigation: Section on Fire, "Short Course, Spring 1974, Indianapolis, Indiana, also Chicago, Illinois; Practicing Architects and Engineers; Sponsored by DCPA; Short Course Presentations covering 13 weeks.

M. L. Doria, "Fire and Smoke Spread in Corridors," NSF/RANN Conference on Fire Research, June 25-27, 1975, Harvard University, Cambridge, Massachusetts; Sponsored by NSF RANN; Representatives for NSF RANN Fire Research Grantee Institutions and from Various Government Agencies and Industrial concerns; Progress Report Presentation.

E. W. Jerger, "Fire Problems in Building Design," Indiana Fire Marshall's Training Program for Fire Science Personnel, June 1975, Fort Benjamin Harrison, Indiana; Indiana State Fire Marshalls and Their Deputies; Sponsored by the State of Indiana; Technical Presentation.

E. W. Jerger, "Multiprotection Design Section on Fire," DCPA-NSF Summer Institute, August 1975, Battle Creek, Michigan; Practicing Architects and Engineers and University Representatives; Sponsored by NSF: Technical Presentation.

J. R. Loyd and V. W. Nee, "Fire and Smoke Spread in Corridors," Fire Research Seminar, March 1, 1976, NBS; Technical Personnel in the Center for Fire Research, NBS; Progress Report Presentation.

Appendix C

PRESENTATIONS TO COMMUNITY GROUPS

J. L. Novotny, "Fire Research at Notre Dame," Engineering Advisory Council Meeting, October 1973, University of Notre Dame, Notre Dame, Indiana: Engineering Advisory Council Members (Top Executives from Industry); Sponsored by College of Engineering, University of Notre Dame; Layman Presentation of Notre Dame RANN Project.

J. L. Novotny, "Fire Research at Notre Dame," Student Lecture, American Society of Mechanical Engineers Student Section, April 1974, University of Notre Dame, Notre Dame, Indiana; University Students in Engineering and Science; Sponsored by the ASME Student Section; Layman Presentation of Notre Dame RANN Project.

J. R. Lloyd, "Fire Research at Notre Dame," Kiwanis Club, January 14, 1976, Sheraton Motor Inn, South Bend, Indiana; Kiwanis Club Members (Business and Professional People); Sponsored by South Bend Kiwanis Club, South Bend, Indiana; Layman Presentation of Notre Dame RANN Project.

J. R. Lloyd, "Fire Research in Building Design," St. Joseph Valley Architect Association, January 22, 1976, Ratskeller, 100 Center, Mishawaka, Indiana; Practicing Architects; Sponsored by St. Joseph Valley Architect Association; Layman Presentation of Current State of the Art.

Appendix D

POTENTIAL USERS

(WHO HAVE REQUESTED INFORMATION ABOUT RESEARCH)

Dr. Ricardo A. Bastianon
Instituto de Technologia Naval
Buenos Aires, Argentina

Dr. Walter G. Berl
Applied Physics Lab
John Hopkins University

Dr. Ashley S. Campbell
University of Maine

Mr. G. T. Castino, Managing Engineer
Fire Protection Department
Underwriters' Laboratories, Inc.

Dr. Ivan Catton
School of Engineering and Applied Science
U.C.L.A.

Dr. Joseph E. Clark
NFPCA

Dr. Richard C. Corlett
Department of Mechanical Engineering
University of Washington

Dr. John DeRis
Factory Mutual Research

Dr. I. N. Einhorn
University of Utah

Dr. Howard W. Emmons
Harvard University

Dr. G.M. Faeth
Pennsylvania State University

Dr. Joel H. Ferziger
Stanford University

Dr. Irvin Glassman
Princeton University

Mr. William J. Groah
Technical Director
Hardwood Plywood Mfg. Association

Mr. Jack Kracklauer, Manager
Market Development
Arapaho Chemicals, Inc.

Dr. Yohei Kumano, Director
Fire Research Institute
Mitaka, Tokyo Japan

Dr. Richard Lee
College of Engineering
State University of New York at Stony Brook

Fire Research Station
Borehamwood, England

Dr. F. C. Lockwood
Dept. of Mechanical Engineering
Imperial College, London

Dr. J. M. McGuire
National Research Council of Canada
Montreal Road Laboratories

Mr. L. Maltete
Sours-Directeur der Etudes et de la Prevention
France

Mr. Ray G. Marsh
Building Code Consultants
Dallas, Texas

Mr. J. L. Randall, Deputy Director
Planning and Inspection Department
City of Fresno
Fresno, California

Dr. A. F. Sarofim
Massachusetts Institute of
Technology

Mr. Robert L. Snider
Fire Chief
City of South Bend, Indiana

Dr. Chanf-Lin Tien
Dept. of Mechanical Engineering
University of California, Berkeley

Dr. K. E. Torrance
Cornell University

Dr. Charles Troha
Federal Aviation Administration
Washington, D.C.

Dr. T. Wakamatsu
Building Research Institute
Shinjuku-ku, Tokyo, Japan

Dr. F. A. Williams
University of California at
San Diego

Mr. Foster C. Wilson, Director
Product Testing Laboratories
Owens-Corning Fiberglass Corp.

Dr. Robert Young
M. H. Detrick Company

Mr. E. Zukoski
California Institute of
Technology

RANN UTILIZATION EXPERIENCE

CASE STUDY NO. 28

COMPUTER ABUSES

STANFORD RESEARCH INSTITUTE

Case Investigator:

P. S. McMullan

Research Triangle Institute
P.O. Box 12194
Research Triangle Park
North Carolina 27709

Technical Reviewer:

J. Vaupel

Department of Policy Science
Duke University
Durham, North Carolina 27706

Prepared under:

Contract No. NSF-C76-17165
National Science Foundation
Research Applied to National Needs
1800 G Street, N.W.
Washington, D.C. 20550

COMPUTER ABUSES

Introduction and Summary

As computers become more and more pervasive in society, the opportunities for computer abuse increase. The Principal Investigator of this research originally proposed to demonstrate that computer abuse is a serious and growing problem deserving national attention. He defines computer abuse as: "...all types of acts distinctly associated with computers and data communications in which victims involuntarily suffer or could have suffered losses, injuries or damage, or in which perpetrators receive or could have received undeserved gain." The Research Applied to National Needs program of the National Science Foundation (NSF/RANN) initially provided limited support to the Principal Investigator with the mandate to identify a problem of national concern and establish that the relationship of computers to the incidents of abuse made the problem unique. User response to the research indicates that he was successful in accomplishing these objectives. The history and accomplishments of the project, as reported by the Principal Investigator, Mr. Donn B. Parker, of Stanford Research Institute (SRI) [ref. 1], are briefly reviewed in the following summary. Project information is given in table 28-1.

The project began in 1972 when SRI received a planning grant from the NSF/RANN Social Systems Division to explore the problem of computer abuse as a subject for possible further research. The project resulted in a report, "Computer Abuse," in December 1973 [ref. 2]. A utilization grant was subsequently made to SRI to disseminate the results of the work. SRI distributed 1500 copies of the

Table 28-1
PROJECT INFORMATION

Project Title Computer Abuse	Grant/Contract No. GI-37226
RANN Program Manager Arthur F. Konopka	RANN Program Area Social Systems
Principal Investigator(s) Donn B. Parker	Schedule Start: Feb. 1, 1973 End: Dec. 31, 1973
Institution Stanford Research Institute Menlo Park, California	Funding NSF: NY 72 $21,000 FY 73 $18,000 Other:
Contributors/Collaborators: Susan Hubbell Nycum, S. Stephen Oura	
User Advisory Committee: None	
Precursor Activities: NSF Study "Criminalistics and the World of the Future" AEC Study "Threats to Multi-access Computer Systems"	

report to individuals and organizations worldwide while the grant was active. The National Technical Information Service (NTIS) reports that it has distributed an additional 1,853 copies with requests continuing at a high rate. NTIS charges $5.75 per hard copy.

This seminal work led to the first organized statement of the emerging problem of computer abuse from technological, legal and sociological perspectives. The study coincided with a growing national concern over privacy, a $2 billion computer related insurance fraud (Equity Funding Insurance Company), and other

dramatic incidents demonstrating that problems exist in using computers. The research placed these incidents and issues into a context in which they could be understood and methodically studied.

The Principal Investigator, Mr. Parker, states that the work had a major impact on legislators concerned with privacy, computer scientists doing computer security research, internal and external auditors faced with the new computer technology, potential victims--both large and small--in the private and public sectors, law enforcement agencies, prosecutors, motion picture and television writers and producers, journalists, and many university professors and their students. Many national and foreign magazines, newspapers, and television networks based productions on the computer abuse report and SRI staff interviews and speeches. Among these are Time, Newsweek, Business Week, Fortune, London Financial Times, BBC, CBS News, Canadian Broadcasting, The New York Times, and The Washington Post Magazine. The staffs of Congressman Goldwater, Senators Ervin and Percy, and California Assemblyman Bagley requested and received assistance and information. The Government Accounting Office, Government Services Administration, Federal Deposit Insurance Corporation, Federal Home Loan Bank Board, Federal Bureau of Investigation, National Bureau of Standards, Department of Health, Education and Welfare, Department of Agriculture, Office of Management and Budget, and Office of Telecommunications Policy all have requested and received information and assistance.

The motivation for this interest has been the realization of the increased vulnerability to losses that occur with increased dependence on computers as they take over more sensitive and important functions within organizations. Information about the actual experiences of victims of computer abuse is of

great assistance in identification of threats to users of computers and forms the basis for developing safeguards.

The NSF planning grant has led to ongoing research funded by NSF and several other private and government organizations.

Mr. Parker reports that the project achieved a high level of utilization in that its findings were widely disseminated to both general and specific audiences. This is the appropriate type of utilization for a project of this kind in which the objective is to raise individuals' levels of awareness of a problem. Actions taken as a result of this heightened awareness include:

- additional NSF support to SRI to continue collection and analysis of case information and develop solutions to the demonstrated technical and legal problems;
- contracts to SRI from public and private agencies interested in determining the vulnerability of their computer systems;
- use of the case studies and typology in computer science educational programs;
- requests to purchase all additional reports produced in the continuing research effort;
- frequent requests for oral or written presentations by the Principal Investigator; and
- frequent requests for additional details from the accumulated case files.

This case study confirms that utilization of the study was influenced by the pre-existing awareness of a potential problem by at least three groups: legislators concerned with privacy; computer scientists concerned with security;

and auditors concerned with new computer technology. These groups were interested in any research that might shed light on their problems. The more general audiences and the public media became increasingly interested as publicity increased during the course of the research. Widespread publicity, in turn, led to requests for the specific products of the research; reports, presentations, and the computer abuse case study details.

It is concluded from user responses that the NSF/RANN objective--to demonstrate that computer abuse is a problem of national concern--was successfully achieved. The research is of peripheral value to legislators concerned with privacy, and of direct value in recent actions of the Senate Government Operations Committee. It was of even greater value to auditors and computer scientists faced with new computer technology. The general public awareness was heightened by the numerous public media uses of the research. For a project of such a limited scope, the results have been extremely well utilized.

Research Description

The interest of Mr. Parker in computer abuse problems began in 1969 while he was engaged in the development of a code of professional ethics for the Association for Computing Machinery (ACM).

Following this, the Principal Investigator continued his interest as an avocation and collected an extensive file of papers and newspaper articles on cases of computer abuse. His professional interest grew when, in 1971, he contributed to an NSF supported study at SRI, "Criminalistics and the World of the Future." This study pointed out the growing concern of business and government of the vulnerability of their electronic data processing (EDP) activities. He

linked the potential for computer abuse to the growing national concern for the right of privacy of the individual. Then in 1972, the findings of an eight-month study, "Computer-Related Crime and Data Security," was published by SRI's Long Range Planning Service, informing 500 business participants of the nature of the problem and proposed methods of control.

Extensive research to develop methods of controlling access to computer systems and protecting their contents has been started in other organizations. However, prior to the computer abuse study and its dissemination, the research was mostly based on presumed and potential problems rather than accurately documented actual cases of computer abuse. Mr. Parker felt that better approaches to reducing the potential for computer abuse could be found if the research community were more informed of the nature and extent of the problem. A two-directional approach was taken to fill this need. First, a technically oriented study was performed in 1972 on "Threats to Multi-access Computer Systems" for the Atomic Energy Commission's Lawrence Livermore Laboratory. This study focused on classification of the technical vulnerability of multi-access computer systems. At about the same time, a proposal was submitted to NSF/RANN for a broad interdisciplinary study entitled "Computer-Related Crime" (later changed to "Antisocial Use of Computers" and, finally, to "Computer Abuses").

The broad interdisciplinary study, initially proposed to NSF for about $350,000, was intended to demonstrate the problem's existence, assess its extent, and develop solutions. Despite strong support from some of the reviewers of the original and subsequent proposals, others questioned the need. They did not view the problem of computer abuse as one requiring special attention aside from studies of white collar crime, vandalism, and other more recognized approaches to crime and antisocial behavior analysis. Following months of negotiation, the decision

was finally made to award a grant of $21,000 to SRI to identify the computer abuse problem and to present data confirming its existence. The grant period was February 1 to December 31, 1973, with most of the effort completed by June 28 when a report was presented to a culminating conference.

This relatively limited effort was performed by the Stanford Research Institute's Information Science Laboratory under the direction of Donn B. Parker. A section of the study involving social implications of computer abuse was prepared by S. Stephen Oüra of SRI's Urban and Social Systems Division. Another section dealing with the legal aspects of computer-related crime was prepared by Susan Nycum of the Stanford University Law School. The Principal Investigator prepared the case studies, organized the typology of computer abuse, and in other ways demonstrated the existence of the problem.

The study report was directed to a general audience rather than only to computer specialists. It includes a brief introduction to computer terminology for the uninitiated, and an explanation of the roles of people who are directly or indirectly involved in working with computers. The 148 case studies are summarized and used to illustrate how people have abused computers and abused others with the help of computers. Through these illustrations, it is explained how a crime, such as embezzlement, is changed in scale and character when computers are involved. Also, case studies are used to illustrate the uncertain legal status of computer programs and the novel legal aspects of the unauthorized use of computer time. These characteristics were used to further point out the lack of established professional standards and ethics in the computer science field. After presenting these and other examples of computer abuse, the report presents a typology of computer abuse and the beginnings of a model with which to develop social, legal, and technical countermeasures to these abuses.

The project culminated in the First National Invitational Conference on Computer Abuse, attended by 45 people in the fields of computer technology, law, law enforcement, sociology, and the press. The agenda consisted of a review of the computer abuse study and an assessment of the problems disclosed by the study. The conferees concluded that the study had demonstrated that computer abuses are a growing problem that is expected to increase rapidly to significant proportions, and that computer abuse as a separate study discipline was justified and should be continued.

Throughout the study, Mr. Parker received requests for information from the press and the computer-using community. Press coverage of the conference generated further interest. Because of this demonstrated strong interest by potential users, SRI requested and was granted an $18,000 supplement to enhance the utilization of the study. These funds were used to prepare papers for publication, attend conferences to present invited papers, publish articles, and distribute additional copies of the report. The number of potential users reached has been extensive, as is discussed in the utilization section of this report.

Following the completion of the computer abuses projects, proposals were submitted to NSF to continue the problem assessment and develop solutions. Funds were requested for studies related to the social, technical, and legal aspects of the computer abuse problem. The social aspect was not funded, but the Computer Science Division of NSF granted Mr. Parker $40,000 for a study of the technical aspects and Ms. Nycum was given $40,000 for a study of the legal aspects. These studies are now complete and are to be distributed in the summer of 1976. The investigators have received another three-year grant of $300,000 from the Computer Sciences Division of NSF to continue the technical studies, and SRI has had

numerous contacts with public agencies and private firms to evaluate the vulnerability of their computer processes.

In the absence of a clear listing of national priorities, it is difficult to place a clear ranking on the relevant significance of this research. Computer abuse crimes are rarely violent (even though one case of vandalism at the University of Wisconsin caused the death of a researcher). The significance is perhaps best measured in the pervasiveness of computers in society and their growing importance in all segments of public and private life. While computers are used to reduce the probability of a large number of traditional low level crimes--such as the passing of bad checks--the computer abuse study hypothesizes that the potential for fewer but much more serious crimes is fast developing. As stated in the San Francisco Examiner of July 1, 1973, after the SRI Conference on Computer Abuse: "Computers--there are some 80,000 currently in use in the U.S.--count our votes, get us dates, bombard us with junk mail, and even speed us on BART trains (sometimes). They have brought us to the brink of a cashless, checkless society. ...and the computer revolution has hardly begun. Thus this revolution is at a crossroads. While industry growth has brought increased versatility and sophistication in data processing, it also has bred vulnerability."

The attendees at the culminating conference agreed that the problem of computer abuse could grow to significant proportions. Financial institutions are concerned with the protection of the assets of their customers and stockholders; government agencies and private firms are concerned with the confidentiality of information about individuals; research and manufacturing firms are concerned with the protection of valuable trade data and programs, and computer manufacturers are concerned about the vulnerability of their systems and the cost of

reducing this vulnerability. Finally, the general public, although fascinated by "Mission Impossible" types of technological crime, is most concerned with computer abuse that infringes on their privacy or financial assets.

If the significance of the computer abuse problem is judged by its growing potential for undesirable consequences for a widespread group of institutions and individuals, it is a problem of national significance.

A major thrust of the study was to demonstrate that an understanding of the problem and its nature should permit the development of technical countermeasures for vulnerable systems and of legal deterrents to some of the abuses of presently uncertain legal status. The Computer Sciences Division of NSF has agreed that the problem is of significance and has funded the continuation in these two directions. However, NSF/RANN has not been convinced of the need for continued assessment of the social and behavioral aspects of computer abuses and has declined additional funding of this component. (The Law Enforcement Assistance Administration (LEAA) may fund additional research in this direction.) The Principal Investigator is continuing his personal involvement in the development of guidelines for the ethical behavior of his fellow professionals in the computer sciences discipline.

Utilization Objectives

The potential beneficiaries of the research into computer abuse (that began with the NSF/RANN study under investigation) are essentially all persons and institutions who might in any way be exposed to abuse involving the use of computers. All such individuals and institutions will benefit to the extent that actions ensuing from the research lower the probability that they will be victims of such abuse.

Although the initial computer abuse study was a limited planning grant or problem demonstration study, the planned utilization of this study was as broad as the potential beneficiary group described above. The Principal Investigator planned and carried out a publicity and dissemination program that had the potential of reaching a large majority of the individuals and institutions who are potential victims. Except for a few common sense suggestions about protecting computers from abuse, the study did not suggest solutions. It was, instead, an attempt to raise the level of awareness of the public and institutions to the problem. Thus, the planned utilization was in terms of wide dissemination and the desired result was support for continued research to find solutions to the problems disclosed.

Utilization Obtained

The utilization of the research results has progressed essentially as planned. Starting with a small user group that was in contact with the study throughout the performance period, the community of users expanded into a few thousands who received the full report, another few thousands who heard the many oral presentations of the Principal Investigator, many thousands who read the articles in trade and professional journals, and possibly millions who were exposed to the newspaper and magazine articles in general circulation.

In verifying the actual utilization, telephone interviews were held with one or more representatives of four types of users: those concerned with legislation on privacy; computer scientists doing computer security research; auditors faced with new computer technology; and university professors and students. Other interviews were held with those who support the research which has developed out

of the computer abuses study. Finally, information was gathered on the dissemination of research reports and research results to the broadly defined user audience. Each group of users is discussed in the following paragraphs.

Privacy Legislation

Although the study was of definite interest to those concerned with privacy legislation, this group of users reports that the research results did not have a direct bearing on the Privacy Act of 1975 or subsequent legislative proposals. Mr. Joseph Overton, on the staff of Congressman Barry Goldwater, Jr., explained that the areas of abuse which Mr. Parker's report covered were only peripherally related to privacy issues. However, Mr. Overton reported that Mr. Parker and Ms. Susan Nycum were very helpful to him in developing a bibliography and providing names of persons whom he later interviewed in developing legislative recommendations. Following conversations with Mr. Parker, Mr. Overton visited the General Accounting Office to determine whether general legislation is needed to protect against Federal computer abuse. He found the existing legislation to be adequate, but recommended that GAO investigate technical solutions to reducing computer system vulnerability.

Mr. Overton's comments about the peripheral relationship of the study to the privacy issue were essentially agreed with by Dr. Christopher E. Heller of the Privacy Protection Study Commission. He found the documents to be useful in documenting weaknesses in computer systems. He had volunteered one case study for Mr. Parker's files. Dr. Heller stated that Mr. Parker's interests were only one dimension of the general policy concerns in the privacy protection issue.

Computer Scientists and Manufacturers

Conversations were held with computer scientists in both public and private institutions. Although they were willing to comment about their interest in and use of the research, those in private firms preferred that they not be identified because of the policies of their firms. Some preferred that their interest be kept confidential since they are determining their problems and evaluating alternative solutions. One such individual reported that he had read the report with interest and had used its illustrations in reports to management. It was of particular help in devising control efforts in the computer personnel area. However, the individual did not completely convince his management that the seriousness of the problem justifies the more expensive countermeasures that are available to the company. Facility and personnel security is more quickly understood and funded: software security needs are more difficult to explain convincingly. He intends to re-establish contact with Mr. Parker and his ongoing research efforts.

William C. Martin, director of a computer group in a Federal contract research center, supported the contention of the Principal Investigator that there is a need to clarify the computer abuse problem. He stated: "I think that one of the more important efforts undertaken during the project was the investigative phases, which attempted to validate/invalidate the many reported cases of computer abuse. It has shown that many 'press' reports have been greatly exaggerated, and (it) has helped managers to more fully understand the true nature of the treats." Mr. Martin has not continued his contacts with the project, but he plans to obtain the next scheduled report and review it for applicability to his responsibilities.

Computer manufacturing firms have a direct interest in the research for at least two reasons. First, they are interested in any study which helps in

understanding the vulnerability of computers. Second, they would like to have the issue clarified for the purchasers of this products so that there is a demand for the protective measures which may be needed to reduce this vulnerability.

The computer manufacturing class of users is represented by a company director of data security. This director is a user of the research results, a source of referral, an advisor to other users, and a source of information to the Principal Investigator. He had prior professional association with Mr. Parker and maintained contact with the project about once a month.

Protection of citizens against computer abuse is part of his corporation's responsibility. The study was useful to him in his area of responsibility--to the extent that it clarified and classified some of his concerns about computer abuse. The specific use to which the results were applied were in the assessment of the costs of protecting computer systems against computer abuse in relation to the benefits to be realized by the company and its clients. Obviously, the limited computer abuse study could not provide all that was needed for such a comparison of costs and benefits, but the security director indicated that the research partly met his organization's need by accomplishing its stated objective.

University Users

Members of the academic community have an interest in the research because of their role in preparing students to work with or make use of computers. Professor Howard L. Morgan of the Wharton School of the University of Pennsylvania represents this class of users. He is an Associate Professor of Decision Sciences at Wharton and, as such, is an advisor or consultant to others who will be direct users of the research. He is currently using the research results in teaching his students about computer abuse so that they will "be able to build systems to

withstand such abuse." He played no direct role in the study, but was asked at a conference to help in the dissemination of the research results. He believes that the Wharton School use of the results will spread the influence of the study as students carry the lessons learned into their new organizations.

Auditors

Internal and external auditors have become increasingly concerned with computer abuse and the difficulties that new computer technology may present to auditors in detecting such abuses. Several cases of million-dollar fraud and embezzlement involving computers were documented in the report. These have highlighted a growing concern that more are yet to be uncovered. The reported cases are rarely uncovered by auditors. They are more likely to be reported by an associate of the perpetrator of the crime.

The corporate officer responsible for auditing in one of the nation's largest financial institutions agreed to comment on his use of the computer abuse study. Because he had some concern with the sensitivity of the subject, his comments will be included without attribution. He stated that benefits were derived in the study because a critical and knowledgeable individual had distilled the "signals" contained within the accumulated case studies of computer abuse. "Parker distilled the threads and common elements in the cases and did a skilled job of testing hypotheses. He was able to distinguish the factual from the apocryphal." The publicity given to the project and the Principal Investigator caused the sources of information to improve and increased the value of the repository of case histories.

This respondent's one criticism of the research was: "There is no way to know how incomplete the data base may be. No one likes to exhibit his problems

in public; therefore, many important incidents may go unreported, thus producing holes in the data base."

Research Funders

Another class of users is the program managers at the National Science Foundation and other groups that support research. The NSF research review committee members are also important users. These reviewers of the computer abuses study, for the most part, are computer system specialists in private firms and public agencies other than NSF. After the completion of the computer abuse problem existence study, the Principal Investigator was able to obtain NSF funds for the second phase of problem assessment and the third phase of developing solutions. Knowledgeable reviewers were convinced of the importance of the computer abuse problem.

The Principal Investigator was strongly supported in his successful attempts to obtain follow-on funds from the Computer Science Division of NSF by the RANN Program Manager, Arthur F. Konopka. In a letter to the Principal Investigator, Dr. Konopka states: "Early indications to us are that this project has been an outstanding success especially considering the short time period of performance and the limited level of financial support" [ref. 3]. Dr. Konopka also called special attention to the utility of the findings to the legal process. He believes that there are two aspects of this contribution. First, because the study has made individuals aware of computer abuse, "they are better equipped to protect themselves and to seek professional assistance either from a computer expert or from a lawyer when their newly-trained perception makes them aware of a problem." Second, the study contributes "by making lawyers aware of the legal issues and remedies." With this awareness, the lawyers can better serve their clients. An

article* by Ms. Nycum in the American Bar Association Journal, a house organ with circulation of approximately 350,000, is an example of how this awareness among lawyers has been accomplished.

A follow-on study in the social-behavioral area is now under consideration by the Law Enforcement Assistance Administration (LEAA). Fred Heinzelmann of LEAA reports that negotiations are underway with Steven Oüra, a co-author of the Computer Abuse Study. For his immediate needs, the study dealt with too wide a variety of types of abuses. He was particularly interested in only those which had implications for the Criminal Justice System--relevant, for example, to training needs or methods of prosecution of crimes. Despite these critical comments, Heinzelmann rated the study a "useful first cut at the problem." He has used its findings in deciding to negotiate with Dr. Oüra.

In addition to NSF and LEAA, interest in the subject--engendered in part by the study and attendant publicity--has led SRI to contract with a number of public and private agencies, including these names and contacts:

- General Services Administration, Office of Audit, Jack Nesbitt;
- Federal Home Loan Bank Board, Guidelines for Certified Public Accountants, Michael Serlin;
- Central Intelligence Agency, Carroll Melkerson; and
- General Accounting Office, Report to Congress on Computer Fraud in Federal Government, Walter Anderson.

Lectures were given to the Federal Bureau of Investigation, Federal Depositors

*Susan Hubbell Nycum, "Computer Abuse Raises New Legal Problems," Journal of the American Bar Association, Vol. 6, April 1975, pp. 444-448.

Insurance Corporation and the Department of Agriculture. A study is now underway for Senator A. Ribicoff.

In the private sector, the firms funding studies prefer to remain confidential, but there have been contacts with four banks, a large transportation company, a large security brokerage firm, an international time-sharing company, and a retail department store chain. A representative of one private firm commented that this was the first time in his experience that NSF research had been of direct benefit to private industry.

By the end of December 1973, when the Computer Abuse Utilization Project was completed, the project had disseminated the following:

1. Twelve articles, papers and reports in: Proceedings of the American Bankers Association Operations and Automation Conference, Banking Magazine, The Office Magazine, Encyclopedia of Computer Science, Management World Magazine, Journal of Data Management, Datamation Magazine, Computer Decisions Magazine, State of California Legislation Committee on Efficiency and Cost Control: Testimony on Computer Abuse and Comments and Recommendations on Assembly Bill 2656, Journal of Forensic Science, and of the American Bar Association Journal.
2. Twenty-six oral presentations to over 2,000 people. Others were scheduled at the time of the final utilization study report. Presentations were made to the following organizations: Association for Computing Machinery, U.S. Defense Contract Audit Agency, American Federation of Information Processing Societies, American Society for Industrial Security National Conference, Palo Alto Fellowship Forum, Stanford University Digital Systems Laboratory, Congressman McCloskey,

Canadian Information Processing Society, National Retail Merchants Association, IEEE Computer Society, National Society of Controllers, Kiwanis, American Institute of Certified Public Accountants, American Management Association, Institute of Internal Auditors, and John Hopkins University Applied Physics Laboratory.

3. Distribution of the Final Report from SRI reached 1500 copies at the time of the Utilization Project; the National Technical Information Service reports that by May of 1976, an additional 1853 documents had been distributed by NTIS. Among the more significant requestors of the report were: Ralph Nader, Congressman McCloskey, Senator Sam Ervin, and Congressman Barry Goldwater, Jr.

4. Additional Publicity for the project and about the subject of computer abuse appeared in major news magazines such as Time, U.S. News and World Report, Newsweek, Saturday Review, and the Potomac Magazine. News about the project has been published in numerous other journals, newspapers, magazines, and wire service reports.

The above description of the products of the study and their dissemination support the contention that computer abuse is a subject of considerable general interest to the national press as well as special interest groups. The Principal Investigator reports that this interest has continued until the present. The data bank of case studies has now been expanded to 420, and abstracts have been prepared for use in a time-shared computer service. This service is being provided because of the large number of people who wished to use the file of case studies for a variety of purposes--including the continued preparation of magazine articles and newspaper stories. The list of persons wishing to purchase future reports on the research has now reached 4000.

Features

The utilization of the report was influenced by a number of factors. Those which appear to be most important are:

- The Principal Investigator had a strong commitment to the subject and had put a good deal of thought and effort into it prior to receiving NSF/RANN funding. As one user reported, Donn Parker had the interest and ability to pull significant information out of a diverse collection of case studies. He also has the desire to let the computer-using world know about his findings.
- NSF/RANN supplied additional funds through a Utilization Grant and this permitted a much more widespread dissemination of reports and findings.
- The timing was right for interest in the user community. Several large and well-publicized cases of computer related crime were in their minds. They were ready to have the problem clarified in scope and examine the vulnerability of their systems.

Any assessment of the strengths and weaknesses of the study and its utilization must consider the limited objectives and level of effort involved. The Principal Investigator worked from a rather small set of case studies, highly varied in nature and scope. User criticism of the study was primarily directed at these limitations: too broad a scope, not a representative sample, too little attention to some special interest area. These were certainly weaknesses, but they could not be entirely avoided within the grant's limitations. The Principal Investigator's charge and intention was to show the widespread nature and scope of the computer abuse problem. He was able to accomplish this for a broad audience of users in an effective manner.

He appears to have established, beyond a reasonable doubt, that protection against computer abuse is a national need and that it should be addressed as a special discipline.

Conclusions

The computer abuses study is an outstanding example of utilization of RANN funded research. However, this statement is made in the context in which the study was accomplished, i.e., its intent was to call attention to a potential problem set and it succeeded very well in doing this. Utilization followed. Other RANN projects in which new products, processes, or analytical tools are created have a more difficult task in achieving utilization and do not usually attract the popular audience that was available to the computer abuses study.

Planning studies of this type directed to the establishment of a base of support for future research have a definite place in the RANN program. They are crucial in defining areas of needs. This appears to be a strong example that can be used to support the establishment of more "pathfinder studies."

The lasting benefits of planning studies will come from the follow-on research. In this case, the benefits will be safeguards and deterrents to computer abuses that are devised. The value obtained in utilization of the planning study, itself, is transient unless future research produces such products. At SRI, the effort to do this is funded and underway.

References

1. Letter report to Mr. Arthur F. Konopka, Program Manager, Law, Science and Technology Program, NSF from Donn B. Parker, Senior Information Processing Analyst, Information Systems Group, Stanford Research Institute dated October 27, 1975: Containing one-page report entitled "Computer Abuse Research Accomplishments," dated November 2, 1975.

2. Donn B. Parker, Susan Nycum, and S. Stephen Oura, Computer Abuse. Final Report prepared for the NSF/RANN Contract No. NSF/RA/S-73-017 under Grant No. GI-37226. Stanford Research Institute, Menlo Park, California 94025, November 1973.

3. Letter to Mr. Donn B. Parker from Arthur F. Konopka, January 8, 1974. Letter accepts Final Report on the study.

RANN UTILIZATION EXPERIENCE

CASE STUDY NO. 29

PROBLEMS AND RESEARCH PRIORITIES IN THE ROCKY MOUNTAIN REGION

UTAH STATE UNIVERSITY

Case Investigator:

M. v.E. Rulison

Research Triangle Institute
P.O. Box 12194
Research Triangle Park
North Carolina 27709

Technical Reviewer:

F. J. Convery

Department of Forestry
Duke University
Durham, North Carolina 27706

Prepared under:

Contract No. NSF-C76-17165
National Science Foundation
Research Applied to National Needs
1800 G Street, N.W.
Washington, D.C. 20550

PROBLEMS AND RESEARCH PRIORITIES IN THE ROCKY MOUNTAIN REGION

Introduction and Summary

The Rocky Mountain region is a large but sparsely populated part of the United States. The economy of the area is closely linked to its natural resource base: agriculture, forestry, and extractive industries dominate the economy, and tourism based upon natural and scenic resources is also important. This region is currently growing more rapidly than the nation as a whole and this trend appears likely to continue because of the probable development of coal resources in the region. Increasing pressure will be exerted by population and production activities on an environment that is relatively fragile because of the low-rainfall climate that has molded it.

Given this very large region, still relatively undeveloped, but subject to the likelihood of sharply increasing development pressures, concern has developed for establishing a research agenda that will use available resources effectively to address the more critical environmental problems of the region. This concern appeared among members of the faculties of regional academic institutions, staffs of Federal and State agencies operating in the region, and among staff in the Division of Advanced Environmental Research and Technology at the National Science Foundation. Ultimately, the concern was manifested in this project, "Problems and Research Priorities in the Rocky Mountain Region," funded by NSF/RANN, and known as the Rocky Mountain Environmental Research-Quest for a Future (RMER-Quest) project.

The focus of this project was to identify specific research projects relating to environmental problems of the Rocky Mountain region and to recommend funding priorities for those projects. The project was specifically structured to emphasize collaboration by concerned parties throughout the Rocky Mountain region in carrying out this assessment of needed research with the aim not only of insuring coordination and legitimacy in the result, but also of strengthening the interaction and cooperation forthcoming from individuals and institutions throughout the region in addressing pertinent environmental issues.

From its inception, this project was designed to involve both the research community and other potential users in its development. This was accomplished through a hierarchy of committees and task forces, involving more than 100 persons, who formulated and guided project activities. A Planning Committee Advisory Council set up the structure; task forces developed statements of research needs and priorities; and a Synthesis Workshop was held to draw program recommendations from the task force reports. Project information is given in table 29-1.

The overriding relevance of this type of research is the role it plays in giving perspective and completeness to the ideas developed by many independent researchers. An exercise of this type enables a variety of individuals and agencies to identify mutually supportive common starting points and needs.

This project has two distinct products: the written final report of which some 450 copies have been distributed; and the process of the project itself, in which many people participated directly, forming new relationships and broadening their understanding of the views of other groups on environmental problems in their region and of the capability and limitations of science and technology to help resolve these problems.

Table 29-1

PROJECT INFORMATION

Project Title Problems and Research Priorities of the Rocky Mountain Region	Grant/Contract No. GI 39421
RANN Program Manager Larry W. Tombaugh (initial) Terry R. Sopher (final)	RANN Program Area Regional Environmental Systems
Principal Investigator(s) (Project Directorate) John M. Neuhold, Department of Ecology, Utah State University David E. Herrick, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado Duncan T. Patten, Arizona State University	**Schedule** **Start:** June 1973 **End:** March 1975
Institution The Ecology Center Utah State University Logan, Utah 843321	**Funding** **NSF:** $114,800 **Other:** EPA $15,000 Forest Service $15,000
Contributors/Collaborators Planning Committee of seven persons plus project directorate. Members of eight task forces. Eisenhower Consortium for Western Environmental Forestry Research Committee of Future Environments of the Rocky Mountain Region.	
User Advisory Committee Advisory Council of 28 members plus the Planning Committee.	
Precursor Activities Plans for similar investigations by the Eisenhower Consortium for Western Environmental Forestry Research and the Committee on Future Environments of the Rocky Mountain Region of The Institute of Ecology.	

Participation in the task forces and other project activities is a major positive force, promoting utilization through a sense of involvement and commitment, and because of the additional personal contacts that are made.

For the final report, utilization is related to amount and nature of distribution, and the suitability of the report for each reader group. In this case, the wide variety of user groups means that a single report is likely to fall short of the needs of certain groups.

This project yielded a final report identifying environmental problems and research needs and indicating priorities for some of these needs in eight major research areas. This report has met some, but not all, of the expectations of the sponsoring agency for a set of research problems and associated priorities.

The project has also been effective for bridging the gaps in communication among a variety of academic, geographic, and societal groups throughout the region. This resulted in more interaction, at least among the members of these groups who were involved in the task force and workshop processes.

Research Description

The RMER-Quest project, funded by NSF/RANN, represented the combination of studies conceived independently during 1972 by two organizations and brought together through the actions of the NSF Program Manager. The first of these organizations is the Eisenhower Consortium for Western Environmental Forestry Research, composed of nine southwestern universities and the U.S. Forest Service Rocky Mountain Forest and Range Experiment Station at Fort Collins, Colorado. The second is the Committee on Future Environments of the Rocky Mountain Region (COFE), part of The Institute of Ecology (TIE). COFE is composed of representatives of 24 universities and institutions in the Rocky Mountain Region of the

United States and Canada.

The resulting joint proposal, submitted from the Ecology Center at Utah State University, Logan, Utah, was received by NSF in early 1973. In June of 1973, this project was authorized by NSF/RANN with initial funding of $99,800 for 12 months. Dr. D. Wynne Thorne was the original Principal Investigator. Upon assuming new responsibilities at Utah State University, he was succeeded in this capacity by Dr. John M. Neuhold, President, The Institute of Ecology, in November 1973.

The project was managed by a three-person directorate, part of and responsible to a seven-person Planning Committee. This committee included representatives of three Federal agencies, three research-oriented groups, two regional organizations and a representative of industry. The Planning Committee, which was part of the Advisory Council, met twice during the project in addition to maintaining mail and telephone contact with project operations.

The Advisory Committee was formed over the summer and met in September 1973, at which time it set up seven task forces to work on separate aspects of environmental problems. Five focused on resources, two on human systems, as follows:

- Minerals and energy;
- Recreation, tourism, wildlife, wilderness and esthetics;
- Water resources;
- Forestry and agriculture;
- Residential, second homes, and transportation;
- Human needs and responses; and
- Institutional arrangements and communications.

Subsequent review resulted in an eighth task force devoted to biological (ecosystem) resources.

Project design called for these task forces to meet and prepare reports on their respective subjects during the winter of 1973-74. During this time, 103 task force members plus contributors and consultants volunteered their time for meeting and preparatory work resulting in draft task force reports, which were sent out for review in March 1974. Some 150 additional persons drawn from State agencies, regional and national offices of Federal agencies, industry, and environmental organizations, participated in this review process. Comments were compiled and fed back to the Planning Committee and task force leaders.

At the end of April, the project plan called for a Synthesis Workshop to identify important themes and gaps in the task force reports, to specify research areas, and assign priorities to those areas. This workshop was held with 100 persons participating. Forty persons were new to the project and 60 attendees had participated previously in the project.

The summer of 1974 was spent editing the task force reports and summarizing the work of the Synthesis Workshop. Following this, content analysis was used on prior project reports to establish the importance of some 500 research needs that had been articulated during the workshop meetings. A special writing session was held in October 1974 to complete the introductory and summary chapter stating the major research themes. After reviews and reproduction, the report was issued in 1975, approximately nine months later than scheduled in the project proposal.

This research project has two "products" of differing nature. The obvious product is the printed report of some 250 pages incorporating eight task force reports, introduction and summary, and report on the Synthesis Workshop. To date, 450 copies have been prepared and distributed. Requests have been received from academic institutions, research and consulting organizations, Federal and

State agencies and environmental organizations, mostly in the region, but some nationally as well.

The less obvious "product" is the interchange of knowledge and opinion, the perception of alternative viewpoints, and the establishment of personal relationships among some 150 persons participating in one or more project activities. This product, like the report, is spread throughout the Rocky Mountain region and across a score of disciplines and interest groups.

This study may most accurately be described as "meta-research," that is, it is research about research. Its objective is to use appropriate techniques from the scientific method to identify problems worthy of further attention.

The significance of such meta-research is established by the degree to which it aids society in agreeing on the definition of significant problems and then directing resources into research to remedy them. This includes identifying heretofore unrecognized issues, reaching consensus on importance, and motivating individuals to action--to either propose and carry out research, support and fund it, or acquire and use the results.

Utilization Objectives

The potential set of users of this research consists of all persons concerned about the environmental problems resulting from man's development and use of the nonurban parts of the Rocky Mountain Region. This includes Federal agencies having mission responsibilities in the region, such as the Forest Service, Park Service, Bureau of Land Management, Bureau of Indian Affairs, Bureau of Mines, and Environmental Protection Agency. It also includes the National Science Foundation itself. The Forest Service and EPA also contributed

$15,000 each toward project funding. It also includes counterpart organizations within each State government. Other members of the set are representatives of major economic sectors, including energy, mining and minerals, forestry and timber, ranching and other agricultural activities, recreation and tourism, and land development. In addition, public interest organizations concerned with the development and environment of the region from a variety of viewpoints, are important members of the user community. Finally, graduate students and professional staff of academic and other research institutions within, or concerned with, the region and its environmental problems are also included.

These users represent a wide array of characteristics. Some are highly sophisticated in the design and execution of research. Others are concerned primarily with operating financially successful business enterprises. A vocal subset is especially sensitive to the environmental consequences of man's use of the region's resources. Agency administrators who initiate or react to policies and programs intended to benefit the region or one or more groups therein are perhaps the key users because their decisions are basic to ensuing actions. Most users, of course, are mixed types and have combinations of the above characteristics.

The application of the final project report lies in its usefulness as a source of recommendations for research needs and as a reference to the background thinking of each task force as it developed its lists of research needs. In addition, the report summarizes the Synthesis Workshop for each of the eight subjects under three headings: inventory, response to imposed change, and directing change.

The project proposal describes the effort as follows: "This project [was] designed specifically to provide programmatic guidance to the staff of the [NSF]

Regional Environmental Systems Program concerning research priorities in the sub-element entitled 'Semi-Primitive Environments.' Although the problem assessment deals only with the Rocky Mountain Region, it [was] felt that this region contains most of the existing semi-primitive environments in the United States and [was] representative of the problems facing other such environments." (Project Proposal P311191).

The application of the other "product," namely participation in the task force activities and Synthesis Workshop, is in the new relations that have been fostered among various individuals and the institutions they represent in the region.

By the nature of its operation task forces and other groups, the project involved users from start to finish to an extent far greater than a conventional "laboratory" research project. There were, of course, differences in the representation of various types of users at different stages, but overall the spectrum was broad.

The original proposed utilization plan viewed NSF staff as the primary user of the project, and also identified as users other public agencies, especially the Forest Service and EPA. It did not mention State Government, business and industry, public interest groups, or the academic community.

In a paragraph on implementation in the proposal, the project was committed to contacting both public and private research institutions to insure their awareness of the research recommendations. The use being sought was implicitly to insure that institutions would take project results into account in focusing their reseach efforts.

The dissemination technique implied in the project proposal was that of publishing and distributing a final report for the project. Reference was also

made to publication in academic journals. Involved universities would hold reporting meetings on their respective campuses.

Public meetings for government, industry, and the public would also be held in each state or province. Lastly, the use of television and radio for "developing broad public awareness of problems and potentials of the Rocky Mountain Region" was included as a dissemination techique.

Utilization Obtained

Uses range from those involving use of the final written report to those involving participation in the process of developing that report. Different users of the research project have operated at different ends of this use spectrum.

The initial Program Manager for NSF, Dr. Larry W. Tombaugh (presently Acting Deputy Assistant Director for Analysis and Planning), stressed that a major purpose of this project was to develop research priorities to guide the Regional Environmental Systems Program within the Division of Advanced Environmental Research and Technology. Thus, NSF itself expected to be a user, with the intention of basing funding for further research in the Rocky Mountain Region on the results of this project.

Although some task force reports (e.g., Water Resources and Uses) did not produce any priorities, others (e.g., Mineral and Energy Resources, Recreation and Tourism, and Rural Residential Development), in varying ways, did set priorities for the research needs they developed. The report of the Synthesis Workshop regrouped many of these issues under another set of classifications. There appears to have been no attempt to assert a priority for research across the

major classification boundaries. That is, no decision was rendered between spending research dollars on a high-priority rural residential development issue and spending them on a high-priority rural residential development issue.

Despite unfulfilled desires for stronger statements of research priorities, the NSF/RANN program managers are pleased with overall project results. Mr. Terry R. Sopher, who replaced Dr. Tombaugh as NSF/RANN program manager in November 1974, half a year after the Synthesis Workshop had been held, focuses specifically on the value of the project process, which he believes was "highly successful in getting the institutions of the region to communicate effectively and in opening new doors in terms of regional awareness." He believes the project was successful in enabling participating businessmen, State government policymakers and members of academic institutions to understand their respective interests and concerns. However, from the records it appears that even greater involvement of state personnel would have been beneficial.

Mr. Sopher views the Rocky Mountain Research Institute as being partially an outgrowth of this project and a means of continuing the communication process started in the project.

In hindsight, NSF would recognize the primary importance of the project process in this sort of meta-research and would place greater emphasis upon high involvement of final users in the project from its earliest stages, and in planning and implementing follow-on meetings and presentations to make project findings widely and directly known to various user communities. Indeed, Mr. Sopher states that funds to promote such utilization were available at the time the final report was completed and would be available in the future for such further steps in the dissemination process if justification exists.

Charles Montooth, an architect with the Frank Lloyd Wright Foundation at Taliesin West, Scottsdale, Arizona was a member of the RMER-Quest Task Force on

Rural Residential Development. He views the final project report as a "handy tool," but ascribes greater importance to the process of participation in task group and Synthesis Workshop activities, which broadened his horizons about the relation of his professional interests to other fields. Mr. Montooth believes there was a good cross-section of participants in this project and describes the project leadership as good and magnetic.

Because of his profession, Mr. Montooth is particularly sensitive to the graphic aspects of presentations. He believes that the results have "not been merchandized" to the extent that they might have been through a report with additional graphics. Thus, his recommendations with respect to utilization would be for making project materials useable by persons outside the academic community.

David E. Herrick is Director of the Rocky Mountain Forest and Range Experiment Station at Fort Collins, Colorado. He was also one of the three persons forming the directorate of this project during its period of activity. He views the final report as "an excellent base document" that represents inputs from a wide variety of interest groups. The RMER-Quest project was set up in part through his organization's participation in the Eisenhower Consortium for Western Environmental Forestry Research. Their goal was to get an analysis of research problems across a variety of fields. Recognizing that this objective was too large to accomplish within one agency, efforts to involve both the National Science Foundation and the Environmental Protection Agency were successful. Mr. Herrick emphasized the role of the project process of interaction and the resulting report as a means of establishing the views of groups with differing views about the ends and means for management of natural resources in the Rocky Mountain region.

As a follow-on to the RMER-Quest effort, the Forest and Range Experiment Station will have two university staff members consulting with them during the summer of 1976 to use the RMER-Quest report and move ahead from it to formulate a long-range program (with quantified priorities for the Eisenhower Consortium), using a "convergence analysis" approach.

As recommendations, Mr. Herrick would have put more emphasis on formal papers prepared to start the task forces on their initial work and less emphasis on the Synthesis Workshop at the end of the project.

Perry Brown is Associate Professor of Recreational Behavior and Regional Resource Planning in the College of Forestry and Natural Resources at Colorado State University, Fort Collins, Colorado. He was also chairman of the Recreation and Tourism Task Force during the RMER-Quest project. In his opinion, the project final report does provide priorities, not for specific projects, but for broad problem areas. He feels the items of really low priority were discarded during task force operations. He believes the project is fairly well-known and accepted in State government agencies and presumes that most of the users are persons who participated in some phase of the project.

His recommendations focus on the distribution of the report, which he believes could be improved, for example, for government publication. It would then be more visible than the report of a single project. He is not sure that the report is readily available to graduate students, for whom it might serve as a stimulus for developing theses and dissertation projects.

Russell W. Fitch is on the executive staff of the Federal Regional Council for Region Eight (Colorado, Montana, North and South Dakota, Wyoming, and Utah). At the time of the RMER-Quest project, he was Director of Research and Development

for EPA in Federal Region Eight. To Mr. Fitch, the product of this study is both the final report and the learning that occurred through working with other other persons, with equal emphasis on the task forces and the Synthesis workshop. Mr. Fitch learned of this research through contacts with NSF and was asked by NSF to serve as a member of the Advisory Committee.

Mr. Fitch considers this project to have been highly ambitious in its goals, and rates it as having good, but not high success relative to those goals. He is looking for "research objectives" rather than "research needs" and indicates that additional effort is needed to reach the former. He is aware of a gap between the goals of government agencies and those of persons working in academic institutions, and feels there is a need for orienting such projects toward specific results.

Michael Annison is executive vice president of the Federation of Rocky Mountain States, located in Denver. He says the Federation is using the RMER-Quest final report as a source from which to derive policy issues needing attention by state and regional policymakers. For this purpose, the final report has been a satisfactory and usable document. Mr. Annison is of the opinion that further development of priorities for research should most appropriately be conducted by policymakers rather than within the academic community.

Considering future projects of this type, Mr. Annison believes that public and private decisionmakers should be included as a formal and integral part of the research structure in order to involve such persons deeply and create stronger links between researchers and state or regional agencies.

For example, he suggests that assignments of subtasks from such projects to the states for canvassing their policymakers with respect to project issues would be useful. Aware that government and private policymakers will not necessarily be familiar with research procedures, he nevertheless believes the investment of time and effort to carry out this familiarization process would have excellent benefits in productive relations between these two communities, similar to those that have developed between academic institutions and the Federal government during the past generation.

Paul S. Rattle is manager of the Utah Mining Association and was an active member of the Task Force on Mineral and Energy Resources during the project. He is critical of the project on several respects and was not pleased with its results. He believes the task force report in which he was involved contains inaccurate and uninformed statements and, partly because of the delay in publication of the final report, was not as timely as it should have been. Mr. Rattle wanted a project and process that was more practical and more specific and down-to-earth in the final report. He believes industry and business should have a larger share of representatives in the project activities as opposed to researchers and "bureaucrats."

Craig Bigler, Associate State Planning Coordinator in the Office of the Governor of Utah, served on the project Advisory Committee during the project. He believes most of the benefit of the project came through participation and personal relationships formed. What he has read from the report has not been especially useful because it compiles already-known material, although it has served as a source of quotations. Mr. Bigler feels that the report was too long for use and should have been followed by an audio-visual presentation

for policymakers.

He would have preferred more representatives of government in the mix of project participants. The major barrier to greater utilization is the inability of State government administrators and staff from academic institutions to communicate; interest in this dialogue is lacking and some academic persons are politically naïve.

Donna Parsons is a professor at the College of Idaho (Caldwell, Idaho) and Director of the Snake River Environmental Regional Studies Center. During the project, she was a member of the Task Force on Rural Residential Development and attended the Synthesis Workshop. Mrs. Parsons feels a great sense of accomplishment from her participation in the task force and said the task force had involved persons not directly associated with the project by seeking their critique of drafts.

Mrs. Parsons believes that users in addition to Federal agencies should have been involved earlier in the project life, even though she feels the effort to involve users in this study was stronger than in other projects of this type.

Mrs. Parsons states that one of the outgrowths of RMER-Quest is Continuing Education for Land Use Planning (CELUP), a five-state consortium funded under Title I of the National Education Act of 1965. CELUP sponsored a conference entitled "Community Sprawl--Assault on the Land" in May of 1976 at Utah State University to inform representatives of the media and local government about the effects of residential development.

Another outgrowth is a handbook for county commissioners and local planning staff. The handbook provides a set of checklists and criteria for

judging the primary environmental impact of second home developments.

In addition, Professor Parsons' Regional Studies Center was funded to prepare a workbook in land use planning for use in Idaho. It was based upon a similar one prepared in Utah and is, itself, being used as a model by a group in Arizona.

Dr. H. William Welch is assistant dean of the College of Engineering and Applied Sciences at Arizona State University in Tempe. At the time RMER-Quest was started, he was President of the Eisenhower Consortium for Western Environmental Forestry Research and in this role was responsible for one of the proposals that was later consolidated to form the RMER-Quest to NSF. In addition, during the project he was chairman of the Task Force on Mineral and Energy Resources, and a member of the Advisory Committee and the Synthesis Workshop.

Because of his duties and interests, Dr. Welch has devoted much energy to RMER-Quest and says he has told many persons about it. He understands that the report is being used in the Arizona State Office of Economic Planning and by a committee on natural resources in the Arizona Legislature, among other places. He found the task force experience refreshing and regards the relations established there as very helpful.

Dr. Welch has definite opinions about ways in which such projects might be made more effective. First, he would select only participants who understand the research process, regardless of what type of job they currently hold. Dr. Welch is concerned about having non-researchers setting priorities for research. Second, he would condense the process in time, making it a full-time effort for a short period. Third, he would use the same participants throughout the project to avoid the effort needed to give background to the

40 percent of newcomers, as occurred in the case for the RMER-Quest Synthesis Workshop. Fourth, he would (and did) press for prompt publication of the final report. Fifth, he would allocate a larger proportion of project budget and effort to the dissemination task. He feels the Synthesis Workshop received somewhat more effort than it was worth.

Mr. James Matthews, Research Analyst, Arizona House of Representatives, reported that the RMER-Quest report was used as background material in drafting a bill by him and Representative Keith Hubbard. The bill, which did not survive committee action, proposed the creation of an energy policy office to coordinate all activities associated with energy in the State of Arizona. Representative Hubbard became aware of the RMER-Quest study when he attended a symposium sponsored by the Eisenhower Consortium.

Mr. Dennis Thompson, Associate Planning Director, Arizona Office of Economic Planning, reports that a copy of the RMER-Quest report has been circulated through his office and has been read with interest by him and his staff. He could not identify any direct impact that the research results may have had on his planning. He did state, however, that there have been auxiliary impacts in that the document served to expand the information base available to the planning staff.

Dr. Ralph W. Richardson, Jr. is Director of the Natural and Environmental Sciences Division of the Rockefeller Foundation. He has only recently received a copy of the final report, but having read some preliminary versions, he asserts that the material is very valuable in his work in managing and funding research projects. He finds the report "great the way it is" and feels

ready to set his own research priorities from the material provided, without needing greater emphasis on priorities in the report itself.

Mr. John Baker is Manager of Information Services at Cameron Engineers, Inc., Denver, Colorado. His firm publishes a quarterly information service on synthetic fuels and he has requested a copy of the report. The RMER-Quest report is referenced in a bibliography, but was not reviewed and abstracted by their information service.

Mr. John Reuss is Executive Director of the Montana Environmental Quality Control Council, an agency responsible for providing the legislature with information and policy analysis in the environmental area. During the project, he was a contributor to the Institutional Arrangements Task Force and was associated with the Department of History, Government, and Philosophy at Montana State University.

Mr. Reuss says all of his staff of five persons have read the project report and that it is used "pretty extensively" in the areas of water, forestry and forage, and minerals and energy in their work for the legislature. The report is useful in providing a "sense of the issues" and in strengthening their understanding of the issues and the range of solutions throughout the region.

The barriers to greater utilization, according to Mr. Reuss, are insufficient dissemination and administrative legitimacy. He believes wider dissemination, beyond the conventional channels, would have been desirable. He sees the endorsement of high state officials as a necessary step in getting the project conclusions established as administrative priorities.

Dr. Arnold W. Bolle is Professor of Forestry at The University of

Montana. During the project, he was a member of the Planning Committee as well as Director of the Committee on Future Environments in the Rocky Mountain Region (COFE) of The Institute of Ecology. He served as Co-Chairman of the Task Force on Institutional Arrangements and attended the Synthesis Workshop.

Dr. Bolle considers the report to have been widely distributed and understands that it is being used as a background and source document by graduate students at institutions in the region when developing research interests. He cites the interdepartmental program in land use planning at the University of Montana as a result of the project. Like many other participants, he appreciates the ties developed with other workers concerned about this region during the project. He is aware of some individual or small-scale collaborations arising from the project. He points to the Association of Rocky Mountain Ecologists (ARME) as having developed out of RMER-Quest. On the other hand, he is disappointed in the progress to date of regional organizations trying to move forward from the point at which RMER-Quest ended.

Overall, Dr. Bolle feels the project was very good, but he recommends strongly the need for getting out final reports closer to the bulk of project activity, while both participant interest and the desirability of following through with meetings in each of the states are high.

Features

Continuing professional liaisons established during the course of this project are perhaps the most important form of utilization. For example, Dr. Neuhold, professor in the Department of Ecology at Utah State University and

Principal Investigator for the RMER-Quest project, is being included in some projects undertaken by architects. The final report is voluminous and perhaps not too many persons will take the time to read the entire document. However, a large number of copies were distributed and are being used as sources for research ideas being developed and proposed within the academic community.

Based on the proposal, dissemination--beyond those involving project participants--was only a very minor fraction of total project effort. Some of the activities suggested, e.g., television and radio, were not in fact developed. The effort of the Synthesis Workshop and subsequent writing of the beginning and ending of the final report appears to have left little energy for dissemination.

Dr. Neuhold made some efforts to secure supplementary funding to promote utilization and notes that a two-projector slide-tape presentation was prepared through the efforts of the Rocky Mountain Center on the environment to be used in local meetings throughout the region.

This project involved a large and varied group of participants and users. Inevitably, they came to the project with different values and expectations.

There was a tough, trying confrontation that occurred throughout the project between advocates of differing environmental policies. The work of the project to get such partisans to "learn how to talk to one another" and to work together is one of its major accomplishments. The reports of persons interviewed clearly suggest an increase in understanding of different perspectives and this should be a significant benefit even though satisfactory agreements may not have been reached on certain issues.. A breakdown of the areas of interest of all of the persons participating is given in the Appendix.

Conclusions

The RMER-Quest project is one of several similar efforts funded by NSF/RANN as part of a program to develop research priorities in regional environmental systems for use by NSF/RANN in funding subsequent research. In fulfilling this objective, the project directorate tried to integrate the technical expertise of research specialists with the problem orientation and values of potential users of research from business, government, and public interest groups. This is evidence of a strong desire to bring about cooperation and efficiency in research endeavors. That some participants are continuing relationships formed during the project speaks well of the process and leadership of working groups throughout the project. Differences in opinion about the usefulness of a report on problems and research priorities existed among reviewers of the project proposal and persist today among project participants, reflecting the particular positions from which they speak.

Although opinions of project participants vary about organizing this sort of endeavor, activities to involve a broad spectrum of users should be started very early, possibly even before a final proposal is submitted. It might be well to consider a format in which the project work is accomplished by one set of individuals without changes in composition at the workshop stage. But once the written report is available, meetings between project participants and persons not previously involved could prove useful in promoting dissemination. After initial position papers are prepared, project activity should probably be fairly well concentrated in time to keep attention focused, particularly in the final writing task.

The written document resulting from this project could probably have been produced by a smaller group of persons in less time and been more satisfying to the members of that group. On the other hand, such a process might not have been widely acceptable or credible among various interest groups. The participation and communication occurring in the task forces and Synthesis Workshop and thus, one of the products of the project, however, would have been reduced if the number participating had been lowered. Delays in completing the final report are also viewed by some as detracting from the effectiveness of this project.

The greatest barrier to utilization for this type of research is the "two-cultures" problem: academicians and researchers in one camp, administrators and businessmen and environmental advocates in another. Each lacks understanding of the values and daily problems of the other. This is a major institutional barrier of long standing, but one which this project faced head-on with some degree of success.

Appendix

Interest Areas of Participants in RMER-Quest Activities

	Number	Group Total
Project Directorate	3	3
Planning Committee	7	10
Advisory Council	28	38
Task Forces*	103	
Biological Resources of Regional Ecosystems	17	
Human Needs and Responses	12	
(plus 8 named "other contributors")		
Mineral and Energy Resources	11	
Recreation and Tourism	7	
Impacts of Rural Residential Development	12	
(plus 8 named "consultants")		
Timber-Forage	20	
Water Resources and Uses	13	
Synthesis Workshop**	27	

Source: Final Report, Appendix B.

* A few persons on task forces also served on the Planning Committee or Advisory Council.

** The Synthesis Workshop included these 27 plus 24 persons who served on task forces and 20 from the three levels of projects administration for a total of 71 persons.

RESEARCH TRIANGLE INSTITUTE N.C.

RANN UTILIZATION EXPERIENCE

CASE STUDY NO. 30

DEVELOPMENT OF A PLAN TO MAXIMIZE THE LEARNING FROM DESTRUCTIVE EARTHQUAKES

EARTHQUAKE ENGINEERING RESEARCH INSTITUTE

Case Investigator:

R. Whisnant

Research Triangle Institute
P.O. Box 12194
Research Triangle Park
North Carolina 27709

Technical Reviewer:

D. Stewart

Department of Geology
University of North Carolina at Chapel Hill
Chapel Hill
North Carolina 27514

Prepared under:

Contract No. NSF-C76-17165
National Science Foundation
Research Applied to National Needs
1800 G Street, N.W.
Washington, D.C. 20550

DEVELOPMENT OF A PLAN TO MAXIMIZE THE LEARNING FROM DESTRUCTIVE EARTHQUAKES

Introduction and Summary

Earthquakes can cause great physical damage, disruption to normal activities and loss of life in urban environments. The complexity of the dynamic ground motions and their interactions with physical structures, in addition to permanent ground shifting attended by virtually irresistible forces, severely limits analytical prediction of earthquake effects. The direct observation of earthquake effects remains a principal means of obtaining useful knowledge that can be applied to improved structural design and emergency service procedures aimed at reduced earthquake disaster losses. The collection of information from earthquakes must be done immediately after the event before the evidence has been disturbed or repaired. Thus, preplanning and organization are required, as well as the availability of knowledgeable investigators.

The objectives of this project were to develop a plan to maximize the collection and dissemination of critically needed information emanating from destructive earthquakes. The specific elements of the program were to (1) identify specific subjects and areas of interest in the scientific, engineering and socio-economic fields that urgently require additional investigation; (2) develop a methodology for gathering the required information including guidebooks, banks of baseline information and investigation scenarios of several hypothetical earthquakes; and, (3) develop a methodology for the rapid dissemination of the results of the investigations to the professions, agencies, and organizations concerned.

The project was conducted by the Earthquake Engineering Research Institute (EERI), 424 40th Street, Oakland, CA. The principal Investigator was Dr. C. Martin Duke, Professor of Engineering at UCLA and a past President of EERI. The Co-Principal Investigator and Project Manager was Mr. Donald F. Moran, a private consultant in structural engineering specializing in earthquake risk analysis. Project information is given in table 30-1.

The project staff was aided by three advisory panels, one each for engineering, geoscience and social science. Each advisory panel, consisting of a chairman and four to ten members, had one member selected by the project staff who provided coordination and services to the panels.

The products of the research are contained in a set of five manuals entitled Learning From Earthquakes, Volumes 1-5. The field guides define for the earthquake investigator what to look for, how to recognize it, and what to record. They also present plans for organizing, conducting and reporting investigations. The guides are designed for use by professionals who may be inexperienced in investigating earthquakes and, to a lesser extent, as a refresher for more experienced investigators. The guides are not intended as textbooks, but rather as a basis for enhancing the quality of learning from destructive earthquakes.

Several factors are pertinent to a discussion of the utilization of the manuals developed in the course of this program. First, there has been no major earthquake damage in the United Sstates since the guides were published. Second, the guides are, in a large sense, the culmination of the long experience of a number of experienced scientists and earthquake investigators. A sharp delineation of the use of the guides per se, as opposed to use of knowledge gained in prior experience, is not easy to draw. Third, the formal dissemination of the

Table 30-1

PROJECT INFORMATION

Project Title Development of a Plan to Maximize the Learning from Destructive Earthquakes	**Grant/Contract No.** GI 38318
RANN Program Manager Dr. Charles Thiel	**RANN Program Area**
Principal Investigator(s) Dr. C. Martin Duke Mr. Donald F. Moran	**Schedule** **Start:** May 15, 1973 **End:** December 31, 1975
Institution Earthquake Engineering Research Institute 424 40th Street Oakland, California 94609	**Funding** **NSF:** $189,000 **Other:**

Contributors/Collaborators

Mr. Jack R. Benjamin, Assistant Project Manager, Engineering Advisory Panel Members

User Advisory Committee The main advisory panel consisted of Dr. Duke, Chairman, Mr. Henry J. Dekenkolb (President of EERI), Mr. Gordon B. Oakeshott and Mr. Robert A. Olson. The latter three were chairmen of, respectively, advisory Panels in Engineering, Geosciences and Social Sciences. These Panels included 27 other qualified professionals in various fields pertinent to the Panel's areas of expertise. They represented academic, government and private organizations.

Precursor Activities

EERI has conducted earthquake investigations since 1960, including a funded study of the 1971 San Fernando earthquake. Various advisory Panel members have done earthquake investigations and the Principal Investigators have been active in the field since 1952.

guides on a national scale and orientation of professionals to their use has yet to take place. Fourth, the intended use of the guides is to improve the quality and quantity of data obtained from earthquakes, but it is the data (or knowledge) obtained, and not the guides themselves, which impact reduction of loss from earthquakes. With these factors in mind, however, a reasonable degree of utilization can be seen.

The information developed under this program has had substantial distribution thus far to professionals with a direct interest in earthquake effects. Eleven hundred copies of the guides were printed and about 75% have been distributed to EERI members and others. Three presentations based on the research were made at national professional meetings.

The guides and coordination plan were used to some extent by EERI investigative teams following the Guatemala quake in 1976. The Lima, Peru earthquake of October 1974, and the one at Oroville, California in August 1975, also provided opportunity to use the products of this research. The limited degree of use found among those interviewed was possibly due to no formal program having been implemented to acquaint potential users with the guides and provide training in their use.

In direct contacts with potential users, most felt that the guides would be useful in earthquake investigations, particularly to inexperienced investigators. They also expressed the idea that the guides provided a good technical summary of earthquake related problems useful to their organizations. For example, Mr. R. V. Bettinger, Chief Civil Engineer of the Pacific Gas and Electric Company, stated that the engineering field guide was useful to his company as a checklist of potential structural problems, and that similar information would have been compiled at PG&E had it not been for this project.

It can be concluded, based on the contacts made and documents reviewed for this study, that the products of this research have been moderately utilized. The dissemination of the guides and description of them at technical meetings has served to make professionals in the earthquake related disciplines aware of their potential utility. The technical discussions and checklists of earthquake-induced problems contained in the guides have aided organizations engaged in structural design or building code definition in the conduct of their work. Limited use of the plan in field investigations has taken place following quakes in Guatemala, Peru and California. Earthquakes are certain to occur in the United States in the future, and the products of this research will be utilized assuming that EERI or some counterpart is prepared to provide organizational leadership when they occur.

Research Description

From an historical viewpoint, earthquakes of a magnitude great enough to cause damage to structures or human injury and death are relatively rare. The damage and disruption to urban life, however, can be enormous. The last great earthquake, on February 14, 1976, occurred in Guatemala, killing about 15,000 people and causing damages of hundreds of millions of dollars. The last major damage in the United States resulted from a quake on February 9, 1971, in San Fernando, California. Fifty-eight deaths and nearly a half-billion dollars in damages resulted. Data compiled covering the years since 1500 A.D., show that earthquake deaths by century vary from 90,000 in the 17th Century to 900,000 so far in the 20th Century.* However, no trends can be observed from the data. For

*Personal communication from Dr. David Stewart, Director, McCarthy Geophysics Laboratory, University of North Carolina at Chapel Hill, April 1976.

example, 860,000 were killed in the 16th century. Earthquake loss has thus been a problem throughout man's urbanized history and continues through the present.

Nearly 90 percent of the seismic activity in the contiguous United States occurs in California and Western Nevada. However, three of the great earthquakes of known history occurred in the Upper Mississippi River Valley in 1811-12, and further activity there can be anticipated. Areas around Charleston, S.C., the Northeastern Region, the Northwestern Region, Alaska and Hawaii are other localities that are seismically active.

The essentially random nature of earthquake occurrence and the complexity of energy transmission paths through the earth's crust make prediction of the event and precise definition of local manifestations difficult. The complexity of building structures and their response to motions generated by earthquakes is not an easy problem to handle analytically. Thus, one of the primary means of improving the response of structures to earthquakes is still direct field observation of the results of a given quake. It is important that such observations and investigations of causes be done quickly after an earthquake, since it is necessary that damaged structures be repaired or dismantled to restore normal living and working conditions. Further, the investigation of social disruptions and traumas of these disasters must be made while these exist or are easily recalled by the participants. The conduct of such an investigation, under the pressure of time and the presence of often great social and physical disruption, requires careful planning and organization if the knowledge gained is to be maximized. This project addresses itself to this planning and organization for earthquake disaster investigation.

Earthquake investigations, up to the last few years, have been performed without any centralized coordination. Investigators have pursued their own

special interests with the result that many hazards had never been properly defined or quantified. Building structural performance has been the major subject of investigations until recent years. Literature describing some aspects of certain disasters was available, but for others, none was available. Results of investigations often have not been available for timely incorporation into codes, structural design procedures and emergency service planning. The experience with the investigation of the San Fernando earthquake in 1971, where there was evident lack of coordination, prompted EERI to formulate the project which is the subject of this case study.

A word of background about EERI is helpful in relating the project to previous activities by EERI in earthquake investigations. EERI was founded in 1949 as an organization devoted to finding better ways to protect lives and property from earthquake hazards. It is a national multidisciplinary society of engineers, geoscientists and social scientists; of practitioners, researchers, regulators and teachers; of generalists and specialists; and of building and utility people, totaling about 400 people.

Field investigation of earthquakes by EERI began in earnest with the 1960 Chile quake and has been performed for Peru, 1970; San Fernando, 1971; Managua, 1972; and Gautemala, 1976. The San Fernando study, funded by the National Oceanographic and Atmospheric Administration, was very extensive

A proposal was submitted by EERI to NSF in December 1972, and Grant No. ATA-73-07797-A01 ($189,000), was made on May 15, 1973 for "Development of a Plan to Maximize the Learning from Destructive Earthquakes." The project was completed on December 31, 1975.

Five manuals, entitled Learning from Earthquakes, Volumes 1 through 5, produced during the course of the project contain the planning to maximize learning from earthquakes.

The Planning Guide (Volume 1) contains an executive summary; general information on seismic risk to cities; a discussion of the philosophy, professional involvement and planning needed for earthquake investigations; and background information on the project and EERI. Also included in the Planning Guide is a request for commitment of the reader's organization for participation in future earthquake investigations.

The Engineering Field Guide (Volume 2) contains extensive discussions of the factors involved in earthquake damage to buildings, lifelines (transportation, communication, power, and transmission systems), and soils. Also discussed is collection of quantative loss data. The Engineering Field Guide contains a sample EERI Reconnaissance Building Inspection Form to be used in the initial definition of damage extent in a given earthquake.

The Geoscience Field Guide (Volume 3) includes a review of important seismic parameters of earthquakesas earthquake source mechanisms, ground deformations, accelerations, durations of motions, and topographic, focusing and resonance effects; recommendations for pre- and post-earthquake planning for the various scientific disciplines of the investigators, including availability of maps and photos, potential earthquake site data, and placement of seismic instruments; and extensive data forms for collection of quantitative data. Appendices contain reference information for preparation and conduct of field investigations.

The Social Science Field Guide (Volume 4) defines the purposes and tasks for the reconnaissance team; describes procedures for later research teams to obtain and organize data; and discussion related, lower priority research problems. The

Social Science Field Guide suggests a more rigorous investigative format than the other field guides and also includes suggested forms for data gathering. The basic subjects suggested for investigation are casualties (deaths and injuries), emergency service organizations and their performance, and the formation and effectiveness of search and rescue operations.

Finally, Special Topics (Volume 5) contains earthquake investigative response procedures as embodied in the EERI and California plans. Also contained in Volume 5 are papers on advanced topics including strong-motion seismology, structural motion due to seismic waves, the status of intensity definition and data collection, and submarine earthquake phenomena. The investigative response procedures contained in Volume 5 are an important part of the overall plan in that they provide details of individual responsibilities within EERI and the California Division of Mines and Geology (CDMG) for obtaining initial quake information, initiating investigative teams, establishing field headquarters, training investigators, conducting investigations, and communicating results.

The proposal for this project suggested that it was envisioned as phase one of a three-phase overall program to maximize learning from earthquakes: Phase I, development of a plan to maxime learning; Phase II, establishment of the plan by identifying people, organizations, and agencies who would make the plan viable; and, Phase III, implementation of the plan during an earthquake investigation.

Phase I was further defined to encompass: (1) the identification of subjects requiring investigation, (2) the preparation of materials to facilitate the gathering of information on these subjects, and (3) the development of a methodology to update the dissemination of the information.

Utilization Objectives

The ultimate beneficiaries of this research project are, of course, the general public. Application of the knowledge gained increases the safety of the whole nation to some degree. However, the users of the research products themselves are a more select group. The most general characteristic of these potential users is that they are professional engineers or scientists in the fields of civil engineering, geology or social science. Such users would be interested in knowledge of earthquake effects in order to reduce their impact through improved design of buildings, transportation facilities, lifelines, and emergency services. These professionals would benefit from knowledge gathered by others or from direct observation themselves. The direct utilization of the products of this research occurs, of course, during the course of an earthquake investigation.

The organizational affiliation of users is potentially quite diverse, and would include public and private utilities, public transportation, public building safety, emergency services, building code organizations, university faculty, private consultants, State and Federal research organizations, industrial firms and trade associations, insurance firms and rating bureaus.

Strictly speaking then, there would be no utilization or utilization plan for this project, which represents only Phase I. A proposal for Phase II has been funded recently by NSF for "Implementation of a Plan to Maximize the Learning from Destructive Earthquakes." The principal investigators feel that the Phase II effort constitutes the utilization of the Phase I product.

However, the structure of the Phase I project is such as to promote utilization as a by-product. The potential user involvement in the project has been substantial. The project staff and the advisory panels consisted of 33 professionals,

many of whom are involved on a daily basis with structures or social concerns affected by earthquakes. These advisory panels included persons from academia, private consulting firms, state and federal research and regulatory organizations, private industry, and utilities. Many of these advisory panel members have investigated earthquakes in the past and will do so in the future.

The nature of EERI also promotes utilization since its approximately 400 members are all professionals with an interest in earthquake effects and their investigation. The normal dissemination of information to its members should be an effective means of making the research known and used. EERI also has an official role in coordinating earthquake investigations in California, and carries out a similar role worldwide to the extent feasible.

Presentations at professional meetings and conferences are also part of the dissemination technique. Three such presentations have already been made to national conferences. The program was the subject of a half-day seminar at the EERI sponsored National Conference on Earthquake Engineering held at Ann Arbor, Michigan in 1975. About 350 persons attended the conference and the guides, in slightly abridged form, were printed in the proceedings. Dr. Duke and Mr. Moran presented a paper, "Learning from Earthquakes," describing the program at the American Society of Civil Engineers National Structural Engineering Convention in New Orleans in April 1975. A discussion of the program was also presented (by Mr. Henry Degenkolb, President of EERI) at the Second National Investigational Conference on Natural Hazards held at the University of Colorado in 1975.

Utilization Obtained

The utilization obtained to date has been limited by two factors. First, funding for implementation has just recently been received by EERI. Second, no

major earthquake has occurred in the United States since the project was completed. EERI did organize and carry out investigations in Peru during the project and in Guatemala just after its completion. The planning and organizational aspects of sending investigators to the site and compiling their findings appear to have conformed to the guidelines incorporated in Volume 5 of the guides. Other utilization of the guides was evidently limited, but no formal program of dissemination and familiarization has yet taken place. Several organizations contacted found the guides useful as technical information sources in their normal activities.

The following organizations were contacted by telephone (except one, as noted) to determine the nature of their utilization of the research products. The contacts were selected from three sources: (1) the project advisory panels; (2) those persons who investigated the recent Guatemala quake; and (3) the respondees to the California Coordination Plan. An attempt was made to cover a diversity of organizational affiliations and professional disciplines, and this proved reasonably, but not entirely, successful. Summaries of the contacts follow.

U.S. DOT-FHWA, Office of Res. (HRS-11)
Washington, D.C. 20590

Mr. James D. Cooper
Structural Research Engineer

Mr. Cooper was familiar with the project through attendance at the EERI annual meeting in January 1975. He has also reviewed informally Volumes 1, 2, and 5 of the guides for EERI during the project. He participated with the EERI second team that investigated the Guatemala quake in 1976. Mr. Cooper reread the Engineering Field Guide before going to Guatemala and found it helpful in preparing for that investigation. He felt that during the investigation itself, however, time did not allow for much utilization of the guide.

The function of Mr. Cooper's Division includes a long-term program of

research on seismic damage. Disasters that may provide data for highway and bridge design are investigated by the Division. He felt that the manuals were useful in orienting personnel to post-disaster investigations and as an investigation planning guide. The experience with the Guatemala investigation pointed out that DOT needed a mechanism to allow participation in such investigations, and that mechanism is now being established.

Woodward-Clyde Consultants
Two Embarcedero Center, Suite 700
San Francisco, California 94111

Mr. Thomas Rogers
Project Engineering Geologist

Mr. Rogers was acquainted with the project to a limited extent through his membership in EERI. His only exposure to the guides was a brief one on the way to Guatemala, where he participated in the second EERI investigation. He felt the material in the guide was pertinent to such investigations and would provide a good refresher for his firm's personnel. He was not aware of any other use of the guides by Woodward-Clyde and was of the opinion that many of the staff, like himself, had participated in other investigations and had limited need for the guides. Mr. Rogers suggested that two levels of guides, one for experienced and one for inexperienced investigators, might be useful. He recognized a greater need for the guides in areas of less frequent quakes where experienced investigators were unavailable.

Mr. Lloyd Cluff, Chief Engineering Geologist and a newly elected director of EERI, was also contacted. He supported Mr. Rogers' opinions.

Pacific Gas & Electric Co.
77 Beale Street, Rm. 2653
San Francisco, California 94106

Mr. R. V. Bettinger
Chief Civil Engineer

Mr. Bettinger served on the engineering advisory panel and its subcommittee on utilities. In this capacity he contributed to the writing of the Engineering Field Guide. The guide has been distributed to the Seismic Committee within the

Civil Engineering Department of PG&E. It is used as background information for designers and utilities engineers concerned with earthquake hazards. Mr. Bettinger felt the guide was quite useful to PG&E and that they would have developed the materials on utilities themselves had it not been done through this project.

Center for Building Technology
National Bureau of Standards
Washington, D.C. 20234

Mr. Charles G. Culver
Disaster Research Coordinator

Mr. Culver was familiar with the project and its products by virtue of having served as an NSF reviewer. He also was a member of the second EERI team sent to Guatemala. It was interesting to note that he did not make use of the guides or forms developed during his investigations in Guatemala. However, he confirmed that other investigators did use them. Mr. Culver felt that the guides would be very beneficial to inexperienced investigators, but less so to the experienced.

The Center for Building Technology mission covers all aspects of building technology. Mr. Culver felt that the concept of the guides was very useful to his organization and they have been distributed to all members who do field investigations. He felt that the "data bank" concept discussed in the guides was very useful and that the guides would stimulate their development. Also, some consideration is being given to developing guides tailored to the Center's needs and patterned after those developed under this project.

Office of Earthquake Studies
U.S. Geological Survey
National Center, Mail Stop 905
12201 Sunrise Valley Drive
Reston, Virginia 22092

Mr. James F. Devine
Deputy for Engineering

Mr. Devine reported a limited familiarity with the guides, but had not studied them in detail. One of the functions of this office is reviewing applications for nuclear power plant licensing. The Engineering Guide has been found

useful in defining earthquake hazards as points for consideration in nuclear licensing.

Mr. Devine noted that USGS sent a team of nine people to investigate the Guatemala quake, some of whom were still there (early May 1976). However, the team did not use the guides in preparation or take them along.

Massachusetts Institute of Technology
Cambridge, Massachusetts

Dr. Robert W. Whitman
Professor of Civil Engineering

Dr. Whitman was a member of the Engineering Advisory Panel for the project and attended the two formal meetings. He also contributed through correspondence with panel members. Dr. Whitman is actively engaged in developing structural requirements for earthquake resistance in buildings. He feels that data from actual earthquakes is still the major source of information for structural design and that such information will be useful in developing parameters for prediction models being developed at MIT. Dr. Whitman is active on the Technical Council for Lifeline Earthquake Engineering of the American Society of Civil Engineering. The Council is developing plans for post-earthquake investigations of lifelines and Dr. Whitman felt the guides were useful in that activity.

Dr. Whitman was skeptical that the guides developed under the project would be useful in the Northeast region of the United States due to very infrequent earthquake damage. Also, he felt that establishment of an organization for pre-planning of earthquake investigations would be difficult in that area.

Seismic Safety Commission
1400 Tenth Street
Sacramento, California 95814

Mr. Robert T. Olson
Executive Director

Mr. Olson was Chairman of the Social Science Advisory Panel for the project. He is also a member of EERI and one of its first non-engineer members. Mr. Olson felt it was significant that Volume 4 of the guides was the first formal recogni-

tion by EERI of the importance of the socioeconomic aspects of earthquake investigations. The objective of this volume was to define socioeconomic data useful to engineers and the means for collecting it.

Mr. Olson was a member of the initial EERI team in Guatemala. He used the guide in that investigation and found it helpful. In Mr. Olson's current position, he would not find direct use for the guides, but data from earthquakes which may influence public safety legislation would be of interest, since the Commission advises the legislature on such matters.

University of Colorado
Boulder, Colorado

Dr. J. Eugene Haas
Professor of Sociology

Dr. Haas was a member of the Social Science Advisory Panel for the project and was able to bring to bear his previous experience in earthquake investigations on the format and content of the Social Science Field Guide. Dr. Haas assisted the dissemination of information on the project by arranging a special session of the Second National Invitational Conference on Natural Hazards, held in June 1975 at Boulder, Colorado, where Mr. Henry Degenkolb, EERI President, described the project.

Dr. Haas was a member of an investigative team sent to Guatemala by the State of Colorado. The mission defined was not strictly related to social science issues, thus the Social Science Field Guide was not utilized. Also, the visit occurred about a month after the quake and the Social Science Field Guide addresses itself essentially to the immediate aftermath.

5360 S. Workman Mill Road
Whittier, California

Mr. John Mckinnon
International Conference of
Building Officials

Mr. McKinnon was a member of the second EERI team to investigate Guatemala. He did not use the guides in that investigation. This was partly due to

restriction of his involvement in the investigation by demands on his time from the Guatemalan government. There was considerable pressure from the government to assist them in assessment of damage to certain major structures.

The results of earthquake investigations are of vital importance to ICBO because of the role of its members in establishing building codes. As an example, Mr. McKinnon cited the findings from the San Fernando earthquake showing vertical accelerations greater than previously expected. This caused column failures in the compression mode. The investigation in Guatemala, where buildings had been built with improvements based on findings from San Fernando, showed that improved designs were effective. This is a clear example of the usefulness of accurate investigation of earthquake damage and timely reporting of the results.

Mr. McKinnon is concerned that many buildings continue to be built in the United States without seismic design considerations. This is due to cost factors and public apathy in many parts of the country. Continuing earthquake data acquisition is therefore of importance to ICBO and similar organizations.

Dames & Moore
500 Sansome Street
San Francisco, California

Mr. Raymond Rice
Engineering Geologist

Mr. Rice's specialty is fault hazard analysis and site suitability studies. He was a member of the EERI team in Guatemala, where he made use of the guides and found them helpful. Mr. Rice remarked that he felt the guides and forms were a little cumbersome for initial reconnaissance investigations due to the press of time. This could be alleviated by prior exposure to the manuals and training in their use. Mr. Rice felt that the technical level of the manuals was appropriate to their purpose. He suggested that the Geoscience Guide was a good "cookbook" for evaluating tectonic structures in the course of his normal activities, and the forms contained in it were useful in documenting site conditions near proposed

structures. Mr. Rice was not aware of any other use or influence of the manuals on his firm.

American Plywood Association (APA)
1119 A Street
Tacoma, Washington

Mr. Daniel Brown
Assistant Director, Technical Services

The APA (Mr. Brown) responded positively to a mailing requesting cooperation in the California Coordination Plan. The APA is not listed in Volume 5, however. When Mr. Brown was contacted, he indicated that APA does investigate major earthquakes in California, with particular interest in low-rise structures using plywood. He was not familiar with the guides, but felt they would like to use them when the need arose.

Mr. Brown referred to Mr. John Tissell of APA, who was likewise unfamiliar with the guides. Mr. Tissell is quite interested in earthquake effects and investigated Alaska (1964) and San Fernando (1971). He did not feel the guides would be of value since APA's interests are very specialized.

Water Engineering Division
Department of Water & Power
Los Angeles, California

Mr. LeVal Lund
Assistant Engineer of Design

Mr. Lund was a member of the Engineering Advisory Panel and helped to prepare the utilities portion of the guide. He has not had an opportunity to use the guides since no quakes have occurred in his area since they were issued. Mr. Lund stated that his organization has an ongoing program to lessen seismic vulnerability that began after the San Fernando earthquake (1971). The concepts embodied in the guides have been used in their program and this NSF project provided an opportunity to formalize some of those concepts. One of the objectives of the guide was to eliminate from investigation subjects already well known, and concentrate on more needed subjects. One such subject is effects of earthquakes on lifelines.

Mr. Lund explained that one of the major functions of the Department of Water and Power is emergency services to public utilities. Thus, an earthquake would initiate normal, but intensified, procedures to restore service. This function prevents department personnel from participating in earthquake investigation in the usual sense. However, the records normally kept on utility damage and repair are very appropriate for assimilation into investigative reports. The department has, in the past, cooperated fully in providing such data.

The nature of the department activities prescribed above precludes use of the guides during investigations. Approximately a dozen people, however, are familiar with them and they are a useful resource for the department's work in seismic safety.

Mr. Joseph L. Hegenbart, Water Executive Engineer, who was listed as a contact in the California Coordination Plan, was also contacted. He referred us to Mr. Lund.

Consulting Geotechnical Engineers
711 N. Alvarado Street
Los Angeles, California 90026

Mr. Robert Chieruzzi
LeRoy Crandall and Associates

Mr. Chieruzzi was present for part of the discussions between the case investigator and the project principal investigators in Dr. Duke's office at UCLA. His professional interests are in soils and foundations as considerations in structure siting.

Mr. Chieruzzi was a member of the second EERI team sent to Guatemala. He read the pertinent guides just prior to leaving for Guatamala. Most of the team was inexperienced and Mr. Chieruzzi felt they benefitted from the guides which provided ideas on situations to look for and kinds of information to record. The experience of some of the team was somewhat unusual in that a group of

investigators (including Mr. Chieruzzi) was requested by the Guatemalan government to inspect and advise on the safety of several major structures. These included a major bridge, cathedrals, a water treatment plant, a general hospital, and urban housing. The assistance to the government was a by-product of having an organized, knowledgeable team of investgators at the scene of such a disaster and is a further benefit of the plan to maximize learning from earthquakes.

U.S. Geological Survey
San Francisco, California

Mr. R. B. Matthiesen, Director
Seismic Engineering Branch

Mr. Matthiesen was very familiar with the project and the guides, having served on the Geoscience Advisory Panel and written some of the guide. He had reviewed and commented on the entire five volumes. His branch of USGS is primarily concerned with earthquake investigations and the study of earthquakes. The majority of the staff is very experienced in such matters and he felt the guides had limited utility for them. The less experienced people are generally trained by association with experienced staff. Mr. Matthiesen carried this argument somewhat further by saying that he felt the need for the guides was greater outside California by far, than within California, simply due to the experience factor. This would apply to the eastern United States and foreign countries. For example, recent contacts in the South Pacific area pointed out that information coming to that area from Japan was too technical and the guides would be very useful to investigators in the South Pacific.

Since Mr. Matthiesen felt the guides were most useful in situations necessitating less experienced investigators, the question arises as to whether the guides could be used to quickly train them when needed. He also expressed the opinion that training investigators on the scene of an earthquake is feasible and he had done so in Alaska in 1964. He also cited the use of the guides on

the Oroville quake where portions were quickly copied, distributed and used to assist investigators.

California Division of Mines and Geology
Sacramento, California 95814

Mr. Tom Wooten
Emergency Services Officer

Mr. Wooten was very familiar with the Geoscience Field Guide and felt it would be very useful to members of the Division in investigations and in the clearinghouse activity with EERI. He would like to make it available to their district offices and make it required reading. For certain members who are experienced and investigating within their specialty, the guide would have less benefit, however. The Geoscience Field Guide was looked upon by Mr. Wooten as a worthwhile and useful compendium of information in the field.

We were referred to Mr. Wooten by Mr. Tom Gay, Acting State Geologist in the CDMG who has been in CDMG for only a year, and expressed only a limited familiarity with this project and the clearinghouse arrangement.

Features

A major factor in the utilization achieved thus far has been the EERI organization itself. The investigative teams organized by EERI and sent to Gautemala account for the major use of the guides for their basic intended purpose of post-earthquake investigation. The Peru and Oroville quakes occurred during the course of the program. Many of the investigators who went to Guatemala are members of EERI or are associated with organizations whose management is EERI members. EERI has served as a focus for earthquake investigation and reporting for at least 15 years and its influence in achieving utilization of the products of this research is already apparent.

In addition to organization of investigative teams, the functions of coordination of investigations and reporting of data have also been assumed by EERI. These functions represent another utilization of the plan developed under this project. A report has been published on both the Lima, Peru and Guatemala earthquakes following EERI organized investigations. (See list of Project Publications, Appendix A.)

The role of the principal investigators is also a positive factor in terms of utilization. Dr. Duke is a past president of EERI and both he and Mr. Moran have been active professionally in the earthquake field for over twenty years. Many of the organizations and professionals in the earthquake engineering and scientific fields are well known to the principal investigators. This facilitates their ability to disseminate information, obtain participation in investigations, and plan and conduct training in the use of the plan developed under this contract. As mentioned earlier, NSF has funded a second--or implmentation--phase of this program, with Dr. Duke and Mr. Moran as principal investigators.

The funding of the implementation phase of this program has created some difficulty in encouraging utilization due to the timing of that funding. The first contract was funded May 15, 1973 and completed December 31, 1975. The proposal for the second contract was submitted in April 1974 and funded in April 1976. The several months' gap between practical completion of the first contract and the funding of the second has prevented a smooth transition from the plan development to plan implementation activities, including the revision of the guides to final form, distribution of the guides on a broad scale, and training of investigators. Also, during the funding gap, a major earthquake occurred in Guatemala and one in Italy occurred only a few days after funding of Phase II.

Follow-up investigations and publication of reports have been hampered by lack of funds.

The user participation in the project, in the sense of having broad representation of knowledgeable professionals with earthquake experience, has been excellent. The organizations represented are likewise those with great interest in earthquake effects and in a position to utilize the project findings. Two meetings of the complete advisory panels were held and several of the members contacted felt these were productive. Mr. Moran reported that the original intent of the panel meeting was to (1) develop lists of subjects requiring further investigation (as opposed to those which did not); (2) prioritize those requirements; and (3) develop manuals defining how to collect information required. Mr. Moran felt that items 1 and 2 were only partially achieved, and that trying to accomplish them with panels of the size employed was very difficult. Some of the panels employed a subcommittee approach and this proved more productive. Another difficulty in prioritizing investigative procedure seems to be the variability of the size and nature of earthquake damage situations. The definition of investigative procedures for collection of socioeconomic data was apparently a difficult task, based on some comments of those interviewed. This was no doubt influenced by this being a new area of investigation of EERI.

Most of the users or potential users interviewed who had read the guides were asked if the technical level of the guides was appropriate to their needs, and what changes they might suggest to improve utilization. The response was favorable in that the level and content were judged acceptable by most. There were some comments that the amount of material was too great to be assimilated as quickly as needed following a quake, and this might be remedied by a condensed version of the guides. The only suggestion for improvement mentioned more than once was the

desirability of adding photographs to illustrate key points of investigations.

The significance of this research project is not as easy to define. The lack of investigative coordination, the duplication of effort, the failure to emphasize investigation of areas where knowledge is scarce, and the delay of getting lessons learned into practice are cited by EERI as needs which this research meets in reducing the earthquake problem. The clearest indication that the process of translating investigative findings into reduced earthquake damage works was given by Mr. McKinnon (see Utilization Obtained). He described the results of structure modifications observed following the Guatemala quake that were based on findings following the San Fernando quake. Certainly, if this example is multiplied substantially over a period of time, then, to the extent this project contributes to the process, it will have been significant.

Conclusions

The principal investigators viewed this project as the initial phase of a three-phase effort. Development of the plan to maximize learning was expected to be followed by establishment of the plan and then implementation during an earthquake. Evaluation of utilization now is thus somewhat premature in their view. However, certain utilization has occurred by virtue of the nature of the projects and the occurrence of earthquakes in Guatemala, Peru, and Oroville, California.

The constituency of EERI provides a natural vehicle for dissemination of the research products to concerned professionals who would be users. Several hundred copies of the field guides have been distributed through EERI. Some EERI members are also active in the Structural Engineers Association, another group of potential users. The project Advisory Panels consisted of a broad representation of

users from concerned professional disciplines and provided further dissemination. Three national conferences have heard presentation of the project by the principal investigators and EERI's president. Utilization of the products in the normal course of their work as a technical reference on earthquake effects has been described by several persons contacted during this utilization study. One may assume the same to be true for others who have obtained the guide volumes.

Utilization of the guides by all who have had access to them has not been universal, however. Several EERI investigators used the guides in Guatemala. However, others did not, and a subsequent 9-man USGS investigation team made no use of the guides. Several of those contacted felt that experienced investigators had little need for the guides, but the inexperienced ones would benefit. The most inexperienced will likely investigate quakes outside California. This leads one to the conclusion that the greatest utilization will come from inexperienced investigators who can be oriented to the plan at the time of a disaster. Utilization is thus dependent on an ongoing, effective coordination and training capability. EERI evidently plans to fulfill this role in the foreseeable future. The proof of utilization and the subsequent reduction of earthquake effects thus remains to be shown by future events.

The contribution of the project to this learning process seems to be unresolved at present. There was usage of the guides by some investigators in Guatemala and reports on Peru and Guatemala were promptly compiled. Investigations were organized and coordinated by EERI. However, in contacting the potential users, a surprising number did not use the guides when they participated in an investigation, and several felt they had no need for them due to previous experience and expertise. There was much agreement that the guides should be helpful to the inexperienced investigator. The greatest need for the guides would appear to

be in the area in the United States outside California and in foreign countries. Since in this century, significant earthquakes have not occurred in the middle or eastern United States, there is no means to predict when the plan might be used there or its degree of effectiveness.

One conclusion regarding significance does seem clear. Because of the relative rarity and unpredictability of earthquakes, the utilization of the plan and materials developed by EERI will depend on EERI or some other organization taking the initiative prior to the time of the disaster to train and coordinate investigators. The occurrence of earthquake disasters and the effectiveness of execution of the plan at that time will ultimately determine whether the project has significance.

Appendix A

PROJECT PUBLICATIONS

Earthquake Engineering Research Institute, Learning from Earthquakes (1975 working draft), Vols. 1-5.

ibid., Engineering Aspects of the Lima, Peru Earthquake of October 3, 1974, May 1975.

David J. Leeds, editor, The Guatemala Earthquake of February 4, 1976, EERI Newsletter, Vol. 10, No. 2B, March 1976.

Donald F. Moran and C. Martin Duke, Jr., "Learning from Earthquakes," Meeting Preprint 2448, ASCE National Structural Engineering Convention, New Orleans, LA, April 1975.

Earthquake Engineering Research Institute 1974-75 Brochure.

RANN UTILIZATION EXPERIENCE

CASE STUDY NO. 31

RESEARCH AND DEVELOPMENT ON LITHIUM/SULFUR SECONDARY BATTERIES

ARGONNE NATIONAL LABORATORY

Case Investigator:

R. Alberts

Research Triangle Institute
P.O. Box 12194
Research Triangle Park
North Carolina 27709

Technical Reviewer:
E. Yeager

Department of Chemistry
Case Western Reserve University
Cleveland, Ohio 44106

Prepared under:

Contract No. NSF-C76-17165
National Science Foundation
Research Applied to National Needs
1800 G Street, N.W.
Washington, D.C. 20550

RESEARCH AND DEVELOPMENT ON LITHIUM/SULFUR SECONDARY BATTERIES

Introduction and Summary

The development of more efficient methods for storing energy, particularly electrical energy, is an important national need. This project, the goal of which was to develop lithium/sulfur secondary batteries with high storage capacity and low cost, was focused on two specific applications; peak load-leveling for electric utilities and electric automobiles. The research was initiated at Argonne National Laboratory (ANL) as a response to both these needs; however, the National Science Foundation's funding was focused primarily on the electric automobile storage battery. Project information is given in table 31-1.

The tangible projects of the research include some fifteen different developmental cell structures. These cells vary in size, form factor, anode and cathode materials, electrolytes, structures, casing materials, separators, and, of course, in performance. In an evolutionary manner, there has been a continuing improvement in the energy, power, and cycle life of the cells. At this time, the progress is so significant that the next layer of utilization--namely, an interested set of manufacturers who are willing to participate in the further development, both with contract funds and their own investments--has been established. These manufacturers, in the reasonably near future, will be delivering finished versions of a lithium-aluminum/iron sulfide cell for evaluation by potential users. Integrated multicell batteries will come later.

Table 31-1. PROJECT INFORMATION

Project Title Research & Development on Lithium/Sulfur Secondary Batteries	**Grant/Contract No.** AG 000349
RANN Program Manager Dr. Richard Schoen (Prof. Simpson Linke)	**RANN Program Area** Energy Storage
Principal Investigator(s) Mr. F. J. Cairns Dr. Paul A. Nelson	**Schedule** **Start:** February 1972 **End:** February 1974
Institution ERDA (AEC) Argonne National Laboratory Chemical Engineering Division 9700 S. Cass Avenue Argonne, Illinois 60439	**Funding** NSF: $1,050,000 Other: FY 73 $ 570,000 (AEC) FY 74 $1,066,000 FY 75 Unknown FY 76 $4,000,000 FY 77 $5,500,000
Contributors/Collaborators A large team has participated in this project.	
User Advisory Committee None.	
Precursor Activities This effort was previously funded by NHLI, EPA, AEC and DOD Department of Army.	

The eventual goal of the lithium/sulfur cell project, most simply stated, is adequate performance at a reasonable cost with a life span adequate to meet the needs of the utility and automotive industries. Several breakthroughs have been accomplished in the program, i.e., new concepts such as lithium-aluminum negative electrode which is solid rather than liquid; the use of iron sulfide as the positive electrode; the use of additives in the iron sulfide; and the use of boron nitride separators. These items have more than doubled the capacity of the cell with no degradation in cycle life.

The eventual utilization of the cell will require it to be assembled into batteries suitable for demonstration. The first of these demonstrations will be in a compact automobile in 1978, and the second, a 10 megawatt battery string, will be demonstrated in the Battery Energy Storage Test (BEST) facility in New Jersey in approximately 1981. The BEST facility is being planned by Energy Research Development Administration (ERDA), Argonne National Laboratory (ANL), Electric Power Research Institute (EPRI) and several utilities for testing advanced batteries on a utility network. Although these two demonstrations seem to be quite different, they will utilize basically the same cell.

The reduction in cost of the boron nitride separator seems to be one of the major accomplishments necessary for the transition of the cells from the laboratory to an economically sound pilot line facility. An effort to do this is currently under contract to Carborundum Corporation.

It is estimated that the first pilot plant to produce lithium/sulfur cells will require an investment of $12 and $15 million. If the planned demonstrations are not sufficiently exciting in their implications and

performance, there will be no commitment to a pilot line and the eventual utilization of the lithium/sulfur system will be significantly deterred.

Additional major factors that could reduce the eventual utilization of this concept include the possible development of (1) competitive batteries, such as the lithium/chloride and the sodium/sulfur battery systems; (2) competitive energy storage techniques, such as fly wheels or superconducting coils; and (3) improved engines that minimize pollution and utilize advanced fuels. These approaches are currently under investigation in this country and abroad and offer the greatest threat to the eventual success of lithium/sulfur batteries.

The program of research and development on lithium/sulfur batteries at ANL existed before the period of NSF/RANN support and is continuing. However, NSF/RANN provided support during a critical phase during which the effort might have ceased and the experienced manpower and laboratory facilities redirected to other research fields. In 1974, when RANN support terminated, the activity was of sufficient importance to ERDA that it has been continued and greatly expanded. This process represents a significant type of utilization in itself. At present, the lithium/sulfur battery is an important ERDA thrust.

Because the eventual goal of the program can not be realized without commercialization, the primary information dissemination was directed to industry. Through an industrial participation program and other close associations with industry, as well as through publications and meetings, a continuing flow of technical information has been fostered. This has resulted in the initiation of development efforts on lithium/sulfur batteries among battery manufacturers and a continuing high level of interest

in the automobile industry. However, end-product utilization has not and can not take place until successful commercial batteries become available.

The role of NSF in the development of lithium/sulfur batteries was important in preserving a large and important research effort in a national laboratory. In this role, the utilization effort was limited to that described in the preceding paragraph; i.e., transferring the technology to industry. It does not appear that more should or could have been done at that time. Now, however, it appears that the technology has reached a relatively advanced stage and the promise of major applications for such batteries is sufficient enough that a master plan for their commercialization is necessary--if commercialization is to occur. However, this is not the present responsibility of NSF/RANN.

The conclusion of this case study must be that the lithium/sulfur battery development is important and the NSF/RANN project made significant contributions. Utilization was at a high level for an ongoing development effort and the potential remains that a high level of utilization will eventually ensue from the program.

Research Description

During the 1960's, the Argonne National Laboratory (ANL) conducted research on thermal-galvanic cells. Some six to seven years ago, representatives of industry were invited to examine this particular research and recommend its future directions. As a result of their recommendations, emphasis shifted to molten salt, and finally focused on cells incorporating lithium compounds. The basic research that was supported by the Atomic Energy Commission at ANL since 1961, was then augmented by support form other

agencies. Participating agencies included the National Heart and Lung Institute which was interested in powering an artificial heart; the Army at Fort Belvoir, an agent for the other elements of the Department of Defense, which had broad applications for more efficient electric storage batteries; and the Environmental Protection Agency, which was interested in a pollution-free transportation system to replace gasoline powered engines. Atomic Energy Commission support was motivated by a desire to assist the electric utilities by providing a means of storing power during periods of low utilization and then discharging it through the system at periods of peak utilization.

This broad support base was not to last. The National Heart and Lung Institute discontinued its funding some time before 1972, and the Environmental Protection Agency, which was providing approximately $1.2 million per year, cancelled its support in 1971--as its policy was changed to the support of short-range programs--and it became apparent that there could be no realistic automobile and electric propulsion demonstrations by 1972.

As these funding sources disappeared, Mr. Elton Cairns, then Principal Investigator at ANL, began a search for substitute funding. After several months of delay, NSF/RANN agreed to fund this most important program. NSF's timely recognition of the national need and its anticipation of the energy shortage, as witnessed by the support of this research, is certainly noteworthy. During FY 1972, the initial support from NSF amounted to $500,000 and allowed the program to continue. This was considered a critical juncture in the program, and industrial participants have stated that without this funding the program would have floundered, industrial interest would have waned, and a finite probability exists that this potentially fruitful avenue of research would have been dropped.

In FY 73, an additional $550,000 was provided by the National Science Foundation in support of the electric automobile objective. The Atomic Energy Commission also contributed $570,000 in FY 1973 in support of the load-leveling needs of utilities. Following the 1973 funding, AEC assumed the total funding responsibility and the National Science Foundation has since maintained a role of watchful anticipation. Both ERDA and NSF/RANN are now funding the sodium/sulfur battery as a competitive alternative to the on-going lithium/sulfur work, sponsored by the AEC, now ERDA.

Although a number of materials and designs was being investigated in the project, basically the cells consist of two negative electrodes of a solid lithium-aluminum alloy, a central positive electrode of iron sulfide (FeS_2 or FeS) and an electrolyte of LiCl-KCl eutectic (melting point, 352°C). The operating temperature of the cells is about 400-450°C. Research is focused on the materials, the cell geometry, cell chemistry, and a multiplicity of design, evaluation, and testing tasks. Cells have been either of a flat cylindrical geometry as shown in Figure 31-1 or a so-called prismatic cell that is rectangular in shape (13 by 13 cm, 2 to 4 cm thick). A cylindrical cell such as shown in the figure is 13 cm in diameter, may be 3 to 5 cm thick, and weigh 0.9 - 1.7 kg. Test data on one such cell revealed a 150 A-hr capacity, a 3700 hr lifetime, and a specific energy of about 60 W-hr/kg operating in the range 425-500°C.

As compared to the conventional lead-acid storage battery, the lithium/sulfur battery has already exhibited a large improvement in energy density (W-hr/kg) with no significant decrease in cycle life or increase in energy cost (cents/KW-hr). Performance goals for lithium/sulfur batteries for the

load-leveling application are given in table 31-2*. These are believed achievable by ANL.

ANL has been the lead organization in lithium/sulfur battery development even as other organizations have contributed important developments. The in-depth studies of cell structures, electrodes, materials, chemistry, and battery design are not duplicated in other groups and the integration of these into a development plan has taken place at ANL.

The Standard Oil Company of Ohio (Sohio) has been on a development path parallel to the ANL effort and has contributed important advances in the technology. These developments were often duplicated by ANL including the very important move from lithium to a lithium/aluminum negative electrode. Eventual combination of the lithium/aluminum negative electrode with the iron/sulfide positive electrode, and the introduction of a boron nitride mesh to separate the battery constituents led finally to the demonstration of the 150 watt-hours per kilogram cell in 1974. The conferral of the Industrial Research magazine award to ANL for this achievement recognized it as one of the 100 most important development projects during the year 1974.

Presently, the attempts to involve industrial organizations such as Globe-Union, Gould, C & D, Eagle-Pitcher and Catalyst Research have met with considerable success. Contracts for the development and pilot production of cells and cell components were awarded to Gould, Eagle-Pitcher and Catalyst Research in April 1975. It should be noted that the electrical giants such as Westinghouse and General Electric and the automotive manufacturers, Ford, Chrysler and General Motors, to date have not participated in this government funded program.

---

*R.O. Ivins et al., "Design of a Lithium/Sulfur Battery for Load-Leveling on Utility Networks," Proc. 1975 IEEE Southeastern, Vol. 1, pp. 1-9 (April 1975).

Table 31-2. Performance Goals for Lithium/ Metal Sulfide Batteries for Off-Peak Energy Storage

Battery Capacity	10 MW, 100 MW-hr
Cost of Capacity	$15 - $25/kW-hr
Specific Energy	120 - 150 W-hr/kg
Specific Power	
Peak (15 sec)	
Sustained Discharge	40 W/kg
Discharge Period	4 - 14 hr
Charge Period	4 - 8 hr
Watt-Hour Efficiency	70 %
Cycle Life	1500

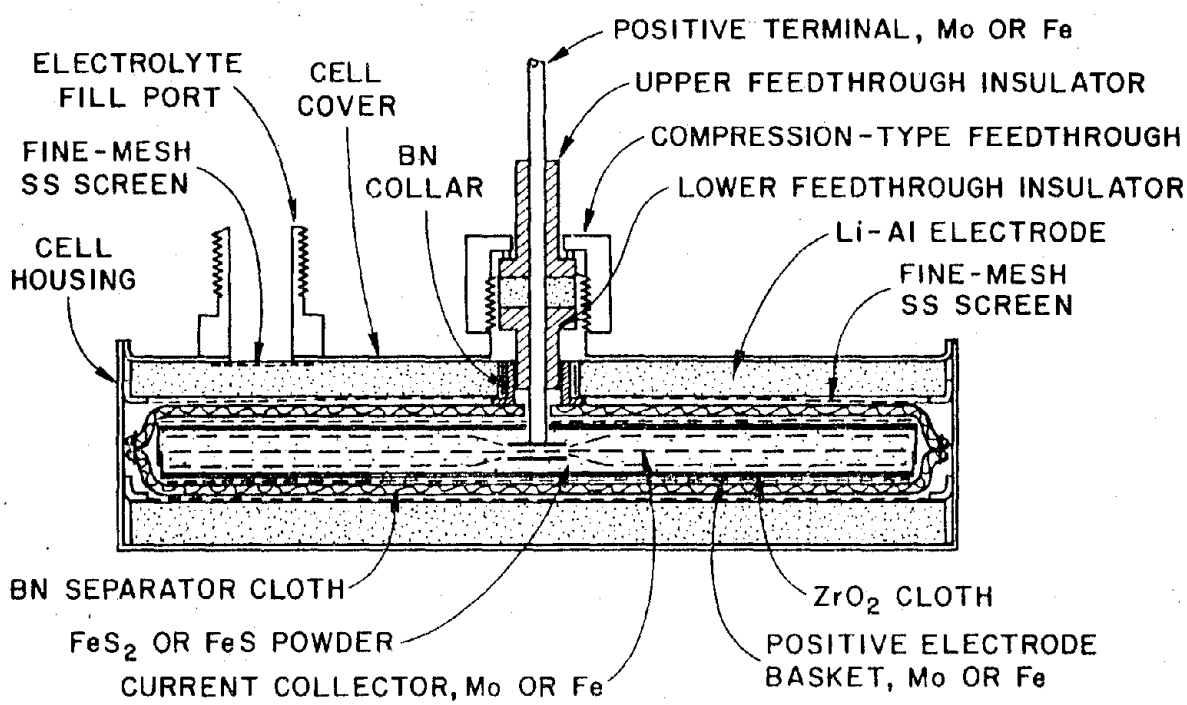

Figure 31-1. General Design of Cylindrical Lithium/Sulfur Cells

It appears that if the development objectives are met at a reasonable cost, the resulting product will be extremely significant and have great impact on all aspects of American industry and life. The consensus indicates that the production of a battery providing 100 watt-hours per kilogram at $30 per kwh of capacity will make the electric automobile economically desirable as a commuter vehicle, even at today's prices for oil and gasoline. For the accomplishment of this goal, the Energy Research and Development Administration plans to allocate $5.5 million (2.5 million in-house, $3 million contracts) in FY 1977 for product development and is providing an additional $600,000 towards continuing research studies. Equal or larger amounts are being spent throughout the world on similar systems using the sodium/sulfur and lithium/chloride systems.

At this time, sodium/sulfur and lithium/sulfur batteries appear to be competitive approaches. In the absence of a breakthrough, both will probably continue to be developed by their primary advocates and the marketplace will be the final testing ground.

Utilization Objectives

There are three distinct tiers of users relating to this particular research; the research and development community, industrial developers, and consumers. The time span from concept to eventual consumer utilization will encompass a period of at least 20 to 30 years. At this time, utilization is occurring in the first tier and efforts are underway to transfer technology from the research and development laboratory to the industrial developers who will eventually produce a product. If this transition is successful and a production capability ensues, the next significant transition

is to the consumer, where the product must compete with the present occupants of the market, e.g., the internal combustion engine. In most instances, it will create wholly new products and applications that are designed around the characteristics of the lithium/sulfur system.

It is presently planned that the output of the development activity will be demonstrated in an electric automobile in 1978 and, after further development, a larger assemblage of cells will be tested in the BEST facility in approximately 1981. If these demonstrations are as successful as anticipated, an effort will be required to refine the product and substantiate manufacturing cost estimates. Early users will have to be identified and a manufacturing plant established that can deliver to developing markets.

In the four years following the first NSF funding, an embryonic utilization plan has been evolved in which the potential second tier user--namely, battery manufacturers--have been invited, along with others, to actually work as researchers in a paid capacity for periods up to one year at the Argonne National Laboratory. This participation allows them to identify the development problems, participate in their solution, and thereby become better qualified to bid on future development contracts necessary to prove the technology and effect its transition to a potential manufacturing organization. This novel scheme, certainly laudatory, has received the endorsement of all participants, appears quite innovative when compared to approaches used in other programs of this nature, and has most likely resulted in a significant shortening of the normally lengthy development cycle.

Information concerning this research has been broadly disseminated through the popular press, scientific literature, technical meetings, information exchanges between contractors, annual meetings, locating contractor

personnel in the Argonne National Laboratory and, finally, through the contracting of important demonstrations so that a number of industrial firms can apply their proprietary techniques to technology improvements and demonstrations.

Utilization Obtained

After extensive research and development activities at the Argonne National Laboratory, the lithium/aluminum/iron sulfide cell has made the transition to the industrial development world through the vehicle of contracting for the delivery of a significant number of cells suitable for demonstration in the 1978 through 1981 time period. Until these cells are delivered and the planned applications demonstrated, there will probably be no commercial production of them for either the industrial or consumer market. Commercial exploitation of this technology appears to be approximately 10 years away.

In examining utilization of this project it is clear that the ANL research project and the lithium/sulfur battery are synonymous to the user. This is because almost all of the available information comes from ANS even though some may have originated elsewhere. In the following reports on user contacts a preponderance of the comments are on the battery.

Mr. Richard J. Rubischko, New Business Division, Gould, Inc. (Research Laboratories), Rolling Meadows, Illinois, is presently serving as program manager on the lithium/sulfur system in the Energy Division of Gould Laboratories. He and approximately eight other professional people are presently pursuing the development of the lithium/sulfur system under contract to Argonne. Mr. Rubischko was a member of the ANL training program and has been able to bring his know-how back to the manufacturing and development organization. Gould has had three other participants in the program. Mr.

Rubischko feels very strongly that the ANL program provides an excellent method of technology transfer. A second method he identified involves the solicitation of consultation from industrial organizations at an early stage in the research process. This allows higher management levels to become involved at an early point in the decision-making process and tends to insure their funding and interest in the project for approximately five years. It is his present opinion that 90 percent of the technical risk has been removed from this area of endeavor. He expects validation from an economic standpoint within five years and further predicts it will take at least nine years before the product is ready for mass production.

Comparing the three competitive battery systems, Mr. Rubischko stated that the lithium/chloride system has by far the highest risk; the sodium/sulfur system is second; and the lithium/sulfur system has the least risk for eventual economic application. The sodium/sulfur system, in his opinion, appears to have life probelms and deteriorates for somewhat unknown reasons. A large amount of money is being spent on this product by Toshiba in Japan and by the British Rail System, as well as Ford, NSF, and U.S. manufacturers, and it certainly cannot be ignored.

Mr. Rubischko gave credit to Sohio for the important lithium/aluminum concept and noted that both ANL and Atomics International claimed the iron sulfide innovation. He also opined that the lithium/sulfur cell is a very "forgiving" system and is without doubt, economically feasible, particularly if the boron nitride separators can be fabricated at a price of $1 per square foot, as is predicted by Carborundum Corporation which is under contract to ANL for their development. On that basis, a target price of $30 per kwh should optimistically be achieved and a 30 kwh package (suitable to power

an automobile) should be producible for approximately $900. If a successful development and manufacturing process is achieved, an extremely timely product will result. At least 200 people are presently involved in this line of research throughout the world and, even though batteries are very slow-moving in their evolution, the next ten years could see a successful commercial application of this product.

Mr. Frederick Tepper is General Manager, Catalyst Research Corporation, Baltimore. Catalyst Research Corporation is a division of the Mine Safety Equipment Corporation. He and approximately 150 of his staff have, for a number of years, been involved in liquid/metal heat exchangers, molten salt primary cells, pyrotechnic cells for Squibb firing, and missile secondary power. They also manufacture lithium-iodine-solid electrolyte batteries for heart pacemakers.

Catalyst Research is under contract to ANL for cell development, and is applying its previous experience to fabricating lithium aluminum/iron sulfide cells in a dry room rather than a dry box as is done by others. The application of such production techniques, common to other products, is necessary if the eventual cost goals are to be achieved.

Catalyst Research first became aware of the ANL program through an Army publication called PIP, Power Information Publications. They attended symposia at ANL and eventually became involved in the industrial liaison program.

Mr. Tepper is enthusiastic about the future of the lithium/sulfur system, and feels that if gasoline cost reaches $1.00 a gallon, electric automobiles with such batteries will be an economically viable alternative. He was quite negative on the competitive sodium/sulfur system because of

the fragility of the ceramics and the large amount of ceramic surface required in the temperature-cycled environment required for this battery. He, like several others who were contacted, was somewhat awed by the size and resistance to technical innovation of the automotive market, and strongly suggests marketing research be performed in order to identify other items such as deep submergence two-man submarines or powered bicycles as a first-order product. He suggested that urban vehicles, such as delivery vans, mail trucks, milk trucks or United Parcel vehicles, in which acceleration is not a dominant performance requirement, be examined for application of lithium/sulfur electric propulsion in the immediate future. This is being done by the Postal Service and others.

The technical problems associated with the eventual successful development of the lithium/sulfur battery are much the same as for other liquid/metal products. A significant failure mechanism appears to be the migration of interstitial impurities in the case material with eventual neutralization of the battery constituents. Original density, migration time, and means of delaying migration are important items affecting the eventual economic viability of the product.

Mr. Earl Carr is Manager of the New Products Development Division, Eagle-Pitcher Industries, Inc., Joplin, Missouri. The Electronics Division of Eagle-Pitcher, Inc. has some 500 employees at three plants involved in the development and production of special purpose batteries. Some two dozen different cells are produced including silver zinc, nickel cadmium, sealed lead acid, thermal cells and soon, hopefully, a lithium/sulfur cell.

Mr. Carr stated that his interest in lithium/sulfur cells stemmed from a newspaper article appearing approximately two years ago, in which it was noted that the lithium aluminum/iron sulfide cell had shown major improvement over previous versions. Their division manager at that time had been recently employed by the Atomic Energy Commission and was aware of the quality of work accomplished at the Argonne National Laboratory. Under his direction, further investigation heightened their interest. Mr. Carr became one of the industry men collocated at ANL as part of the transition program. Subsequently, they received $250,000 in contract funds and recently completed and delivered to ANL a prismatic cell in the 100 ampere-hour class.

At this time, the failure mechanism in the lithium cell produced by Eagle-Pitcher appears to be lithium shorting. The life of the delivered cells is limited to a few hundred cycles and a few thousand hours. The major impediment to the successful development and application of this product appears to be the boron nitride separator which, according to Mr. Carr, is "just not good enough". Work needs to be done on this item, and such is presently contracted by ANL at Carborundum Corporation. "Unfortunately, you can't buy separators and, if you could, they would be too expensive", were further quotes by Mr. Carr. Eagle-Pitcher would be selling batteries today if materials were available. Since they are not, it appears that it will be 1980 or later before such production can be accomplished, mostly because of the separator and other materials problems.

Among competitive products, Mr. Carr particularly noted the British work in sodium/sulfur, but did not consider it significant competition if

the lithium/sulfur development can be successfully completed. Although Eagle-Pitcher has been involved in lithium/sulfur for only two years, their interest is very high and they are well aware of the magnitude of potential markets for a successful product.

Mr. Charles Pax is in the Transportation Energy Conservation Division, Alternative Automotive Sources Group, Energy Research and Development Administration, Washington, D.C. He was associated with EPA's Office of Alternative Automotive Services in 1972 when the EPA funding of the lithium/sulfur battery at ANL was cancelled. He felt the cancellation was more an enforcement of, rather than change in policy, and possibly was a horsetrading operation involving funding levels and programs. In 1975, his organization was transferred from EPA to ERDA, and is presently an element of the Office of Conservation.

Mr. Pax and his group are still concerned with the auxiliary items associated with the battery for automotive propulsion. The Research and Technology Organization of the Office of Conservation is now responsible for battery improvements. Mr. Pax felt that their original interest in the lithium/sulfur battery stemmed from normal contacts made in the scientific community concerning state-of-the-art developments. He was unwilling to make any forecasts of economic viability of the battery system or target goals, other than noting that the ones identified in the literature appear to be the target goals of the battery manufacturers.

Dr. Steven Weiner, Chemistry Department, Ford Motor Company, Dearborn, Michigan, is the Principal Investigator on the NSF/RANN sodium sulfur battery program, presently contracted through June 1977. Ford is also

a contractor of ERDA on the same subject under a larger contract. The present plan is to demonstrate in 1980 an electrically propelled automobile and a one-megawatt battery string for the BEST facility. These are similar goals to the lithium/sulfur battery program except that automobile demonstration is two years later than the lithium case. Ford, in its laboratory, has built experimental cells that have performed adequately. A pre-prototype cell has been demonstrated that has adequate performance, but inadequate durability. The basic problem appears to be corrosion of the container and its effects on cell performance and electrolyte durability. Ford seems to be reasonably confident that its contract goals will be met.

Of particular interest in the discussion with Dr. Weiner were his feelings concerning the eventual utilization or production of the electric automobile. It would appear that, for such an automobile to be mass produced, it would have to sell at a somewhat higher price than the present automobile with an internal combustion engine and would provide at most a 150-mile range. Studies performed at Lincoln Laboratories by Mr. Margolas have apparently developed some well-defined data concerning the economics of electric propulsion. These studies indicate that it will require an investment of over $200 million in the production plant for the battery alone. This information is quite interesting. It indicates that because of economies of scale, eventual utilization of the originally funded research at NSF on lithium/sulfur, as well as sodium/sulfur will depend upon the development and eventual acceptance of the electric propelled automobile. This is not at all assured. This does not address the battery market for utility load-leveling, which may be a somewhat different design.

Dr. Weiner pointed out that a joint venture of the British Government, along with several companies, has created Chloride Silent Power, Limited. Mr. Byron Halliwell was identified as a knowledgeable member of that organization. It is probably the largest single effort in the high performance battery area. They have frozen their cell design and are now in the process of building hundreds of sodium/sulfur cells and expect to demonstrate fleet vehicles and train applications in the fall of 1976. This product and its demonstration will certainly be of interest to all concerned in the future of high performance battery systems.

Since a cost-effective electric automobile will require a high performance battery such as the lithium or sodium/sulfur system, intermediate batteries such as zinc/chloride, zinc/bromine or zinc/air are not considered significant contenders for this market by Dr. Weiner, although they are being developed for other markets.

Mr. William Wylan is Chief, Battery Engineering Division, Delco-Remy Division, General Motors Corporation, Anderson, Indiana. Delco-Remy is the operating division of General Motors charged with the production of automotive electrical products and batteries. They currently produce lead acid cells as well as special batteries for other purposes such as military applications. If a high temperature battery is to be produced by General Motors, Mr. Wylan's organization will most likely be the production location.

In the opinion of Mr. Wylan, it is too early to seriously consider production problems relating to high temperature batteries. The lithium/sulfur battery is in the province of the General Motors research

organization and they are just now beginning to educate the operating division on its potential. On the basis of a recent briefing and a cursory examination, Mr. Wylan feels that the lithium/sulfur system appears to be at least as good as any other system and perhaps better. He currently holds reviews with the General Motors research division every 60 days and, therefore, will constantly be apprised of the status and progress of the lithium/sulfur battery development. It is Mr. Wylan's feeling that the packaging materials at this time are still prohibitively expensive for any production vehicle. He, like other respondents, estimated that the lithium/sulfur battery is at least 10 years away from a production status. In the interim, ambient temperature batteries, such as nickel/zinc, are now in an advanced development stage and could be available in a production version within five years. These batteries offer approximately a 2 to 1 improvement in energy density over lead-acid cells, and if there is a market for a suburban car, they would offer an improvement over the present state-of-the-art and might be so used. He noted that interest for such a vehicle is beginning to surface in Japan, Taiwan and Mexico City.

There are many constraints and pressures concerning the possible utilization of the lithium/sulfur battery in a production American automobile. Economic, political, environmental and competitive pressures all exist and in many cases may be at cross purposes to each other. To forecast the eventual utilization at this time would appear to be foolhardy.

Mr. Elton Cairns is in the Research Division, Electrochemistry Department, General Motors Corporation, Warren, Michigan. General Motors Research Laboratories were considered to be an important respondent to this particular

appraisal since they are the research arm of the largest potential automotive user of the resulting product; and they have been developing lithium/sulfur battery systems over the last several years at what appears to be a reasonably high level of effort. In March 1973, they hired Mr. Cairns, who was previously manager of the lithium/sulfur battery development at Argonne National Laboratory. He presently serves as Assistant Manager of the Electrochemistry Department and is intimately involved with the General Motors high temperature battery effort. Mr. Cairns' arrival at General Motors was a key event in their starting a lithium/sulfur battery program. Previously, General Motors had been involved with lithium/chloride systems.

Although General Motors is not a contractor to Argonne National Laboratory, they are presently visiting that organization approximately twice a year and attend annual meetings reporting progress on the ANL effort. They have pursued their own particular version of the lithium/sulfur battery and, at this time, feel they may have demonstrated the best life cycle performance. There are many proprietary aspects in the design of their particular cell. GM has continued with the cylindrical battery and are purported to have some important improvements on the boron nitride separators that are troubling other developers.

Mr. Cairns noted several other shorter-range battery developments, using zinc/chloride and nickel/zinc systems that do not appear to have the same utilization potential as the high temperature batteries. He is also well apprised of the sodium/sulfur effort. Although it is receiving maybe twice as much worldwide support as the lithium/sulfur battery, it is still only a competitive effort and Mr. Cairns believes it is too early to predict the

eventual survivor. Eventual utilization of either battery is ultimately dependent upon economic viability, and that is related to lifetime, cost of materials, and manufacturing approaches.

Features

The significant features of this research that impacts its utilization include the following:

- The NSF project was one phase of an ongoing research effort that had a long prior history and which will not obtain fruition for another decade.
- NSF funding was provided at a critical phase when, without it, the research might have terminated resulting in the loss of much of the prior investment.
- NSF funding was provided with no chance of getting credit for originating the research and little chance of being associated with the final products.
- Apparently, during the course of the project, technical decision-making was left to ANL.
- There was no reluctance by ANL to accept technical innovations that originated elsewhere.
- Industrial dissemination was accomplished through an innovative collaborative program assuring rapid transfer of the technology.
- Research results were made readily available to all interested parties through active publication efforts and encouragement of direct peer contacts.
- A plan for demonstration of the lithium/sulfide battery has been formulated and is being followed.
- Large investments and adoption by major industries are required for ultimate success.
- The resignation of the original Principal Investigator resulted in a temporary loss of productivity but has contributed to the transition of the technology to industry.
- The research efforts are so comprehensive that their full value lies in the integrated results--successful cells and eventually successful batteries--rather than in discrete breakthroughs.

The utilization of this RANN project is difficult to analyze. As an applied research project, progress is being made, technology is being transferred to industry, dissemination has been active, and eventually applications will probably ensue. The difficulty lies in the transitory nature and relatively small amount of the NSF support and the lengthy development period and vast sums required for commercialization and application.

Utilization is therefore primarily associated with the fact that the NSF support preserved a program that was of sufficient importance to the Nation's energy efforts to receive over $9 million of ERDA funding in the 1976-1977 period. The transfer of research to mission oriented government agencies is a logical and constructive form of utilization.

No lithium/sulfur battery has yet been made; cost analyses are perhaps optimistic; there may be safety problems in their use; and adjunct developments are necessary. The technical reviewer (Prof. Yeager) for this case study believes that a master plan outlining the orderly steps that government and industry must take to realize large-scale applications is important and sorely needed. Lastly, the industries that will make and use the batteries are basically conservative with respect to radically new technology. These barriers must be penetrated to achieve ultimate utilization.

The research accomplished appears to be competent and thorough. No one contacted during the preparation of this case study deprecated the work or identified shortcomings.

In the context of the research and of the results obtained, the project outputs are well utilized and projects of this type appear to be a worthy element of the RANN program.