AD-A131 827 RESOURCE MANAGEMENT TECHNOLOGY: LOS ALAMOS TECHNICAL CAPABILITIES FOR EMERGENCY MANAGEMENT(U) LOS ALAMOS NATIONAL LAB NM B G KILLIAN ET AL. 18 JUL 83 1/3

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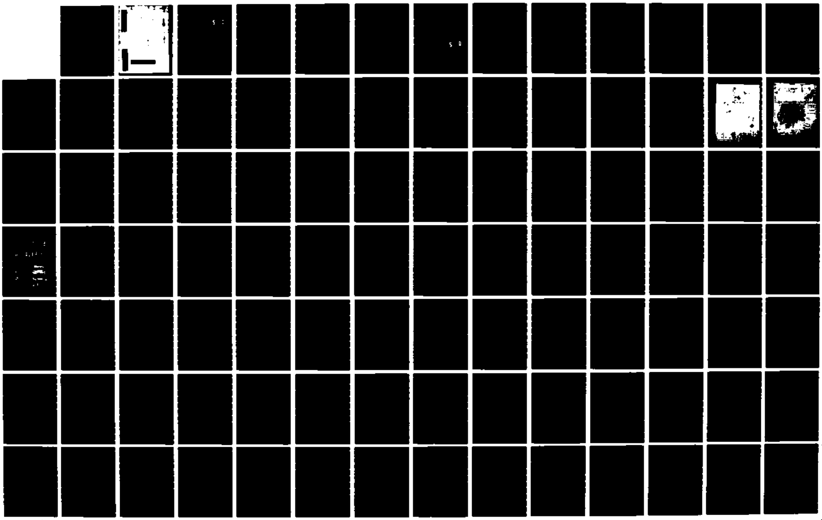

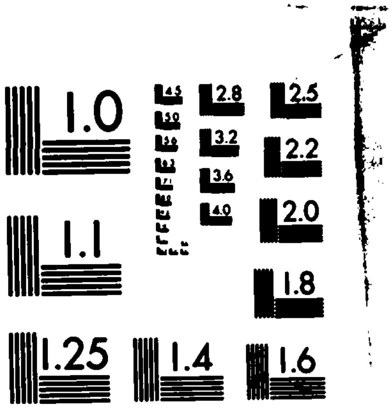

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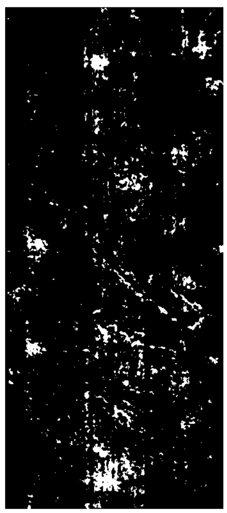

Los Alamos

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Dr. James Kerr
Assistant Associate Director
Office of Research
National Preparedness Programs
Federal Emergency Management Agency
500 C Street S.W.
Washington, DC 20472

Dear Dr. Kerr:

This letter is intended to serve as a summary description of the work performed by Los Alamos under contract #10023 82-7-1312-2590-2-6600, titled "Resource Management Technology."

Introduction

The objectives as delineated in the Interagency Agreement for the project titled "Resource Management Technology" are as follows:

1. To analyze with FEMA, in a cooperative and iterative manner, the FEMA needs in the areas of resource management.

2. To assess Los Alamos' abilities to participate in meeting those needs.

3. To formulate a program for cooperative research and development that will exploit Los Alamos' capabilities in optimal fashion as well as those of other laboratories and/or agencies.

4. To develop a plan to be implemented by FEMA for a cooperative venture among the government agencies, national laboratories, industry, and universities that will accomplish effective management of the nation's resources.

The first phase of the work for FY82 was to cover the first two objectives. The second phase of the work was to consist of the last two objectives; it was to be performed with FY83 funding, "subject to availability of funds." Because funds were not available for FY83, the last two broader planning objectives were not achieved. However, the third objective was begun. Suject to the availability of future funding and the identification by FEMA of a specific resource area(s), Los Alamos would be interested in completing the last two objectives.

Approach

When Los Alamos embarked upon this project, a general description of the breadth of FEMA's potential interests and needs was obtained from Dr. Kerr, the FEMA project officer. Using this description, which was intentionally kept broad and general, all of the technical divisions and some of the support divisions at Los Alamos were contacted. Most of the divisions responded enthusiastically with various inputs regarding the types of activities they could perform to aid FEMA in meeting its missions. In addition, the interdisciplinary Strategic Materials working group at Los Alamos responded with a wide variety of technical concepts regarding the development of mineral resources.

The various inputs were reviewed and assembled into four categories:

I. Strategic Materials
II. Natural and Technological Disasters
III. Communications and Training for FEMA Missions
IV. Counterterrorism

A small group of individuals was then assigned the task of working with the various divisions in order to bring together the concepts in each category. The results of this effort were presented to FEMA on 10 November 1982 at a meeting of FEMA personnel which was hosted by Jim Kerr. At that time, copies of the report "Los Alamos Technical Capabilities, Concepts for Assisting the Federal Emergency Management Agency in its Various Missions" were provided to FEMA. The reports left with FEMA also included two large appendicies which contained a significant amount of background material regarding technical capabiliies and related projects at Los Alamos. The report without the appendicies is Enclosure 1, herein. It represents the completion of objectives 1 and 2.

In January 1983, Dr. Kerr identified five items from the "Los Alamos Technical Capabilities--" report which had received major attention. He requested that two or three papers be prepared which provided greater depth in these items:

- Drought - Legal and Institutional Options
- Fire Modeling
- Subsidence Monitoring
- Volcanic Forecast, Hazards
- Training and Communications - Computer Simulating Emergency Management

There was no FEMA interest in the research concepts for strategic materials because the concepts were more long term than FEMA's time frame of involvement, three years.

After conversations with a wide variety of FEMA personnel who had expressed interest in the five items, Los Alamos personnel visited FEMA in February to obtain a better perspective of specific interests, particularly on the items of Subsidence Monitoring and Volcanic Forecast, Hazards. As a result of these conversations, reports were prepared which described the last four items listed above in greater depth. These reports were made available to FEMA in April and are enclosed herein as Enclosure 2.

Los Alamos personnel have also been in direct contact with FEMA personnel regarding the item of Drought - Legal and Institutional Options. They are now in the process of trying to determine specifics of a program in this area, should funding become available in FY84.

In the April submission to FEMA, a letter to Ugo Morelli was included which additionally described a possible joint project between Los Alamos personnel and the US Geological Survey. This joint project would deploy infrasound arrays to detect microbaric signals. This activity could provide an inexpensive means of monitoring potential volcanic activity. It would be an add-on to some similar existing joint activities currently underway between Los Alamos and the USGS Astrogeophysical Laboratory at Flagstaff. To date, there has been no further communication with FEMA regarding interest in this possible joint interagency project.

Recommendations For Future Work

Personnel at Los Alamos have expressed considerable interest in further interactions with FEMA and would welcome the opportunity to further explore possible areas of mutual interest wherein the Laboratory's technical expertise could be utilized to address FEMA's needs. In particular, the papers provided in Enclosures 1 and 2 describe a number of specifics regarding potential future work. If a timely match between FEMA's current interests and Los Alamos' capabilities can be determined, Los Alamos would be pleased to pursue such areas in greater depth. In particular, if a small set of FEMA interests could be identified for more in-depth exploration than already provided, Los Alamos could pursue the broader planning objectives described in the Introduction.

Los Alamos personnel have recently been having conversations with the Air Force regarding land based sensors, monitoring techniques, and information management techniques for use during and post a nuclear attack. Similar concepts and techniques which include applications of engagement modeling could also be applied to FEMA's crisis management activities. For instance, they could be utilized in response to nuclear attack, chemical and biological releases, or a wide variety of unanticipated toxic emissions. These techniques can provide real-time information to the decision makers regarding what is happening in the environment and what is likely to happen in the future. They also enable present estimates of the environment and future predictions to be updated as additional real-time information becomes available. By utilizing recent concepts in management information systems and artificial intelligence, information which is of use to the decision maker can be made available in real-time.

That is, the crisis manager or decision maker would not be faced with endless quantities of data from multitudinous sources. Rather, they could have available assessments of the variety of decisions that could be made, and these assessments would be based on real-time data obtained from the environment.

Conclusion

The staff at Los Alamos has been stimulated by its interactions with FEMA and finds many of the missions and needs of FEMA compatible with our technical capabilities. It is our desire that these technical capabilities actually be applied in aiding FEMA to effectively meet its missions.

Sincerely yours,

Barbara Killian

Barbara G. Killian

BGK:maf

Enc. a/s

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RE: Classified References, Distribution Unlimited
No change per Mrs. Margaret Garner, FEMA/L&R

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18. SUPPLEMENTARY NOTES

Report consists of a 4-page letter plus an Appendix of 263 pages containing technical articles providing specifics on Strategic Materials, Natural and Technological Disasters, Communications and Training, and Countermeasures

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Los Alamos; Federal Emergency Management Agency; Emergency Management; Strategic Materials; Natural Disasters; Technology Disasters; Communications; Training; Counterterrorism

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report examines FEMA mission requirements in the area of resource and emergency management. It reviews the experience of the Los Alamos National Laboratory in resource management technology consonant with FEMA's mission. This experience is presented in the form of internal appraisal of the following mission areas: Strategic Materials; Natural and Technological Disasters; Communications and Training; and Counterterrorism.

ENCLOSURE 1

LOS ALAMOS TECHNICAL CAPABILITIES

CONCEPTS FOR ASSISTING THE FEDERAL EMERGENCY MANAGEMENT AGENCY IN ITS VARIOUS MISSIONS

Prepared by:
Los Alamos National Laboratory

Compiled by:
B. G. Killian, S. D. Gardner,
K. L. Mathews, M. G. Wilson, and
H. N. Planner

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* See Appendix B for supporting material. [Material in the Appendix has corresponding numbers to those in this Table of Contents (I.A.2., I.A.3., etc.)]

I. STRATEGIC MATERIALS (cont.)

* See Appendix B for supporting material. [Material in the Appendix has corresponding numbers to those in this Table of Contents (I.A.2., I.A.3., etc.)]

* See Appendix B for supporting material. [Material in the Appendix has corresponding numbers to those in this Table of Contents (I.A.2., I.A.3., etc.)]

* See Appendix B for supporting material. [Material in the Appendix has corresponding numbers to those in this Table of Contents (I.A.2., I.A.3., etc.)]

IV. COUNTERTERRORISM

* See Appendix B for supporting material. [Material in the Appendix has corresponding numbers to those in this Table of Contents (I.A.2., I.A.3., etc.)]

§ This paper does not appear in this document. It is classified and will be provided only upon written request.

FOREWORD

The technical capabilities of the Los Alamos National Laboratory have been assessed with respect to their potential use for aiding the Federal Emergency Management Agency (FEMA) in addressing its missions. This report consists of the results of that assessment and is assembled into four major sections:

I. Strategic Materials
II. Natural and Technological Disasters
III. Communications and Training for FEMA Missions
IV. Counterterrorism

The attached Appendix A contains additional information of a general nature regarding the technical capabilities and activities of the Laboratory. Appendix B contains additional information relating to some of the papers that are presented in the four sections.

Each section contains an Introduction and a number of brief "concept" papers describing specific technical capabilities that could be applied to the FEMA mission of that section. These papers are of a general nature and emphasize the basic concept rather than details regarding specific tasks that could be performed at various levels of effort. The intent of this report is to present FEMA with Los Alamos' concepts. Should more technical information be desired regarding any of the concepts, it can readily be provided.

All of the enclosed concepts could be meaningfully developed at various levels of effort. In those concept areas where FEMA has particular interest, details of specific tasks and levels of effort will be developed.

The introduction to each section provides an overview of the contents of that section. Each introduction is also intended to serve as an Executive Summary of that section.

As a result of this assessment, the following conclusions have been derived:

- The staff at Los Alamos has a high interest in applying its capabilities to the challenging technical problems inherent in FEMA's missions.

- The types of problems that could be addressed are compatible with the Laboratory's mission as well as the goals of the various technical divisions wherein the capabilities reside.

- The Los Alamos National Laboratory could bring already-developed capabilities to bear on these problems.

As a national laboratory, Los Alamos represents a national resource of capabilities that could assist FEMA in its efforts to develop and implement US emergency preparedness.

I. STRATEGIC MATERIALS

I. INTRODUCTION

FEMA's planning and preparedness missions are varied in relation to critical resources and their shortages. These missions include identification of strategic and critical materials, setting goals for the national stockpile, and developing practical research applications for the mitigation of shortages that could constitute a threat to national security.

This section is divided into six subsections or general technical areas that focus on problems associated with strategic materials. These subsections are arranged somewhat in the order of the actual material cycle. In order to address these areas, there are included in this section concept papers on the following subjects:

I.A. Resource Characterization
I.B. Processing
I.C. Materials Sciences
I.D. Inner Space and Outer Space - New Sources of Strategic Materials
I.E. Rock Mechanics
I.F. Planning

I. STRATEGIC MATERIALS

I.A. RESOURCE IDENTIFICATION AND CHARACTERIZATION

*I.A.1. Enhanced Resource Identification and Characterization Through Integration of Satellite Imagery with Multiple Data Sets

*I.A.2. Neutron Activation Analysis of Reconnaissance and Process-Study Samples

*I.A.3. Alternative Approaches to the Assessments of Strategic Mineral Resources in the United States

I.A.4. Geochemical Characterization of Ore Deposits

* See Appendix B for supporting material.

RESOURCE IDENTIFICATION AND CHARACTERIZATION

This first subsection of Strategic Materials contains concept papers regarding resource identification and characterization. The first concept paper in this subsection represents capabilities that were initially developed at Los Alamos during its participation in the National Uranium Resource Evaluation (NURE) program (Appendix B, I.A.1.)]. The first concept utilizes satellite data, additional geologic, geochemical, and geophysical information as available, and state-of-the-art computer technologies for identifying areas of high resource potential. These data integration techniques have recently been successfully verified by field work.

The second concept paper, I.A.2., describes a unique neutron activation facility at Los Alamos that has been used for geochemical analysis of field samples in the NURE work. Los Alamos' reactor and the associated analysis system can provide fast, accurate, nondestructive analyses for up to 400 samples per day for 31 elements.

The third concept paper, I.A.3., proposes that the current state-of-the-art resource identification methods, as practiced by other countries, be reviewed. Recommendations regarding improvements in current US methodologies would be made. In particular, South Africa, Canada, Australia, and the United Kingdom have recently been utilizing new advanced technologies for conducting national surveys.

The fourth, and last, concept paper, I.A.4., in this subsection describes some basic geochemical work that would aid in clarifying the genesis of ore deposits. Particular ore deposits with high potential strategic material content are emphasized in this paper.

See Appendix B,I.A.1.

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TITLE: ENHANCED RESOURCE IDENTIFICATION AND CHARACTERIZATION THROUGH INTEGRATION OF SATELLITE IMAGERY WITH MULTIPLE DATA SETS

OBJECTIVE:
To develop and apply a data integration methodology for resource identification and characterization.

BACKGROUND:
Evaluation of satellite imagery with multiple, integrated geologic, geochemical, and geophysical data sets is a more reliable method to estimate the resource potential of an area than evaluation of just any one data set alone. For nearly a decade, geologists have attempted to use Multispectral Scanner (MSS) data from Landsats I, II, and III to identify new, as yet undiscovered, mineral deposits. These efforts have been largely disappointing because the four Landsat radiometric bands are not optimized for spectral responses specific to geologic materials and the bands are so broad that wavelength resolution is poor. Also, pixel resolution on the ground is 80 m, whereas surface manifestations of many important mineral deposits are often confined to smaller areas. In addition, multispectral data is uncorrected for atmospheric distortion, though ongoing research shows indications of mitigating this problem. Landsat IV's Thematic Mapper (TM) will correct some of the deficiencies of the earlier Landsat data. Thematic Mapper has a ground resolution of 30 m and seven narrow spectral bands that are optimized to distinguigh between a variety of geologic materials.

While Landsat IV is an improved platform for geologic studies, we feel that its utilization can be greatly enhanced by integration with supplemental data sets. Large amounts of regional geologic, geochemical, and geophysical data have been compiled by programs such as NURE, CUSMAP, AMRAP, and the Wilderness Studies. These data cover major portions of the United States and are available in digital form. Like Landsat, these data bases are so complex and voluminous that they have overwhelmed the geologic community and their full potential is rarely realized. Computer technology is the obvious answer to the management problems of very large data bases, and integration of the various data sets allows for a more powerful evaluation of potential mineralization within an area of exploration. Los Alamos is unique in that we have integrated large, diverse data sets (geochemical, geophysical, geologic, etc.) for large regions of the country. Furthermore, the Laboratory's computer facilities enable us to perform this work in a timely, cost-effective manner.

Examples of Data Integration Techniques

(1) A 20,000-km^2 test area (in the Montrose quadrangle of southwest Colorado) containing known base metal mineralization is "explored" using three integrated geochemical parameters--zinc, lead, and copper. The Montrose

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quadrangle is transected by the Colorado Mineral Belt, a northeast-trending zone of major metal deposits. The principal mining districts in this region and their commodities are shown on Fig. 1. Correlative relationships for zinc, lead, and copper are shown by plotting concentrations one standard deviation above the mean for each element (Fig. 2). Values of zinc are portrayed in red, lead in green, and copper in blue. The data can be interpreted by rules of color addition. Pure colors indicate no correlation; yellow indicates zinc and lead correlate; magenta indicates lead and copper correlate. White indicates a strong correlation between all three elements. Note that all major mining districts are haloed by white, indicating not only a strong geochemical signature but a clear association of zinc, lead, and copper. In addition to the known districts, there are several areas that have a strong zinc, lead, and copper signature that are not known to contain mines or prospects. Two of these areas (just north of the Lake City and Ouray districts) were field-checked and found to contain either copper or lead mineralization. Though only integrated regional geochemical data are illustrated, this simplified example demonstrates the utility of data integration methodology. Not only are known mineralized districts recognized, but new areas with similar characteristics are identified. Interpretation of Landsat IV imagery for this area would be extremely difficult without other types of supporting information. Obviously, the interpretation could be enhanced if digitized imagery was integrated with other geologic, geochemical, and geophysical data sets.

(2) In our second example, we show ongoing work in data integration on a state-wide scale. Los Alamos is presently compiling a Geochemical Atlas of Alaska that includes geochemical data for 62,000 sample locations, each analyzed for 40 elements. The atlas will not only portray the geographic distribution of individual elements (Fig. 3), but will also include selected groups of integrated elements that illustrate significant geologic features. The geochemical data are also being integrated with digitized geologic information. This atlas graphically presents voluminous data in such a way that it can be easily assimilated. In a graphic form, new relationships between geochemistry and geology can be explored. The Alaska atlas and its compiled data base can be applied to mineral exploration, regional geology, geochemistry, land use and planning, and environmental studies. The atlas will also be a useful reference for the interpretation of Landsat data.

SCOPE OF WORK:

(1) We propose to apply the data integration approach to resource assessment to the Brooks Range, Alaska. The Brooks Range is an excellent area to develop integration methodology because of the diversity and number of undisturbed metal deposits known to occur there. In addition to the availability of Landsat spectral data, two major systematic geochemical surveys (NURE and AMRAP) have been conducted in the region. These two surveys provide aerially complete coverage of the area and include analyses for up to 40 elemental parameters as well as detailed geologic information about the lithologic

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units present. Airborne magnetic and gravity studies are available for some parts of the study area. Using statistics and computer color graphics, geologic, geochemical, and geophysical measurements can be registered to the same sample density as the Landsat spectral data and be compared for correlations. Classification models can be developed using known mineralized areas as training sets to identify all other areas with similar characteristics. These classifications can be weighted to these parameters known to be most strongly related to mineralization.

(2) Because of its importance as a base- and precious-metal producer, a state-wide data base (consisting of reconnaissance-scale geochemical analyses) will be compiled for the state of Colorado. The analysis consists of about 17,000 stream sediment locations; each location contains up to 40 elemental analyses. This atlas will serve as a cost-effective base for continued data integration (i.e., Landsat, geology, etc. can then be added) and for the evaluation of mineral resources for the state. The data base will also aid in determining the boundaries of the Colorado mineral belt, a metallogenic province that contains many strategic resources.

Once integrated, the data will be graphically portrayed in a geochemical atlas, similar to the one being prepared for Alaska. Each element will be graphically displayed as color level images. Basic statistics, such as mean, median, and standard deviation, will be included with each color image. Each element will be displayed for the entire state on one map. The critical strategic elements, such as chromium, cobalt, manganese, etc., will be additionally included in ratio displays, e.g., Fe/Mn; Cr/Ni. The critical elements (cobalt, manganese, and chromium) will also be displayed in three-element color combinations (e.g., Fe,Mn,K; Mn,Ti,Cr). This methodology allows for a rapid assessment of interelement correlations. The entire state will be displayed on each page for each element, elemental ratio, or three-element color combination. The atlas will contain about 50 total pages (40 elements, 5 ratios, 5 color combinations). The scale will be 1:2,000,000 and an appropriately scaled geologic map will be included.

SPECIAL CAPABILITIES:

Los Alamos has already completed a data integration study of a 20,000-km^2 area in southwest Colorado using 4 Landsat MSS bands, bedrock geology, known mineral occurrences, 24 geochemical parameters, and 4 geophysical measurements (copy of report in Appendix B). Presently, Los Alamos is compiling a geochemical atlas of Alaska that will display the distribution and concentration of 40 elements using color graphics. In addition, Los Alamos has conducted a comprehensive regional geochemical survey (NURE) throughout the Rocky Mountains and Alaska. Over 200,000 samples were collected and analyzed for this study. This survey was largly an in-house project and has given the Laboratory broad experience in the collection, analysis, and interpretation of geologic and geochemical data.

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To support our research, the Laboratory has four CRAY-1, four CDC 7600, and one CDC 6600 mainframe computers. Our graphics work is supported by three FR-80 microfilm recorders and two Versitec plotters. Image processing can be done either on a Comtol 8000 or Vision 120 image processing system. A complete library of software is available for all computational or image-processing needs.

The Laboratory maintains a trained staff of geologists, geochemists, and geophysicists, many of whom have experience in resource assessment. Space and atmospheric physicists, familiar in satellite imagery and image processing, work with the geoscientists. Statisticians, computer programmers, and data base managers are available both on a consulting basis or as participating investigators of many Laboratory projects such as this.

The unique computer facilities at Los Alamos provide a very promising environment for developing the technology that is necessary to handle large data sets now available to the scientific community.

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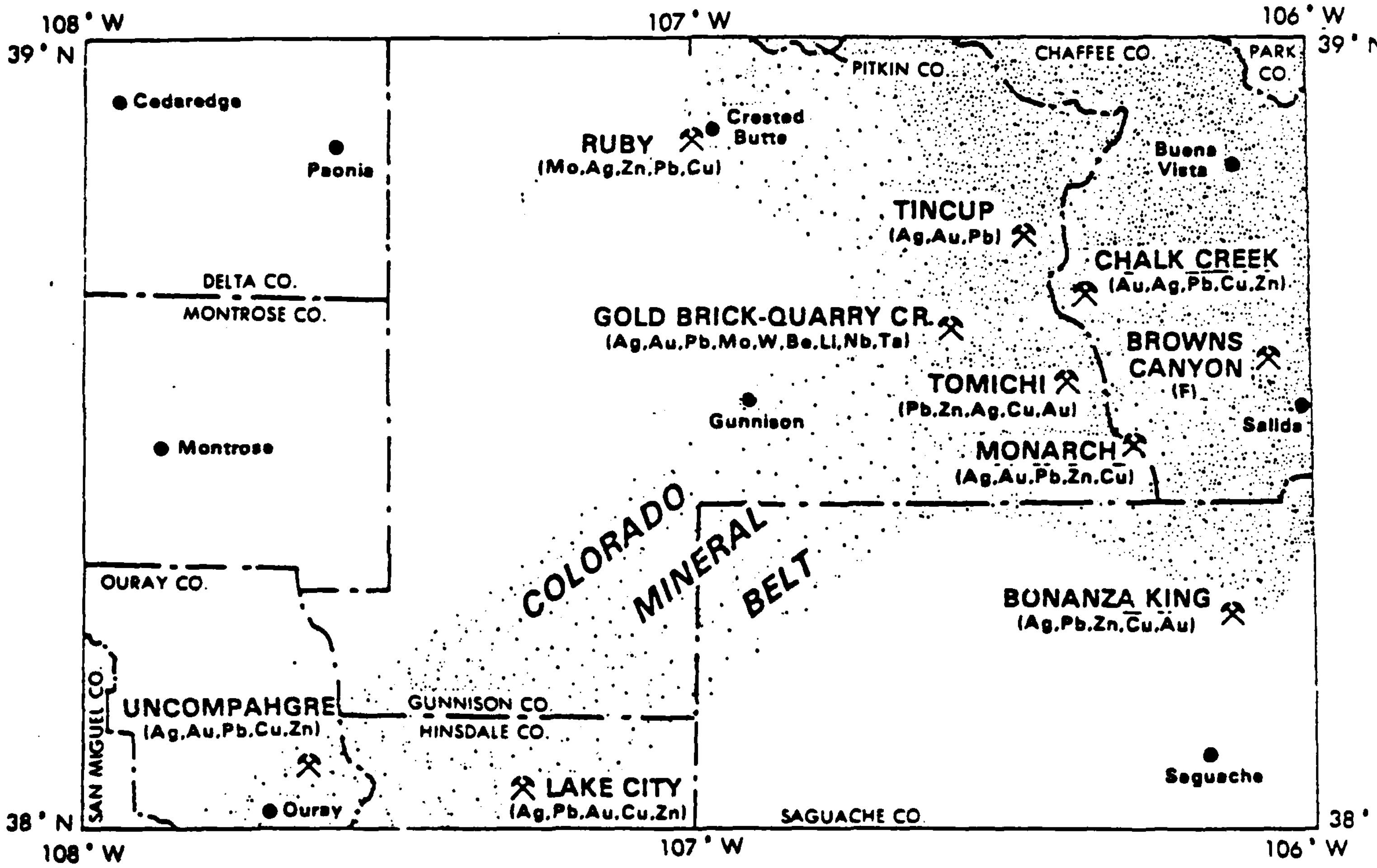

Fig. 1. Major mining districts in the Montrose 1° x 2° quadrangle (stippled area is Colorado Mineral Belt).

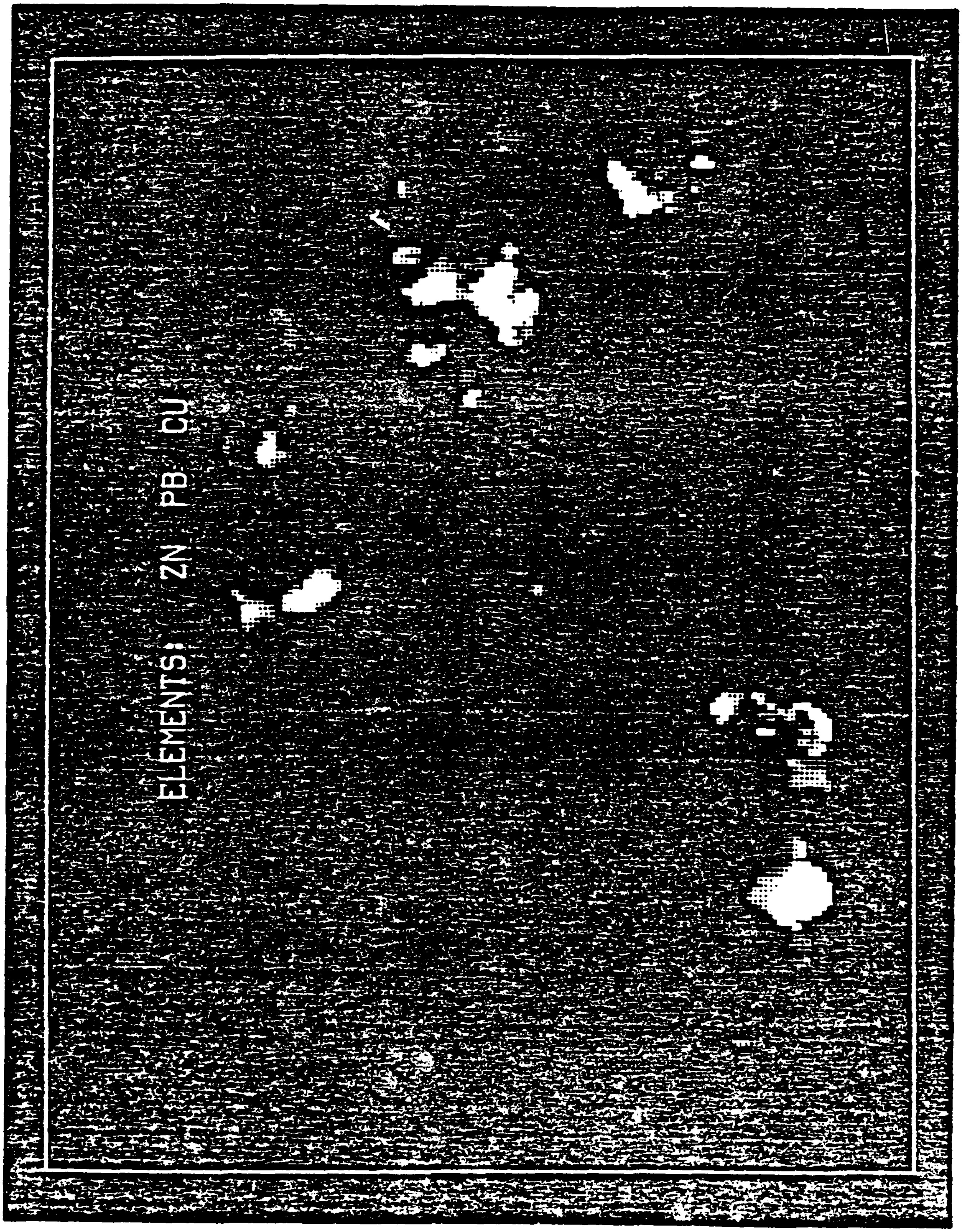

Fig. 2. A three-color overlay for the elements Zn (in red), Pb (in green), and Cu (in blue). White indicates that all three elements are correlative.

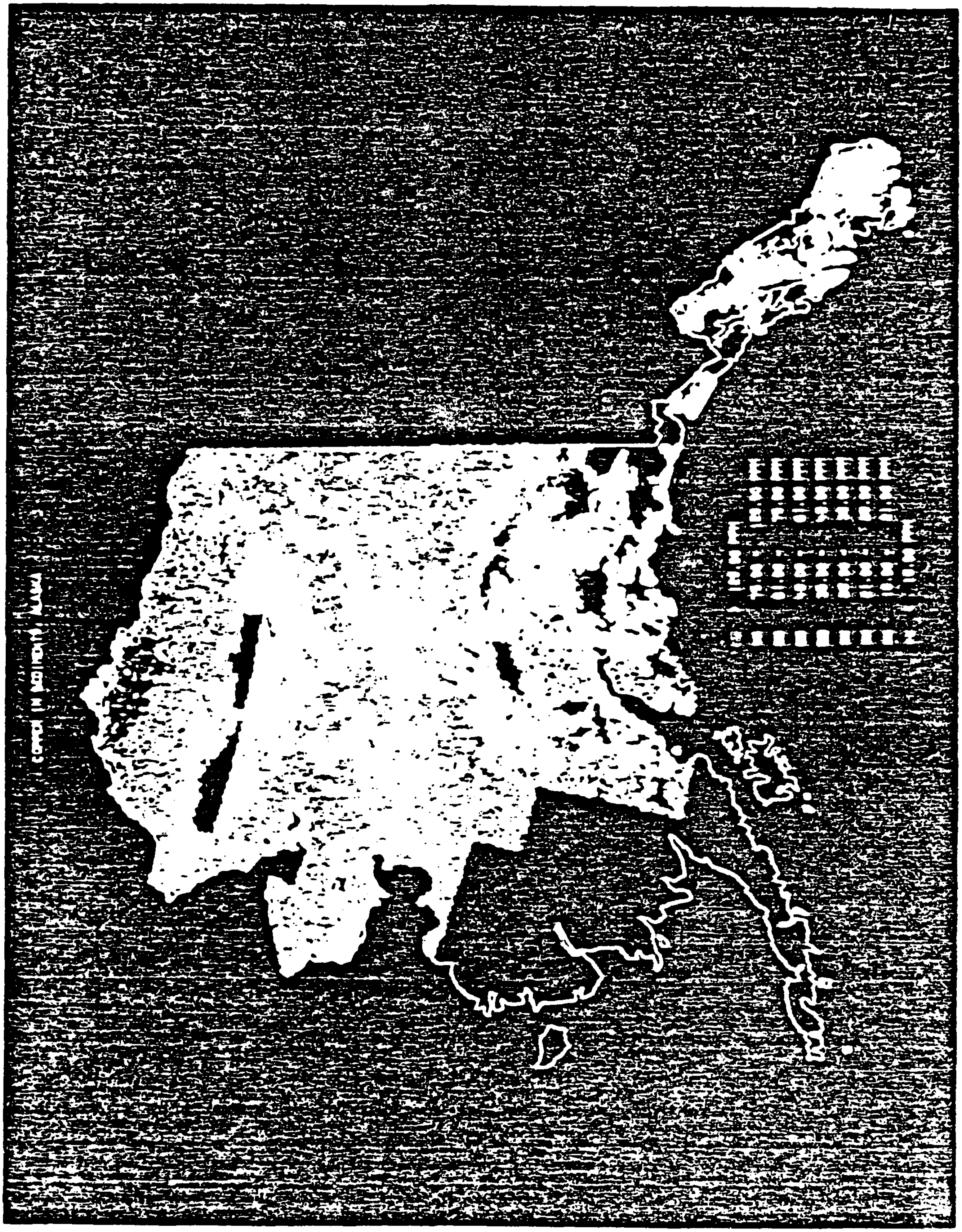

Fig. 3. Geographic distribution of individual elements from 62,000 sample locations in Alaska.

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TITLE: NEUTRON ACTIVATION ANALYSIS OF RECONNAISSANCE AND PROCESS-STUDY SAMPLES

OBJECTIVE:

To conduct rapid neutron activation analysis (NAA) of soil, stream sediment, and rock samples from federal, state, or private enterprise field reconnaissances, drill core samples, and mineral migration studies.

BACKGROUND:

Los Alamos has in operation state-of-the-art NAA facilities, possibly the best in the world. Up to 400 samples per day can be analyzed for 31 elements.

Neutron activation analysis is a rapid, nondestructive, highly sensitive method of assaying bulk materials for trace elements. The technique is especially well suited for assaying geologic reconnaissance samples, as well as solid and liquid samples generated in laboratory research projects related to strategic materials problems. Elements that can be easily assayed by this technique are shown in Table I. Among them are the "strategic" metals--chromium, cobalt, manganese, tantalun, titanium, and aluminum. Additional elements, such as iridium (which belongs to the platinum group), can be detected by subjecting the samples to post-irradiation chemistry.

SCOPE OF WORK:

We are prepared to support large-scale reconnaissance studies and mineral-recovery studies through our analytical measurements. We would prefer a sample throughput of no more than 30,000 samples per year and a program duration of at least three years.

As part of this effort, we could analyze archival samples that exist at Los Alamos and other laboratories (including the USGS). For example, Los Alamos has in its possession over 150,000 stream sediment samples collected from the states of New Mexico, Colorado, Wyoming, Montana, and Alaska. This valuable set of samples could be analyzed more thoroughly for strategic minerals than was required by the parent National Uranium Resource Evaluation (NURE) program. One approach would be to scan the existing NURE multielement data for unusual anomalies in concentrations of cobalt, chromium, manganese, etc. A finer-mesh reconnaissance would then follow in the areas surrounding these anomalies in an effort to locate the parent ore bodies. The discovery of only one major new ore body would more than pay the government (through taxes alone) for the cost of a reconnaissance program.

SPECIAL CAPABILITIES:

- An 8-MW research reactor, unavailable at most industrial laboratories and universities, is used to irradiate 4-g samples with neutrons.

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- Irradiation times can be varied to optimize counting statistics for the element or suite of elements analyzed.

- Data reduction is performed with a PDP-11/60 computer, and element concentrations are stored on disk. Results are transferred to the requesting organization through hard copy or magnetic tape.

- Automated systems permit high throughput.

- Personnel consist of highly qualified nuclear physicists, a nuclear chemist, and a technician.

- NAA facilities already existing at Los Alamos represent a two-million-dollar analytical resource; one-half million dollars in hardware and one and one-half million dollars in software.

M. E. Bunker/M. M. Minor

TABLE I

LOWER LIMITS OF DETECTION*

Element	Detection Limit	Crustal Average	Element	Detection Limit	Crustal Average
Al	3200	8.23%	Mg	2700	2.33%
As**	3	1.8	Mn	55	950
Au	0.05	0.004	Na	1000	2.36%
Br**	4	2.5	Rb	13	90
Ba	150	425	Sb	1	0.2
Ca	1000	4.15%	Sc	0.9	22
Ce	10	60	Se	5	0.05
Cl	50	130	Sm	0.4	6.0
Co	1.7	25	Sr	110	375
Cr	10	100	Ta	1	2
Cs	2	3	Tb	1	0.9
Dy	0.7	3.0	Th	1	9.6
Eu	0.4	1.2	Ti	750	0.57%
Fe	1100	5.63%	V	6	135
Ga**	5	15	Yb	1	3.0
Hg	1.3	3	Zn	11	70
K	3400	2.09%	U	0.01	2.7
La	7	30	W**	1	1.5
Lu	0.1	0.5			

* All values are given in parts per million, except as noted. Detection limits were calculated on the basis of a typical 4-g sample of stream sediment run at maximum throughput.

** Observation requires an additional count at 4 days.

S. S. Shannon
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TITLE: ALTERNATIVE APPROACHES TO THE ASSESSMENTS OF STRATEGIC MINERAL RESOURCES IN THE UNITED STATES

OBJECTIVE:

- To expedite the completion and to improve the cost effectiveness of various United States' programs for the assessment of domestic mineral resources.
- To use or modify ideas and techniques gleaned from foreign resource-assessment programs.

BACKGROUND:

South Africa, Canada, Australia, and the United Kingdom are conducting or have completed surveys to inventory known strategic mineral resources and programs to search for latent resources using geological, geophysical, and geochemical techniques.* Technologically, the United States is even with or ahead of other nations in resource-assessment procedures. However, domestic approaches have tended to be expensive, such as the National Uranium Resource Evaluation (NURE), or slow and site-intensive, such as the US Geological Survey's CUSMAP and AMRAP programs. Although another critical review of past domestic undertakings might be helpful, time can be saved and more can be learned by discussing instead procedures and methods with foreign scientists and engineers who have completed successful national surveys and have used alternative, less expensive, and quicker ways to assess and explore for strategic mineral resources. Specifically, the United States can learn from assessment programs and research being conducted in South Africa, Canada, Australia, and the United Kingdom.

Obtaining current information on successful foreign procedures and methodologies for searching for critical minerals and applying what has been learned to the design of a domestic program would be a significant breakthrough leading to expediting the discovery of such resources in this country. Intramural recycling of domestic procedures used and reused by companies, agencies, universities, and laboratories will not accomplish a breakthrough as rapidly. Fresh ideas are needed to accomplish national goals within the time and money constraints previously cited.

SCOPE OF WORK:

To design an alternative strategic-mineral resource-assessment program that can be completed for the conterminous United States, Alaska, and Puerto Rico within five years, quick and inexpensive techniques must be selected that seem to have the best chances for success based on the experience of other

* See, for example, National Geoscience Programme being undertaken by South Africa (Appendix B,I.A.3.).

nations that have conducted resource-assessment surveys. Initial specific tasks will include in-depth discussions with foreign scientists who have designed, managed, and conducted national resourse-assessment programs. Because of the need for critical minerals that are readily available to the United States only from South Africa, it is particularly pertinent to learn techniques for searching for such ores that could be included in the proposed resource-assessment program for the United States.

SPECIAL CAPABILITIES:

Los Alamos can design an aggressive, practical, goal-oriented, short-term program to run successfully on a lean budget. The mining industry does not have the priority nor the overall resources to conduct a systematic nationwide search for critical minerals, some of which may be unprofitable under normal economic conditions. Los Alamos scientists can expedite preparation and implementation of this proposal because they have close personal relationships with key counterparts in resource assessment in other countries.

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TITLE: GEOCHEMICAL CHARACTERIZATION OF ORE DEPOSITS

OBJECTIVE:

To investigate and document the geochemical characterization of ore deposits.

BACKGROUND:

The United States imports a large percentage of the strategic materials required to maintain its national security. Domestic resources are not necessarily in short supply for some of these metals. However, effective exploration and strategies for locating those resources need to be developed. This investigation would focus on the collection of new geochemical data that would clarify the genesis of ore deposits and identify resource origins.

SCOPE OF WORK:

1. Develop a genetic model for the geochemical behavior of tantalum in the pegmatitic environment.

The Harding pegmatite has long been known to contain large quantities of tantalum resources, but the origin of the deposit is poorly understood. Detailed whole-rock and mineralogic analyses using new analytical techniques are needed to verify and refine the genetic model proposed by Montgomery (1950) or to generate new genetic models for the concentration of tantalum.

Tasks:

- Field sample the Harding pegmatite and the cogenetic (?) Embudo granite.
- Perform whole-rock chemical analyses for major and trace elements using the electron microprobe and scanning electron microscopy (SEM).
- Perform mineral separations on pegmatite and granite.
- Perform major and trace-element analyses on mineral phases using electron microprobe, SEM, and neutron activation.
- Calculate mass balance for tantalum in pegmatite and granite.
- Investigate partitioning of tantalum between phases in granitic magmas.
- Evaluate Montgomery genetic model or develop new model.
- Using this model, develop and test exploration strategy.

A. W. Laughlin/S. L. Bolivar/
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2. Acquire fundamental data on copper-molybdenum ore-genesis mechanisms and develop a new quantitative technique for distinguishing between barren and mineralized plutons.

Barren and copper-molybdenum mineralized plutons of Laramide age (75-55 Myr) are common in the southwestern US and adjacent Mexico and are a major source of US copper and molybdenum. Past exploration has identified those plutons in which mineralization is exposed at the surface. This investigation focuses on the collection of new geochemical data that will help clarify the genesis of these deposits and provide a new method of distinguishing plutons with unexposed mineralization.

Tasks:

- Samples of biotite from the two pluton types (made available by the University of Arizona Geochronology Laboratory) will be physically and chemically characterized using optical, electron microprobe, and x-ray diffraction techniques.

- The samples will be fused and the gases released and analyzed.

- Correlations will be sought between gas contents and gas compositions and the presence and type of mineralization, the composition of the biotites, or presence of inclusions in the biotite.

The results will provide new evidence on the nature of the fluids that transport copper and molybdenum as well as a new rapid method of distinguishing between mineralized and barren plutons.

3. Investigate the genetic relationship between certain essential metals and alkalic intrusive rocks.

Several essential metals (e.g., Ti, Ba, Nb, Ta, and V) are commonly associated with alkalic intrusive rocks such as nepheline syenites and carbonatites. Little is known of the genetic links between these metals and the alkalic rocks.

Nepheline syenites and related alkalic intrusive rocks are common in the Gulf Coastal region of the US. In Arkansas, nepheline syenites and carbonatites are exposed at the surface in several places; similar rocks have been encountered in drill holes over larger areas along the Balcones fault zone, the Ouachita geosyncline, and the east Arkansas syncline. Ti, Fe, Mo, and Nb mineralization are associated with the ring complex at Magnet Cove, Arkansas, and vanadium is being mined from syenite and carbonatite at Potash Sulphur Springs, Arkansas. Small deposits of mercury and antimony also are found along the same trend in Arkansas. Because of the wide distribution of these rocks, detailed investigation of ore deposit genesis could lead to the identification of additional domestic sources of these metals.

A. W. Laughlin/S. L. Bolivar/
R. C. Gooley

Tasks:

- A literature search focused on: location of alkalic intrusive rocks in Arkansas, Texas, Oklahoma, Mississippi, and Louisiana; the location and distribution of ore and mineral deposits of this region; structural geology of Balcones fault zone, Ouachita geosyncline, east Arkansas syncline; and National Uranium Resource Evalution (NURE) data. This reconnaissance-scale data will consist of geochemical information and airborne geophysical information.

- Field trips to producing mines of the region to collect ore and host-rock samples. NURE reconnaissance data will be analyzed in relation to known ore districts and structural geology. An initial evaluation will be made of the potential of the Gulf Coast alkalic rocks for the strategic metals titanium, barium, niobium, tantalum, and vanadium. In addition, a map will be compiled showing the locations of all known alkalic bodies from surface and subsurface data.

4. Complete mineralogical and chemical characterization of the complex cobalt-bearing ores of the Mississippi Valley type.

In contrast to some other essential strategic materials, the US has relatively large resources of cobalt. Still, the US imports about 90% of its cobalt (1979 figure); about 70% of the cobalt imported by the US comes from Zaire.

Cobalt is used principally in heat- and wear-resistant materials, high-strength alloys, permanent magnets, tool and die steels, and various non-metallic chemical applications. For many applications, no satisfactory substitutes for cobalt have been found. Nickel may be substituted in some cases, but only with a loss in effectiveness.

The mixed sulfide ores of the Mississippi Valley type are one of the great resources of cobalt and nickel in the US. However, the mineralogy of the sulfides of the Mississippi Valley type has proven to be more complex than formerly realized and requires study with the aid of modern analytical instruments so that better commercial separations and concentrations can be made.

Tasks:

- Conduct literature search.

- Collect samples from deposits in Missouri and Wisconsin.

- Identify and analyze mineral phases using optical microscopy, electron probe microanalysis, and x-ray diffraction. Mineral separations may be performed if necessary to obtain pure mineral phases for chemical analysis. Whole-sample analysis will be conducted using x-ray fluorescence and neutron activation techniques. Analyses will be conducted on both ore and gangue minerals in order to characterize the total mineral assemblage.

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- Attempt to develop a model for genesis of the ore deposit, including partition coefficient determinations for cobalt in various mineral phases.

A secondary benefit from this work will be a complete characterization and description of associated nickel-bearing phases. Since we propose a complete mineralogical and chemical characterization of the complex sulfides, it follows that the work will include nickel.

SPECIAL CAPABILITIES:

Los Alamos has a wide range of state-of-the-art analytical equipment for chemical characterization of ore deposits. Microprobe and neutron activation capabilities are especially good. Experienced staff for operation and maintenance of this equipment is available. The Laboratory's unique computer capability allows for rapid and cost-effective evaluations.

I. STRATEGIC MATERIALS

I.B. PROCESSING

I.B.1. Explosive Comminution

*I.B.2. Trace Element Recovery from Rock Waste Drainages and from Industrial Effluents

I.B.3. Development of Advanced Separations Materials for Strategic Materials

I.B.4. Automated Sorting of Niobium and Tantalum Ores from Other Pegmatite Minerals

I.B.5. Utilization of Metal Binding Proteins from Metal Resistant Plant Species to Sequester Strategically Important Metal Ions

* See Appendix B for supporting material.

PROCESSING

This subsection contains four concepts for technology development related to the improved processing of ores. The first paper (I.B.1.) on explosive comminution, represents the utilization of a number of unique Los Alamos capabilities in an innovative high-risk but very large potential payoff area of research and development. The concept of pulverizing rock by chemical explosives, rather than grinding, is not restricted to a particular type of ore body; it has generic application to any ore requiring comminution for the subsequent beneficiation process.

The second paper, I.B.2., addresses the recovery of strategic materials from industrial wastes. This concept paper describes how the chemical knowledge that is necessary to concentrate the elements of interest from coal waste can be acquired.

The third concept paper, I.B.3., discusses studies that could lead to the design of advanced separation and recovery methods for strategic materials from solid and liquid wastes containing these metals. These studies, stimulated by earlier reported work, would consider the chemistry of thioether ligands as extractants.

The fourth concept paper, I.B.4, addresses the use of advanced technologies for the automated sorting of niobium and tantalum ores from other pegmatite materials. Currently used techniques employ hand labor; our domestic industry cannot compete with foreign markets in such currently labor-intensive products. A technological advance in automated sorting could economically revitalize domestic industry.

The fifth paper, I.B.5., proposes an investigation of plant cells and plants that are resistant to normally lethal levels of strategically important metal ions. By determining the mechanism by which these cells have become resistant, it should be possible to utilize any proteins overproduced by the cells and to segregate the desired metallic ion.

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TITLE: EXPLOSIVE COMMINUTION

OBJECTIVE:
Investigate the efficiency and economic competitiveness of using conventional explosives in containment vessels to comminute ores.

BACKGROUND:
Comminution is a single or multistage process by which mineral ores and other materials are reduced by crushing and grinding to those sizes required for beneficiation, in which the severed components are separated into concentrate and tailing products. On the order of a billion tons of rock ore alone is crushed and ground every year in the United States. In May 1981, the Committee on Comminution and Energy of the National Materials Advisory Board (NMAB) reported that annual comminution of approximately one billion tons of ore in the US consumes approximately 2% of the national production of electricity and is only approximately 1% efficient in increasing the surface area of the ore (Document NMAB-364). The 2% of US electrical energy consumed by the comminution process in the US is equivalent to 47.6 million barrels of oil. At $30/barrel, this energy cost approaches $1.5 billion yearly. If explosives could increase the energy efficiency of comminution just a few tenths of one percent, hundreds of millions of dollars yearly could be realized by the industry. A miniscule fraction of one year's potential savings could develop the required technology and allow for industry demonstration.

High explosives are routinely used to quarry or block out large volumes of ore bodies to produce large-size rubble for subsequent comminution by the energy inefficient mechanical grinding and milling operations. High explosives have not been used to directly effect comminution of the large rubble. Virtually no research and development has been done to specifically investigate the further size reduction of large rubble through use of explosive comminution. Explosive comminution could be highly energy- and cost-effective, and may be performed before haulage from the mine.

It is difficult or impossible to fragment an unconfined pile of rock by explosives because only a small fraction of the energy is coupled into the rock itself. Most of the energy is released to the environment (air) or simply serves to throw the rock into a ballistic trajectory.

However, if the explosive and rock were placed in a confined environment, the energy could be effectively utilized for breaking the confined rock. Los Alamos has performed relatively small energy tests on non-rock materials with explosives in confined vessels. In these tests, which were related to weapons programs, the materials were minutely pulverized. The results of these tests have led us to the concept of utilizing large containment vessels for the explosive comminution of rock. Our concept is briefly sketched on page 2.

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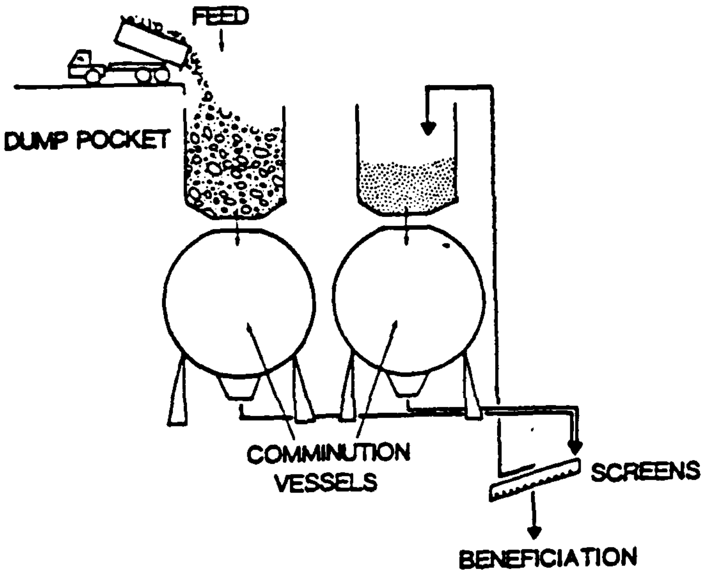


The explosive confinement vessel could conceivably be located at or near the mine site or near the beneficiation facility. Performing the pulverization at the mine site could possibly reduce transportation costs because packing fractions are higher (by about 10-20%) for pulverized rock than for irregular rubble.

The confinement vessels used to date by Los Alamos have been spheres of up to approximately 2 m in diameter. The ultimate size for feasible construction of such vessels has not been determined.

It is envisioned that the confinement vessel would be designed in a manner that would optimize the use of the energy in the shock waves being multiply reflected from the walls of the vessel. The release of energy from the explosive would also be tailored with the shape of the confinement vessel and the geometry of the rock pile inside.

Generally, the cheaper and more insensitive commercial explosives, such as nitroquandine, burn more slowly than the higher energy, more expensive explosives. The combinations of geometry of the explosive emplacement, type of explosive used, shape of the vessel, and shape of target rock to be pulverized are the types of design parameters that will require investigation.

SCOPE OF WORK:

- Begin feasibility studies regarding explosive comminution of ores on such topics as explosive efficiency, economic feasibility, computer-based simulations, and small, unscaled experiments. They would also delineate the specific tasks required in order to answer the following questions:

B. G. Killian/H. Sheinberg/
G. W. Taylor/H. N. Planner

1. How much energy is required to explosively pulverize various sizes of rock? Energy required for: size original → size final.

2. What properties of the explosive are most relevant for rock pulverization in a containment vessel, and how would their emplacement be designed?

3. What range of rock sizes can be explosively pulverized, simultaneously, in a containment vessel? What degree of presorting would be required (if any)?

4. How energy efficient can a containment vessel be made? What is maximum feasible size for a containment vessel?

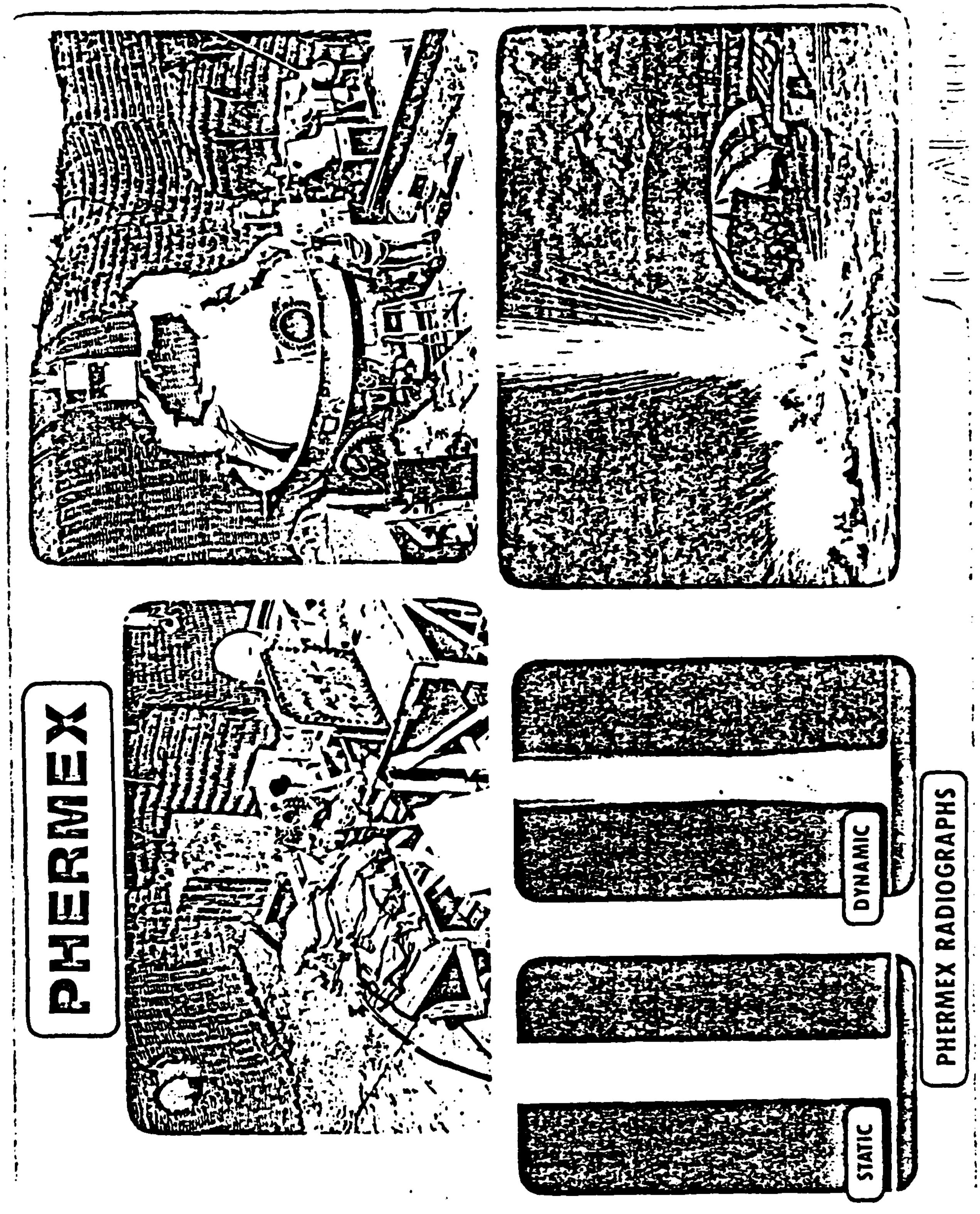
5. What are the basic economics of utilizing explosives for rock pulverization?

- Identify the fracture mechanisms and fracture rates operating at individual particle size levels to tie in energy efficiency with the comminution process. Common classes of ores will be investigated.

- Determine experimentally the efficiencies of low and high explosives for reducing primary size rubble to fine powder of size suitable for chemical or pyrolytic beneficiation. Explosive experiments at both the local Los Alamos facilities and larger-scale field experiments at the Nevada Test Site on specific rock types could be conducted.

- Utilize an existing numerical model based on statistical fracture mechanisms to simulate the fragmentation process and compare the numerical results with the experimental results. The numerical model can simulate both the energy source and the fragmentaton process. It will provide a means for understanding the various mechanisms at work during fragmentation. Rate dependencies will probably need to be added to the existing model, which has been tested to date on the rubbling of oil shale.

- Use existing computer codes to numerically study design parameters related to the explosive and the containment vessel. An existing code, the bedded crack model (BCM), which utilizes crack statistics--the number of cracks per unit volume as a function of crack size and orientation--has been tested on oil shale experiments. This numerical model can be modified to calculate the coalescence of cracks, which is the fragmentation process. This fragmentation (both particle size and shape) could be studied and predicted as a function of the stress-time and velocity-time histories of the impinging shock waves (as determined from the existing computer codes and experiment).



Containment vessel that could possibly be used for comminution of rock.

B. G. Killian/H. Sheinberg/
G. W. Taylor/H. N. Planner

SPECIAL CAPABILITIES:

- Extensive explosive testing facilities and experienced personnel.
- Tested numerical fracture models and world-class computer facilities.
- The ability to readily perform field tests locally and at the Nevada Test Site, where a variety of relevant rock types are available.
- Material scientists and equipment for examining in the laboratory the various mechanisms operating during fracture.
- Capabilities for characterizing explosives--energy release over time, sensitivity.

See Appendix B,I.B.2.

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TITLE: TRACE ELEMENT RECOVERY FROM ROCK WASTE DRAINAGES AND FROM INDUSTRIAL EFFLUENTS

OBJECTIVE:

To develop the scientific knowledge and the methodology required for the extraction of low concentrations of strategic materials from the drainages that result from the disposal of fossil and nuclear-related mineral aggregate wastes and from solutions that are by-products of industrial processes (e.g., geothermal brines).

BACKGROUND:

Rock wastes from energy-related extraction and benefication technologies with gross weights in the billions of tons exist in surface disposal sites. These are now readily accessible in a mined and comminuted form, and many have metal contents that are enhanced over crustal abundance. In regions of high pyrite (FeS_2) concentrations, the resultant acid drainages effectively perform a first step extraction and solubilization for most of the elements listed in the table below. These wastes comprise an enormous, unassessed, partially processed, strategic element resource. Other industrial effluents also contain large quantities of recoverable strategic elements that would be assessed for their potential to yield elements in sufficient quantity to be of national importance.

The drainages and solutions referred to above may contain a number of elements in quantities large enough that, if recovered, could satisfy a substantial fraction of the nation's needs. For example, the following table compares the elements that we have identified in the drainages from coal rock wastes in the course of our past control technology research, with a list of those that are imported in large quantities.

Element	Percent Imported	Identified in Coal Waste Drainages
*Al	93	X
Ti	100	X
*Cr	90	X
*Mn	98	X
*Co	90	X
Ni	77	X
*Zn	58	X
Nb	100	
Sm	86	
Ta	96	
W	59	
Pt group	92	

* These have been designated "long-term supply problem minerals."

P. Wagner/R. C. Heaton

To illustrate this discussion, cobalt will be used as a typical case; however, it is to be recognized that each element listed can be viewed individually in the context of its domestic supplies and its potential for extraction. Should the supply of imported cobalt be interrupted, known domestic supplies could not meet the demand. In view of the strategic importance of this element, new and innovative extractive methods should be investigated. The payoff from such a program would be the generation of new knowledge that would permit us to utilize our wastes and industrial effluents as a mineral resource. We estimate that 5 to 10% of the country's cobalt needs could be met using only the drainages from the acidic wastes resulting from coal extraction in the eastern United States. In this particular case, there are no mining or comminution costs--these have been paid for before disposal. Our preliminary evaluation of the element recovery potential from mineral waste drainages is documented in the enclosed Appendix B,I.B.2..

Our examination of the literature, coupled with our own past research experience with coal and shale-related mineral aggregate wastes and their leachates, has supported our view that these rock wastes are a viable resource, the lack at this time being the chemical knowledge necessary to concentrate the elements of interest to the point where they may be recovered using existing technology. Identification of the necessary chemical principles would have application not only to the drainages described here but to any solubilized system including mine waste waters, geothermal brines, sludge concentrate solutions, solution mining streams, and any number of solid wastes that have the potential of being wholly or partially solubilized. For example, one geothermal brine that we have analyzed contained 3 ppm of Co, 1200 ppm of Mn, and 1400 ppm of Zn. The research costs would be measured in hundreds of thousands of dollars. If US cobalt sources are interrupted, this knowledge will be invaluable and would be immediately applicable to the steel and electronics industry. In general, having the "on-the-shelf" methodology ready for an emergency could be critical to the national security and defense.

SCOPE OF WORK:

The general objective of this research is to develop the chemistry and technology for the extraction of trace elements that exist in low concentrations in energy-related mineral, rock, and industrial waste drainages. The elements of greatest interest are those whose continued supply is important to the security of the nation.

Once again, using cobalt for purposes of illustration, in our first experiments we propose to concentrate the cobalt from acidic coal waste drainages by:

(1) controlled precipitation (this is actually no more than a pH modification of the alkaline neutralization procedures used by many mines and coal cleaning plants) probably in conjunction with

P. Wagner/R. C. Heaton

(2) an iron oxidation step,

(3) separation of the Co (II) ions using electrodialysis, solvent extraction, or some other chemical procedure, or

(4) concentration and recovery by further electrodialysis, electro-deposition, ion exchange, or chromatography.

This recovery protocol has been devised by coupling our experience on control technology for mineral waste drainages with chemical theory. Concomitant with the cobalt recovery, we expect to concentrate the iron and aluminum in the drainages and gain insight into the chemical behavior of other trace elements of interest.

All of the above steps would require some laboratory chemical research work, with step (3) appearing to be the most critical and uncertain at this time. Due to the highly indeterminate nature of this research, we would estimate that the cobalt concentration work would take a scientist plus a technician about one year to define the probability of success and, if encouraging, another year to complete. Other individual elemental extractions would have to be examined in terms of their chemical behavior in order to develop a strategy for concentrating and separating them from the containing medium and to estimate levels of effort.

SPECIAL CAPABILITIES:

Manpower with high interest in these studies as well as the appropriate training and experience are available at Los Alamos, along with extensive laboratory facilities. The attached LA-9175-MS, Appendix B,I.B.2., represents preliminary work in this area.

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TITLE: DEVELOPMENT OF ADVANCED SEPARATIONS MATERIALS FOR STRATEGIC METALS

OBJECTIVE:

To explore the fundamental coordination chemistry of thioether ligands with strategic metals that include Ru, Os, Rh, Ir, Pd, Pt, Ag, and Au; and to apply the results of the synthetic and structural studies of these complexes to the development of homogeneous and polymer immobilized thioether extractants. It is anticipated that these extractants will provide highly specific separations for strategic metals present in a variety of process waste solutions.

BACKGROUND:

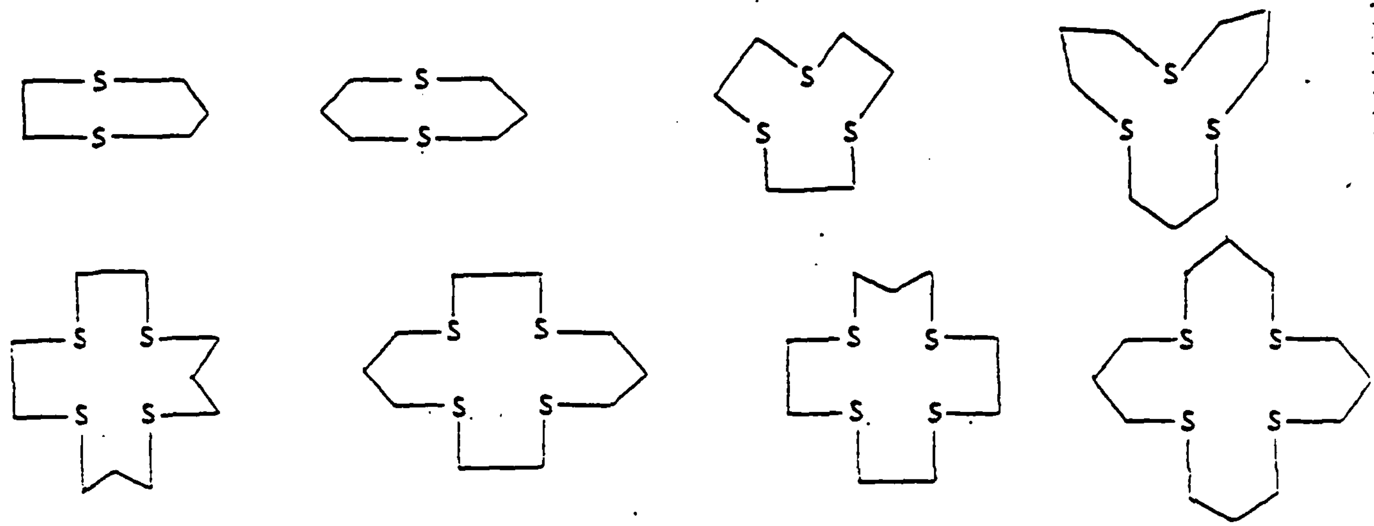
The increasing use of precious (strategic) metals in catalysts, alloys, electronic components, and other modern materials has dramatically increased the volume of liquid and solid wastes containing these metals. Since strategic metals are essentially a nonrenewable resource with a politically uncertain supply, the development of schemes for the efficient reclamation of the metals is of great interest. It has been previously established that some heavy metals, e.g., Hg and Cd, can be separated, concentrated, and recovered from aqueous industrial waste streams by complexation with an organic solvent soluble ligand. Therefore, it should be possible to design advanced separation and recovery methods for strategic metals if appropriate complexing ligands can be found.

The coordination chemistry of acyclic, cyclic, and macrocyclic crown ethers has been extensively studied, and these ligands have been found to be particularly effective complexants and solution extractants for "hard" or Class A-type metal ions, e.g., alkali metals, early transition metals, and uranium. General inorganic theoretical principles suggest that related thioether ligands should be excellent complexants for "soft" or Class B-type metals, e.g., Ru, Rh, Pd, and Ag. Very little coordination chemistry between thioethers and strategic heavy metals has been explored; however, a few very stable complexes between macrocyclic thioethers and Ru and Pd have been reported. These results clearly indicate that thioether ligands should be effective and selective heavy metal extractants.

SCOPE OF WORK:

An experimental program will be initiated at Los Alamos to survey the fundamental coordination chemistry between multidentate thioether ligands and strategic heavy metal ions. Primary attention will be given to the following ligands:

D. C. Moody/R. T. Paine (VSM)



These and a series of 5 and 6 sulfur atom macrocycles will provide an adjustable cavity size for the chelation of metal ions. Each complex will be spectroscopically and structurally characterized and formation constants will be estimated. Based upon these results, it should be possible to predict which ligands would be most effective in practical metal ion separations.

A synthetic program will also be initiated to seek methods for covalent binding of the S-macrocycles to polystyrene-divinyl benzene copolymer. The immobilization of the sulfur ligands on a solid polymer substrate will permit construction of ion specific chromatography columns.

SPECIAL CAPABILITIES:
The Laboratory has uniquely centralized facilities and experience in general synthetic inorganic coordination chemistry, spectroscopic characterization methods, crystallographic structural methods, sulfur chemistry, and ligand-polymer immobilization chemistry. Specifically, appropriate investigators have extensive experience in the chemistry of second- and third-row late transition metals and sulfur macrocycle chemistry that will permit efficient performance of this project.

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TITLE: AUTOMATED SORTING OF NIOBIUM AND TANTALUM ORES FROM OTHER PEGMATITE MINERALS

OBJECTIVE:

To develop standby mining and milling operations that could be utilized to acquire domestically most or all of the niobium and tantalum required in the event of a national emergency, when foreign supplies are unavailable.

BACKGROUND:

The United States is totally dependent on uncertain foreign sources for ores of the strategic metals, niobium and tantalum. Resources of these commodities occur in the US but have not been mined since 1959. Worldwide, niobium and tantalum minerals are recovered from pegmatites by hand-sorting of crystals and fragments. Domestic operations closed because they could not compete with low-cost foreign labor. This concept paper addresses the possibility of utilizing new technologies to develop automated sorting techniques. Such techniques might prove to be cost-effective enough to revitalize domestic production. If not, they could serve to enhance our position of preparedness in the event of a national emergency when foreign supplies are unavailable.

SCOPE OF WORK:

The development of a process for the automated sorting of niobium and tantalum minerals from pegmatites would encourage the development of a viable domestic industry in the US by enabling it to compete more successfully with manual low-cost, but undependable, foreign producers. The tonnage of recoverable domestic reserves of these critical materials available at various metal prices would increase significantly by using a modern method of separating tantalite and columbite from other pegmatite minerals. Given technological assistance in developing automated ore-dressing techniques, domestic mines could operate on a small scale at a profit or with minimal subsidization in the case of an emergency. Their output could be expanded during a crisis to meet all domestic requirements of niobium and tantalum ores.

Research toward the development of automated sorting of niobium and tantalum pegmatite minerals will include possible utilization of materials-handling and ore-dressing techniques such as:

(1) a self-learning optical scanning system whereby output from an optical sensor is analyzed using a microprocessor that maintains the data base as a reference;

(2) an x-ray fluorescence system combined with air jets, trapdoors, or other guidance mechanisms;

S. S. Shannon

(3) size sorters;

(4) shape sorters used in diamond recovery;

(5) ferrosilicon density separation whereby the density of a water slurry is increased, permitting sink-float separation at a specific gravity of about 3; and

(6) ferro- and paramagnetism.

SPECIAL CAPABILITIES:

A broad base of experience in both practical mining engineering and geosciences exists with the staff at Los Alamos.

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TITLE: UTILIZATION OF METAL BINDING PROTEINS FROM METAL RESISTANT PLANT SPECIES TO SEQUESTER STRATEGICALLY IMPORTANT METAL IONS

OBJECTIVE:

- To select plants and plant cells for resistance to normally lethal concentrations of specific metal ions.
- To induce the overproduction of metal binding proteins in these plants and plant cells.
- To characterize the binding proteins involved in order to determine the feasibility of utilizing these plants to sequester useful amounts of these strategic metal ions.

BACKGROUND:

It has been known for some time that plants do not exclude normally toxic levels of specific metal ions while taking in ions necessary for metabolism. This has suggested the presence, within plant cells, of complexes capable of binding these toxic ions, sequestering them, and rendering them non-toxic to the cell. Since the mechanism of toxicity of most toxic metal ions normally is related to the binding of the ion to specific metabolically important proteins, if the cell is to sequester a particular ion, it must produce a binding complex with a slow turnover rate and very high binding affinity (higher than any metabolically important site within the cell). Such proteins have been shown to exist in plant cells. Since, normally, concentrations of toxic ions are rather low in most soils, these proteins comprise a very small percentage of the total protein within the cells. Our recent results from studies of cadmium toxicity in plant cells (manuscript in preparation), however, suggest that one can select for plant cells resistant to normally lethal levels of specific metal ions. Resistance, up to 100 times the level of normal toxicity, can readily be obtained. Resistant cells can then be utilized as a source of material to regenerate plantlets that are resistant to normally lethal levels of the metal ion. The mechanism of resistance is directly related to overproduction of the metal binding proteins within the cells--from levels undetectable in the original metal sensitive cells to approximately 1% of the total cellular protein in resistant cells.

SCOPE:

Several strategic metals, including cobalt, copper, manganese, mercury, nickel, silver, and tungsten, are toxic in ionic form, at rather low concentrations, to plants. This suggests that it may be possible to, first, select for plant cells and plants that are resistant to normally lethal levels of one or more of these metal ions; determine the mechanism by which these cells have become resistant; and utilize any proteins overproduced by the cells, to sequester the metallic ion in question.

P. J. Jackson

It should also be possible, once resistance is obtained, to isolate the genes responsible for this resistance; determine the genetic mechanism by which they confer resistance; then transfer them, via recombinant DNA techniques, to a more appropriate organism, perhaps a bacterium, for utilization in sequestering useful amounts of the metallic ion in question.

SPECIAL CAPABILITIES:

The Life Sciences Division already has the capability of selecting metal-tolerant plant cell lines. A manuscript detailing the process of selection for cadmium-resistant cells is in preparation. There is currently active research being conducted to characterize the two Cd-binding proteins that are overproduced in resistant cells in response to a challenge with Cd^{+2}.

The Genetics Group of the Life Sciences Division has the capability of isolating and cloning genes from plant, animal, bacterial, or fungal cells. Once cloned, genes can be "mapped" and further characterized; in some cases they can be placed back into another recipient.

Members of LS-6 have the capacity to both regenerate plants from single cells (cloning), and of characterizing the whole plants' response to a challenge by a specific metal ion under different environmental conditions.

Combined, these resources provide an excellent environment in which to pursue such a project.

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MARGE WILSON
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I. STRATEGIC MATERIALS

I.C. MATERIALS SCIENCE

*I.C.1. Nonconventional Cobalt-Free Hard Materials

*I.C.2. Alternate Catalytic Materials: Fundamental Studies

I.C.3. High-Energy Beam Surface Treatment of Metals

*I.C.4. Ultrasonic Characterization of the Microstructure of Metals and Polycrystals

* See Appendix B for supporting material.

MATERIALS SCIENCE

Los Alamos has extensive facilities and expertise in materials sciences that were developed for the weapons program. As described by the four papers in this subsection, these capabilities could readily be applied to specific strategic materials or generic studies.

The first concept paper, I.C.1., and Appendix B,I.C.1. describe a new "hard metal" that was made by reaction hot-pressing of tungsten, nickel, iron, and boron carbide. This metal has hardness values comparable to the hardest commercial tungsten carbide-cobalt compositions and could find wide application in reducing US demand for cobalt. Further modest work on this new metal would provide a basic understanding of the nature of the fabricating process. This work would enable a family of such metals to be developed for a wide variety of cobalt substitution applications.

Considerable theoretical and experimental expertise in catalytic materials has also been developed at Los Alamos based on the needs of the weapons program. This expertise exists in a number of separate divisions, but the combined theoretical and experimental approach described in the second concept paper, I.C.2., would represent an integrated, laboratory-wide thrust to the understanding of catalytic activity and the development of alternate catalysts for strategic materials.

The third concept paper, I.C.3., describes the use of state-of-the-art, high-energy laser and/or electron beams to modify the surface properties of certain metals and alloys. The selective modification of surface microstructures and/or chemistry can significantly reduce the use of strategic materials as alloying elements in the bulk material.

The sensitivity of the propagation of an ultrasonic wave to changes in the microstructure of a material is well known, and ultrasonic methods are used today for the nondestructive evaluation of engineering materials. Current methods for determining grain sizes in all materials but ceramics (which have elastically isotropic grains) are based on approximate scattering relations, and the resulting analyses are only semiqualitative. By utilizing recent theoretical advances, improvements can now be made in the scattering relations for most other materials (which have elastically anisotropic grains).
Improvements in the analysis of ultrasonic nondestructive methods, as described in I.C.4., could lead to the conservation of strategic materials in certain key industries, such as titanium in aerospace.

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TITLE: NONCONVENTIONAL COBALT-FREE HARD MATERIALS

OBJECTIVE:
Provide cobalt-free hard materials as substitutes for the strategic materials, cobalt and tungsten.

BACKGROUND:
Strategic materials are commodities essential to this country's military security and economic welfare that are in such short supply in the United States that they must be obtained from foreign sources. The US imports more than 96% of its annual cobalt consumption requirements, and the imports are from potentially unstable sources. Tungsten carbide-cobalt is the conventional "hard metal" used worldwide for munitions, machine tool bits, and rock bits for energy exploration and extraction, and accounts for approximately 20% of total cobalt consumed. Approximately 60% of the strategic tungsten consumed in the country is also imported. About Mkg of tungsten base munitions were expended in the "Six-Day" war.

A new "hard metal" (metal-boron-carbon) made at Los Alamos principally by reaction hot pressing tungsten, nickel, iron, and boron carbide has hardness values comparable to the hardest commercial tungsten carbide-cobalt compositions, and demonstrated superiority for high-pressure anvil application. It has been demonstrated that molybdenum, a nonstrategic material, can be substituted in part or totally for the tungsten with minimal reduction in hardness. Thus, the new type hard metal has potential for significantly reducing requirements for two strategic materials.

This cobalt-free metal-boron-carbon "hard metal" was originated by H. Sheinberg at Los Alamos. Developed to its fullest potential, this material could reduce the US imports of strategic cobalt and, to a lesser extent, strategic tungsten. The chances for timely success are good. Adequate expertise and facilities are available with which to commence work on this system.

The hardness of this material has attracted worldwide industrial attention. Among those expressing interest are the world's largest producer and the four largest US producers of conventional hard material tool bits. The armed services have expressed interest in the new material as have tungsten and molybdenum powder producers and manufacturers of bearings, rock bits, and machinery.

The ability to vary the density of this family of materials from about 10.2 to 17.0 Mg/m^3 portends usage from tire studs, to munitions of many types, to rock bit inserts for drilling, and new machinery capabilities.

H. Sheinberg/T. I. Jones

SCOPE OF WORK:

The specific objectives of the work required are: to gain an understanding of the nature and extent of reactions involved in fabrication of this cobalt-free "hard metal," to identify and quantify grain and grain boundary phases, and then to optimize composition, raw material properties, and fabrication techniques and parameters to achieve structure uniformity, fine grain size, and an improved combination of toughness, compressive strength, flexure strength, hardness, and abrasion resistance.

Preliminary evidence indicates that the high hardness results primarily from formation of molybdenum/tungsten borides with a secondary contribution from formation of carbides/borocarbides. The first phase of the investigation will identify the phases, quantify the metal-boron-carbon reactions, determine the liquid phase sintering kinetics, and establish the activation energy of the processes. The contribution to densification of the customary material transport mechanisms such as evaporation/condensation, viscous flow, diffusion and plastic flow will be established. The second phase of the program will entail determination of effects of composition, raw material properties, and fabrication parameters on structure. The third phase will interrelate these parameters to optimize structure to achieve an improved combination of toughness, hardness, compressive strength, and abrasion resistance.

SPECIAL CAPABILITIES:

See the attached Los Alamos National Laboratory report LA-8934, Appendix B,I.C.1., Nonconventional Hard-Metal Composition, November 1981.

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TITLE: ALTERNATE CATALYTIC MATERIALS: FUNDAMENTAL STUDIES

OBJECTIVE:

To develop, from both an experimental and a theoretical viewpoint, a fundamental understanding of the role of structural, compositional, and electronic properties in determining catalytic activity. To apply this knowledge to the development of alternate catalysts and to help alleviate our national dependence upon strategic catalytic materials.

BACKGROUND:

It has been estimated that more than 20% of the United States gross national product is generated through catalytic processes. As such, fractional improvements in any given major catalytic process would have economic benefits sufficient to pay for many research programs.

Large quantities of strategic materials are used in catalytic processes (e.g., platinum metals in oxidation, hydrogenation, cracking, reforming and isomerization, and cobalt-molybdate catalysis in hydrodesulfurization). If such materials became unavailable due to wartime or cold-war embargoes, the American economy would be severely threatened. A reduced production capacity for petroleum fuels, for example, could result in diminished military mobility. By providing a fundamental insight into the mechanisms by which catalytic properties may be modified, we hope to lead the way to the future development of alternate catalytic materials that could reduce our dependence upon strategic materials in catalysis.

There is a firm basis for believing that certain uranium and thorium compounds might be efficient catalysts, useful in industry as replacements for platinum-group catalysts. Additional applications include catalytic production of synthetic fuels from coal (analogous to the Fischer-Tropsch process), olefin polymerization, and flue-gas desulfurization.

In order to successfully attack the problems, a combined theoretical and experimental approach is required. Los Alamos is in a strong position to field such a program. Particularly pertinent are: (1) a state-of-the-art experimental facility for mechanistic studies in heterogeneous catalysis, (2) recognized expertise in organo-actinide chemistry and transition metal/ SO_2 chemistry, and (3) unique capabilities and computational facilities for understanding the electronic structure of transition metal complexes and clusters.

D. C. Moody/
R. L. Martin/P. J. Hay
C. T. Campbell/T. N. Taylor

SCOPE OF WORK:

We propose to combine these three complementary capabilities in an effort aimed at understanding the fundamental details of catalyst activity and modification with the goal of developing alternate catalytic materials.

(1) Mechanistic Studies in Heterogeneous Catalysis. The aim here is to develop a microscopic understanding of how surface structural, compositional, and electronic properties can be selectively modified to tune the activity of a solid catalyst. The approach will be: (a) to systematically modify a model catalyst surface using UHV preparative techniques (this involves starting with a simple, single crystal surface and introducing crystallographic changes, surface additives, and/or a support material); (b) to characterize the modified surface in detail using ultra-high vacuum (UHV) surface analysis immediately before and after high-pressure catalytic reaction; and (c) to observe how these modifications influence the kinetics and product distribution of the catalytic reaction. Central to this effort will be a powerful and unique apparatus, recently acquired through other laboratory programmatic funding that combines detailed, UHV surface analytical and preparative techniques with real-pressure (up to 15 bar) transient and steady-state catalytic rate measurements. Thus, we presently have the capability to modify, under highly controlled conditions, the structural, compositional, or electronic properties of catalyst surfaces and to observe in detail how and why these modifications affect catalyst activity and selectivity.

Initial studies will involve the ethylene epoxidation reaction over silver, the simplest example of a kinetically controlled, selective heterogeneous catalytic reaction. This serves as an excellent model system in that it displays a wide range of fundamental phenomena of generic interest to the entire class of surface-modified catalysts: structural sensitivity, site specificity, promotion, poisoning, and metal-support effects. Further studies will concern the hydrodesulfurization reaction, a reaction vital to our efficient utilization of fossil fuel resources.

(2) Theoretical Studies of Chemisorption. The interaction between theory and experiment in surface science is particularly synergistic--the experiments suggesting additional calculations and the theory suggesting additional, more discriminatory experiments to test hypotheses as they evolve.

Current theoretical capabilities at Los Alamos involving relativistic effective core potentials enable one to replace the core electrons in heavy atoms (such as Ag or Pt), to include the major relativistic effects, and carry out the molecular calculation treating only the valence electrons explicitly. This has opened the door to previously intractable ab initio molecular orbital and configuration interaction calculations on clusters of second- and third-row transition metals and their interaction with adsorbates.

D. C. Moody/
R. L. Martin/P. J. Hay
C. T. Campbell/T. N. Taylor

A program aimed at understanding the mechanism of C_2H_4 epoxidation on Ag surfaces has been initiated in FY 82 in Los Alamos' Theoretical Division to complement the above-mentioned experimental program. This reaction is used widely in the industrial preparation of epoxides, and Ag is a unique catalyst in its selectivity for epoxide formation vs complete oxidation. Our theoretical studies are helping to understand photoemission spectra, adsorbate geometries, vibrational frequencies, bond energies, and the role of the work function in the chemisorptive bond.

We propose to extend our studies on the electronic properties of the Group IB members (Cu, Ag, Au) to those of the platinum group (Ni, Pd, Pt). The platinum group is a logical next step since the presence of a partly filled d-band should provide insights into the role of the d-orbitals in making this group effective catalysts. In particular, we hope to examine the bonding of O_2, CO, NO, and hydrocarbons to Pt, since it is of central importance to catalytic processes in the petroleum industry, in emission exhausts, and in the ammonia-oxidation reaction.

(3) Organo-Actinides as Substitute Catalysts. The thrust here is to utilize our unique background in homogeneous organo-actinide complex chemistry to develop substitute catalysts for processes presently reliant upon strategic platinum-group materials.

Initial emphasis will be placed on basic chemical studies of organo-uranium and thorium hydride complexes where homogeneous catalytic properties will be explored. These data will be transferred to studies of supported systems where a comparison to platinum group catalysts can be made directly. If promising catalysts are developed, Los Alamos is prepared to undertake engineering studies (possibly including the construction of a small test facility) to examine how well the process works in a production mode.

SPECIAL CAPABILITIES:

The research will receive broad-based support from the Laboratory's wide-ranging facilities and capabilities, including: (1) theoretical and experimental gas-phase and gas/solid reaction dynamics, (2) surface analytical capabilities and surface studies in materials science, (3) gas/surface energy exchange, (4) new surface analytical techniques using MeV ion beams at the Van de Graaff facility, (5) homogeneous- and electro-catalysis, (6) neutron inelastic scattering at the Los Alamos pulsed neutron facility, and (7) a powerful computing network consisting of four Cray-1 and four CDC-7600 mainframes. In addition, uranium and thorium chemistry is probably better understood at Los Alamos than anywhere else in the world. It has been a major research effort here for decades. Also, in the area of desulfurization of flue gases, Los Alamos scientists have been engaged in $SO_2 \rightarrow S$ research for over six years, and Los Alamos is now recognized as the principal center of research on transition-metal SO_2 chemistry.

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TITLE: HIGH-ENERGY BEAM SURFACE TREATMENT OF METALS

OBJECTIVE:

To use high-energy lasers and/or electron beams to modify the surface properties of certain metals and alloys. By selectively modifying surface properties, the use of strategic materials as alloying elements in the bulk material can be significantly reduced.

BACKGROUND:

There are numerous potential applications for the technology of treating metal surfaces with high-energy laser beams. Enhanced surface properties, i.e., corrosion, wear, and fatigue resistance, would have an obvious impact in the use of structural materials. We could alleviate the problems of corrosion and material compatibility in the processing of synthetic fuels, the fabrication of heat exchangers in high-temperature reactors, etc.

This technology could have a significant impact on our use of strategic materials/resources. For example, the selective modification of surface microstructures and/or chemistry can significantly reduce the use of critical alloying elements in the bulk materials; the processing is infinitely more efficient than conventional coating processes with respect to reduced process energy usage, and the overall reduction of associated processing steps (forming, machining, and heat-treating operations).

Our objective is to use high-energy lasers and/or electron beams to modify the surface properties of specific metals and alloys, while maintaining the engineering properties characteristic of the bulk material. The state-of-the-art (SOA) is reasonably well developed for the more conventional heat-treatment processing, but there is enormous scope for exploring the concepts of controlled surface alloying and rapid solidification processing. Our high-energy beam (HEB) technology is essentially SOA.

SCOPE OF WORK:

Rapidly quenched structures offer unique material properties, and we propose to examine the response of commonly used engineering materials to laser and energy beam glazing where metastable phases or fine-grained microstructures may offer improved properties. We would expand this analysis to include eutectoid alloys that form amorphous phases when laser glazed.

Our primary effort would be in the area of surface alloying with HEB processing. The development of efficient and effective controlled surface alloying with rapidly quenched substrates would represent a major breakthrough in a developing technology and would have a substantial impact in US manufacturing technology.

H. Casey

SPECIAL CAPABILITIES:

Los Alamos is one of the few institutions in the country to have the extensive processing capability, analytical support, and specialized expertise necessary to make an effective contribution to this technology. Industry has very specialized interests and few companies have laboratory equipment of this type available for other than short-term payoff projects. We know of no universities that have the necessary processing capabilities available "in-house."

See Appendix B,I.C.4.

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TITLE: ULTRASONIC CHARACTERIZATION OF THE MICROSTRUCTURE OF METALS AND POLYCRYSTALS

OBJECTIVE:

To improve the use of ultrasonic nondestructive methods for the evaluation of engineering materials. This improvement will provide a more quantitative base for determining those microstructural qualities of a material that affect its mechanical behavior. Such nondestructive testing techniques are finding industrial applications in quality-assurance testing of machined parts. Improved testing techniques could lead to the conservation of strategic materials in certain key industries, such as titanium in aerospace.

BACKGROUND:

The sensitivity of the propagation of an ultrasonic wave to changes in the microstructure of a material is well known. Both in the foundry and laboratory, measurements of the attenuation of the wave are routinely made in the nondestructive evaluation of the average grain size of metals and ceramics. Generally, the grain size is determined from three approximate formulas, each based on approximate scattering relations, each valid for different ranges of frequency, and each asserting a specific power law dependence for the frequency. Except in unusual circumstances, the observed frequency dependence only approximates these power laws; consequently, the analyses of the measurements are only semiquantitative.

Recently, partial steps toward a more quantitative, and hence more effective, analysis were taken by several investigators who replaced the three approximate formulas with exact scattering relations spanning the entire range of frequency. The most significant limitation of the newer approach is its restriction to materials that have elastically isotropic grains. As such, they are appropriate for ceramics, and indeed, good comparisons between theory and experiment exist. For most other materials, however, the grains are elastically anisotropic. Improved analyses of these materials are necessary if interpretation of the ultrasonic measurements is to become more effective. Contrary to the isotropic case, exact scattering relations are impossible, but recently developed approximations (e.g., the T-matrix method, the Method of Optimal Truncation) are able to produce highly accurate results for a variety of scattering problems. These methods are extendable to the scattering from elastically anisotropic regions.

SCOPE OF WORK:

It is proposed to extend the recently developed Method of Optimal Truncation to the scattering of anisotropic grains and then use the calculated scattering in the analysis of the frequency dependence of the attenuation of an ultrasonic wave propagating through metals and polycrystals. Initially, an alloying (composite) situation will be studied as the sensitivity of the wave propagation to the volume fraction of a material embedded in an isotropic host will be calculated. Next, a pure metal and polycrystal situation will be studied and the sensitivity to distribution of grain sizes will be calculated.

The proposed calculations, as well as previous calculations, ignore correlation effects between different grains, but part of the sensitivity of the wave propagation is due to different metallurgical correlations present in the microstructure. It is also proposed to study the effects of the correlation in position of isotropic grains.

This research will advance the state-of-the-art use of ultrasound in nondestructive evaluation of engineering materials. It will provide a more quantitative base for determining some of the microstructural qualities of a material that affect its mechanical behavior. The research will also pave the way for more advanced studies that include texturing effects of wave propagation.

SPECIAL CAPABILITIES:

The proposed research is a natural spin-off from the DOE/BES project in ultrasonic flaw characterization being pursued at Los Alamos. This theoretical effort is the leading effort at DOE laboratories, and the mathematical Method of Optimal Truncation was developed as part of this project. Whereas the existing project focuses on the scattering from single defects, the proposed project focuses on the scattering from an ensemble of defects, which utilizes the ability to solve the single-defect scattering problem.

I. STRATEGIC MATERIALS

I.D. INNER SPACE AND OUTER SPACE - NEW SOURCES OF STRATEGIC MATERIALS

*I.D.1. _In Situ_ Recovery of Non-Fuel Strategic Materials

I.D.2. Analysis of Strategic Materials Content in Fluids Circulated Through Basement Rock

I.D.3. Innovative Drilling Technologies

I.D.4. Characterization of Precambrian Basement Rocks in Colorado, New Mexico, Arizona, and Utah: Implications for Strategic Materials Production

I.D.5. Tectonics and Ore Deposits: Tectonic and Geochemical Controls on Copper-Molybdenum Porphyry Mineralization in the Southwestern United States

I.D.6. Development of Techniques for the Determining of $^7Li/^6Li$ Ratios: Applications to Geochemistry

I.D.7. Thermodynamic Properties of Aqueous Solutions at High Temperatures and Pressures

I.D.8. Asteroids: A Source of Strategic Materials

* See Appendix B for supporting material.

INNER SPACE AND OUTER SPACE - NEW SOURCES OF STRATEGIC MATERIALS

During the last few decades, mankind has made major steps toward the understanding and utilization of outer space. Virtually no effort has been undertaken for understanding and utilizing inner space, i.e., crystalline, basement rocks overlain by surficial cover. Yet, the potential benefits to mankind (from inner space) could be as large and perhaps could be acquired at less cost. Los Alamos personnel are now engaged in tapping the inexhaustible energy resources present in the Earth's basement rocks for the Department of Energy (DOE) Hot Dry Rock (HDR) Geothermal Program (Appendix B,I.D.1.). The technologies being developed for the utilization of hot dry rocks can be expanded and utilized for tapping other basement resources. For instance, the drilling, rock mechanics, hydraulic fracturing, geochemistry, and seismology technologies utilized for HDR can be further developed and utilized in tapping inner space for its tremendous mineral resources.

Some fundamental technological questions need to be addressed in order to effectively tap inner space. Of these questions, the following are addressed in this subsection:

1. Can we modestly advance current technologies and utilize in situ leaching techniques to acquire minerals present in the basement in low concentrations? The first concept paper, I.D.1., describes the types of developments required for advancing in situ leaching technology. The second paper, I.D.2., discusses a small project that would analyze the waters circulated in the HDR loop for strategic material content.

2. Can we gain access to inner space in a less expensive manner than current drilling technology permits? The third concept paper, I.D.3., describes how inner space might be accessed less expensively by utilizing innovative drilling concepts suited to deep, stressed, hard, hot rock.

3. What geophysical and geochemical processes influence or regulate the formation and concentration of ore bodies and mineral belts? How can these concentrations be identified and located? Concept papers I.D.4. through I.D.7. in this subsection describe small-scale studies that would aid in answering this important fundamental question.

Concept paper I.D.4. describes an effort for the characterization of Precambrian basement rock in the Western Mineral belt (Colorado, New Mexico, Arizona, and Utah). The Fenton Hill HDR system is in Precambrian basement rock and this concept paper is related to I.D.1 and I.D.2. Paper I.D.5. suggests a small-scale study of the tectonics related to the Laramide porphyry copper deposits in the southwestern US. Paper I.D.6. would develop techniques for measuring $^{7}Li/^{6}Li$ ratios. Differences in this ratio from natural lithium would provide information regarding mass fractionation occurring in the past. Such information obtained from mineral deposits can in turn be related to the evolutionary processes of the deposit. Paper I.D.7. would examine the thermodynamic properties of aqueous solutions under conditions similar to those found in the basement.

We have recently witnessed the dawning of the space age and are only beginning to recognize the potential that outer space has to offer. The last concept paper in this subsection, I.D.8., recommends an evaluation of the feasibility of utilizing asteroids as a source of strategic materials. There have been preliminary estimates that such a feat could be accomplished within the next 20 to 40 years at a relative cost of about the Apollo Project. While the US may not decide to muster such resources for the acquisition of strategic materials, it is not entirely clear that other economies with advanced technologies will make a similar choice. Thus, not only the US but foreign technologies should be assessed.

It is obvious that a harnessed asteroid in Earth orbit could be utilized for military means other than strategic materials. What kind of a national emergency could occur in the US if the Soviets put into orbit and controlled an Earth-orbiting asteroid? How possible is such a scenario? If possible, when? What would/could we do about it?

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TITLE: IN SITU RECOVERY OF NON-FUEL STRATEGIC MATERIALS

OBJECTIVE:

- To assess the United States resource base of non-fuel strategic materials that may be recoverable by in situ leaching processes.

- To develop the scientific background and technical capabilities required both to locate and characterize potentially exploitable mineral deposits amenable to leaching and to construct and operate in situ leaching systems that are economically viable and environmentally acceptable.

BACKGROUND:

Many mineral deposits are known to exist that cannot be exploited economically because of low grade, excessive depth, unstable rock conditions that make underground mining impractical, incompatibility with conventional ore-dressing or extraction processes, or some combination of these factors. In general, they have been discovered by surface prospecting, core drilling, tunneling, or as low-grade or very deep extensions of ore bodies that have already been mined. Together with higher-grade and more-easily exploited mineral occurrences, many more such deposits will undoubtedly be discovered as advanced techniques are applied to prospecting and resource evaluation. They represent a tremendous resource base of a wide variety of minerals and, if means are developed to exploit them at reasonable cost, they have the potential of greatly reducing US dependence on foreign sources for many strategic materials.

In situ extraction processes have already been developed and applied commercially for a few materials, including salt, potash, copper oxides, and uranium. These are chemical leaching operations that, in favorable circumstances, can be quite inexpensive. Their general usefulness, however, is limited by several factors.

- The unavailability, high cost, or lack of selectivity of chemical agents that will dissolve or react with valuable minerals in the rock.

- Corrosion problems associated with injecting, recovering, and treating the leaching solutions at the surface.

- Drilling and well-completion costs in prospecting for, evaluating, and developing mineral deposits, especially when they are very deep or in very hard or incompetent rock.

- Inability of the leaching solution to percolate through the mineral deposit at a usefully high rate if permeability of the rock is low.

- Localization and short-circuiting of flow if the deposit is penetrated by open joints or fractures, resulting in inadequate contact of the leaching solution with the main body of rock, probable loss of solution and its mineral content from the rock volume to be leached, and possible contamination of nearby aquifers.

- A similar danger of fluid loss and aquifer contamination if the mineral deposit has high matrix permeability.

- Environmental concerns, related principally to aquifer contamination and disposal of spent leaching solutions.

Research of both fundamental and applied types can undoubtedly lead to development of improved and more flexible in situ leaching methods that are economically viable and environmentally acceptable and that can be used to increase significantly US production of a variety of industrial and strategic materials. Important research areas include the following:

- Development of fundamental guidelines as to where and how to begin the search for subterranean deposits of specific minerals for whose presence there is no direct evidence at the earth's surface. (Such mineral deposits have occasionally been discovered fortuitously while drilling or tunneling for other purposes.) This will require basic studies of the sources of elements of interest, of the chemical and physical paths of their migration, of the mechanisms of their deposition to form ore bodies, and of any concurrent or subsequent metamorphism, together with the thermodynamics, physical chemistry, and fluid and rock mechanics of these processes. Laboratory, computer, and field investigations will be involved.

- Improved surface, airborne, satellite, and computer methods of prospecting for, characterizing, and evaluating natural deposits of strategic minerals.

- More rapid, economical, and versatile methods of drilling and well completion both for prospecting and resource evaluation and for subsequent development of in situ leaching systems.

- Geochemical studies, including dissolution, mineral alteration, and precipitation reactions and reaction rates, and control of scaling, formation plugging, and corrosion of system components.

- Materials investigations, including metals and alloys, cements, ceramics, and polymers, to make possible a rational choice of the most useful and economical material for each downhole and surface component of a leaching and recovery system.

- Development of improved methods to insure effective permeation of the mineral deposit by the leaching solution and of containing and recovering that solution.

    * Controlled fragmentation by downhole detonation of explosives is one method of producing flow passages and new surface area for dissolution and chemical reaction. It produces a rubblized zone of limited volume within which permeability can be very high and diffusion paths quite short.

    * Repeated hydraulic fracturing is another method of producing flow paths and new surface. The thin cracks produced can extend for great distances (at least hundreds of meters) through the mineral deposit but, unless they are closely spaced, they may (in rock of low initial permeability) leave long diffusion paths for mineral extraction.

    * Downhole flow-control devices will probably often be required to localize fluid injection and avoid loss to isolated fractures, joints, brecciated zones, and permeable barren formations.

    * Corrosion-resistant downhole pumps will be required to recover leaching solutions and maintain reduced pressure in the recovery wells in order to encourage fluid migration toward them.

All of these techniques and equipment items require further development.

SCOPE OF WORK:

(1) Long-range, fundamental studies of ore-forming processes as a guide to where mineral deposits should be sought, particularly those that are deeply buried and have no surface exposure. This work should be fully coordinated with that of the US Geological Survey and with the Continental Scientific Drilling Program.

(2) Continued development and field application of prospecting, resource characterization, and evaluation techniques, including collection and correlation of data from the literature; detailed geologic mapping; extensive sampling; geologic, geophysical, and geochemical explorations; interpretation of satellite information; collection and detailed laboratory investigation of cores and cuttings from deep holes drilled anywhere, supplemented by core drilling where deep holes have not been drilled; and (perhaps most important) computerized analysis, correlation, and display of all information collected.

(3) Continued development of drilling and well-completion techniques and equipment, including innovative drilling methods such as spallation drilling; continuous-coring and directional-drilling systems; sidewall samplers;

methods of lost-circulation control; improved cementing formulations and techniques; and innovative casing, cementing, perforating, and valving programs for downhole flow control.

(4) Development of corrosion-resistant, temperature- and pressure-protected downhole tools, instruments, and cables for well-logging, fluid-sampling, monitoring flow distribution, acoustic mapping, and other purposes.

(5) Development of reliable, corrosion-resistant downhole pumps and armored cables for them.

(6) Dissolution, solubility, alteration, and precipitation studies on mineral specimens and core and cuttings samples in a non-interacting, continuous-flow loop with elevated pressure and temperature capabilities.

(7) Corrosion studies of candidate materials for field-system components, considering rates, mechanisms, effects, monitoring methods, and chemical and electrical means of control.

(8) Continued development of safe shaped-charge downhole explosive devices for fragmenting rock around a borehole, reducing flow impedance at exits from and inlets to the wellbore, and expanding, perforating, and cutting casing and drill pipe.

(9) Continued development of equipment and techniques for controlled, repeated, hydraulic fracturing in a variety of geologic environments. This should include theoretical studies, laboratory and field experiments, and equipment-development subcontracts in such areas as control of fracture-initiation locations; effects of borehole inclination, rock structure, in situ stress, and pressurizing schedule on fracture propagation; forced flow between parallel fractures in formations of low but appreciable matrix permeability; use of proppants to reduce flow impedance through fractures and plugging agents to increase it; and flow patterns within and around well arrays in highly permeable formations.

(10) Continued development of downhole triaxial-stress-measuring devices to evaluate the in situ stress field as a function of depth.

(11) Laboratory measurements of physical, mechanical, and permeability properties of representative rock samples as functions of temperature, pressure, and exposure to leaching solutions.

(12) Physical and mathematical modeling of rock fracturing, fluid flow through matrix and fracture permeability, and chemical reactions throughout the leaching and recovery system.

(13) Continued development of equipment and techniques for evaluating and mapping natural rock structure at and away from the wellbore and evaluating the effects on it of explosive and hydraulic fracturing and leaching operations. Acoustic-transmission and -reflection methods and source-location of microseismic events deserve particular attention, together with computer techniques for analyzing, interpreting, and displaying the data acquired.

(14) In situ leaching experiments using existing boreholes or specially drilled slim holes, with flow between wells where that is possible, or huff-puff methods (alternate injection and recovery in a single well) where it is not.

SPECIAL CAPABILITIES:

Los Alamos National Laboratory is broadly interdisciplinary and is staffed, equipped, and organized for maximum flexibility in initiating, organizing, and conducting research and development programs of many types. It has and maintains a unique balance among theoretical, laboratory, and field capabilities.

As is implied by the phrase "continued development" in the above paragraphs, Los Alamos has had or now has projects in or directly related to most of the research and development areas listed, either internally, as cooperative work with others, or as subcontracts to individuals, universities, other laboratories, and industrial organizations. It has special expertise and facilities in nearly all of the disciplines required to develop in situ materials-recovery systems, including geology, geophysics, petrology, vulcanology, hydrology, geochemistry, chemical engineering, rock mechanics, fluid mechanics, computers and mathematical modeling, materials behavior and development, drilling, well-completion, explosive and hydraulic fracturing, surface and downhole instrumentation, data acquisition, environmental studies, reporting and publication, technical liaison, subcontracting, and contract monitoring.

Los Alamos, then, has special capabilities and experience that qualify it uniquely for a lead role in the development of in situ recovery systems for non-fuel strategic materials.

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TITLE: ANALYSIS OF STRATEGIC MATERIAL CONTENT IN FLUIDS CIRCULATED THROUGH BASEMENT ROCK

OBJECTIVE:

To determine the content of strategic materials in the waters circulated through the Hot Dry Rock (HDR) geothermal loop. Determination of material content in the circulating water will enable good estimates of in situ concentrations and leaching rates.

BACKGROUND:

The 3-mile-deep HDR geothermal system is nearing completion at Fenton Hill. After completion, water will be circulated in the system in order to produce energy. Water samples will be routinely (automatically) obtained for analyses of direct interest to the geothermal resource. These or other samples could be routinely obtained and analyzed for strategic material content by utilizing the Los Alamos neutron activation facility (see concept paper I.A.2.).

There exist few drill holes in this country that penetrate deep into basement rock. The facility at Fenton Hill is a unique experimental facility that could be used to provide information regarding the large-scale elemental content of basement rock and its in situ leaching characteristics. This unique information could be acquired almost immediately for a very small cost by utilizing the existing facilities at Fenton Hill and the Los Alamos reactor. Information regarding element content and leaching properties is fundamental to an effort of utilizing the tremendous resources in inner space (see I.D.1.).

SCOPE OF WORK:

- Develop an experimental program for obtaining the number of samples, frequency of samples based on flow rates, and routine techniques for data presentation. Such a program would be planned over a relevant period of circulation times that will be difficult to determine until preliminary data are available. However, of the order of 3 months might be a reasonable time frame to start.
- Perform neutron activation of the fluid samples obtained and of representative samples of the Precambrian rocks comprising the system.
- Relate the results of the neutron activation analyses to in situ element content and leaching characteristics.
- Assess information obtained from the above three activities and determine what additional information would be pertinent and/or possible to obtain from the existing facilities.

B. G. Killian/A. W. Laughlin

SPECIAL CAPABILITIES:

Both the Fenton Hill HDR geothermal system and the automated neutron activation facility are unique facilities. Experienced personnel are also available at these facilities.

R. M. Potter/B. G. Killian
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TITLE: INNOVATIVE DRILLING TECHNOLOGIES

OBJECTIVE:

To investigate innovative drilling technologies that could substantially reduce drilling costs. Such cost reductions would greatly facilitate exploration and assessment for strategic materials and in situ recovery technologies.

BACKGROUND:

Today, the exploration for mineral deposits and the subsequent assessment of their economic potential is greatly limited because of the cost of drilling. Unless a potential mineral location is deemed to be very promising, based on data acquired from the surface, drilling is not performed; exploration data (cores, samples, and logging information) from depth is usually unavailable.

Successful innovative drilling techniques could enable the acquisition of valuable exploration data. They could also provide economically viable access to the basement rock, which is known to contain tremendous heat and, geoscientists believe, possibly also tremendous mineral resources. In situ recovery technologies utilized on basement rock could provide a new source of strategic materials.

Last year, under contract with the national Hot Dry Rock Geothermal Program, Browning Engineering Corporation demonstrated its capability to drill, by thermal spallation, a 12-in. hole in granite to a depth of 1000 ft at rates of 50 to 100 ft/hr. In conjunction with Browning, a drill bit that will be capable of both spalling and melting rock is being designed and fabricated at Los Alamos. This drill bit will also be compatible with a conventional rotary bit. A first demonstration of this conventional, thermal spallation and melting technique is planned for next year.

If this combination of conventional, thermal spallation and melting techniques is viable, drilling technology could be improved by as much as an order of magnitude reduction in drilling costs. This technique will be particularly suited to the hard, hot, stressed rock of the basement, which is the most difficult type of medium for conventional drilling.

SCOPE OF WORK:

The intent of this scope of work is to accelerate and broaden the current activities underway at Los Alamos. These current activities will need to obtain outside funding if they are to continue beyond FY 83.

R. M. Potter/B. G. Killian

- Extend the demonstration now planned for next year into a broader test program for a variety of rock types. Actual sites of potential mineral interest could be investigated.
- Accelerate theoretical and laboratory studies of spallation and melting phenomena and broaden these studies to various rock types of mineral interest.
- Evaluate the experimental program and the theoretical and laboratory studies. Make any desirable modifications to the drill bit. Develop a prototype capability to reach depths of 3000 ft.
- Test the 3000-ft capability in a variety of rock types representative of mineral-bearing ores.

SPECIAL CAPABILITIES:

- Preliminary work performed and currently underway with Browning Engineering Corporation.
- Scientists, engineers, and technicians experienced in state-of-the-art drilling technologies exercised in actual field conditions.

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S. L. Bolivar/S. B. Freeman/
D. E. Broxton
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TITLE: CHARACTERIZATION OF PRECAMBRIAN BASEMENT ROCKS IN COLORADO, NEW MEXICO, ARIZONA, AND UTAH: IMPLICATIONS FOR STRATEGIC MATERIALS PRODUCTION

OBJECTIVE:

To determine the age, composition, and tectonics of Precambrian basement rocks of the four-state region and to apply this information to an evaluation of the strategic materials potential in these rocks and the controls by Precambrian structure of younger ore genesis processes.

BACKGROUND:

Precambrian basement rocks serve not as host rocks for many types of metal deposits but also as sources of metals for younger ore genesis processes. In addition, structures originally developed during Precambrian time are commonly reactivated and may serve as conduits or controls for ore-depositing fluids.

Recent work has indicated that certain petrologic assemblages are associated with specific tectonic settings and types of ore deposits. These petrologic assemblages are distinguished on the basis of lithology, major and trace-element geochemistry, and age. Recognition of these assemblages can then lead to a better understanding of ancient tectonic settings and to the location of hidden (covered) metal deposits.

Tectonic and geochemical data derived from detailed investigations of Precambrian basement rocks are powerful tools in recognizing sources of metals in younger deposits and paths of migration for ore-forming fluids.

SCOPE OF WORK:

Existing geologic maps and reports will be used to identify exposures of Precambrian rocks within the region and to locate deep drill holes that penetrate the basement. Compilation of data from these localities will identify gaps in the geochronological, compositional, and structural data base. Where gaps exist, the exposures or cores will be sampled for age determination, chemical analysis, and petrologic study. This compilation and new data collection will lead to the production of a map series showing age, lithology, and tectonic setting of the basement rocks.

A. W. Laughlin/M. J. Aldrich/
S. L. Bolivar/S. B. Freeman/
D. E. Broxton

At this point, National Uranium Resource Evaluation (NURE) geochemical data and the location of known mineral occurrences will be integrated to examine correlations between metal concentrations and the nature of the basement rocks. Explanation will be sought for the distribution of both Precambrian and younger ore deposits and extrapolations will be made into areas where Precambrian rocks are covered by younger sediments. These extrapolations will be used to evaluate strategic materials potential in covered Precambrian basement rocks.

SPECIAL CAPABILITIES:

Los Alamos National Laboratory has the in-house staff and equipment required for the investigation. In particular, state-of-the-art analytical facilities are available for chemical analyses for both major and trace elements. As a result of prior NURE work, the Laboratory is experienced in the automated analyses of large quantities of samples. Unique computer facilities are available to process the large amounts of resulting data.

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TITLE: TECTONICS AND ORE DEPOSITS: TECTONIC AND GEOCHEMICAL CONTROLS ON COPPER MOLYBDENUM PORPHYRY MINERALIZATION IN THE SOUTHWESTERN UNITED STATES

OBJECTIVE:

To determine the plate tectonic controls on the formation and distribution of Laramide porphyry copper deposits (about 75 to 55 Myr) in the southwestern United States. This study will shed light on fundamental questions about tectonic controls on the formation of porphyry copper deposits. Are the deposits related to a subductive plate beneath the western US? What is the role of older structures in controlling the distribution of deposits? The results will have significant implications on the formation of other types of magmatic deposits. Understanding the processes that regulate the development of mineral deposits is critical to any long-range solution of mineral shortages.

BACKGROUND:

The formation of copper-molybdenum-bearing porphyritic plutons in the southwestern US, the source of about 75% of US copper, was strongly constrained temporally and spatially. The vast majority of the plutons were emplaced between 75 to 50 Myr ago during the Laramide orogeny. Spatially, they are concentrated in a long (1890 km) narrow belt which parallels the Pacific Coast and extends from northwestern Arizona to west-central Mexico. Throughout most of its length in Mexico, the belt is no more than 100 km wide, but in southeastern Arizona its width increases to a maximum of 350 km before abruptly decreasing to 35 km. This sudden change in width occurs across a northeast-trending feature (Jemez lineament) that passes through the Globe-Miami and Ajo mining districts (see attached map).

Although the existing data indicate the Jemez lineament is in some way fundamentally related to the distribution of the copper-bearing plutons, there is nothing to show exactly what form this relationship takes. Plate tectonic models, which associate subduction-related magmatism with the formation of porphyry copper deposits, suggest that the angle of dip on the subducting plate and the depth to the plate during the Laramide was different on either side of the Jemez lineament. The purpose of this study is to determine if the configuration of the subducting plate was different north and south of the lineament and if any differences found can account for the distribution of the prophyry copper deposits.

SCOPE OF WORK:

A three-stage approach will be utilized to accomplish the objectives of this work.

(1) Literature search and data compilation. The investigation will begin with a search of all available geologic literature to locate barren and mineralized plutons of Laramide age in New Mexico and Arizona. These data will be

compiled on 1/500,000-scale overlay maps of the two-state area. Separate overlays will be prepared for barren plutons and for plutons associated with specific metals or groups of metals, e.g., copper-molybdenum, tungsten, lead-zinc, gold, etc. Whole rock chemical data, radiometric ages and strontium isotopic data will also be compiled for all possible plutons. Data gaps will be identified.

(2) New data collection. Plutons, which have been identified as lacking data, will be sampled for chemical analysis and/or radiometric dating. Care will be taken during sampling to ensure that samples are fresh and unaltered and that as wide a range of compositions as possible is obtained. If plutons have not been dated, K-Ar ages will be obtained from academic or commercial laboratories. Analysis of the samples for at least SiO_2, CaO, Na_2O, and K_2O will follow and the results plotted as Harker variation diagrams. Depths to the subducting plate at the site of the pluton at the time of its emplacement will be calculated. Data from plutons that are located north of the Jemez lineament will be treated on different Harker variation and depth to Benioff zone diagrams from plutons that lie south of the lineament.

(3) Data synthesis, interpretation and modeling. Because post-Laramide and the Basin and Range extension has shifted the locations of plutons, a palispastic reconstruction to 50 Myr will be made. Calculated depths to the subducting plate or plate segments can then be used to determine the dip of the plate on either side of the Jemez lineament at several times between 75 and 50 Myr. Calculated depths will also be compared between barren and mineralized plutons. Correlations will be sought between plate depth and the presence and type of mineralization and between plate dip and the width of the copper-molybdenum belt. Where strontium data are available, the amount of crustal interaction will be evaluated. A metallogenetic model will be developed that is consistent with observed correlations and the regional geology.

(4) Additional Research. If promising results are obtained on this project, it will be expanded in area to include western Mexico and Nevada and, in time, to include the younger mid-Tertiary mineral deposits.

SPECIAL CAPABILITIES:

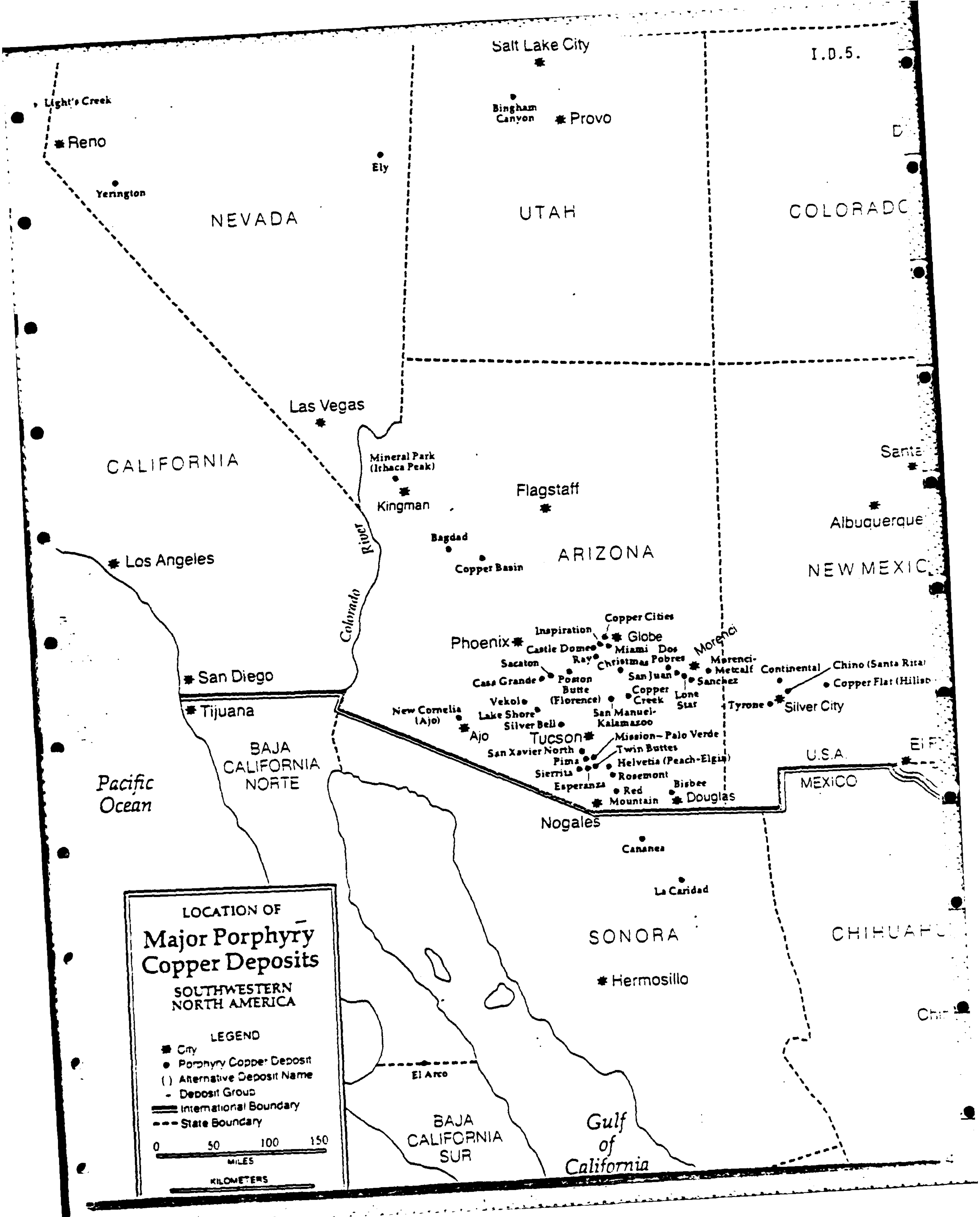
Previous or on-going work conducted by proposal investigators, which relates to the project, includes:

(1) Field studies in the southern Basin and Range Province.

(2) Geochronology and geochemistry of igneous rocks and ore deposits in Arizona and New Mexico.

(3) Tectonic studies of the Basin and Range Province and southeastern Colorado Plateau.

(4) Investigation of the Jemez lineament.


I.D.5.
Salt Lake City
Bingham Canyon
Provo
Light's Creek
Reno
Ely
Yerington
NEVADA
UTAH
COLORADO
Las Vegas
CALIFORNIA
Mineral Park (Ithaca Peak)
Kingman
Flagstaff
Santa
Albuquerque
Bagdad
Copper Basin
ARIZONA
NEW MEXIC
Los Angeles
Colorado River
Copper Cities
Inspiration
Globe
Phoenix
Castle Dome
Miami
Dos Pobres
Morenci
Ray
Christmas
Morenci-Metcalf
Continental
Chino (Santa Rita)
Sacaton
San Juan
Copper Flat (Hillsb
Casa Grande
Poston Butte (Florence)
Sanchez
San Diego
Vekol
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SONORA
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Hermosillo
Chi
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MILES
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A. W. Laughlin/S. L. Bolivar
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TITLE: DEVELOPMENT OF TECHNIQUES FOR THE DETERMINING OF ^{7}Li/^{6}Li RATIOS: APPLICATIONS TO GEOCHEMISTRY

OBJECTIVE:

There are two objectives: development of techniques for accurately, precisely, and inexpensively measuring ^{7}Li/^{6}Li ratios in geologic materials; and examination of natural variations in these ratios.

BACKGROUND:

The relatively large mass difference between ^{7}Li and ^{6}Li suggests that strong fractionation should occur during a number of geologic processes. Despite this, little attention has been paid to natural variations in the ^{7}Li/^{6}Li ratio. Isotopes of other light elements such as hydrogen, carbon, oxygen, and sulfur have been widely used in geochemistry for the solution of genetic problems. Documented fractionations resulting from isotope exchange, kinetic processes, or as the result of physicochemical processes (e.g., evaporation-condensation) have been used in geothermometry and to identify sources of fluids, mineral deposits, alteration products, and vein fillings. For example, oxygen isotopes have proven useful in geothermometry and, when combined with hydrogen isotopic data, in determining the origin of various waters. Sulfur isotopes are commonly used to identify the source of sulfur in sulfide mineral deposits, and carbon isotopes have provided much useful information in organic and inorganic geochemistry and in hydrology.

Natural lithium is composed of two isotopes ^{7}Li = 92.6% and ^{6}Li = 7.4%. Fractionation should thus be detectable in minerals formed before and after resurgent boiling during pegmatite formation, in the weathering products of Li minerals, in Li-rich clay minerals, and perhaps in geothermal fluids. The large mass difference between ^{7}Li and ^{6}Li also offers the possibility for developing a geothermometer that, although of limited applicability, would have a high sensitivity. This thermometer could be used in the evaluation of geothermal prospects.

SCOPE OF WORK:

The initial approach will be to develop and evaluate atomic absorption techniques for determining absolute quantities of ^{7}Li and ^{6}Li in geologic materials. From these absolute quantities, the ^{7}Li/^{6}Li ratio can be determined. Development of the atomic absorption technique will involve the preparation of standards using known quantities of separated ^{7}Li and ^{6}Li isotopes, selection of the best methods of sample dissolution for solid materials, and modifying where necessary standard Li atomic absorption analytical procedures. Results will be compared, if possible, with results from mass spectrometric isotope dilution. After the analytical technique development is completed, a reconnaissance survey will be made of samples from environments most favorable to fractionation.

A. W. Laughlin/S. L. Bolivar

SPECIAL CAPABILITIES:

Los Alamos National Laboratory has staff experienced in applying stable isotope techniques to the solution of geologic problems. A well-equipped modern atomic absorption laboratory is operating and available for this work.

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TITLE: THERMODYNAMIC PROPERTIES OF AQUEOUS SOLUTIONS AT HIGH TEMPERATURES AND PRESSURES

OBJECTIVE:
To achieve significant improvements in prospecting strategy and possibly in solution-mining technology as the result of an increased understanding of ore genesis and dissolution processes.

BACKGROUND:
Knowledge of the thermodynamic properties of electrolytes at high temperatures and pressures is critical to understanding hydrogeochemical element transport and deposition, of relevance to ore genesis, the formation of chemical halos around ore bodies, and solution mining. Very few high-temperature/high-pressure studies of electrolytes have been undertaken.

SCOPE OF WORK:
Measurements would be made to determine the constant-pressure heat capabilities (C_p) of various aqueous solutions in the temperature range 25-350°C and at pressures up to 500 bar, using the technique of flow calorimetry. The information acquired would be used to determine the activity coefficients of the major ions in hydrothermal systems. Chloride ions are important ligands for metal transport, and variation of Cl^- activity due to increased complexing with major cations (Na^+, K^+, Ca^{++}, Mg^{++}) at elevated temperatures is thought to be an important effect. Thus, initial measurements would be made on such systems as $NaCl$-$CaCl_2$-H_2O and $NaCl$-KCl-H_2O. Ion activities derived from these measurements would quantify the variation of Cl^- activity with temperature and solution composition.

SPECIAL CAPABILITIES:
These basic studies would make use of existing expertise, equipment, and facilities, which include chemistry and radiochemistry laboratories, permeability and porosity equipment, instruments for tracer analysis (mass spectrometers, HPLC, spectrophotometers), and the Van de Graaff accelerator for isotope analysis. The studies would complement and represent extensions of ongoing programs within the Laboratory concerned with waste management.

T. D. Kunkle
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TITLE: ASTEROIDS: A SOURCE OF STRATEGIC MATERIALS

OBJECTIVE:

To investigate the feasibility and technical engineering advances that would be required to acquire strategic materials from asteroids.

BACKGROUND:

Potential sources of many strategic minerals exist in the form of asteroids. Using either atomic munitions or electromagnetic mass drivers, suitable objects can be moved into earth orbit. The energy expenditures are comparable to the mining of terrestrial ores. The facilities and techniques necessary for the identification of suitable objects currently exist. Once in earth orbit, the asteroid can be fragmented and processed using zone refining furnaces powered by solar energy. The metallurgical aspects of this process are known in general, and the engineering designs are based upon current space construction technology.

Nickel-iron asteroids are extremely rich sources of certain strategic minerals, being composed principally of iron, nickel, and cobalt in their metallic form, along with recoverable quantities of chromium, platinum, and platinum group elements. Because of their existence in near-earth space, the technology necessary for the recovery of these minerals is largely in hand or could be developed during the remainder of this century. In view of the strategic and commercial value of cobalt and nickel, it would seem pursuant to the national interests to investigate the feasibility of exploiting these extra-terrestrial mineral resources.

SCOPE OF WORK:

Basic research in three areas is suggested: investigation of the metallurgical properties of asteroids, and zone processing of this material; renewed study of atomic detonation propulsion systems; and categorization and evaluation of near-earth asteroids.

(1) Investigation of metallurgical and mineralogical properties of asteroids, and zone processing of this material.

The petrology of asteroids is not well understood. Questions to be answered center on the elemental abundance patterns. Why, for example, is the chromium oxide abundance constant throughout the various classes? What was the origin of these classes? If collisions were important, what were the dynamics of such encounters to produce the observed size distribution seen today? Before processing, it will probably be necessary to rubble the asteroid. What are the characteristics of fragmentation explosions in nickel-iron materials? Can blasting methods be developed that will adequately fracture this material without imparting high velocities to the fragments?

(2) Renewed study of atomic detonation propulsion systems.

When moving the asteroid with atomic munitions, how does the device interact with the surface? What fraction of the device energy is coupled into the impulse and how much residual radioactivity remains on the driving surface? How can the device be utilized at optimum efficiency? Can devices be designed for even higher efficiency?

(3) Categorization and evaluation of near-earth asteroids.

Scientists at TRW, JPL, and several universities have already expressed interest in asteroid discovery programs. What are the capabilities of the USAF/AVCO GEODES satellite tracking network for finding near-earth asteroids? Once a list of near-earth asteroids has been developed, how can remote sensing be used to categorize these objects by their mineral composition?

A final consideration is the military application of this work - the use of near-earth asteroids as weapons to be used in general warfare and as military materiel. A suitable asteroid could be started on its way to a predetermined impact site on Earth with a relatively small energy investment; having reached a distance at which it could be easily detected, it would require considerable atomic arsenal to deflect. As a second strike weapon, this system could operate with little or no chance of being defended against. The mass of an asteroid brought into orbit could provide shielding against both natural and man-made radiation.

SPECIAL CAPABILITIES:

Because the national laboratories are uniquely qualified to pursue long-term high-payoff research, this research into asteroids as a source of strategic materials is appropriate for Los Alamos. University support and industrial participation are unlikely in the early stages of such an undertaking. The Laboratory and the Institute of Geophysics and Planetary Research share some common goals and interests, and cooperative effort could be expected.

Chemistry and metallurgical expertise at Los Alamos is immense, and the multi-disciplined nature of the organization here would lend itself to an investigation of this magnitude. The Laboratory's nuclear device design capability make it uniquely capable to do some of this work. Recent rail gun developments could possibly be applied to propulsion system/mass driver requirements.

The closed environment of the Laboratory ensures protection of information/study sensitive to national security.

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I. STRATEGIC MATERIALS

I.E. ROCK MECHANICS

*I.E.1. Rock Mechanics

* See Appendix B for supporting material.

ROCK MECHANICS

Through various Department of Energy programs, ranging from weapons testing to Hot Dry Rock geothermal and fossil energy, Los Alamos has developed capabilities in experimental and theoretical rock mechanics. Rock mechanics is an essential and pervasive discipline in resource recovery. A recent publication by the National Academy of Sciences (NAS) identifies major research needs in rock mechanics that are relevant to the recovery of resources. The concept paper in this subsection discusses integrating Los Alamos' theoretical, experimental, and field testing capabilities in rock mechanics in order to address some of the important research needs identified by the NAS report. The document Appendix B,I.E.1. contains a general description of Los Alamos' capabilities in rock mechanics.

R. E. Riecker
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TITLE: ROCK MECHANICS

OBJECTIVE:

To use the capabilities of Los Alamos National Laboratory for rock mechanics research and development that could directly benefit the domestic mining of strategic materials.

BACKGROUND:

Costs of underground mining and extraction of ore are inherently high and growing. Mining is becoming even more energy intensive. High costs can be exacerbated by unusual conditions underground including unstable ground, excessive water, and rock bursts. Research is needed in order to provide new methods (1) to break rock more efficiently, and (2) to keep rock from breaking. This research should lead to less costly methods of recovering strategic materials. The research is long-range, high-risk, high-potential payoff research.

A recent report of the US National Committee for Rock Mechanics and published by the National Academy of Sciences identifies major research needs relevant to resource recovery. These are the major needs identified in mining:

- Development of improved methods for determining in situ stresses, especially on a regional scale and at higher pressures and temperatures underground;

- Development of methods for detecting discontinuities remotely and nondestructively (faults, joints, cavities), for determining their three-dimensional orientation, for determining their effects on fluid flow;

- Study of the physics of fracture, especially fracture propagation caused by explosives, mechanical forces, and fluid pressures (the use of explosives is still an art!);

- Development of in situ techniques for measurement of hydraulic properties of discontinuities, especially in rocks of very low porosity and permeability at high pressures and temperatures;

- Development of improved numerical models to handle realistic geoscience problems including three dimensions, large strains, fracture propagation over a wide variety of strain rates, instability, effects of discontinuities, and importantly, the coupling of simultaneous effects of thermomechanical, fluid-flow, and thermochemical processes;

- Improved understanding through laboratory and full-scale field tests of the thermochemical, thermomechanical, and thermophysical properties of rocks;

R. E. Riecker

- Resolution of the divergence that exists between results of laboratory and field tests, of the effects of scale on rock properties.

All of these needs are of immediate relevance to FEMA. Also, resolution of these needs would provide important technological transfer potential, inasmuch as these needs are common to weapons and energy technologies, especially in geothermal energy, waste management, fossil fuel development, and underground nuclear testing.

SCOPE OF WORK:

We propose to tackle several of the important research needs identified by the NAS report on research needs in rock mechanics.

We are especially interested in developing new and better methods for detecting discontinuities remotely and nondestructively inasmuch as existing programs at Los Alamos require this capability.

We propose to study the physics of fracture through expanding current research with a focus on fracture propagation especially under hostile conditions including higher temperature and pressure in a wet environment.

We propose to improve existing numerical models incorporating three-dimensional behavior, large strains, fracture propagation at variable strain rates, instability, effects of discontinuities and coupling.

We propose to study effects of scale on mechanical and hydrological properties of rock masses and to compare these results with carefully controlled field experiments. The advantage of large-scale laboratory experiments over field tests is the control one can maintain in the laboratory. But to be relevant to field conditions, one must demonstrate how the laboratory results apply to field conditions.

We propose to study the thermomechanical properties of rocks to demonstrate how water, high temperatures, and pressures affect mechanical properties.

SPECIAL CAPABILITIES:

The research proposed is an expansion of existing capabilities. Current research supports major programmatic needs. Our proposed work therefore is a logical continuation and expansion of existing talents.

Remote sensing, search for discontinuities, has been highly developed at Los Alamos in support of the hot dry rock geothermal experiment performed at Fenton Hill, New Mexico. Laboratory scientists have extended the state-of-the-art employing novel geophysical techniques in hostile environments.

R. E. Riecker

The physics of fracture, expecially in hot rock, is a major current research thrust at Los Alamos because advances apply to almost all energy and weapons programs. This research is especially important also for materials scientists who work with ceramics and metals as well as rocks.

Los Alamos currently has the strongest computing capability in the world. Numerical code development is a major Laboratory activity.

The Laboratory operates one of the largest hydraulic presses in the world. The 5000-ton load capacity of the press is capable of breaking a meter cube of granite under conditions of elevated temperature and water pressure. This press is currently being modified to study mechanical properties of granite, basalt, and tuff with discontinuities on a variety of scales.

Due to unique personnel, Los Alamos is a leading laboratory in research on thermomechanical properties of rock. Major research is performed on creep of rock at widely varying conditions of temperature, pressure, and strain rate.

Almost everything that the Department of Energy touches turns to rock, and usually to rock underground. Understanding Earth is vital to energy and weapons technologies. Therefore Los Alamos, among DOE contractors, needs and has developed numerous special capabilities in rock mechanics in support of its programs.

I. STRATEGIC MATERIALS

I.F. PLANNING

I.F.1. Supply and Demand Analysis of Strategic Materials

I.F.2. Technology Arsenal for Strategic Materials

PLANNING

This subsection contains two concept papers of a general planning nature for strategic materials. They are particularly aimed at aiding FEMA's mission of managing the stockpile. Activities in this subsection would have to be performed with closer and more frequent interactions with FEMA personnel than activities in other subsections.

The first paper, I.F.1., describes a national supply and demand analysis for strategic materials. Such a national analysis could facilitate planning for the strategic materials stockpile. Activities similar to some of those described in this paper are underway now, in fragmented forms, in the various federal agencies. It is the intent of this concept that such presently fragmented efforts would continue within the respective agencies. However, they would be utilized, linked together with feedback loops, and enhanced in a manner such that the total meaningfulness is greater than the sum of the individual parts.

The second paper, I.F.2., will develop planning concepts in order to assess the feasibility of the development of a national technology stockpile (arsenal) for those technologies that are critical to the production of strategic materials.

The domestic and foreign market place will and should always be a dominant factor in the supply of materials for the US economy and defense needs. To simply decide to import materials is one issue with certain ramifications. To lose the technical ability to acquire domestic raw materials, should we want or need to, is quite another issue with many different ramifications. Present US policy favors importing materials. But, it has not addressed the loss of technical capability.

The concept of a technology arsenal is to continue to develop those technologies required for acquiring and processing raw strategic materials. Such development would occur in a joint government/private-sector environment whereby the developments could lead to the export of the advanced technologies developed. Through such a joint program, the US could be in the position of importing the materials themselves but retaining the required technologies in a manner that could be self-supporting.

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TITLE: SUPPLY AND DEMAND ANALYSIS OF STRATEGIC MATERIALS

OBJECTIVE:

To develop an analysis and assessment of the characteristics of the existing domestic and international strategic materials supply and demand structure.

BACKGROUND:

An accurate assessment of the strategic materials supply and demand structure is needed to evaluate the self-sufficiency of the United States in meeting overall domestic needs and to determine the production capability of the US to meet current and projected stockpile requirements. Then informed decisions can be made regarding tradeoffs (cost, time, and feasibility) of strategic materials options such as resource development, materials substitution, stockpiling, and/or new technology development. A strategic materials tracking and early warning system can also be developed to assist responsible government and industry officials.

Federal and state agencies have already developed considerable information relating to the resources, production, and marketing of materials. The supply/demand analysis program will be designed to build on such work to consolidate and complement existing information. Relevant data bases, results of previous studies, special analyses, and university and industry expertise will be utilized in the course of the project.

SCOPE OF WORK:

1. Natural (In-Place) Resource Data Base Development

Once a preliminary list of strategic materials has been established, a preliminary natural (in-place) resource data base for the materials must be assembled. The data base will consist of geographic, geologic, and physical characteristics of all known or projected deposits of each strategic material, including deposits from which the strategic materials could be produced as byproduct. A standardized classification system must be established to identify the reliability of mineral occurrences and must be equally applicable to each type of mineral occurrence. Such a system will probably be comprised of two main segments--ore reserves and potential resources. Each reserve estimate will consist of the total mineral inventory (or grade/tonnage distribution) contained in a given known deposit and will be initially defined independently of economic factors. The potential resource elements will initially consist of any estimates currently available for areas adjacent to known deposits, along known trends, or in areas where geologic environments favorable for the occurrence of a given mineral are known to exist.

D. W. Morris

As geologic investigations proceed, new potential data wll be added to the data base. Potential estimates will be in the form of probability distribution functions. If development of new technology results in the increased criticality of minerals previously not on the list, the reserves and potential of such minerals will be added to the file.

2. Resource Development, Production, and Supply

Supply will be considered from the following sources:

- Natural (in-place) mineral resources,
- Evaluating stockpiles,
- Inventories (ore, in-process, finished product), and
- Waste recycle products.

The production chain for each source will be defined in terms of available facilities and capacities for transportation, processing, and refining, as well as fabrication of applicable end products. For natural resources, the added factors of load time for mineral development and extraction (open-pit and underground mining or leaching) will also be considered. The costs developed in the "FINANCIAL" section will be assigned to all current and projected operations and ranges of feasible lead times for construction of new facilities or expansion of existing ones will be estimated. Overall requirements for labor, power, materials, and supplies will be determined for each production element.

The overall current supply of each mineral to the various demand centers will be established, and capability for future production will be projected and related to alternative demand situations. In projecting supply, the production center concept will be utilized. A production center may be defined as a processing plant, together with associated extraction operations and minerals resources tributary to the plant as a result of ownership, proximity, or other economic considerations. Where there exists the possibility of establishing new production centers on the basis of potential natural resources, new technology, or other factors, such centers will be projected on the basis of feasible lead times.

Each overall projection of future supply will include annual quantities and types of materials to be produced, the associated capital and operating costs, and requirements for manpower, supplies, and significant secondary materials. The distribution of the applicable end products will be related to the demand centers established in the "DEMAND" segment of the project.

3. Economic/Financial Considerations

Without a firm background of the economics associated with the supply/demand structure of the strategic materials, it will not be possible to make good judgments with regard to tradeoffs in development of new technology or new mineral supplies. Financial aspects are:

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Product Costs:
Capital and operating costs for all elements of the supply chains will be determined. Such costs will include royalties, lease payments, production taxes, and reclamation expenditures, as well as costs for labor, power, equipment, supplies, maintenance, and prorated administration.

Production Economics:
Estimation will be made of feasible prices at which materials can be sold under various assumptions for cost of money, debt/equity ratios, and required rate of return on investment. In addition, potential revenue streams and overall profitability resulting from new investment for critical materials production will be evaluated.

Capital Formation:
The availability of capital for resource development, production facility expansion, and new technology development will be determined in context with current financial conditions and established economics indicators. Factors such as market and investment risk and project community appeal, as well as potential effect of market syndicates and commodity markets will be considered. The benefits of existing tax structure relating to investment tax credits and depreciation and depletion allowance will also be examined.

Federal and International:
The effects of projected inflation, cost escalation, foreign exchange perturbations, and possible national policies on mineral floor prices will be taken into account. Effects of bartering, trade balances, and balance of payments, cartels, and foreign investment in the US will be determined.

4. Constraints to Materials Production

Current and anticipated constraints and limitations to production, movement, and sale of each strategic material will be determined and essentially superimposed onto the supply system. Such constraints include:

Local and Regional:

- Land ownership and policies.
- Specific corporate policies on profitability or expansion; relationship of critical material production to other corporate objectives.
- State and provincial regulations pertaining to transportation, environments (land, air, water), mine and plant safety, reclamation, and waste disposal.
- Availability of manpower (skilled and unskilled), labor union agreements.

AD-A131 827 RESOURCE MANAGEMENT TECHNOLOGY: LOS ALAMOS TECHNICAL CAPABILITIES FOR EMERGENCY MANAGEMENT(U) LOS ALAMOS NATIONAL LAB NM B G KILLIAN ET AL. 18 JUL 83 2/3

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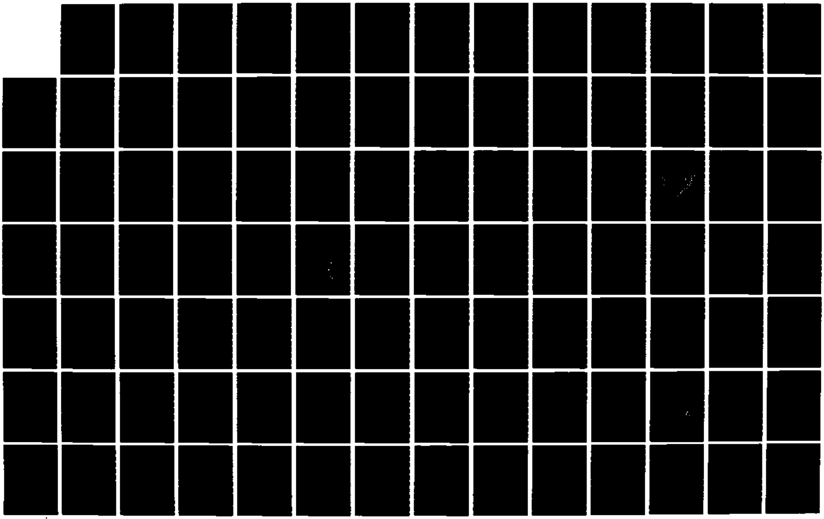

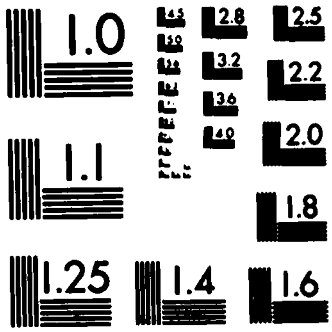

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963 A

- Availability of power and other requirements, supplies, equipment, and materials.
- Adequacy of housing, recreational facilities, towns, other infrastructure.
- Availability of transportation facilities.

National and International:

- National political, legal, institutional, and social and economic constraints to industrial development.
- International trade agreements, protective trade barriers.
- Patents and other proprietary considerations, licensing and know-how agreements.
- Overall structure of the applicable industries and concentrations of particular industry type within material production sectors, cartels.

5. Demand and Overall Market Structure

One of the most important aspects of the study will be the identification of the overall demand structure for the various strategic materials. The current and projected markets to which the materials are sold, the quantities and types of end products delivered, the distribution patterns and timing of deliveries, and the prices involved must be firmly established at a level of detail that will permit accurate assessment of any perturbations on the existing structure. Of equal importance is the source (type and location) of the materials delivered to various demand centers; in this context, certain supply aspects of the study must be developed hand-in-hand with the demand segment. Current and future competitiveness of demand among industrialized and less-developed countries will be evaluated.

The effects of national (US and other nations) stabilization, stockpiling (both government and private), and conservation policies will be considered. There will be major emphasis on added material requirements engendered by new and developing technologies such as advanced equipment for reindustrialization, computer, telecommunications, and military weapons systems.

Special market characteristics such as commodity dumping or hoarding trigger price mechanisms and pricing policies; general elasticities may also play a significant role in affecting demand levels.

United States spectorial demand analysis will provide a basis for determining industry and material security vulnerability that would result from supply disruptions.

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6. Technology Interface

It will be important that the supply/demand framework contain mechanisms for evaluating the significance of the strategic materials plans and studies involving technology applications, geologic investigations, and other research and development efforts. One of the principle values of the framework will be that of assessing supply/demand impacts of forecasted new technology, technology stockpiling, and technology life cycles and degrees of obsolescence. Such factors will have strong bearing on any decision relating to new technology developments.

Without a close interface between the supply/demand assessment studies and other elements of the strategic materials studies, much valuable time and money may be wasted.

SPECIAL CAPABILITIES:

An analysis and assessment division exists at the Los Alamos National Laboratory with the capability of completing any or all of the elements of this proposal. It is experienced in systems modeling and employs experts in diverse fields. These include statistics, economics, computer modeling and programming, environmental planning, engineering, physics, data-base management, sociology, geography, biology, and technical communications.

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TITLE: TECHNOLOGY ARSENAL FOR STRATEGIC MATERIALS

OBJECTIVE:

To investigate whether viable planning can be developed for the productive utilization of technologies that are critical to assuring continued (or developing new) supplies of strategic materials for joint government and industry use.

BACKGROUND:

The United States' stockpile of strategic materials is intended to alleviate national emergencies caused by supply cutoffs of imported materials. Being technologists, we ask the questions, "Could technology also be effectively stockpiled?" and "If so, how?"

The terminology "technology stockpile" presents a semantics problem because technologists and scientists recognize that technology cannot lie dormant in warehouses, in unused laboratories, or on library shelves. A viable technology must be continuously used, improved, and readily mobilized. Thus, the word "arsenal" rather than "stockpile."

The intent of the tasks described below is the development of national planning for those technologies required to assure continued or newly developed supplies and solutions to some of our country's specific strategic material problems. Such planning would include the initial and continual involvement of industry. The "technology transfer" efforts of the Department of Energy have had varying benefits for industry in recent years. However, one criticism of those transfer efforts has been that the transfer was of technologies already underway at the laboratories. It is envisioned that industry would be involved during the early planning stages for a technology arsenal. This would assure that: (1) industry's needs will be factored into required technology developments; (2) the productive exercise of those technologies would be specifically planned for mobilization; and (3) the transfer can be two-way.

The recent loss of many mines and processing facilities in the US has resulted from the declining demand for those commodities and the economic reality that other countries can produce many materials at less cost than the US. The marketplace will always be a dominant factor in US material supply. However, can the US, as an industrial nation, afford to lose technological expertise in acquiring raw materials? This is quite a different question than just asking whether the US can afford to import strategic materials. To import raw materials from another country is one thing; the inability to acquire domestic raw materials should we want or need them is quite another.

The intent of a technology arsenal is the productive exercise and improvement of technologies that would enable us to: (1) retain and improve our knowledge regarding how to acquire raw materials; (2) rapidly mobilize those technologies in time of need; and (3) develop new technologies that could lead to exports in the areas of mining and processing.

In addition to aiding FEMA's missions for the strategic materials stockpile, the technology arsenal could aid FEMA's missions in industrial mobilization. However, we believe joint industrial, academic, and governmental laboratory ventures in a technology arsenal could also lead to new technologies and potential exports aimed at increasing productivity and real gross national product.

The following tasks begin by assuming that a set of strategic materials has been identified as being the most essential for national security and national economic stability. In the following, this set of materials is referred to as the "selected set of essential materials" (SSEM). If such a SSEM is not identified, essential classes of ores could be readily identified.

Because of the recent loss of many mining and processing capabilities in the US, the emphasis of the tasks described below are on the front-end of the material cycle--exploration, mining, milling, and processing. A somewhat similar set of activities could be performed for the material utilization or back-end of the material cycle.

SCOPE OF WORK:

The scope of work identified below would be of an information gathering and planning nature. The end products (C and J below) would consist of an information system and a draft-planning document, which would be subjected to appropriate review. If possible, FEMA might then consider implementation strategies.

The following tasks would be accomplished by participation of a broad cross section of representatives from industry and academia, as well as from relevant government agencies. Such participation could be partially achieved through industrial channels, which may already exist within FEMA for industrial mobilization. A variety of options would be possible for achieving broad participation, and such options would need to be explored before embarking on the following scope of work.

Los Alamos activities could consist of acting as facilitator and/or active participant in areas A, B, D, E, G, H, I, and J and taking a lead role in areas C and F, as described below.

A. Identify those technologies that would be required for the US to attain domestic supply independence for each essential material of the SSEM. The specific technologies required, as well as the level of employment required in these technologies, should be identified for each material. Also, the amount of training and experience required in such fields as mining, engineering, economic geology, process engineering, etc. need to be identified.

B. Identify those key technologies that the US could lose due to reliance on other countries for material included in the SSEM and the technologies that may be underdeveloped due to low levels of operations.

C. Develop an information system for those key technologies, the industrial companies, and personnel working in these key technologies. The information system would include data as described in A, B, D, E, and F.

D. In each key technology, assess what is required to productively and adequately exercise its use and to keep abreast of current national and international developments.

E. Identify current and potential domestic utilization of the key technologies in closely related technical areas.

F. Identify foreign utilization and development of the key technologies.

G. Develop plans for exercising and advancing certain of the key technologies. Such planning might include:

- Idenfification of cadres of technical personnel in the key technical areas.
- Pooling of key technologies between academic, industrial, and the governmental laboratories for joint SSEM projects.
- Enchange programs, foreign and domestic.
- Job sharing.
- Cooperative planning and exercise of required research and development.

H. Develop plans for the rapid development of a to-be-determined set of domestic resources for the SSEM. Begin to execute these plans on a non-emergency basis. Joint industrial, government and academic endeavors might consist of:

- Exploration for resources, using new and advanced techniques such as satellite data and computerized processing of such data, the utilization of new geophysical data, etc.
- Low-level utilization of certain mines or pits that could produce SSEMs as training and/or testing grounds for new technologies such as comminution, earth moving and mining equipment, mine stability, etc.
- Utilization of beneficiation and ore processing plants for full-scale testing of new technologies developed in laboratories.

Besides enabling rapid mobilization of the mining industry, the low-level utilization of certain mines and plants would serve to test (in full scale) new technologies that might eventually be sold to mines and plants in the countries from whom we now import. It is conceivable that some of the technologies developed could also contribute to the economic viability of the national mining industry.

I. Assess the cost-benefits of the various specific plans developed in G and H.

J. Submit a draft-planning document for appropriate reviews by relevant agencies, industry, and academic institutions.

II. NATURAL AND TECHNOLOGICAL DISASTERS

II. NATURAL AND TECHNOLOGICAL DISASTERS

II.1. Assessment of Priorities Regarding Natural and Technological Disasters

Volcanic Disasters - An Overview

*II.2. Volcanic Eruption Prediction and Evaluation of Physical and Health Hazards

II.3. Emergency Seismic and Ground Movement Display System

*II.4. Emergency Management Information System

II.5. Differential Absorption LIDAR Measurements for Weather Modification by Atmospheric Injections

*II.6. Sampling and Characterization of Volcanic Injections into the Atmosphere

II.7. Airborne Lidar System for Aerosol Detection

*II.8. Application of Los Alamos Capabilities in Transport Phenomenology to Address Needs of the Federal Emergency Management Agency (FEMA)

Other Disasters

II.9. Subsidence Monitoring and Prediction

*II.10. Flash Floods - Identification of Frequency and Areas of Potential Occurrence

II.11. In Situ Determination of Dynamic Elastic Moduli in Earth-Fill Dams

*II.12. Planning Legal and Institutional Options for Coping with Drought in the Rocky Mountain States

*II.13. Application of Reactive Flow Numerical Modeling Techniques to Predict the Dynamics and Damage Potential of Large-Scale Fires

*II.14. Radiation Monitoring

* See Appendix B for supporting material.

II. INTRODUCTION

A substantial portion of FEMA's responsibilities regard preparedness for the management of emergencies resulting from natural and technological disasters. Preparedness is: "A condition in which policies, plans, people, resources, and procedures are ready to prevent, mitigate, or mobilize for an emergency." A wide variety of specific activities are required in order to develop a state of preparedness for disasters; and these activities will, of course, differ for each type of disaster under consideration. A partial list of the types of activities that can be performed to prevent, mitigate, and mobilize for an emergency resulting from a disaster consists of:

- Monitoring for the occurrence and predictions of the occurrence and its effects. Monitoring provides early-warning, which can be utilized in mitigation.
- Possible mitigation of the occurrence itself or mitigation of the predicted effects.
- Rapidly acquiring post-occurrence information characterizing the scope and effects of the occurrence.
- Deployment of emergency measures, including evacuation/isolation/quarantine.
- Restoration.

The following Table II.A. lists a variety of the natural and technological disasters that could occur within the United States. Table II.A. also indicates the types of activities, taken from the above partial list, that can be performed. The disaster-activity matrix of Table II.A. contains reference to the concept papers presented in this section.

An essential element of emergency preparedness is the development and dissemination of information, training of emergency managers, and other aspects of response and recovery. Concept papers describing how Los Alamos' capabilities could be utilized in these activities, listed as "Deployment of Emergency Measures" in Table II.A., are contained in the next section, Section III., Communications and Training for FEMA Missions.

As indicated in Table II.A., this section on "Natural and Technological Disasters" deals primarily with the two activities: monitoring and predicting, and characterization of effects. In general, the monitoriong and predicting activities are aimed at providing information to disaster managers that can be used to mitigate the event or its effects before it occurs. The rapid characterization of effects occurring after a disaster event would also be aimed at providing managers with current information that they can utilize to mitigate possible additional damage and loss of life resulting from secondary effects. Thus, the mitigation activities and deployment activities are closely linked; both of these activities are addressed in Section III, Emergency Training.

It is obvious that national resources are not available to address every potential disaster in the same level of detail. A possible framework for making decisions regarding which potential disasters need the most attention and which actions would be the most beneficial to take is described in concept paper II.1. Because such a framework is not currently available to us, the potential natural and technological disasters are presented in this section in the same relatively arbitrary order as they appear in Table II-A.

In the following, a number of concept papers are presented that identify areas where Los Alamos' expertise with relation to volcanoes could be applied to FEMA's mission. This is an area of particular interest to Los Alamos scientists, as witnessed by the number and variety of concept papers in this area. Because of the variety of papers addressing volcanoes, an overview is first presented that describes the time sequence of activities that could occur while monitoring a volcano. The subsequent concept papers, II.2 through II.9, are identified in Volcanic Disasters - An Overview.

The first two natural disasters, volcanoes and meteoroid impact, both present long-term potential effects on changes in climatology, due to aerosols and particulates being entrained and remaining in the stratosphere for extended periods. Therefore, some of the concept papers identified for volcanoes also appear in Table II.A. with meteoroid impact and climatology.

The remaining concept papers in this section address the utilization of Los Alamos' capabilities for other natural disasters: earthquakes (II.3 and II.4), fire storms (II.13), floods (II.10. and II.11), and landslides and mudflows (II.11.). Concept papers regarding technological disasters include dam failure (II.11.) and subsidence (II.9.). Considerable expertise exists at Los Alamos for radiation monitoring.

TABLE II.A.

POSSIBLE ACTIONS TO BE TAKEN FOR EMERGENCY MANAGEMENT OF DISASTERS

Natural Disasters	Monitoring and Predicting	Mitigation	Characterization of Effects	Deployment of Emergency Measures	Restoration
Volcanic Eruption	II.2. thru II.8.	See	II.2. thru II.8.	Section III is aimed	Not
Meteoroid Impact	--	Section III	II.4. thru II.8.	at providing train-	addressed
Climatology Change	II.6. thru II.8.		--	ing and education	in this
Earthquake	II.3., II.4		II.3., II.4.	for this activity.	document.
Firestorm	II.13.		II.13.	All of the natural	
Flood	II.10., II.11.		--	hazards and disas-	
Tsunami	--		--	ters listed here,	
Landslide	II.11.		--	and perhaps others,	
Mudflow	II.11.		--	could be addressed.	
Tornado	--		--	Section III would	
Hurricane	--		--	also be applicable to	
Lightning	--		--	addressing counter-	
Drought	--		II.12.	terrorist activities	
				described in Section IV.	
Technological Disasters					
Radiological Accident	See Sec. IV.4.		See Sec. IV.4.		
Subsidence	II.9.		II.9		
Dam Failure	II.11.		--		

Section IV contains a number of concept papers that could be applied to various technological disasters.

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TITLE: ASSESSMENT OF PRIORITIES REGARDING NATURAL AND TECHNOLOGICAL DISASTERS

OBJECTIVE:

To develop information whereby priorities might be assigned to the various actions that could be taken for managing an emergency induced by natural or technological hazards.

BACKGROUND:

As discussed in the introduction to this section, a large variety of disasters could occur within the United States. A variety of activities could be taken both before such an event and after the event that could enhance the effectiveness of managing the resulting emergency. However, resources are limited, and different disasters have varying degrees of both likelihood of occurring and impact on our society. Therefore, it is not feasible to devote the same levels of effort to each potential disaster. Statistical and earth-science information regarding various disasters can be combined to develop probabilities of occurrence at various locations. This information can be combined with an assessment of possible levels of resulting damage to life, facilities, etc. at the various locations. Such combined information would provide a framework of information for decision makers regarding which preparedness activities should be undertaken.

For instance, means of monitoring exist that can provide early-warning regarding the occurrence of a potential disaster. Such monitoring techniques are commonly used for meteorological disasters--hurricanes and tornadoes. The value of preknowledge for mitigating damage is often tremendous. Similarly, favorable cost benefits might (or might not) occur from monitoring volcanoes, meteoroid impact, changes in climatology, earthquakes, etc.

SCOPE OF WORK:

A framework for decision making must be tailored to the needs of the decision makers. Therefore, the actual scope of work would depend upon the needs of FEMA and its potential specific use of the information to be developed. If such an information system is of use to FEMA, it is envisioned that a joint scoping of these efforts would occur.

SPECIAL CAPABILITIES:

Interdisciplinary capabilities consisting of statisticians, systems analysts, volcanologists, seismologists, and meteorologists brought together from Los Alamos' Analysis and Assessment Division and the Earth and Space Sciences Division could be utilized for these studies.

VOLCANIC DISASTERS - AN OVERVIEW

Scientists at Los Alamos have a long and continued history of involvement with volcano research. Their involvement has spanned the range from basic geologic research to geophysical measurements, volcanic assessment of nuclear waste storage sites, tracking and acquisition of airborne samples, analyses of the samples, and a variety of publications on the topic of volcanic hazards.

In the following, a brief overview is given of the kind of activities that could be of importance in mitigating the possible loss of life and/or property resulting from a volcanic eruption. This overview is not intended to be a comprehensive assessment of what could or should be done. Rather, this overview is intended to: (1) put into some perspective the scope of worthwhile activities that could/should be performed, and (2) indicate where Los Alamos' expertise could be utilized in the "big picture." Activities, as outlined below, could occur during three time periods: pre-eruption, during eruption, and post-eruption.

The pre-eruption phase is essentially the monitoring activity on Table II.A. Monitoring various phenomena (earthquakes, temperatures, released gases, etc.) exhibited by the pre-eruption volcano will provide information regarding where, possibly when, and the type of eruption likely to occur. Such early-warning information can be used to provide guidelines for possible action during and after the eruption. Pre-eruption activities that would be of value include:

- Geologic investigations. A thorough geologic investigation of the history of past eruptions at a prospective site can provide significant information regarding what the future eruptions will be like. Geologic investigations can provide answers to such questions as: Were past eruptions phreatic or magmatic? What was their chemical composition? What was the particulate size, volume of eruption, cooling processes, etc.?

- Periodic background measurements of gaseous particulates in the atmosphere can often provide excellent early warning at a very early stage. Currently, three annual Airstream deployments are conducted. These deployments cover from the equator to 75°N, and 45,000 ft to 63,000 ft.

- A seismic network can be linked to on-line data processing for determining frequency, location, and magnitudes of the earthquakes that are prevalent during pre-eruption. Tri-axial gages can be pre-emplaced and the relevant information analyzed in a preliminary manner by algorithms and plotted immediately. The data then would be stored for future refined analyses.

- A geodetic and tiltmeter network can provide information on inflation and deflation amplitudes and lateral motions of the possible eruption area. Time histories of such motion can be accumulated and displayed.

- Aerial overflights are exceedingly useful for photographic determination of earth motions. Thermal and aeromagnetic surveys are often best performed from aircraft. They allow determination of the thermal and magnetic fields and changes in the fields due to pre-eruption activity.

- Thermal infrared surveys (IR) can be used to further locate the probable eruption centers. Continuously operating instrumentation can be ground installed, and thermal information from satellites and aerial overflights can be utilized and integrated.

- Chemical information on gases released can provide clues to the type of eruption expected. Laser techniques can be used for quick, remotely obtained information, which can be correlated with spectroscopic data from samples obtained at the site or by overflights.

- Historic wind patterns and terrain flow modeling, including trajectory paths, can be developed during the pre-eruption phase to aid in predicting possible areas and extent of damage.

- Information management. Extensive and good data have minimum or no value unless it can be assembled into the type of information required by decision makers to mitigate the possible effects to life and property. Such information can be available in real time and in a form that integrates all of the individual types of data, as described above.

Activities during the eruption can provide further clues regarding what to expect in the near future as well as scientific information that can be utilized to provide better future predictive capabilities during the pre-eruption phase. The types of activities that could occur during the eruption include:

- Continuation of information being gathered pre-eruption: seismic, tilt, thermal, and chemical.

In addition, valuable data specific to the eruption can be obtained from:

- Video cameras. Remotely operated and automatically triggered, high-speed cameras can provide information regarding plume activity, air blast, and mass movements. This information represents the source function for the deposition of particulate.

- Radar and lidar measurements can be made of plume formation and air blast and compared with the video information.

- A microbarograph array can be used for measurement of overpressures.

- Thermogram measurements of plume and magma temperatures can also provide essential information regarding the properties of the source.

- Recoverable projectiles can be shot through the gas/particulate cloud. Such projectiles can be designed to obtain samples of the environment through which they have passed. They can also be designed with special materials and shapes to provide information regarding ablation rates. Such sample and ablation information can be worked backwards to obtain information regarding the density and particulate size of the environment through which the projectile passed.

- High-altitude aircraft sampling. The safe operation of such aircraft could be determined based on real-time information available from a lidar system within the aircraft.

Post-eruption monitoring activities would begin to occur during the time period of greatest public confusion and will therefore need to be readily and smoothly deployable. The types of monitoring and predictive activities that can be of value during the post-eruption phase are described below.

The post-eruption phase is divided into two time frames: near-term and long-term.

Near-Term Post-Eruption

This time frame is described as the period during which the eruption cloud is dense and particulate fallout could be dangerous to life and/or seismic, tilt, and effluents are still occurring. The types of monitoring and predictive activities that can be made near-term post-eruption are:

- Continuation of pre-eruption activities to determine whether subsequent eruptions are likely and/or whether activity is subsiding.

- Lidar and radar monitoring of the cloud(s).

- Aircraft sampling and interrogation of the cloud(s).

- Prediction of dispersion of the particulate cloud. It is the near-term period when high densities of particulate are present and likely to be dangerous. The accuracy of predictions regarding the movement of this particulate is directly related to the quality of data obtained during the eruption and near-term post-eruption.

Long-Term Post-Eruption

This time frame is described as the period during which the particulate cloud(s) are no longer of a dangerous level to life and seismic and other activity has ceased or is nearly quiescent. The types of activities that can be of value in the long-term are:

- Lidar monitoring of the cloud(s) for small particulate.

- Aircraft sampling and interrogation.

- Prediction of dispersion.

- Assessment of climatological effects.

- Equip aircraft with lidar instrumentation that can detect invisible particulate that could damage aircraft engines.

In the following are presented concept papers for activities that were identified in the above general discussion.

See Appendix B,II.2.

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TITLE: VOLCANIC ERUPTION PREDICTION AND EVALUATION OF PHYSICAL AND HEALTH HAZARDS

OBJECTIVES:

- Predict volcanic activity and its hazards.
- Provide actual pre-eruption prediction and early warning.
- Provide continued geological and geophysical observations.
- Provide predictions of atmospheric effects of the eruption.
- Identify possible associated effects on machinery (including but not limited to aircraft), weather, crops, and health.
- Provide scientific analyses of tephra.

BACKGROUND:

A large number of Los Alamos scientists and technicians have had considerable experience with volcanoes. This concept paper emphasizes the geologic aspects of volcanoes that could be directly applied to a FEMA early warning and hazard mitigation effort. This paper should be considered part of a package that includes "Application of Los Alamos' Capabilities in Transport Phenomenology to Address Needs of Federal Emergency Management Agency," by S. Barr, which emphasizes atmospheric transport technology, and "Emergency Seismic and Ground Movement Display System," by C. A. Newton, which emphasizes geophysical measurements.

Geophysical and geological methods would be used to predict volcanic activity and to monitor its resultant physical and health hazards. Areas of potential volcanic activity will be identified based on the composition and extent of older deposits and the history of their previous volcanic activity, recurrence, and periodicity. The possible effects of volcanic activity on health, crops, and machinery will be determined and the potential effects on the atmosphere and weather will be modeled.

SCOPE OF WORK:

1. Pre-eruption:

   - Identify geophysics.
   - Evaluate the area of potential activity, including (1) analysis of composition, volume, and extent of older deposits, and (2) age and past history (recurrence, periodicity, type of past activity).

2. <u>During eruption</u>:

   - Provide an early warning system, including observation and monitoring activities.
   - Analyze composition, extent of ashfalls, pyroclastic flows, possible health and crop effects, effects on local or distant equipment, etc. Field work, sampling, and analysis.
   - Model potential effects on the atmosphere and weather, based on plume sampling and analysis. High- and low-altitude sampling. With data in hand, model absorption and scattering of solar radiation and fallout times.
   - Relay all of the above information to FEMA for distribution to government agencies and local authorities.
   - Release data to health officer, USDA, flood control people, utilities, etc., without delay.

3. <u>Post-eruption</u>:

   - Prepare report, to include recommendations/suggestions for future volcanic events.
   - Recommend observatories and monitoring systems for many potentially dangerous volcanoes in the US.

SPECIAL CAPABILITIES:

Expertise

Geophysical and geological methods applied to volcanic hazard prediction.

- Analysis of previous volcanic hazard; prediction of affected zones.
- Application of geophysical methods used at Nevada Test Site. Downhole geophysical packages.
- Statistical evaluation.
- Prediction, measurement of the eruption cloud and plume and its effects (possible physical and health hazards).
- Physical effects.
- Chemical and health effects, including physical characterization, chemical characterization (surface correlated elements and total bulk analysis), and particle concentrations.

K. H. Wohletz

Equipment

- Probe, scanning electron microscope for physical characterization, thin-section facilities.
- All types of equipment for chemical analysis of soluble materials.
- Computer facilities for modeling.
- Lidar systems for measuring cloud height.
- WB57F for particle sampling, concentration, composition.
- Reactor for neutron activation analysis.

Experience

- First to correctly identify ash particles as older lithic fragments in phreatic activity at Mt. Baker, Washington, 1973, and Soufriere de Guadeloupe, 1976.
- Contacts with veterinary schools, medical schools, and airline manufacturers in the Pacific Northwest concerning the probable physical and chemical hazards of Mount St. Helens ash (mostly within two days after the major eruption of May 18, 1980). We were able to tell them what to look for, for example, potential hazards of fluorine on ash-particle surfaces. They, in turn, analyzed immediately for fluorine and were able to advise population and farmers what to do about respiratory problems, ash on livestock feed, etc. Airline companies wanted information on size and composition of ash to evaluate effect on engines.
- Cooperative work of various Los Alamos technical divisions on eruption plumes (St. Helens, south of St. Vincent, others) are applied to overall effects on weather and, indirectly, crop yields.

Uniqueness

- Diverse and comprehensive abilities to tackle any problems in observation, measurement, and analysis.
- Multidisciplinary team capability, including the earth sciences, atmospheric sciences, chemistry, physics, and health sciences.
- Ability to analyze diverse problems; modelers; computer muscle.

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TITLE: EMERGENCY SEISMIC AND GROUND MOVEMENT DISPLAY SYSTEM

OBJECTIVE:

- Provide instantaneous measurements of seismic energy release and hypocenter locations.

- Provide continuous raw and diurnal corrected tilt measurements.

- Issue eruption warnings based on seismic and tilt observations and any other available pertinent data.

BACKGROUND:

Mount St. Helens activity demonstrated the value of seismic, tilt, and geodetic monitoring for issuing eruption warnings, but that experience also revealed how important real-time reporting can be for avoiding and mitigating volcanic hazards. Real-time seismic and tilt measurements and analysis may also be used to limit losses in situations of reservoir (surficial and underground) -induced earthquakes and areas of subsidence due to mining or fluid removal activities.

SCOPE OF WORK:

- The specific field activities described below could be deployed on short notice at any particular site. In order to assure a state of readiness, equipment and software development and maintenance should be on-going continuously, even if at only a low level.

    * Deploy arrays of seismometers and/or tiltmeters, some telemetered to a computer processing center and some auto-recording on cassette tape.

    * Develop hardware and software for real-time analysis and display of seismicity and/or ground inflation (or deflation).

    * Develop and maintain available equipment and methods for data processing to provide timely warnings of hazardous conditions or activity.

- Provide FEMA and other civil authorities with immediate reports of all possibly significant seismic and tilt events.

C. A. Newton

SPECIAL CAPABILITIES:

Los Alamos seismologists and technicians have operated a telemetered regional seismograph network for nearly 10 years and periodically issue earthquake catalogs for north-central New Mexico. We have also mapped micro-earthquake activity around underground nuclear tests and a hot dry rock geothermal reservoir during fracturing operations. Other members of the staff have been developing computers and seismic data acquisition systems for remote site operation. Still others have deployed tiltmeter arrays to monitor the La Soufriere volcano and for monitoring coal mine subsidence.

See Appendix B,II.4.

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TITLE: EMERGENCY MANAGEMENT INFORMATION SYSTEM

OBJECTIVE:
To provide a real-time management information system to FEMA personnel directing activities aimed at mitigating the effects of natural and technological disasters.

BACKGROUND:
Effective understanding and control of complex emergency situations requires the close cooperation and coordination of diverse units of people and equipment. The accurate and immediate reporting and evaluation of many sources and types of data are essential for effective emergency operations.

A typical potential disaster situation (an earthquake, volcano, etc.) is often considered to be an exciting and rare scientific happening. Scientists with a wide variety of technical interests will appear on the scene with various types of instruments and gadgets for measuring most everything. Public curiosity and the press become involved, and the flow of information often becomes "confused." This situation makes the effective management of the emergency situation difficult to impossible.

Being scientists, we of course believe that scientists should be allowed "managed" access to natural happenings. The question posed here is, "How can the scientific community that arrives at a happening be best utilized by FEMA to meet its needs for reliable, accurate, quickly obtainable, and usable information?"

Our suggestion is that teams of people in the relevant scientific communities be identified. These teams would have expertise and field capabilities for obtaining the types of data (such as those described in the overview outline to this section) that could be used for mitigating the possible effects of the disaster. These teams, who would maintain a readiness posture, could be identified from among the various agencies, universities, etc. They would be able to provide the scope of data required. Access to the happening should, of course, also be available to others making various scientific measurements.

Having teams acquiring data, however, does not really help FEMA unless that data can be rapidly developed into information that can be used by the emergency managers. The objective of an emergency management information system is to provide a system for data acquisition, preliminary reduction of the data, integration of the data with other data already available, and the presentation of the data in the form of information that can be rapidly utilized by the emergency manager.

The system hardware (computers) could be located in, for instance, a "trailer" that could be readily moved to any particular site. The system could be designed to respond to earthquakes, meteor impact, or other disasters, in addition to volcanoes. The individual teams could have individual hardware and/or software within the trailer. However, they would at least have a common interface with the central computer. The central computer would contain relevant data from the individual measurements, combine the various types of data, and present it in a variety of forms. The emergency manager and/or key technical people could interact with the computer to obtain specific combinations of the data desired. Certain algorithms could be developed that would routinely examine the data in order to provide specific warning signals for possible response.

The management information system described above is essentially geared toward scientific information that can be of use to the emergency manager for mitigating possible effects from the disaster. Other types of information will also be of great value to the emergency manager providing it is made readily available in an integrated form during deployment: support services between units, damage incurred, operational facilities that can be utilized, location, and progress of relief and medical teams, etc. This type of information could also be made available and integrated by the same or an associated management information system for immediate use by the manager.

SCOPE OF WORK:

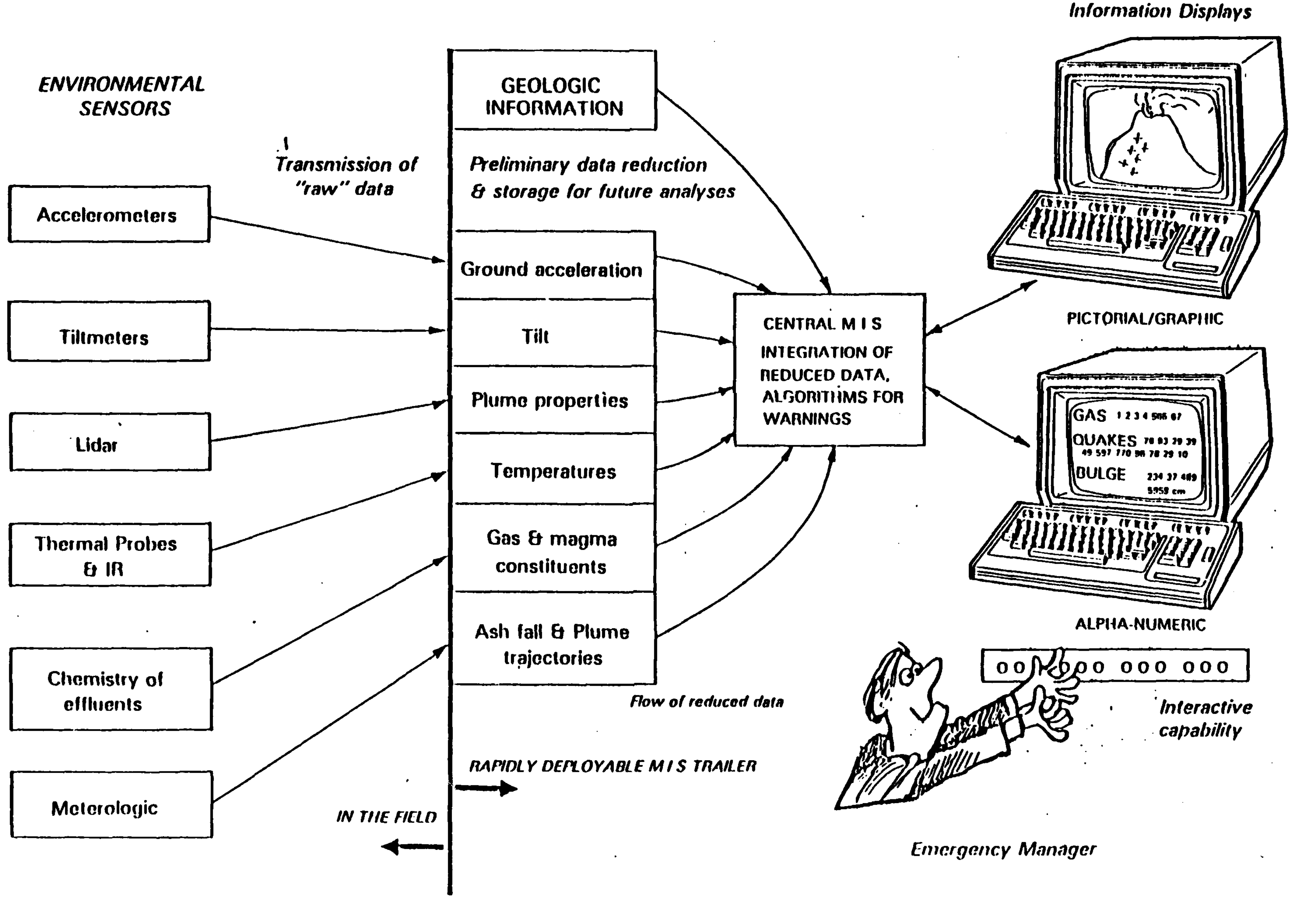
- With FEMA, identify the characteristics of the desired system.
- Prepare a program plan with costs. This will require working with the identified scientific teams.
- Assemble the required hardware and develop the desired software.
- Test in a simulated disaster environment (see Section III).
- Improve the management information system while maintaining a continued state of readiness for deployment.

SPECIAL CAPABILITIES:

- Extensive experience with a wide variety of computer hardware and software developments.
- Field experience, often in adverse environments, with data acquisition systems.
- Los Alamos is currently performing studies for the Air Force aimed at providing a management information system to assess and evaluate damage from a nuclear attack at a deep underground MX missile base. These studies involve a system far more complex than the one described here, but similar technical capabilities would be involved.

CONCEPT FOR AN EMERGENCY

MANAGEMENT INFORMATION SYSTEM (MIS)



R. R. Karl
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TITLE: DIFFERENTIAL ABSORPTION LIDAR MEASUREMENTS FOR WEATHER MODIFICATIONS BY ATMOSPHERIC INJECTIONS

OBJECTIVES:

- Provide continuous remote monitoring of the altitude resolved atmospheric burden of natural and disaster produced aerosols. This gives immediate temperature prediction based upon atmospheric solar attenuation and does so in an inexpensive ground-based method.

- Measure the carbon dioxide and ozone concentrations profiles to observe changes to predict the global consequences of modifications to earth infrared emissions.

- Develop a doppler LIDAR remotely to measure the clear air velocities. This would measure the volcanic blast conditions and the atmospheric motions that transport debris.

BACKGROUND:

The global effects of a large natural disaster can overwhelm the equilibrium of the atmospheric temperature oscillations. The large influx of visible solar radiation can suffer severe scattering and attenuation losses from the injection of large quantities of atmospheric aerosols. These effects would initially be localized and severe; with time they would spread to much greater extent. The long-term vegetation response would cause a secondary carbon dioxide increase of possibly large proportion. The emissions going to high altitude would disturb the equilibrium of the atmospheric ozone and affect the energetic ultra-violet rays reaching the earth.

The operation of such a continuous monitoring program is essential for the pre-event data acquisition and the capabilities for immediate response during an emergency. Currently, no sampling program of the required accuracy exists with inexpensive remote sampling capabilities nor with the altitude coverage required--ground to 50 km and beyond. These altitude resolved measurements immediately show any striated or localized effects of consequence long before they become apparent in total column measurements or suffer the risk of being missed in grab samples.

SCOPE OF WORK:

- Develop systematic operation plans for the Los Alamos LIDAR to continue its soundings up to 40-km altitude.

- Add the laser tuning ability to perform the carbon dioxide and the ozone altitude resolved concentration measurements.

R. R. Karl

- Develop the infrared LIDAR doppler portable instrument for measurement of the wind velocities. This is an essential instrument for the measurement of blast pressure ratio and shock front propagation velocities. This measurement at 15 or more kilometers remote from the predicted event location is necessary to prevent instrument damage.

Continuous Pre-Disaster

This time requires that inexpensive ground-based continuous measurements be performed of the atmosphere to have background measurements in the 0- to 60-km regions and to identify any changes that occur, such as the January 1982 Mystery Volcano. This was first located at 17-km altitude by ground-based measurements that performed altitude resolved aerosol abundance up to 35 km.

Near-Term Predicted Event

Field portable doppler LIDAR to probably event location. Evaluate the necessity of repositioning the portable LIDAR within 500 km of the event location for evaluation of possibly high-density and potentially dangerous particulates.

During Event

Measure the event propagation and blast characteristics.

Near-Term Post-Event

Make measurements of the dispersal relative to aircraft and population exclusion areas.

Long-Term Post-Event

Identify the altitude and extent of the modification to the aerosols, ozone, and carbon dioxide of the atmosphere.

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TITLE: SAMPLING AND CHARACTERIZATION OF VOLCANIC INJECTIONS INTO THE ATMOSPHERE

OBJECTIVE:

To characterize particulates injected into the atmosphere from a volcanic eruption. This characterization is aimed at providing information that will aid in (1) assessing the toxicity of the particulates, (2) developing climate-volcano relationships, and (3) determining the phenomenology associated with the eruption.

BACKGROUND:

Appendix B,II.6. contains general background information from an internal Los Alamos proposal. While Appendix B,II.6. is only partially applicable to this concept paper, it is useful here for describing the link between volcanic particulates and climatology.

The WB-57F high-altitude aircraft was effectively utilized to obtain samples from the Mount St. Helens eruption and is normally used as part of DOE/OHER's Project Airstream. These samples were obtained within 48 hours after the eruption and could have been obtained earlier had minimal logistic preparations been made (see Appendix B,II.6.). This concept paper proposes to utilize the WB-57F for sampling and to develop the logistics required for rapid deployment.

There have been recent examples of damage to aircraft engines from volcanic particulate. The WB-57F could be safely operated during the eruption and during very near-term time periods post-eruption, provided it could rapidly detect what lay ahead. A forward-looking lidar system can be developed for this purpose (see concept paper II.7.). The during-eruption, very near-term sampling operations described in the following SCOPE OF WORK would require such a look-ahead system.

Sounding rockets could be utilized for close-in plume sampling and for ablation measurements (see introductory statements to this subsection). The operational deployment schemes for sounding rockets may present many difficult problems unless they can be air-launched.

SCOPE OF WORK:

- Develop rapid deployment plans for the WB-57F high-altitude aircraft.
- Continue pre-eruption background measurements on the three annual Airstream deployments. The coverage is presently from the equator to 75°N and between 45,000 to 60,000 ft altitude.

P. R. Guthals/A. S. Mason/
E. J. Mroz

- Provide sampling and measurements to consist of the following:

  * Filter samples - mass mixing ratios of sulfate, nitrate, and ammonia.

  * Lundgren impactor - particle morphology and chemical composition.

  * Lucite plate impactor - particle morphology.

  * Quartz crystal microbalance (QCM) cascade impactor-aerosol concentration of size distribution, and samples for morphological study by scanning electron microscopy (SEM).

  * Whole air sampling - stable trace gases (OCS, N_2O, CO, and CO_2).

  * Molecular sieve sampling - CO_2 (possibly SO_2).

  * Brewer spectrometer - total column abundances of O_3 and SO_2.

  * Real-time instruments - ozone, hygrometry, and CO.

- Eruption phase and post-eruption measurements both near-term and long-term could be provided. The long-term data will enable estimation of the mass of the stratospheric injection. Lidar equipment will be required for safe sampling during the eruption and very near-term, post-eruption periods (see concept paper II.5.).

- Investigate the feasibility of launching sounding rockets from aircraft, including determining suitable aircraft types.

SPECIAL CAPABILITIES:

The highly interdisciplinary capabilities in geology, meteorology, instrumentation and remote sensing, and atmospheric sampling and chemistry required for these activities are present at Los Alamos. Laboratory personnel also have had long experience in working as a team, having contributed to Soufriere in 1979, Mount St. Helens in 1980, and El Chichón in 1982.

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TITLE: AIRBORNE LIDAR SYSTEM FOR AEROSOL DETECTION

OBJECTIVE:

To develop lidar systems that could be used on research aircraft and possibly on commercial aircraft.

BACKGROUND:

A variety of cases have recently come to the public's attention that involved the damage of aircraft engines by volcanic particulate. Volcanic particulate, which is invisible to the viewer, can cause damage to aircraft engines. As discussed in concept paper II.6., lidar systems could be utilized to detect invisible volcanic particulate. A small, portable, inexpensive lidar system could be developed for use on aircraft. Such a system could be developed in a readily usable format with a built-in minicomputer for providing meaningful but simple information. Such a system could be tested on the routine WB-57F flights (see concept paper II.6.) and would also be used to determine safe flying conditions for the WB-57F during near-term and eruption phases.

SCOPE OF WORK:

- Develop portable lidar systems for the detection of volcanic particulate.

- Test the system.

SPECIAL CAPABILITIES:

Interdisciplinary capabilities are the same as those identified in concept paper II.6., plus electronic engineers who have extensive experience in field deployment of minicomputer systems. A state-of-the-art laser development capability is available.

See Appendix B,II.8.

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TITLE: APPLICATION OF LOS ALAMOS' CAPABILITIES IN TRANSPORT PHENOMENOLOGY TO ADDRESS NEEDS OF FEDERAL EMERGENCY MANAGEMENT AGENCY (FEMA)

OBJECTIVE:
To apply Los Alamos' capabilities in atmospheric transport and other areas to FEMA's needs.

BACKGROUND:
The Los Alamos National Laboratory has a broad set of capabilities that are being and could be applied to the monitoring and prediction of the transport of gases or particulates in the atmosphere.

The objective stated above is purposefully broad because of the types of possible applications we envision. Generally, our capabilities can be utilized to monitor and predict the concentrations of gases and particulates entrained into the stratosphere or troposphere from such sources as volcanoes, meteors, industrial accidents (including nuclear), fossil fuel plants, and urban emissions.

Natural geophysical phenomena such as volcanoes and meteor impacts may be rare but can have profound effects on the atmosphere, both locally and, eventually, worldwide. Volcanoes occur often enough to be a major source of stratospheric trace materials such as sulphates. Also, in the last decade, we have had the opportunity to study atmospheric effects of volcanic emissions with models and field data. Planning for disastrous geophysical events such as volcanoes in populated areas, super large volcanic eruptions, or a meteor impact can be done on the basis of selected scenarios with the atmospheric consequences being projected from the known conditions of previous volcanoes. Plans are necessary for both the acute local emergency and the long-term climate or crop damage impact. Los Alamos could undertake planning studies in both areas and provide a readiness capability for the execution of contingency plans.

The longer range effects due to stratospheric injection of material can result in climatic changes. Such changes could be predicted based on various assumptions, and plausible scenarios for action could be developed and made ready to implement. For instance, specific data may need to be collected or monitoring performed for the verification of first predictions. If the best predictions continue to indicate, for instance, a one-degree change in temperature for three years at latitudes above 41°N, what does this mean and what should be done? Again, plausible scenarios for possible action could be ready for rapid implementation--limit exports, stockpile, encourage production in the southern hemisphere, conserve grains for people (not cows), etc. The options for food, should it become a critical commodity, could be quite similar to those for strategic materials.

S. Barr

An important tool in the management of an emergency involving airborne materials is the prediction of the hazard corridor. This can be done with the use of meteorological trajectories and the physics governing dispersion, transformation, and deposition. There is a wide range in the usefulness of trajectory forecast methods, depending on the atmospheric physics underlying the method. Techniques may rely on a basis of constant altitude, pressure, or entropy with departures depending on processes of buoyancy, gravitational settling, and turbulent diffusion. It is important to account for the height variation of wind fields in the preparation of forecast trajectories. Different principles govern free atmosphere and boundary layer trajectories and the utilization of forecast meteorological fields introduces new problems over post-analysis using observed and documented fields.

The preparation of high-quality trajectory forecasts (over periods of hours to months) is a dominant problem in emergency management and one for which only a start has been made by the research and development community. Los Alamos is an active participant in this work and is well equipped to pursue the required extensions. Our meteorological physics, computational capabilities, and field experience are extremely valuable resources to address this critical problem.

Thus, the types of activities that could be performed would emphasize capabilities in atmospheric transport but would also include expertise from our systems analysts, radiation transport physicists, and communications experts.

SCOPE OF WORK:

The scope of work to be performed would be dependent on the type of early warning or predictive capabilities and the scope of activities that are of most interest to FEMA. Generally, work would consist of devising an experimental or data gathering component for the desired application. This could range from small stationary samplers to utilizing our field equipment (see SPECIAL CAPABILITIES) to special flying missions. In conjunction with the experimental efforts, our models would be reviewed and special versions adopted for the particular application. We would refine our trajectory forecast capability for the series of particular scenarios (altitude range, duration, underlying surface, contaminant character) and develop practical procedures for employment in emergency situations.

SPECIAL CAPABILITIES:

The uniqueness of Los Alamos' capabilities in atmospheric transport lies in its well-balanced and integrated blend of theory, modeling, and experimental thrusts. We work in teams of theorists and experimentalists who work together to provide models and data that lead to predictions of physical phenomena.

In particular, we maintain a portable field observation system for:

- Meteorological measurements--surface network, vertical soundings, remote sensing systems, and access to conventional meteorological data networks. The system is mounted in a van for mobility.

- Pollutant sensing systems--three mobile Lidar systems with the capability to observe natural and pollutant aerosols, gaseous components (differential absorption), and fluorescent tracer released under known conditions. Also, we operate or have access to tracer release sampling and analysis for a wide variety of natural or released tracer materials applicable on scales of less than 1 km up to 5000 km.

Intimately tied to the observing capability is our simulation and prediction capability based on an extensive series of computer codes that cover simple rapid assessment techniques up through the most comprehensive first principles models. We employ techniques of higher order closure for turbulent flux estimation and stochastic theoretical and practical (Monte Carlo) methods for turbulent diffusion, deposition, and precipitation modeling. The models have been successfully tested in a variety of complex environments, including shorelines, mountains, and valleys with variable forest cover.

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TITLE: SUBSIDENCE MONITORING AND PREDICTION

OBJECTIVE:
The objectives of this program are to:

(1) Clarify the chain of cause-and-effect that leads from construction of underground openings to subsequent damaging subsidence at the surface. Present indications are that there is a regulatory gap at an important point in the chain.

(2) Assess the subsidence problem on a national basis, using a stratified-sampling technique that should provide a national assessment, without the cost of a national investigation, to estimate the future cost of subsidence-mitigation, to the Federal Government in particular. One estimate is that current federal costs are $16 million per annum with a backlog that is a multiple of $30 billion. We would get a more precise estimate on a regional and annual basis.

(3) Identify high-risk situations where subsidence could be damaging to populations, essential highways, or strategic military installations. In particular, examine closely the question of whether oil can be recovered from the Strategic Petroleum Reserve (SPR), at the rates required to meet an emergency, without disastrous effects and loss of the reserve.

(4) Examine various mining methods to determine: (1) which industrial practices will best reduce the subsidence problem, and (2) will provide the means of promoting the use of these practices. Present indications are that methods of mining that reduce subsidence are also the most profitable, and their use is being inhibited by state and local regulations drafted in ignorance of the geomechanical processes involved.

(5) Transfer knowledge of long-term behavior of underground openings from mining industry experience to engineering design of openings intended to have a long lifetime. A particular case is radioactive waste disposal sites, where it appears that long-term processes have not been considered.

BACKGROUND:
The United States depends upon underground openings for a large variety of military, economic, and social purposes. Military examples are underground command centers; communications centers; the SPR; storage of critical defense documents, supplies, and equipment; underground storage of radioactive waste; and key installations used as missile silos, underground weapons storage, and underground nuclear reactor plants. Their importance to the US is that the only military installations secure from Russian missile attack are either located on submarines or in underground cavities.

Economic examples are mines for metals or solid fuels; commercial repositories of key corporate documents, supplies, and equipment; and disposal of noxious waste. An estimate is that US corporations far outstrip the rest of the world combined in their use of underground space, with over 7000 private repositories in use, many under major cities such as Dallas and Houston.

Social examples include the biographical repository operated by the Mormon Church under Salt Lake City; and subways and service tunnels beneath major cities such as New York, Washington, Philadelphia, and San Francisco.

Included with underground openings, because of similar behavior and effect, are zones of low permeability, either natural or man-made, used for extraction of oil, water, gas, and the disposal of noxious waste. Underground cavities and low-permeability zones are invisible from the surface and their size and extent is not easily recognized. The attached figures are an illustration.

In Figure 1, the cavities left by coal mining in the eastern states are shown in black (with a black margin to show the area liable to undermining). Very large proportions of the states of Illinois, Indiana, Ohio, Kentucky, Pennsylvania, West Virginia, Tennessee, and Alabama are undermined.

Figures 2 and 3 show the undermining in more detail. Figure 2 shows that the city of Pittsburgh is almost completely undermined. Figure 3 shows undermining of the city of Des Moines. Note particularly the undermining of US 80 in three places and US 35 in three places within a very small area.

Figure 4 shows the distribution of deep cavities due to metal mining. Most of these are in the western states. Underground openings for nonmetallic minerals are largely in the Midwest and East, and some have been taken over for corporate repositories.

Low-permeability zones for extraction of gas, oil, water, and disposal of waste are largely in the Midwest, with scattered regions throughout the continent. The largest regions are the Ogalalla aquifer of the western high plains from Wyoming to Texas, large areas of Texas and Louisiana, and areas in California.

Causes for Concern

There are causes for concern in (1) the ability of these cavities to serve their purpose, particularly under emergency conditions or over prolonged periods of time, and (2) the serious effects of failure of underground cavities on uses of the surface, particularly damage to buildings, highways, and drainage. Examples are:

(a) In 1978, Los Alamos National Laboratory conducted microseismic monitoring of a trial extraction of oil from the SPR. The results indicated that oil could not be withdrawn at the rapid rate that would be required in an emergency without collapse of the structure and total loss of the oil reserve.

(b) In 1981, Los Alamos produced the first computer-predictive model of the likelihood of collapse of coal mine openings in such situations as under the cities of Pittsburgh and Des Moines. These results show that collapses are occurring at a rate of over 130 events per year in Pittsburgh alone. More importantly, they show that peak extraction rates for coal occurred in 1930, but the peak rate of mine collapse will occur in 1983, some 50 years after mining.

Results (a) and (b) show that underground openings may be adequate for their initial use (storage of oil or extraction of coal), but inadequate for a subsequent use (extraction of oil or support of surface buildings). The original user is often not concerned with the subsequent use, and the liability often falls to the subsequent user. In the case of the SPR, the military user is left with a serious extraction problem. In the case of abandoned coal mines, the Federal Government is left with a serious problem of restoring the ground for ordinary surface uses. Current expenditure on direct restoration is $16 million per annum and is rising steeply. One estimate is that $30 billion is required to restore eastern Pennsylvania alone.

The result (b) shows there is an important time-deterioration effect in the strength of rocks exposed by development of underground cavities that is not taken into account in engineering designs for the initial use. In coal mining, the situation has reached such devastating proportions in some regions that the state of Illinois, for example, has formed an emergency "Subsidence Task Force" that visits sites of surface subsidence over abandoned mines and attempts to minimize the damage to homes and highways. In Wyoming, subsidence has rendered the surface useless for even such low-grade purposes as agricultural production.

Extension of these results to the WIPP site in New Mexico leads to the prediction that the repository will deteriorate some 50 years after sealing, with establishment of leakage paths between the repository and the surface. The Carlsbad region is famous for its numerous "collapse channels" due to subsidence, and this process, which strongly resembles subsidence over coal mines in the East, has not been taken into account in repository design.

Examples of the effect of subsidence into underground cavities are numerous and widespread. Figure 5 shows a house being swallowed in a subsidence pit. The collapse may occur slowly, over several days (as for this house), or rapidly, such as the collapses in Minnesota copper mines that are accompanied by roaring winds and ground tremors. The subsidence can affect one or two buildings at a time, as in Florida or Pittsburgh; larger regions, such as the lake that was recently swallowed in Louisiana; or extremely large regions, such as the thousands of square miles of Texas that have subsided due to withdrawal of ground water and oil. Secondary effects include flooding, such as the lowering of New Orleans due to groundwater removal under the city.

K. L. Burns

The US is fortunate in that catastropic subsidence events have so far occurred in sparsely settled regions of the country, and the damage has affected only a few people and nonsensitive installations. However, the increasing use of underground space for sensitive military and corporate purposes and the increasing extraction of fuels are leading to an increasing probability of a serious emergency involving large numbers of people or sensitive underground installations.

Distribution of Responsibility

At present, responsibility for subsidence-mitigation is distributed amongst a host of agencies, both federal and state.

Control of subsidence during initial use of the cavity is the responsibility of the owner, subject to the property rights of surface owners, and is subject to safe operation requirements of the Mine Safety Health Administration (MSHA). Licenses to operate are granted by state governments in relation to collection of severance taxes and protection of public property such as roads, pipelines, reservoirs, and public buildings.

Control of subsidence at the point of abandonment or end of the initial use is the function of the Office of Surface Mining (OSM) of the Department of Interior, in relation to restoration of the disturbed surface, particularly with regard to drainage. The OSM has no control over the stability or safety of the underground cavity and accepts the cavity in the condition it was left by MSHA.

Because MSHA has no interest in cavities not being actively worked, there is a regulation gap between MSHA and OSM regarding the stability of the opening that is left on termination of initial use. Pennsylvania has moved partway toward filling this gap by requiring that no cavity be left under designated surface structures. In Illinois and Pennsylvania, insurance schemes have been started to compensate surface owners should the cavity collapse at some time in the future. In other states there are no provisions to deal with the problem of unstable cavities left underground. Note that Los Alamos work, supported by foundation engineers worldwide, shows that no underground cavity is stable in the long term.

Control of subsidence during second use of the cavity, or after abandonment of the cavity, falls to the new owners of the surface. Because of their inability to deal with the problem, a program of emergency assistance is provided by some agencies. These include the "Subsidence Task Force" in Illinois and the "Backfilling Program" operated by the OSM at Bruceton, near Pittsburgh. This latter is the currently operating on $16 million per annum levied from current mine operators.

Expenditure on this program has been increasing at a rate of nearly 100% per annum in recent years. The program is barely scratching the surface of the problem and, as noted above, there is a backlog of restitution that is estimated at $30 billion in eastern Pennsylvania alone.

K. L. Burns

One result of the lack of effective control and assistance is the rapid growth of subsidence insurance in Pennsylvania and Illinois and public pressure for similar schemes in states such as West Virginia. Another result is the growth of lucrative practices in Foundation Engineering, which adds between 5% and 10% to the cost of all new construction in the coal-mining states.

The US is faced, in the long term, with either controlling the stability of abandoned underground openings or accepting the cost of not doing so. This cost is effective abandonment of regions such as Wilkes-Barre and Scranton as sites for future human habitation, an increase of 5% to 10% in other regions for costs of new development, and the exposure of persons, property, and vital installations to risk of subsidence for the indefinite future.

SCOPE OF WORK:

It is important to note that subsidence takes two forms: "immediate subsidence," which occurs during construction and first operation of an underground cavity; and "delayed subsidence," which occurs after abandonment (on the average, 50 years after abandonment).

Federal concern should be with delayed subsidence as this is the most widespread and most likely to cause an emergency situation with life, property, and sensitive installations; is currently not effectively regulated; and whenever a serious problem arises, there is an immediate call for Federal assistance. Scientifically, the two problems connect at the state of the cavity on abandonment.

Los Alamos is currently engaged in research designed to determine how different mining methods affect the stability of the cavity at abandonment. This includes work on transient stress-fields generated during one abandonmnet method, the removal of pillars, and geomechanical modeling of the process, using an established computer code, TSAAS. Work is also progressing in the development of a new computer code, BREBEM, designed to determine the state of the cavity after abandonment following longwall mining methods. This program is supported by the Office of Coal Mining, DOE, in collaboration with the mining industry and will indicate which mining methods will reduce the subsidence problem most effectively.

Regional and national studies of the potential impact of subsidence have been made for the Appalachian Regional Commission and Department of Housing and Urban Development. These studies have suffered from lack of precision and the failure to relate surface impact to the geomechanical conditions in the abandoned cavity. Using methods somewhat analagous to those employed in reactor safety design, Los Alamos has produced the first time-prediction of delayed subsidence for the Pittsburgh region. The work could be extended to other regions to give a national assessment and could also be extended to give a precise estimate of the type and time of failure of any particular cavity. This would have particular significance in relation to the long-term stability of particular sites, such as the WIPP site in New Mexico.

Program priorities would therefore be:

(1) Completion of the code BREBEM to deal with the particular problems of laminated, inhomogeneous anelastic materials that occupy most of the central plains region of the US and are host to the majority of sites for extraction of oil, gas, coal, underground water, and the disposal of chemical and radioactive waste. Present codes are better suited to the hardrock environment of western metal mines than to coal fields. The result will contribute to the prevention of disasters during mining and to mining methods that will reduce the likelihood of disasters after abandonment.

(2) Extension of the work on delayed subsidence to determine the relation between the method of working mines and the subsidence effect that occurs many years later. The result will be new scientific knowledge on the long-term stability of openings of this type. A particular application of the knowledge will be in engineering waste disposal sites for long-term stability.

(3) Extension of the work on delayed subsidence to other regions of the US, and extension to natural as well as man-made causes. The result will be a greatly improved assessment of the national impact of subsidence, an estimate of restitution costs to the Federal Government, and an identification of sensitive highways, fixed installations, or population centers that face a particularly high risk.

(4) Extension of the work on stress-transients to other methods of mining than pillar removal. The result will be guidelines on the resistance of man-made structures to strains generated during mining, new methods of assessing the likelihood of disasters in operating mines, and increased scientific knowledge of the effect of shocks on structures such as command centers and missiles mounted underground.

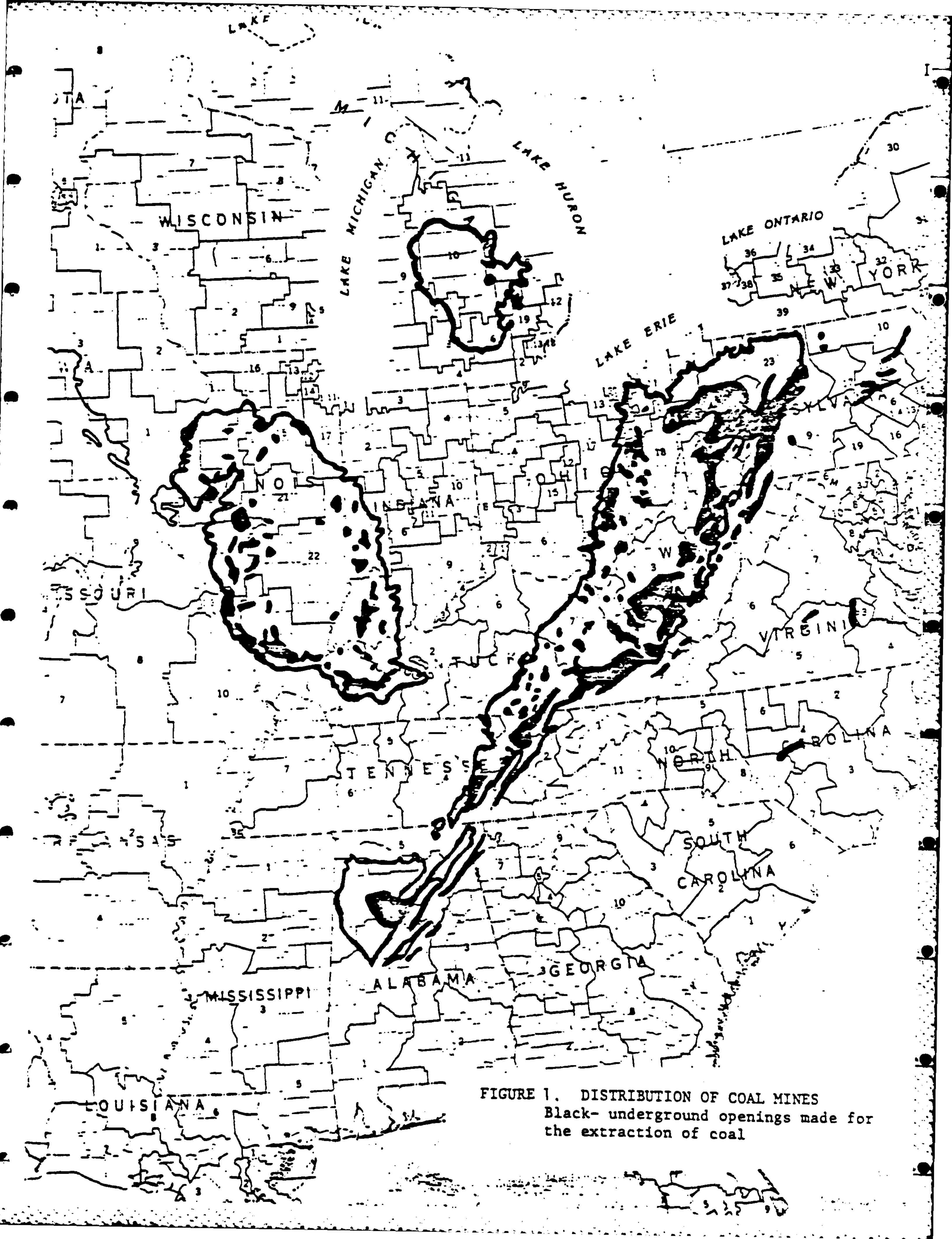


FIGURE 1. DISTRIBUTION OF COAL MINES
Black- underground openings made for the extraction of coal

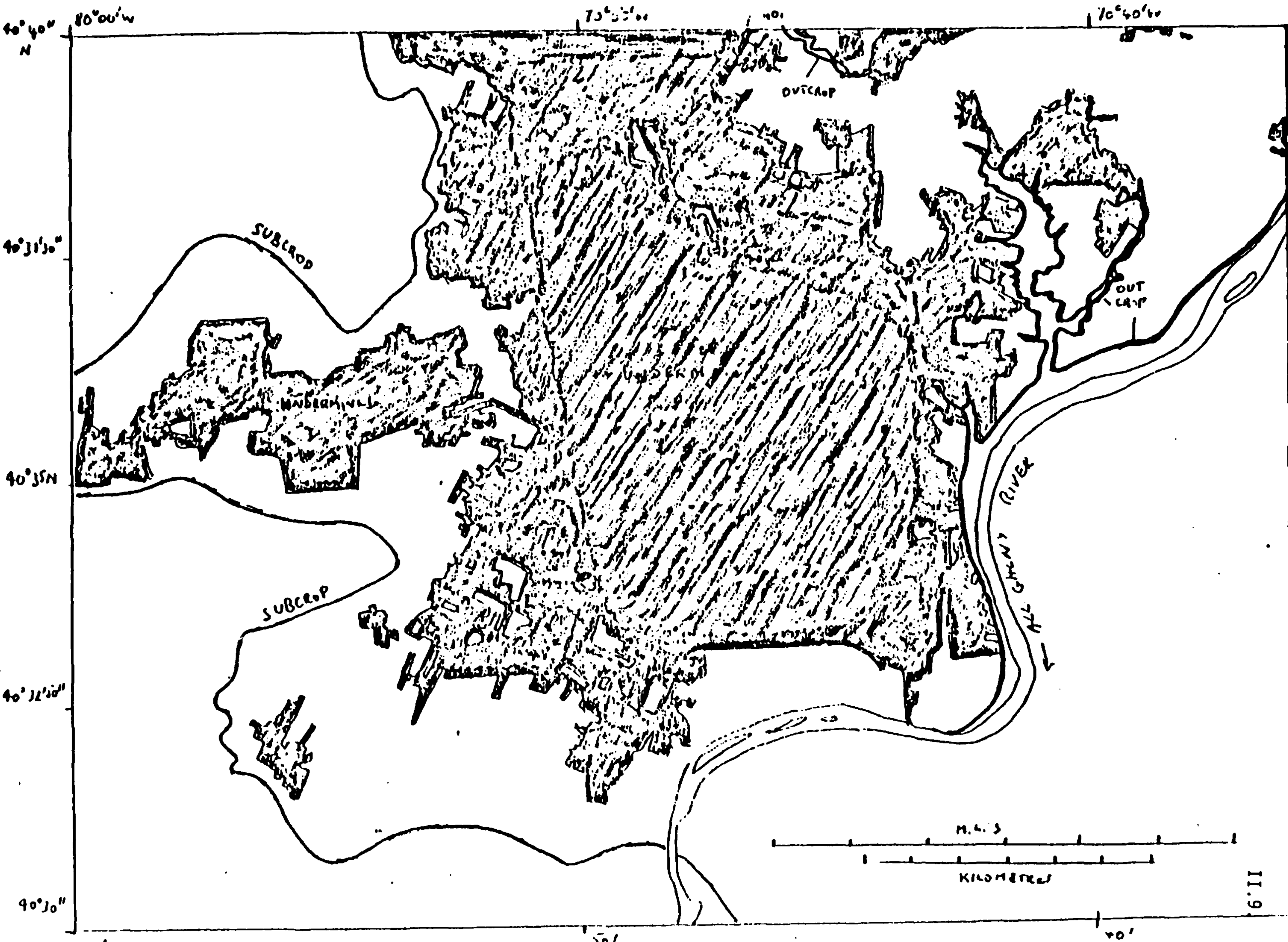


FIGURE 2. MINE OPENINGS UNDER PART OF THE CITY OF PITTSBURGH

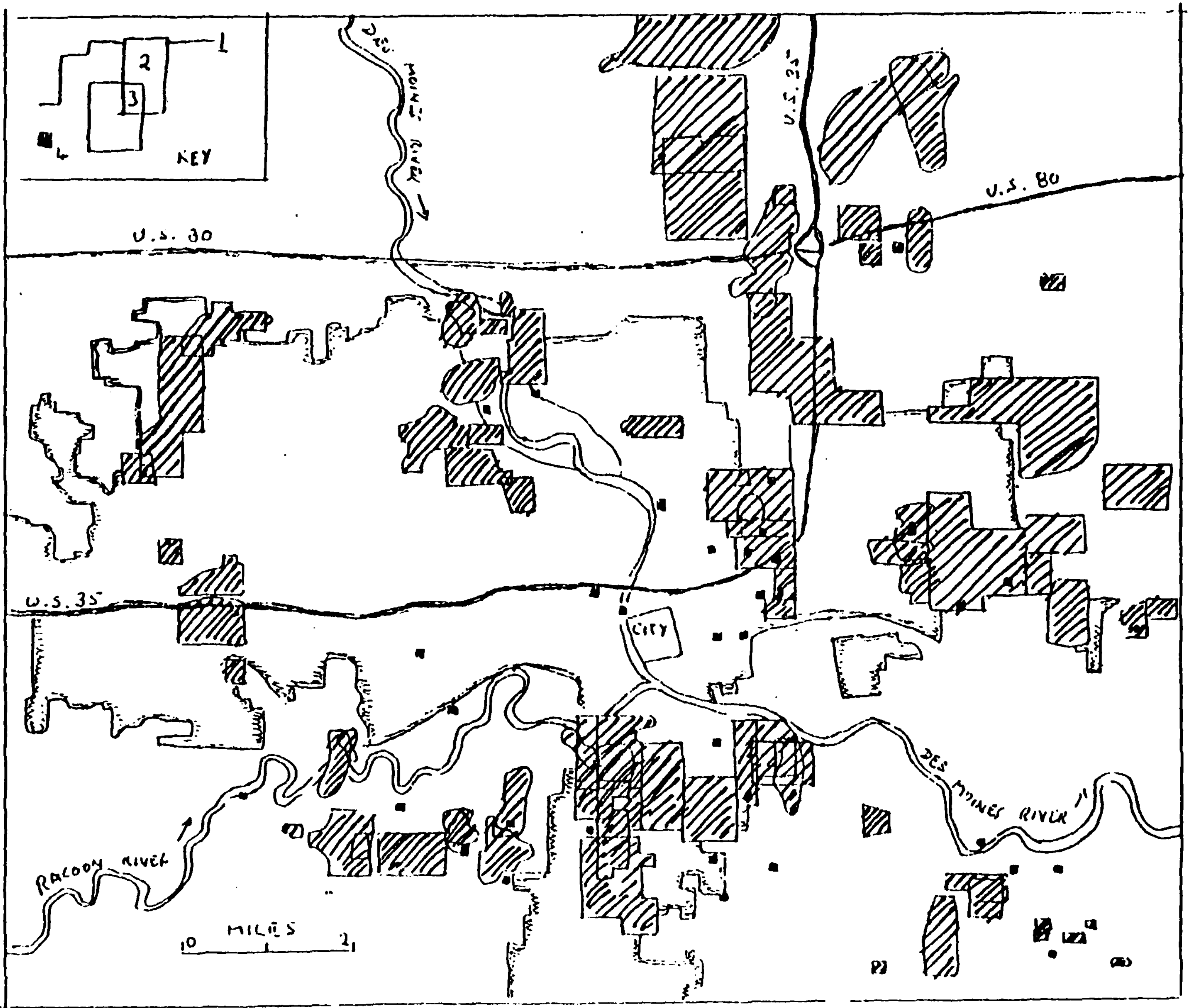


FIGURE 3. EXTENT OF UNDERMINING UNDER THE CITY OF DES MOINES

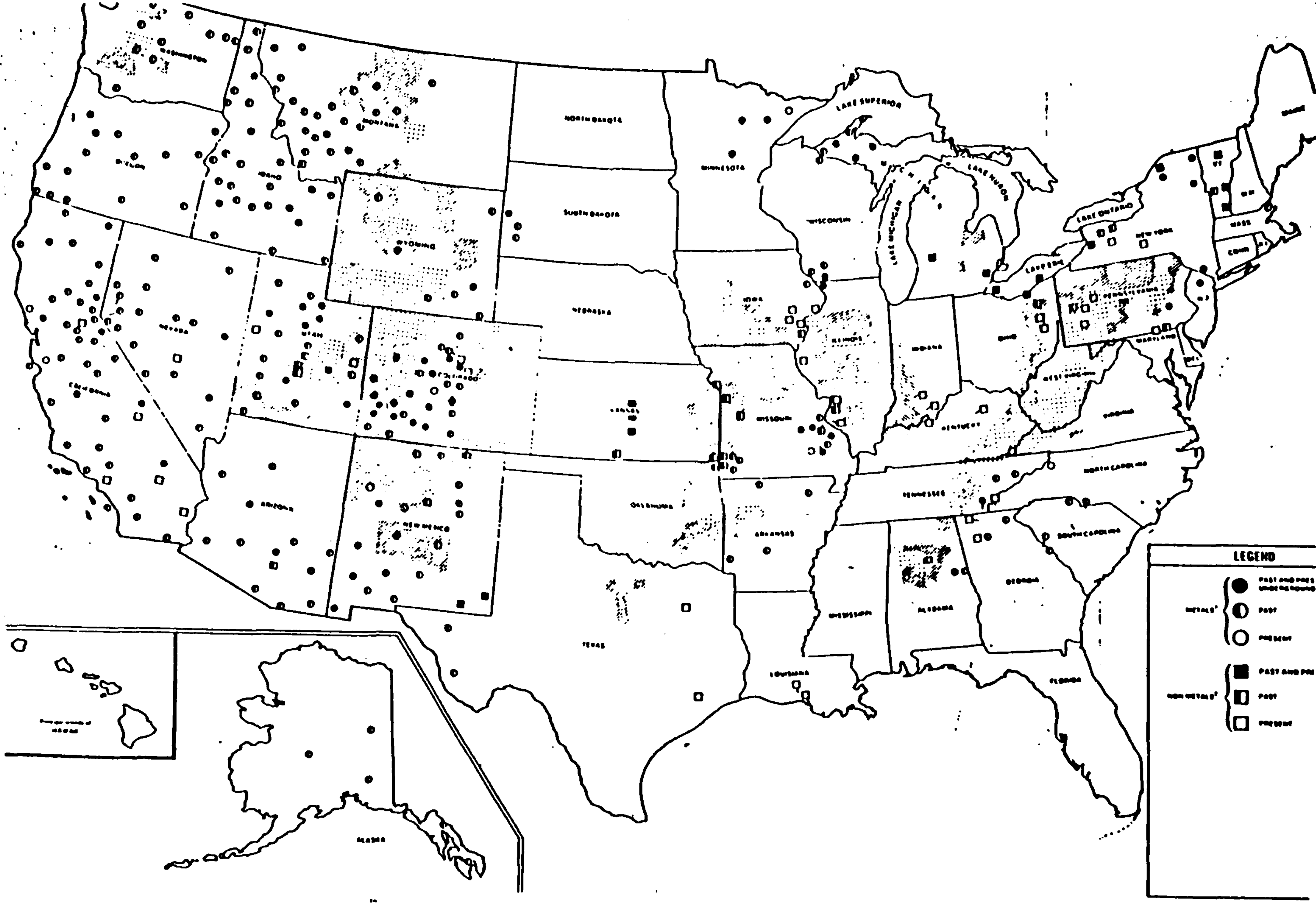
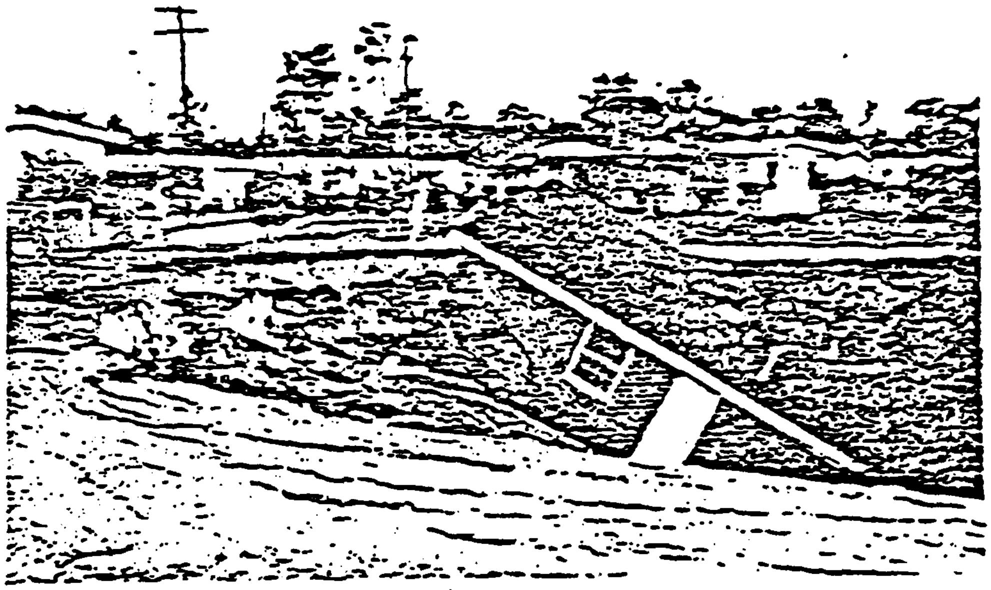


FIGURE 4. DISTRIBUTION OF METAL MINE OPENINGS
underground openings made for
the extraction of metals



Individual houses and even entire cities have suffered major property damage owing to subsidence.

FIGURE 5. Example of property damage due to subsidence. No known man-made structure can resist damage or destruction. Structures affected include houses, schools, factories, public buildings, highways, pipelines, reservoirs, and lakes.

See Appendix B,II.10.

F. M. Byers
(505) 667-8753

TITLE: FLASH FLOODS--IDENTIFICATION OF FREQUENCY AND AREAS OF POTENTIAL OCCURRENCE

OBJECTIVE:

To identify flash-flood frequency and potential in major washes in northern New Mexico.

BACKGROUND:

Northern New Mexico contains extensive defense and governmental facilities. What are the probabilities that these facilities could be endangered and activities disrupted by a flash flood? What could be done to lessen any significant probabilities?

To answer these questions, modern and prehistoric flash-flood deposits will be examined, mapped, and dated to determine the frequency and intensity of flash floods in the area. Drainages vulnerable to flash floods will be mapped and procedures will be recommended to mitigate the effects of future flash floods.

SCOPE OF WORK:

- Review literature on surficial geology, climatological data, records of historic flash floods, and stream-gaging records of the US Geological Survey.
- Identify modern flash-flood deposits (mudflows, etc.) with historic events. Sample, analyze, and look for wood (C_{14} age-dating). Contract out mechanical analyses of sediments.
- Go back in time to study similar prehistoric, Holocene (post-glacial), and possibly older flash-flood deposits, dating them by C^{14} analysis, and calculating frequency of occurrence of major floods. Use soil profiles as mapping tool to identify relative age of deposit.
- Identify source areas: burned-out forest areas exposing loose clay soil, hydrothermally altered areas with high smectite clay, and mudslide-dammed lakes.
- Use Zia excavation equipment as needed; dig wells, trenches, etc.
- Develop maps showing flash-flood deposits colored or patterned according to age.
- Develop maps showing areas ranked according to vulnerability from flash floods.

F. M. Byers

- Produce a report that includes maps and discusses vulnerable flash-flood areas. Include recommendations to mitigate effects of flash floods.

SPECIAL CAPABILITIES:

Geological, mineralogical, and geochemical expertise, including x-ray diffraction and scanning electron microscopy equipment of the Earth and Space Sciences Division. Excavation equipment of the Zia Company, supporting contractor at Los Alamos. (Mechanical analyses could be contracted out to an engineering laboratory, and isotopic C^{14} and K-Ar age dating could be contracted out to commercial laboratories.)

M. J. Aldrich
(505) 667-1495

TITLE: *IN SITU* DETERMINATION OF DYNAMIC ELASTIC MODULI IN EARTH-FILL DAMS

OBJECTIVE:

To predict potential failure of earth-fill dams if they were subjected to seismic events.

BACKGROUND:

To predict whether an earth-fill dam will fail under certain loading conditions, such as those induced by an earthquake, data on static elastic moduli are usually obtained. Samples of dam materials are obtained by drilling and retrieving core samples. These samples are taken to laboratories where static measurements are made to determine the moduli. This process is repeated periodically because the *in situ* materials are subject to change because of hydrologic conditions, settling, etc.

However, the seismic waves generated by an earthquake cause dynamic loading conditions and therefore dynamic moduli values are needed to accurately predict if a seismic event of some given magnitude can cause the failure of an earth dam. Dynamic moduli values are typically larger than static moduli by factors of 5 to 10.

A portable prototype torsional shear (SH)-wave generating device (Fig. 1) has been field-tested. As presently designed, this equipment can provide data for determining *in situ* dynamic elastic moduli for up to three geologic layers to a depth of about 10 m. Recently the importance of taking *in situ* measurements has been stressed through studies that show *in situ* wave velocities can be as much as a factor of 2 higher than those obtained in the laboratory. Emplacement of this device is nondestructive to the site being tested and no

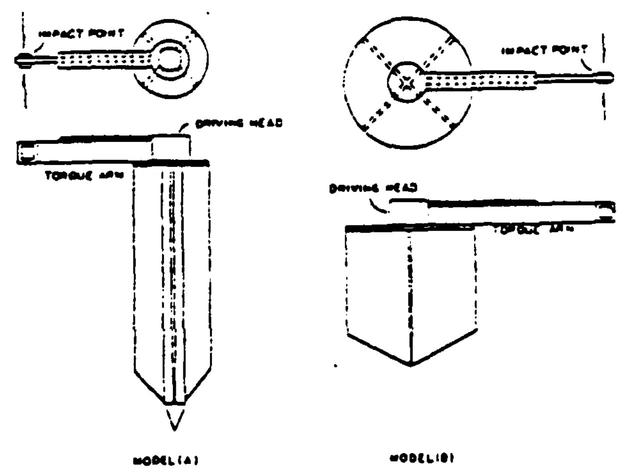


Fig. 1. Two prototype torsional shear-wave generator models. The vertical dimensions are 50 cm for model A and 30 cm for model B. From Won and Clough (1981).

drilling is required. Previous use of this new device has been limited to field tests in different geologic terrains and one earth-fill dam. The test results to date show that the device performs well (Figure 2).

The *in situ* determination of the dynamic elastic moduli device described here has *not* been used for practical applications yet because it was only recently developed. Previously developed SH-wave generators were limited by the P-waves they generated. These P-waves interfered with determining the SH-wave arrivals or were far too heavy and cumbersome to be used for routine engineering applications. This new device is highly portable, simple to use, and does not have the problem of P-waves interfering with detection of SH-waves.

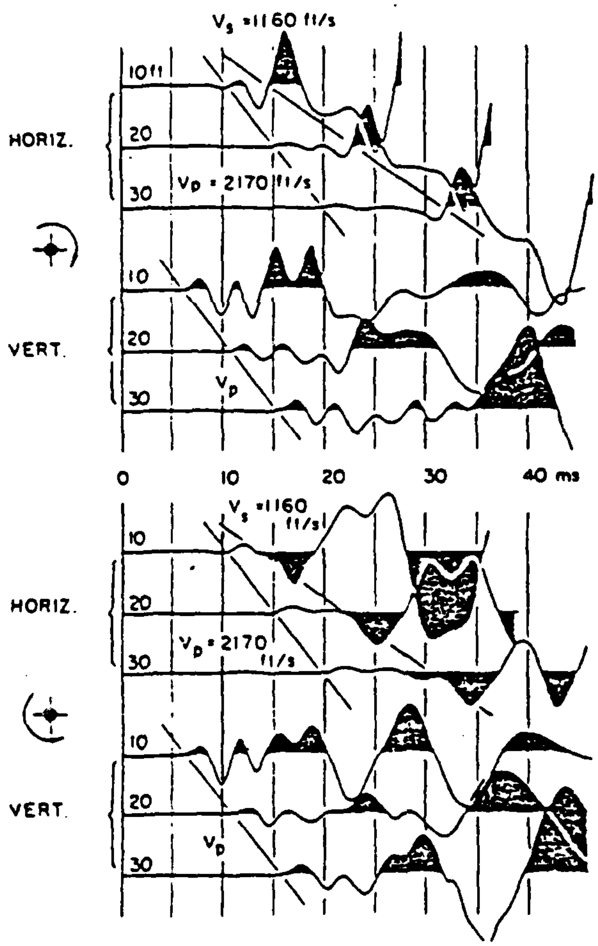


Fig. 2. Seismograms obtained from a torsional shear-wave generator using both horizontal and vertical geophones simultaneously. The upper half is obtained by a clockwise impulse, while the lower half is from a counter-clockwise impulse. The vertical geophone outputs have an amplification 40 times higher than that of the horizontal geophones. From Won and Clough (1981).

M. J. Aldrich

SCOPE OF WORK:

(1) Upgrade the present equipment to include:

- Improved shock source to increase depth to which dynamic moduli can be determined, and
- Improved recording capability to permit determination of three component (triaxial) ground motion.

(2) Utilize equipment to determine dynamic elastic moduli of materials in an earth-fill dam.

(3) Compare dynamic moduli with static (laboratory) and dynamic (explosive) moduli obtained on samples from a drill hole in the dam.

(4) Evaluate use of dynamic moduli data in predicting the possibility of a seismically induced earth-fill dam failure.

(5) Provide drawing(s) showing improved equipment design with specifications. Will include list of manufacturers' names and model numbers of all associated instrumentation.

(6) Report on earth-fill dam case study, to include an evaluation of the equipment and technique.

SPECIAL CAPABILITIES:

- The Los Alamos National Laboratory has developed and performed previous preliminary testing of the portable prototype torsional shear-wave generating device. Geophysicists, geologists, and instrumentation development personnel with extensive and relevant field experience are available.
- Los Alamos has facilities for determining a wide variety of material properties, both statically (rock mechanics laboratory) and dynamically (explosive testing).

See Appendix B,II.12.

Ann Stroup
(505) 667-3941

TITLE: PLANNING LEGAL AND INSTITUTIONAL OPTIONS FOR COPING WITH DROUGHT IN THE ROCKY MOUNTAIN STATES

OBJECTIVE:

To define the problems of water transfer between agriculture, industry and residential users in case of a major drought, and identify options for dealing with these problems.

BACKGROUND:

The single most critical resource in the Rocky Mountain region is water. The acquisition of water resources for new industries, especially heavy water users like mining and energy industries, is a major source of uncertainty. Because a major drought has not been experienced in this region for many decades, legal and institutional arrangements for water reallocation have not been tested and, in many cases, have not been formulated.

A serious drought at this time could conceivably cripple mining and energy industries because they are not, in most cases, senior appropriators.

SCOPE OF WORK:

Extending recent studies of water resources law into such areas as taxation policy, land use planning law, and historic means of dealing with water shortage will allow the definition of emergency allocation options within existing institutions. Industrial options, such as application of new but not currently cost-effective technologies, and changes in agricultural cropping and land use practices must be examined from the standpoint of costs vs water use efficiency. Many small studies of the individual technology costs have been conducted. We suggest incorporating data from these studies, and newly generated data, into an analysis of demand, availability, conservation technologies, and costs for the entire region and its several major watersheds. This would involve the laws of interbasin transfer, interstate export, and international flow agreements.

SPECIAL CAPABILITIES:

Los Alamos National Laboratory has long been involved in studies of water availability and quality in the western United States. During 1982, an analysis of legal uncertainties in the acquisition of water for industry was completed. We have a lengthy list of credits in this area, including the recent book Acquiring Water for Energy: Institutional Aspects with Gary Weatherford of John Muir Institute, published by Water Resources Publications in 1982.

See Appendix B,II.13.

E. J. Chapyak/D. J. Cagliostro
(505) 667-3852/(505) 667-2125

TITLE: APPLICATION OF REACTIVE-FLOW NUMERICAL MODELING TECHNIQUES TO PREDICT THE DYNAMICS AND DAMAGE POTENTIAL OF LARGE-SCALE FIRES

OBJECTIVE:

Our initial objective is to apply existing reactive-flow numerical modeling techniques to predict the evolution of nuclear explosive-induced, large-scale fires as a function of fuel source distribution, atmospheric conditions, terrain conditions, and other identified parameters. Our ultimate objective is to develop a numerical modeling capability to estimate fire damage from nuclear explosions as a function of the above parameters. The feasibility of accomplishing this objective will be addressed during the initial study period.

BACKGROUND:

Continuing developments in strategic-warfare technology toward more compact and accurate delivery systems have slowly but steadily altered United States' strategic deterrence policy from the mutual, assured destruction of civilian population centers toward an emphasis on the threatened destruction of military and industrial facilities. Because of the relative abundance and hardened nature of these targets, the US targeting community is at, or is certainly approaching, the state of being "target rich." Under such circumstances, it is clear that the elimination of any sources of conservatism in our weapon allocation procedures would help to ensure the efficient use of our strategic stockpile. Likewise, the identification and quantification of "new" weapon effects, producing damage in addition to that caused by conventional blast and shock phenomena, could have a significant impact on both future stockpile requirements and current targeting procedures.

One such effect is the fire damage likely to result following a nuclear detonation. Nuclear explosive-induced fires did occur after the Japanese events, and there is every reason to believe that they would be a factor in modern nuclear warfare. However, the variability in the extent of fire damage caused by uncertainties in atmostpheric conditions, combustible-source distribution, multiburst effects, terrain effects, or other unknowns, and a lack of motivating factors in the past have precluded the use of fire damage predictions in present targeting methodologies.

SCOPE OF WORK:

During the past two years, researchers in the Energy (Q) Division at Los Alamos have developed a two-dimensional, time-dependent, hydrocode analysis capability for modeling turbulent, reactive, multiphase, multicomponent, compressible flows with convective and radiative heat transfer. We believe that this modeling effort and the associated code verification program have progressed to the point where realistic estimates of the reactive-flow phenomena of significance to energy conversion systems can be made with some confidence. We further believe that the major phenomana involved in large-scale fire growth and propagation are sufficiently similar to those in fossil-energy combustion processes that our existing capabilities, with minor modifications, can be applied successfully to model such phenomena.

Task 1. Preliminary Analysis of Large-Scale Fires. We would identify the range of input, boundary condition, and submodel parameters of interest to this study. These parameters would include, but not be limited to, fuel source distributions, atmospheric conditions (including swirl), terrain variations, reaction rates of combustible materials and rate of firebrand production, initial fire ignition or radiative field distributions, parameters describing the interaction of combustible fuel with the thermal radiation and the radiation transport process itself.

It appears that only one modification to our existing two-dimensional hydrocodes must be made so that large-scale fires can be modeled realistically. This would involve an extension of the heterogeneous combustion model (currently used to describe burning particles in motion) to describe the burning of stationary fuel sources. (An immobile structure field is an existing feature that can be used to describe these source materials.) Included in this extension would be the generation, transport, and burning/extinction of firebrands.

Task 2. Sensitivity Analysis. Before entering into a full-scale applications program, we believe that a careful examination of numerical constraints and limitations (such as zone size and time-step size stability requirements and the impact of numerical diffusion) are a necessity. Other important issues to be addressed include whether the required mesh size for physical accuracy conflicts with practical considerations of machine storage, run times, and cost. If so, modeling techniques must be developed to account for microscale features in an integral, more approximate fashion. In addition, the definition of appropriate far-field boundary conditions and their permissible distance from the active regions of the problem need to be established.

After numerical constraints have been firmly established, we would investigate the sensitivity of the model prediction to uncertainties in key input or submodel parameters, as listed under Task 1. This type of analysis is often useful in pinpointing areas where research activity should be concentrated.

Task 3. Scaling Studies/Experimental Support and Verification. We would assess the importance of scale size in experimental programs and provide assistance and guidance in the design of such experiments. Both large-scale and separate-effects experimental results will be used, as they become available, to determine model accuracy and to provide estimates of critical phenomenological parameters.

As results become available from related programs, we would update key model parameters or modeling techniques in a timely fashion. This should help ensure that the numerical modeling effort reflects up-to-date information and interacts with the overall program in an efficient manner.

Task 4. Feasibility Assessment of Fire Damage Predictions. We would make a preliminary feasibility assessment for hydrocode-based nuclear fire-damage prediction methodologies. Key problem areas will be identified and recommendations for future research programs will be made.

SPECIAL CAPABILITIES:

The Los Alamos National Laboratory has an established reputation, the facilities, and the technical expertise to develop, verify, and apply large, transient, multidimensional, multiphase codes for modeling a variety of physical processes. Two examples of such codes are the TRAC (Liles, 1978) and SIMMER (Bell, 1977) codes used by the Laboratory's Energy Division to predict the response of nuclear reactors under emergency conditions. The latter code has been modified recently for turbulent, reactive-flow applications. The multifield methods used in these codes were developed by the Laboratory's Theoretical (T) Division, which has a long history of such innovative advances in fluid dynamics computational methods (Amsden and Harlow, 1974; Butler et al., 1980).

A. Related Work

More directly relevent to the proposed project, the Energy Division's Thermal-Hydraulics Group, Q-8, has applied and verified physicochemical models of coal combustion and gasification processes. Our approach has been to contribute to understanding the interactive nature of the turbulence, mixing, chemistry, and multiphase models and to assess their accuracy within the framework of our two-dimensional, time-dependent hydrocode, SIMMER, against analyses and experiments (Chapyak and Blewett, 1981).

Since October 1980, we have added to the SIMMER hydrocode models for turbulence stress, gas-phase specie, and thermal diffusion an improved Eulerian particle description, particle interaction with gas-phase turbulence, gas-phase chemistry, and radiative heat transfer. All these models have been verified, to some extent, against experiments. We are adding particulate devolatilization and heterogeneous reactions. Table I summarizes the scope of this project. Table II lists the main features of the basic SIMMER code structure.

B. Facilities

The Los Alamos Integrated Computer Network contains 11 major computers: four Cray-1s, four CDC 7600s, one CDC 6600, and two CDC Cyber-73s. They are supplemented by distributed processors, which are VAX computers produced by Digital Equipment Corporation. The total computing capacity of the Network exceeds that of any other computing center in the world. This computer network is managed and maintained by the Computing (C) Division, which has 120 staff members and 180 support members. The computing speed of the Cray is the highest, ranging from four times higher than that of the CDC 7600 for most commonly programmed codes to 10 times higher for codes optimally programmed for the Cray (for example, "vectorizing" the code).

TABLE I

MODELING FEATURES FOR TURBULENT REACTIVE FLOWS

Feature	Status
Turbulent Stress Closure	Available
Gas-Phase Specie Diffusion	Available
Gas-Phase Termal Diffusion	Available
Gas-Phase Chemistry	Available
Particle/Turbulence Interactions	Available
Particulate Devolitalization	Underway
Heterogeneous Chemistry	Underway
Radiative Heat Transfer	Available
Swirl Flow	Available

TABLE II

BASIC FEATURES OF THE SIMMER-II CODE

Two-dimensional, Transient, Multiphase, Multicomponent, Eulerian
Semi-Implicit (Material Courant Condition)
Tunable Upwind-Centered Differencing
Flexible Boundary Conditions
Two Momentum Equations for Gas and Liquid Fields
Separate Energy Equations for Liquid Field Components
Interaction with Structure Field
Extensive Verification Program

C. J. Umbarger
(505) 667-6249

TITLE: RADIATION MONITORING

OBJECTIVE:
To provide FEMA with radiation instrumentation and measurement techniques.

BACKGROUND:
Los Alamos' Measurement and Instrumentation Group has had recent correspondence with FEMA/RADEF regarding instrument and measurement areas that could be candidates for joint FEMA-Los Alamos collaboration. The attached letter to Mr. Siebentritt is a copy of that correspondence for your information.

SCOPE OF WORK:
The attached letter to Mr. Siebentritt presents our concepts regarding how Los Alamos might implement this proposal to meet United States needs for radiation monitoring.

SPECIAL CAPABILITIES:
We have developed six separate radiation monitoring and/or analysis systems that are now commercially available. The marketing literature for the six all thank Los Alamos for developing the original concept. Three of the six instruments, including the WC-11 Field Computer, received IR-100 awards. Our technology transfer program is a rather vigorous one.

III. COMMUNICATIONS AND TRAINING FOR FEMA MISSIONS

III. COMMUNICATIONS AND TRAINING FOR FEMA MISSIONS

*III.1. The Simulated Photograph Technique as a Tool for Disaster Response Training and Planning

*III.2. Computer Simulations for Emergency Management Planning and Training

III.3. Analyses and Evaluations of Simulated Accidents in Emergency Preparedness

*III.4. Audio-Visual Tools for the Dissemination of Information Relating to Emergency Preparedness

* See Appendix B for supporting material.

III. INTRODUCTION

An essential element of emergency preparedness is the development and dissemination of information, emergency management training, and communication regarding other aspects of response and recovery, such as mitigation and deployment activities.

The concept papers in this Section address various kinds of communication methods. Concept papers III.1. and III.2. use the superb computer facilities at Los Alamos for two different kinds of simulation for training and planning purposes. Paper III.3. proposes still another kind of simulation--simulated accidents for preparedness evaluation. Paper III.4. presents possible ideas for audio-visual tools, which could be provided by the Laboratory's motion picture and video production group, that FEMA might use for the dissemination of information.

See Appendix B,III.1. III.1.

M. D. Williams
(505) 667-2112

TITLE: THE SIMULATED PHOTOGRAPH TECHNIQUE AS A TOOL FOR DISASTER RESPONSE TRAINING AND PLANNING

OBJECTIVE:

To facilitate civil defense planning and training by visually demonstrating density and dispersal of airborne toxic substances under terrain and meteorological conditions characteristic of each threatened city or community.

BACKGROUND:

A technique exists (see Appendix B) for transferring numerical data on meteorological patterns and pollutant characteristics into a computer-generated photograph of the pollutant plume distribution over given terrain. This technique, developed at Los Alamos National Laboratory, has been used successfully in planning and development activities related to power plant construction and studies of Clean Air Act effects.

SCOPE OF WORK:

Terrain, meteorological data and background photographs will be collected for areas identified as being at risk from airborne toxic substances due to industrial accident, attack by hostile forces, or other causes. Simulated photographs showing "cloud" density and movement patterns under varying meteorological conditions will be developed for use in planning civil defense activities such as evacuation patterns and locations of emergency personnel and equipment. As a training tool, the simulated photographs will allow emergency personnel to visualize the conditions under which they will be working and utilize this data in the field under emergency conditions.

SPECIAL CAPABILITIES:

This technique is unique to the Analysis and Assessment Division at Los Alamos National Laboratory where it was developed and tested.

See Appendix B,III.2.

J. F. McClary
(505) 667-5911

TITLE: COMPUTER SIMULATIONS FOR EMERGENCY MANAGEMENT PLANNING AND TRAINING

OBJECTIVE:

Establish a FEMA Computer Simulation Center to support:

- Computer simulation of complex emergency situations and proposed responses to these situations. Such simulations will allow the rapid evaluation of proposed response scenarios and the training of individuals charged with managing emergency situations.

- Computer simulation of power, communication, transportation, and other critical systems in order to identify and eliminate vulnerabilities before an emergency can occur.

- Development of low-cost (less than $5000, including hardware) computer simulations and systems that can be placed in the field to train local authorities charged with managing emergency situations.

- A FEMA computer network that will allow rapid promulgation of emergency management information and remote access to the more complex simulation programs.

- Other computer support to FEMA as needed.

BACKGROUND:

Anyone who has seen or played the modern video games must recognize the power of a well-designed computer simulation and especially its effectiveness in training. Computer simulations are also a very cost-effective way to evaluate the usefulness of a proposed response to a disturbance to the system being modeled. While computer simulations are not new, the creation of a Computer Simulation Center to service FEMA and the emergency management community is a step that will make the capability available to many more people and eliminate much duplication of effort. The existence of such a center, with its computing capacity and expertise, will provide new tools to more managers concerned with emergency preparedness and allow them to concentrate on problem solving rather than computing.

SCOPE OF WORK:

During the first year, two Los Alamos staff members will generate an implementation plan for the Center. This will define the initial simulations to be developed, the hardware and software necessary to support the Center, and the needed future staffing. The cost for this initial year would be $250,000.

J. F. McClary

SPECIAL CAPABILITIES:

The computing capabilities of the Laboratory range from the most modern CRAY supercomputer to the least expensive microcomputers such as the APPLE or TRS-80. In addition, Los Alamos computing systems provide proper levels of security to protect classified, sensitive, or proprietary information. This wide range of secure computing capability, combined with decades of experience with the most complex computer simulations, make the Laboratory uniquely qualified to develop a FEMA Computer Simulation Center. Additional information describing Los Alamos computing capabilities is included in Appendix B.

R. E. Malenfant
(505) 667-5950

TITLE: ANALYSES AND EVALUATIONS OF SIMULATED ACCIDENTS IN EMERGENCY PREPAREDNESS

OBJECTIVE:

To inject uncertainty into simulated emergencies to analyze and evaluate the effect on response and to recommend ways to improve performance.

BACKGROUND:

All too often, the exercise to practice for response to an emergency is the rote performance of an expected role which assumes that all goes as planned. An example is the classic school fire drill in which students dutifully troop to the nearest exit and evacuate the building in an orderly fashion. How orderly would the procedure be with one small but likely twist, for example, the complete loss of lights? In complying with the requirements of Department of Energy orders and the Laboratory Health and Safety Manual, some organizations at the Los Alamos National Laboratory have included unusual but possible events in emergency drills to prepare participants for the unexpected in a real emergency. Results have been startling, instructive, and, in some instances, humorous. Simple things, such as a door that is not normally locked, a busy telephone, or the near impossibility of giving detailed instructions while outfitted with a respirator have demolished the expected order in an emergency drill. But the participants learned to cope with the unusual rather than rely on rote.

SCOPE OF WORK:

The Los Alamos National Laboratory will fully document the observations on planned but realistic responses to emergency situations that incorporate the unexpected. As a result of the observations, recommendations will be made on how best to prepare people for the unexpected in an emergency. One exercise that is already planned will involve a simulated explosion, release of radioactive gases and liquid, and a fire. Although participants will be notified of the fact and date of the simulated emergency and made aware of the simulation throughout, a significant portion of the training will involve the unexpected. Extreme care will be used to maintain the simulation to keep the exercise safe. At least five exercises will be planned and analyzed for this work.

SPECIAL CAPABILITIES:

This effort will be much more than a paper study in the abstract. Work at the Laboratory involves explosives, all forms of radiation, nuclear reactors, cryogenic fluids, toxic materials, lasers, etc. An additional asset is a large group of technically competent people who are familiar with the scientific methods and are tolerant of tests. Implementation of this proposal would place the analysis and evaluation of the results of emergency planning and preparedness on a scientific basis. The exercises will be real and full of real requirements of the documents cited. Only the detailed analysis and evaluation for FEMA will be added. The Emergency Preparedness Coordinator of the Laboratory will be a participant in the study.

See Appendix B,III.4.

K. L. Mathews
(505) 667-1857

TITLE: AUDIO-VISUAL TOOLS FOR THE DISSEMINATION OF INFORMATION RELATING TO EMERGENCY PREPAREDNESS

OBJECTIVE:

To create a variety of audio-visual (AV) products that would assist FEMA in the dissemination of information and the preparedness training of personnel.

BACKGROUND:

The areas of information dissemination, training, and education usually have more impact with AV aids. Areas where these aids might be of benefit to FEMA include the following:

(1) FEMA to Congress. FEMA needs to be able to communicate with Congress. Congress needs to know how FEMA is fulfilling its mandate. What is being done? How is FEMA accomplishing its missions? Group IS-2 could produce informative productions geared to Congressional audiences.

(2) FEMA to FEMA. Sub-organizations within FEMA need operational guidelines. How does a particular sub-organization fit into the overall picture? How does their function or task mesh with others within the structure? AV productions could aid in the understanding of roles. AV productions could assist in bridging communication gaps that may exist between FEMA management and operational or field organizations. AV material could be used by lower level organizations in briefing management on planning and/or operational status. Films, video tapes, and slide shows could facilitate the orientation and training of employees.

(3) FEMA to Contributing Organizations. Contributing organizations, such as the Los Alamos National Laboratory, need to know FEMA's missions and any special requirements that could be uniquely filled by the particular contributor. FEMA needs to know the special attributes, facilities, expertise, and problem-solving capabilities of the contributor. Informational AV productions could fulfill these needs with concise programs of both an informational and educational nature. It is in this area that IS-2 could be most useful to FEMA and to Los Alamos by providing AV experience and "in-house" facilities for communicating scientific problems, procedures, and solutions to scientists and non-scientists alike.

(4) FEMA to Public. What is FEMA? Why is FEMA? How can the public make use of FEMA's services? What are these services? Saving lives is the bottom line and the most effective way is through education. Informational and educational AV productions could best inform the public via public schools, universities, community organizations, public and cable TV, etc.

K. L. Mathews

SCOPE OF WORK:

Specific areas where AV tools might assist FEMA with its tasks are:

- Nuclear weapons effects. What could be expected from a nuclear blast or nuclear war? How could you protect yourself and your family? How could you plan for this disaster? Is planning effective? Dangers involved in prompt and residual radiation.
- Shelters you can build yourself.
- Radiation. What is it? How can you detect it? How can it affect you? How can you protect yourself?
- Radiation detection and monitoring devices. How to use and interpret.
- Anti-contamination procedures. What to do if you become contaminated with radioactive or other hazardous materials.
- Medical treatment and first-aid procedures for radiation victims.
- Safety procedures involved in: radiation, explosives, high temperatures and pressures, large electric currents, lasers, cryogenics.
- Environmental surveillance; environmental studies.
- Non-destructive analysis and its applications to extortion schemes, nuclear and other.
- Safeguard and accountability methods for special nuclear materials.
- Detection methods for SNM, portable and mobile.
- Los Alamos National Laboratory's NEST (Nuclear Explosive Search Team). What is it? How does it work?
- Biannual NUWAX (Nuclear Weapons Accident Exercise). What is it? How does it work?
- Civil defense. What are today's civil defense procedures? Where can one go for civil defense information. The updating of outdated information.
- Weapons technology. What constitutes a nuclear weapon? How safe are they? What are the possibilities of accident? What are improvised nuclear weapons? Are they a possible threat? How can the public be protected?

- Mathematical modeling of complex phenomena. Cheap way of experimentation. Accident simulation.
- Emergency response training.
- The role of the Los Alamos National Laboratory in the Department of Energy's accident response group.
- An AV production on the capabilities of the Los Alamos computing facility and how this resource could be used in FEMA's mission plan--data storage, computation, analysis, disaster simulation.
- Waste management.
- Pollutant transport.

SPECIAL CAPABILITIES:

The Los Alamos National Laboratory's motion picture and video production group, IS-2, occupies an extraordinary position in serving as an informational conduit between all elements of a large national laboratory's endeavors and audiences of all categories. Years of experience have given IS-2's staff unique insight in interpreting complex scientific subjects into visually interesting and informative AV productions that can be tailored to specific audience levels and client needs. Existing contracts provide expert post-production and animation services for both classified and unclassified subjects.

Since the early years of the Laboratory, IS-2 and its predecessor organizations have produced hundreds of AV productions on a variety of subjects that reflect the multidisciplinary role of the Laboratory. IS-2's productions have won more than 50 awards in film festivals worldwide.

IS-2 has a complete video and motion picture studio with all equipment for professional 16-mm motion picture, 1/2- and 3/4-in. format color video, and multi-media productions. IS-2's modern facilities are available for a complete spectrum of AV productions from simple documentation to full-scale films and video tapes with professional narration, photography, special effects, synchronized sound, music, and animation. IS-2's highly trained personnel offer expert assistance in conceptualizing, research, script writing, and original photography, including high-speed, time-lapse, and special purpose scientific photography.

IV. COUNTERTERRORISM

IV. COUNTERTERRORISM

IV.1. Assessment of the Potential for Major Industrial Perturbation Caused by a Sudden Cutoff of Imported but Domestically Available Mineral Commodities Such as Copper, Cobalt, Tungsten, Gold, and Uranium

IV.2. Vulnerability Assessment of the United States Energy Supply Systems to Acts of Sabotage, Including Potential Impacts of Such Acts on Defense, Industry, and Civil Sectors

IV.3. Emergency Response Radiological Measurements and Assessment Capability

*IV.4. Radiation Monitoring

IV.5. Portable 8-MeV Electron LINAC Development

IV.6. Flowing Afterglow Detector for Gas Chromatography (FAD/GC) Application to High Explosives Detection

IV.7. Application of Artificial Intelligence Techniques to Crisis Management

IV.8. Support to Nuclear Weapon Accident Response

IV.9. Large-Area, Real-Time Radiography

IV.10. Detection of High Explosives by Nuclear Interrogation

IV.11. Quantitative Ultrasensitive Detection of Trace Amounts of Materials

IV.12. High Explosive Vapor Detection Using Immunologic Techniques

IV.13. Protection of Essential Water Supplies from Pathogenic Microorganisms

IV.14. Statistical Study of Terrorism Data

IV.15. Identification of Stressed Individuals

IV.16. Human Performance Enhancement (or Degradation) in a Counterterrorist Context

* See Appendix B for supporting material.

IV. COUNTERTERRORISM (cont.)

IV.17. Rapid Entry Technology Development

IV.18. Protein Mutations

IV.19. Microwave Radiation

IV.20. Contributions to the Controlling of Agricultural Terrorism

IV.21. Computer Model for Anti-Terrorist Training

IV.22. A Detector for Toxic Chemicals

IV.23. Detection of Liquid Combustibles

IV.24. Detection of Nitro Compounds in Explosives

IV. INTRODUCTION

A. Terrorist Incidents and Major Toxic Accidents

The effectiveness of FEMA's role in managing or coordinating the response to a major terrorist incident or toxic accident is directly related to the preparedness and capabilities of the several individual agencies with the more restricted response roles. Where significant deficiencies in preparedness and comprehensive capabilities exist, it may be necessary for FEMA to directly support remedial measures. At the minimum, FEMA should ensure that all major threats and vulnerabilities are both recognized and understood. Moreover, it should ensure that workable interagency response procedures and capability standards are established.

Of significant concern is whether there exists adequate provisions for issuing and coordinating health safety advisories to the public and public health agencies in cases of unfamiliar threat agents or terrorist acts. There is also a basis for concern for the adequacy of inter- and intra-agency communication systems for managing the incident as well as the public relations function. Finally, there is no evidence of a nationwide coordinated technological support effort for increasing countermeasure capabilities.

To a limited extent, the Laboratory's research and development (R&D) capabilities can assist in rectifying some of these shortcomings. As an adjunct to the Laboratory's principal R&D missions in nuclear weapon and energy development, it has operational response roles on behalf of the DOE for nuclear terrorism incidents, nuclear weapon accidents, terrorist "sophisticated" high-explosive device threats, and other nuclear incidents. Response capabilities of the Laboratory and DOE are being enhanced by an ongoing R&D program in support of its operational mission. Recently, the Laboratory expanded the R&D scope to include sponsored projects in those technologies that might counter terrorist activities in nonnuclear as well as nuclear-related incidents.

A list of the types of Laboratory capabilities in these areas is given in Section B. The designated capabilities signify that either we have or had active R&D programs in these areas or we have the interest and appropriate technology base to pursue them in the future. Section C contains a selection of expanded descriptions of candidate projects.

B. Los Alamos Capabilities

1. Threat and Vulnerability Analysis

Threat Agent Identification: Definition of a principal threat agent, its general nature or construction, and principal potential adverse effects. Major threat agents include the following.

- Explosives/firearms/military ordnance.
- Toxic chemicals.
- Biological agents.
- Unconventional (potential) weapons; e.g., lasers and RF devices.

Threat Potential: Identification of factors bearing on the likelihood of use by a terrorist/insurgent, such as:

- Relative availability by purchase, theft, self-fabrication, etc.
- Special capabilities and knowledge necessary to employ the threat agent.
- Terrorist attributes and activities that suggest potential use.

Vulnerability Analysis: Assessment of potential target (e.g., person, facility, or vehicle) susceptibility to attack by a particular threat agent, identification of available countermeasures, and recommended actions to eliminate or mitigate residual vulnerabilities.

2. Defensive Countermeasures R&D

Physical Protection:

- Light-weight (ceramic) armor for personnel, vehicles, and equipment or facilities
- Protective equipment: e.g., face masks, eye protection

Access Control:

- Detectors/monitors for radiation, explosives, toxic chemicals, and biological agents
- Radiography
- Personnel ID
- Human Stress Detection

Surveillance Countermeasures:

- Electro-optic, aural, electronic intercept countermeasures
- Computer security
- Secure communications

Tracking:

- Personnel, equipment, and vehicles
- Taggants
- Vehicular ID

3. Incident Response R&D

Crisis Management:

- Field-response procedures development
- Computer-based resource management, system modeling, artificial intelligence, etc.
- Training

Search/Surveillance:

- Portable radiation, chemical search
- Taggant detection
- Wide-area radiography

Rapid-Entry Technology:

- Explosive breeching (e.g., for hostage/barricade)

Device Diagnostics/Disablement:

- Portable radiography
- HE, chemical/biological identification
- Explosive/electronic device disablement

Effects Predication/Mitigation:

- Explosives, chemicals, biological agents, etc.
- Aerosol dispersal and transport
- Chemical/biological antidotes
- Site restoration

4. Technology Support

Technology Assessment: Assessment and surveys of equipment availability and capabilities, state-of-art assessments, technical project evaluations, etc. for input into project selection decisions guidance.

Technology Transfer: Development or adaptation of existing technologies for specialized or field application (when the commercial assistance is not appropriate or forthcoming).

Modeling/Simulation: Ad hoc simulation or modeling of explosive devices, chemical dispersal devices, etc., for rapid test or assessment purposes.

Training/Orientation: Seminars or other presentations on a variety of technical topics for training or orientation purposes.

Forensic Science:

- Metallurgical, chemical, biological analyses
- Photograph/image analysis or enhancement

P. L. Aamodt
(505) 667-6922

TITLE: ASSESSMENT OF THE POTENTIAL FOR MAJOR INDUSTRIAL PERTURBATION CAUSED BY A SUDDEN CUTOFF OF IMPORTED BUT DOMESTICALLY AVAILABLE MINERAL COMMODITIES SUCH AS COPPER, COBALT, TUNGSTEN, GOLD, AND URANIUM

BACKGROUND:

The United States has come to rely so heavily on cheaper foreign sources of metal and non-metal mineral commodities in recent years that numerous domestic mines and mills have closed. In the event that foreign supplies, either selectively or in total, were suddenly not available, what would be the impact on US industry? How soon would industry be affected, and how fast could domestic supplies be sufficiently increased?

OBJECTIVE:

To assess the effects on the industry and security of the US if the foreign supplies of strategic mineral commodities were interrupted.

SCOPE OF WORK:

This study would consider a number of potential problem areas related to the current condition of the US mineral industry. The first question that needs to be addressed is: what is the present status of the US mineral industry? From a thorough compilation of all active and inactive mines and mills with such information as commodities produced, location, condition, equipment requirements, labor requirements, and estimated time to reactivate or bring to full production, the present state of the industry can be clearly defined. Once the compilation is completed, a number of other questions can be addressed, such as:

- For each selected commodity, how much of the present US requirement is being met by imports?
- How long at present-use rates would currently stockpiled commodities last?
- Other than designated stockpiles, what domestic sources might be available in time of crisis?
- How fast could adequate production of each domestically available commodity be achieved?
- What response plans does FEMA have in the event of a partial or total minerals embargo?
- What additional planning or other government actions are needed to mitigate the impacts of such an embargo?

- What is the likelihood of either selective or total embargoes in view of the present geopolitical situation?

SPECIAL CAPABILITIES:

The study will result in a complete updated status report on domestically available mineral commodities, their current production, and the quantities being imported. It will indicate how fast and to what extent imports could be replaced should the need arise and would assess the potential impacts of mineral embargoes on US industry. In addition, it will provide an indication of how likely such embargoes might be in view of the present or possible future world political situation. Finally, it will point out critical areas where current federal action or contingency planning needs modification, either to reduce US vulnerability or enhance mitigation response.

P. L. Aamodt
(505) 667-6922

TITLE: VULNERABILITY ASSESSMENT OF UNITED STATES ENERGY SUPPLY SYSTEMS TO ACTS OF SABOTAGE, INCLUDING POTENTIAL IMPACTS OF SUCH ACTS ON DEFENSE, INDUSTRY, AND CIVIL SECTORS

OBJECTIVE:

To understand and prepare for both the likely impacts and optimum forms of response to sabotage of major energy production and/or distribution facilities in the United States.

BACKGROUND:

In the event that a terrorist organization or other unfriendly entity decided to sabotage the major energy production and/or distribution facilities in the US, it is imperative that both the likely impacts of, and optimum forms of response to, such acts be understood and prepared for in advance. The US power supply systems are extremely vulnerable to acts of sabotage for several reasons:

(1) they are generally on or near surface;

(2) it is impossible to guard or protect major electrical transmission lines;

(3) regional switching stations, though protected somewhat from vandalism, are vulnerable to planned acts of sabotage;

(4) power stations, whether thermal, hydro, nuclear, geothermal, or arrays of diesel generators, though guarded to a greater or lesser degree depending on the type of facility, are still subject to penetration and disruption by a prepared and committed force;

(5) oil, gas, and coal slurry pipelines and pumping stations are either totally unprotected, or are manned only by a few operators and maintenance staff who at best could only notify others in the event of an attack; and

(6) the design of energy distribution systems is such that relatively few well-placed attacks could disrupt energy supplies over large regions for substantial periods of time.

SCOPE OF WORK:

Some of the more obvious questions that could be addressed by this study are:

- What terrorist groups in the US and the world are capable of effectively carrying out such acts of sabotage?

P. L. Aamodt

- How likely is it that such acts of sabotage might be undertaken?
- What are the key points of vulnerability in US energy systems as they exist today?
- How can existing and planned systems be hardened, and to what extent, for increased protection against such acts?
- For various attack scenarios, what would be the impacts on the defense, industry, and private sectors?
- For various response scenarios, what actions would be paramount to most rapidly mitigate the impacts of such acts?
- As the federal agency responsible for both prior-preparedness and response coordination, what can FEMA do to enhance its present ability to respond to such acts of sabotage?
- As identified by this study, what related issues need additional examination to more fully comprehend their possible impacts and/or the optimum response actions to mitigate them?

SPECIAL CAPABILITIES:

This study would result in a report to FEMA that would address each issue identified above from combined engineering, technological, modeling, and strategic points of view, as appropriate, in a manner that will provide both current understanding of the potential threat and guidance to protect against, or respond to, acts of intentional sabotage to US energy networks.

W. R. Hansen
(505) 667-5021

TITLE: EMERGENCY RESPONSE RADIOLOGICAL MEASUREMENTS AND ASSESSMENT CAPABILITY

OBJECTIVE:

Provide a mobile, rapidly deployable emergency response capability for early assessment of the long-term radiological hazards following an incident involving dispersal of radioactive materials from weapons transport, weapons manufacture, acts of terrorism, nuclear facilities, or radioactive materials transport.

BACKGROUND:

The Department of Energy (DOE) has sponsored development of mobile equipment for detection of radioactive materials in special forms or dispersed from some type of incident. Los Alamos National Laboratory provides mobile radiation detection instrumentation and expertise for the Nuclear Emergency Search Teams (NEST) and the Radiological Assistance Teams (RAT) of DOE. Both capabilities are strongly oriented toward detection and assessment of the immediate radiological significance of dispersal of hazardous materials involved with weapons material or nuclear facilities.

In the event of dispersal of radioactive materials, the radiological hazards assessment has two phases. The first phase involves assessment of immediate hazards to a population. Current capability allows such an assessment. The second phase involves radiological assessment of the long-term (weeks to years) radiological hazards and is used to guide any remedial actions needed. The same capabilities for immediate assessment with some modification and preplanning, can be utilized in the second phase of an incident involving radioactive materials.

SCOPE OF WORK:

The assessment of the long-term (weeks to years) radiological significance of dispersal of hazardous materials from an incident requires development of techniques to utilize available equipment and expertise. To preplan the best use of equipment and expertise would entail:

- Survey and report on the equipment and expertise available from federal, state, and local agencies or facilities.
- Assessment report on what types of radiological incidents the equipment and personnel can respond to.
- Develop and report guidance for use of existing equipment and expertise for radiological assessment of long-term hazards from an incident.

- Supplement the existing equipment at Los Alamos National Laboratory to provide an integrated monitoring system for radioactive materials that allows optimum use of expertise in response to radiological emergencies.

SPECIAL CAPABILITIES:

- Nuclear Emergency Search Team personnel and equipment.
- Radiological Assistance Team personnel and equipment including rugged terrain vehicles equipped with radiation detection instruments and portable air sampling.
- Meteorological instruments and personnel for support.

See Appendix B,IV.4.

C. J. Umbarger
(505) 667-6249

TITLE: RADIATION MONITORING

OBJECTIVE:

To provide FEMA with radiation instrumentation and measurement techniques.

BACKGROUND:

Los Alamos' Measurement and Instrumentation Group has had recent correspondence with FEMA/RADEF regarding instrument and measurement areas that could be candidates for joint FEMA-Los Alamos collaboration. The attached letter to Mr. Siebentritt is a copy of that correspondence for your information.

SCOPE OF WORK:

The attached letter to Mr. Siebentritt presents our concepts regarding how Los Alamos might implement this proposal to meet United States needs for radiation monitoring.

SPECIAL CAPABILITIES:

We have developed six separate radiation monitoring and/or analysis systems that are now commercially available. The marketing literature for the six all thank Los Alamos for developing the original concept. Three of the six instruments, including the WC-11 Field Computer, received IR-100 awards. Our technology transfer program is a rather vigorous one.

R. Morgado/D. W. Reid
(505) 667-1814/(505) 667-7463

TITLE: PORTABLE 8MeV ELECTRON LINAC DEVELOPMENT

OBJECTIVE:

To significantly expand fieldable nuclear diagnostic capabilities by development of a portable, self-contained electron linear accelerator (LINAC).

BACKGROUND:

The planned LINAC modular design will provide the portability and maneuverability required for field use in adverse and confined environments. Taking an inexpensive LINAC to the object(s) being examined will, in many cases, save expensive disassembly costs incurred in taking the object(s) to existing stationary LINAC facilities. (See attached figure.)

This portable accelerator would utilize the LINAC's unique capabilities in the areas of enhanced radiography, photofission, and pulsed neutron and gamma interrogation techniques. These techniques can be utilized to:

- Identify the presence of various objects and materials, for instance, x-ray and/or neutron radiographs;
- Examine, without disassembly, critical components in reactors;
- Remotely assess isotopic contents of "black boxes"--for emergency, terrorist, and nuclear waste disposal applications;
- Test machined parts and/or adhesive bonding for quality assurance inexpensively and nondestructively, thereby conserving strategic materials;
- Examine, without disassembly, various machinery including airplanes, missiles, etc.

Design of the portable LINAC has already been completed on internal Los Alamos program development funding. Preliminary testing at Pantex and EG&G/Santa Barbara has been encouraging.

SCOPE OF WORK:

Participate in the operational development phase of the LINAC, as follows:

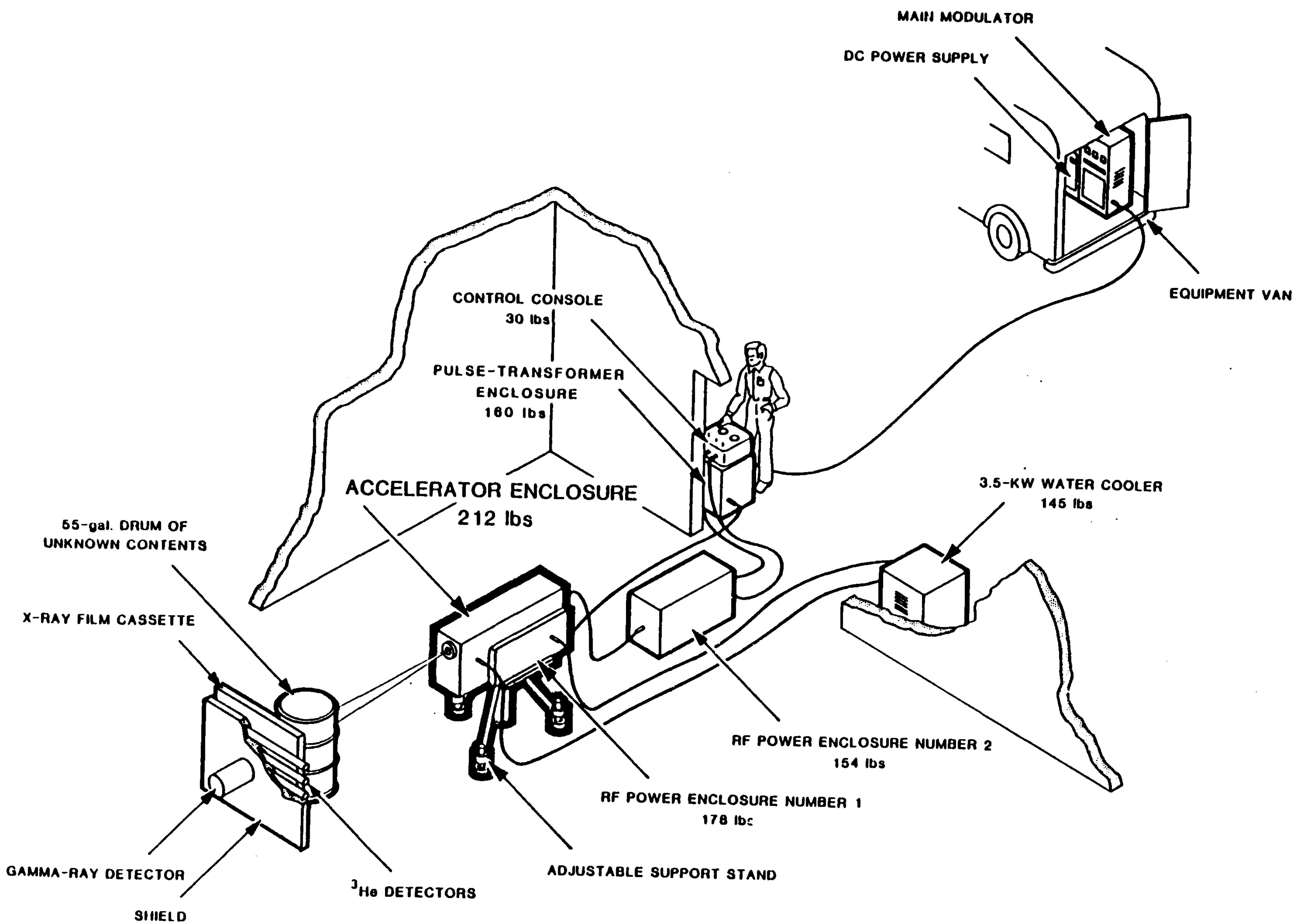
- Assemble components and acceptance testing.
- Develop testing procedures and safety requirements.
- Develop techniques and instrumentation for quickly and accurately determining the primary electron beam energy in the range of 8 to 10 MeV.

R. Morgado/D. W. Reid

- Optimize the neutron production assembly-bremsstrahlung spectrum and neutron yield.
- Determine x-ray intensity as a function of distance from the central axis.
- Determine spot size of the electron beam and its relationship to resolution.
- Determine resolution for various material thicknesses and combinations.
- Evaluate different radiographic film types and film screen combinations for materials of potential interest.
- Evaluate real-time radiography system.

SPECIAL CAPABILITIES:

The expertise of personnel in the Accelerator Technology (AT) and nuclear reactor (Q) Divisions as well as the diverse facilities at Los Alamos that could be applied to this research are special capabilities that can be found in few places.


MAIN MODULATOR
DC POWER SUPPLY
EQUIPMENT VAN
CONTROL CONSOLE
30 lbs
PULSE-TRANSFORMER
ENCLOSURE
160 lbs
ACCELERATOR ENCLOSURE
212 lbs
3.5-KW WATER COOLER
145 lbs
55-gal. DRUM OF
UNKNOWN CONTENTS
X-RAY FILM CASSETTE
RF POWER ENCLOSURE NUMBER 2
154 lbs
RF POWER ENCLOSURE NUMBER 1
178 lbs
GAMMA-RAY DETECTOR
3He DETECTORS
ADJUSTABLE SUPPORT STAND
SHIELD

Q2L-3-1

G. W. Taylor/E. J. Dowdy
(505) 667-4002/(505) 667-6912

TITLE: FLOWING AFTERGLOW DETECTOR FOR GAS CHROMATOGRAPHY (FAD/GC) APPLICATION TO HIGH EXPLOSIVES DETECTION

OBJECTIVE:

To develop and engineer an experimental Flowing Afterglow Detector for Gas Chromatography (FAD/GC) based on the principles of Flowing Afterglow Spectroscopy (FLAGS).

BACKGROUND:

FLAGS is a sensitive spectroscopic technique utilizing energy transfer reactions of rare-gas, electronically metastable atoms with trace additives, resulting in sensible emissions. It is anticipated that the sensitivity of gas chromatography will be markedly increased by the addition of a FLAGS detector. Applications include high explosives detection, pollution control, capillary column analysis, and chemical kinetics studies at low temperatures.

FLAGS was first used to study upper-atmospheric chemical reactions. Later, the rare-gas, flowing afterglow was used as a source for molecular spectroscopy of transient species. More recently, the authors have applied FLAGS to the analysis of trace gases and moisture in the helium coolant gas of a high-temperature, gas-cooled reactor. Currently, FLAGS is being used in the study of solid-phase thermal decomposition kinetics of energetic materials.

The principles of FLAGS have been applied to the construction of a FAD/GC. The principle of the FAD involves the interaction of rare-gas, metastable atoms with the compounds separated by GC to produce sensible light emissions, the suppression of background emissions, or detectable ions.

The FAD offers several advantages over conventional GC detectors. In addition to the three separate modes of detection from a single operation just described, the FAD can utilize metastable species varying in energy from $\sim$19.7 eV to $\sim$6 eV. This capability offers the possibility of selective reactions and highly specific analysis from one detector. The FAD is at least as sensitive as the Flame Ionization Detector (FID) and Photoionization Detection (PID) techniques, and, in some cases, probably more sensitive. Because of FAD's versatility, it is adaptable to many levels of instrumentational sophistication. It has the advantages of: responding to all gases and volatiles except helium; a variety of modes of operation that alter the principle of detection; and the capacity to identify the GC eluent qualitatively by individual spectroscopy.

SCOPE OF WORK:

A prototype detector has been constructed and tested on a few components. We propose to build a more compact and engineered version of FAD/GC that can be systematically tested and calibrated. The determination of FAD/GC operating parameters is crucial to taking advantage of its versatility.

G. W. Taylor/E. J. Dowdy

After the characterization of the FAD/GC has been completed, specific applications will be addressed. A primary application will be the detection of high explosives and the development of methods of analysis of explosives. A sampling system has been designed that will be of immediate use in this application.

SPECIAL CAPABILITIES:

FLAGS was invented by the authors. A prototype of the FAD/GC has demonstrated the versatility of the system relative to conventional GC detectors. FLAGS is used routinely now for the study of thermal decomposition limits of organics and inorganics. The detection and identification of high explosives is a high priority Nuclear Emergency Search Team objective.

J. G. Marinuzzi/R. J. Douglass
(505) 667-6000

TITLE: APPLICATION OF ARTIFICIAL INTELLIGENCE TECHNIQUES TO CRISIS MANAGEMENT

OBJECTIVE:

Develop a computer-based capability using artificial intelligence techniques for assisting decision-making by a crisis manager.

BACKGROUND:

A terrorist incident, whether it be of catastrophic proportions or a less complex hostage-barricade event, typically involves a response force drawn from many agencies to deal with a complex set of problems. A number of simultaneous, coordinated actions must be taken with urgency and effectiveness if a successful outcome is to be expected. Yet, predictable success requires skills, training, and tested procedures that are usually absent except in highly trained military-like organizations. Courses of action must often be selected without full knowledge of the resources available or the detailed nature of the problem. Indeed, even if complete knowledge were at hand, a crisis manager can easily be overwhelmed by its complexity, to the extent that his decisions will be based on only the broadest considerations, without the time or capacity to explore alternate paths and assess their potential for success or consequences of failure.

Emerging artificial intelligence techniques, when applied to complex scenarios such as these, should dramatically improve contingency planning, option identification and evaluation, phased response planning, etc.

SCOPE OF WORK:

- Construct a generic model of a crisis scenario in terms of resource sets to be applied toward multiple objectives that are characteristic of a complex terrorist incident.
- Develop methods for identification and evaluation of action options, to include estimates of success and consequences of failure, both in cases of complete and partial knowledge of the scenario.
- Explore methods for producing a versatile, highly interactive manager-computer interface such that relatively untrained personnel can quickly and effectively use the system under crisis circumstances.

SPECIAL CAPABILITIES:

Los Alamos has one of the largest computer facilities in the world, with ongoing programs in systems analysis and simulation.

S. D. Gardner
(505) 667-6394

TITLE: SUPPORT TO NUCLEAR WEAPON ACCIDENT RESPONSE

OBJECTIVE:

To improve the national response to a nuclear weapon accident through additional training, interagency coordination, and technical support to crisis management.

BACKGROUND:

Los Alamos, Lawrence Livermore National Laboratory, and Sandia National Laboratories provide the technical support through the DOE to the DoD in the unlikely event of a nuclear weapon accident. Over the years, identified personnel at the laboratories and at DOE/AL have responded to assist the DoD in emergencies involving nuclear weapons. To provide training for the technical people in DOE and DoD as well as developing a working relationship among the various local and national agencies that would be involved in such an emergency exercise every odd year were initiated in 1979 as the Nuclear Weapon Accident Exercise (NUWAX-79).

SCOPE OF WORK:

- Provide exportable training to various agencies that are likely to be involved in nuclear weapon accidents.
- Provide improved radioactive contamination survey techniques using remote readout dose rates while at the same time providing data about the spatial location of the detector.
- Establish cleanup limits and guide lines prior to accidents. Present proposed limits are based on the most pessimistic assumptions. Limits can be developed that take into account different ecosystems and land uses. Not all situations can be analyzed, but broad areas of differing vegetation cover, soil types, water pathways, and land use can be reviewed and preplanned limits derived. As a part of this effort, other response groups could be involved in determination of standardized approaches to dose calculations.
- Translate the number of ASTM standards that are under development for soil, water, air, and vegetation sampling for application to the nuclear weapon accident problem.

SPECIAL CAPABILITIES:

Los Alamos has been heavily involved in the development of training packages and exercises for the nuclear weapon accident emergencies and has participated in those accidents involving Los Alamos weapons. Special fieldable instrumentation has been developed at Los Alamos and the other nuclear weapons laboratories.

E. J. Dowdy/N. Nicholson
(505) 667-6912/(505) 667-4512

TITLE: LARGE-AREA, REAL-TIME RADIOGRAPHY

OBJECTIVE:

To provide a capability of doing real-time radiography of large volumes during a crisis.

BACKGROUND:

In a scenario such as hostages being held in a building, information regarding the internal details of the building are required as rapidly as possible to assist in planning for a possible assault by SWAT teams or other counterterrorism elements. The proposed system would be useful for looking through buildings as well as aircraft, automobiles, and trucks. Past studies have led us to conclude that designing a system to perform radiography on buildings or other structures is feasible, and that the resulting radiographic information will be very timely and useful.

SCOPE:

- Perform room-size radiographs of a simulated terrorist situation on film. Determine the total radiation dose to potential hostages and terrorists. Evaluate the usefulness of the approach.
- Participate in the development of a portable LINAC currently underway at Los Alamos for radiography and other active interrogation techniques and evaluate its usefulness for this application.
- Conduct a proof-of-principle demonstration of a fluorescent screen/TV camera system and provide a critical review of the proposed approach.
- Build a fieldable prototype based on the conceptual design.

SPECIAL CAPABILITIES:

Los Alamos has extensive experience in developing fieldable instruments, in LINAC development, and in radiographic techniques, which could be applied to the project.

N. Nicholson/J. J. Malanify
(505) 667-4512/(505) 667-4839

TITLE: DETECTION OF HIGH EXPLOSIVES BY NUCLEAR INTERROGATION

OBJECTIVE:

To develop a fieldable high-explosive (HE) detection/identification capabiliity using nuclear techniques.

BACKGROUND:

Currently, HE detection technology is largely based on passive techniques that rely on detection of the emitted vapor from the explosive. For those cases where the explosive is relatively well sealed or is a low vapor pressure explosive such as the RDX and HMX PBXs, vapor detection techniques currently are not sufficiently sensitive.

The presence of explosives has been inferred in the Nuclear Emergency Search Team (NEST) program by observing secondary nuclear interactions in the HE originating from radiation emitted by concomitant nuclear materials. As an extension of this technique, if the HE is exposed from external sources to both gamma and neutron radiation at selected energies and intensities, it is possible to ascertain both the principal elemental constituents and an estimate of the HE quantity. Based on well-known nuclear interactions, this can be done by active interrogation of an explosive package using a portable LINAC (currently under development at Los Alamos) to probe the explosive at several energies and observe the photoneutron yield. The explosive can also be probed using a pulsed 14-MeV neutron generator, which, together with the LINAC observations, will provide a quadri-element assay (H, C, N, and O) with a detection threshold of about 10 g of HE.

SCOPE OF WORK:

Most of the work in developing a practical HE assay system will focus on technique development and integration of the combined LINAC/14-MeV neutron interrogation concepts. The principal tasks are as follows:

- Characterization of the portable LINAC operational parameters and photoneutron detection system, as applied to HE detection.
- Characterization of the 14-MeV pulsed neutron generator operational parameters, neutron moderators, and the neutron-gamma detectors, as applied to HE detection.
- Integration and demonstration of the sensitivity of the combined techniques.

SPECIAL CAPABILITIES:

Los Alamos has a large, ongoing Department of Energy research and development program in nuclear safeguards and security in which a wide variety of advanced nuclear assay instrumentation is developed and fielded for the entire nuclear fuel cycle. In addition, Los Alamos develops and provides fieldable nuclear detection and diagnostics equipment and procedures for NEST.

R. A. Keller
(505) 667-3018

TITLE: QUANTITATIVE ULTRASENSITIVE DETECTION OF TRACE AMOUNTS OF MATERIALS

OBJECTIVE:

To develop and characterize new techniques for the quantitative measurement of trace quantities of materials.

BACKGROUND:

Many potential terrorism countermeasures depend on the detection of trace quantities of materials under a variety of conditions. Examples include high explosive detection, measurment of airborne or liquid effluents for localization of taggant sources, and monitoring air or liquid supplies for covertly introduced toxic chemicals or biological contaminants. One ongoing broad-based program at Los Alamos is evaluating and improving state-of-the-art ultrasensitive detection technology for application to the Laboratory's programmatic missions, including nuclear weapon development and chemical and biological warfare countermeasures. Counterterrorism technology would also benefit from the Ultrasensitive Analysis Project if the counterterrorism mission and support are included in the Project.

SCOPE OF WORK:

- Determine the performance of single-molecule techniques as applied to fluorescent taggants for tracking personnel and material.
- Examine the suitability of single-molecule techniques for high explosive detection.
- Develop an isotopic analysis technique with high sensitivity and a selectivity approaching 1 part in 10^{15} for identification of nuclear effluents.

SPECIAL CAPABILITIES:

The Los Alamos National Laboratory has recently become a national resource center for flow cytometry. Availability of state-of-the-art instrumentation in this area greatly facilitates our work in single molecule detection in fluids. Other capabilities include: laser photoionization mass spectrometry, accelerator-based mass spectrometry, optogalvanic spectroscopy, and high resolution atomic spectroscopy.

G. C. Saunders
(505) 667-8775

TITLE: HIGH EXPLOSIVE VAPOR DETECTION USING IMMUNOLOGIC TECHNIQUES

OBJECTIVE:
To develop detection methodology for low vapor pressure explosives such as RDX and HMX.

BACKGROUND:
Immunologic technologies provide some of the most sensitive and specific methods for the identification and quantitation of small amounts of biological and chemical substances. We have calculated that at equilibrium vapor pressure enough molecules of RDX (3.29×10^{10} molecules/liter) and HMX (3.28×10^{5} molecules/liter) are present to theoretically allow detection by immunologic methods.

SCOPE OF WORK:

- Derivatize RDX and/or HMX to suitable protein molecules to render them immunogenic.
- Immunize rabbits with the derivatized material.
- Develop mechanism to trap ambient explosive molecules on a vehicle (solid phase) suitable for immunologic detection.
- Use antibodies produced to develop sensitive immunoassays for RDX and HMX.
- Field test detection system.

SPECIAL CAPABILITIES:
In-depth explosive capabilities; fully equipped life sciences laboratories.

G. C. Salzman
(505) 667-2734

TITLE: PROTECTION OF ESSENTIAL WATER SUPPLIES FROM PATHOGENIC MICRO-ORGANISMS

OBJECTIVE:

To construct an apparatus based on the principle of circular intensity differential scattering (cids) that will permit continuous flow. Monitoring of a water supply including an appropriate alarm system if toxic agents are detected.

BACKGROUND:

We have shown that cids, which depends on the optical activity of biological molecules, can rapidly distinguish (few minutes) a wide variety of microorganisms including the agents of plague, tularemia, and paratyphoid as well as among a variety of viruses harmful to man.

SCOPE OF WORK:

- Develop means to negate nonspecific scattering due to extraneous particulates present in water.
- Adapt existing flow cytometry instrumentation to meet the objective of this proposal.
- Test system with appropriate microorganisms, such as botulinal toxin.

SPECIAL CAPABILITIES:

The resources of the Engineering Division coupled with the flow cytometric instrumentation capabilities of the Life Sciences Division will have a strong positive impact on this work.

M. C. Bryson/H. F. Martz
(505) 667-3308/(505) 667-2687

TITLE: STATISTICAL STUDY OF TERRORISM DATA

OBJECTIVE:

To develop a comprehensive report, including summary findings, regarding (1) the patterns inherent in observed terrorism data, and (2) future short- and intermediate-range forecasts of terrorist behavior based on observed patterns.

BACKGROUND:

The nature of terrorist activities makes them amenable to the following analyses.

1. Analysis of Terrorist-Event Point Processes

The occurrence of terrorist events can be viewed as a mixture of many different point processes. The complete collection of events includes individual elements that may be categorized in several different ways: by what groups have claimed responsibility, by the type or nationality of the victim(s), by the nature of the terrorist act, etc. Selection of any one such characterization--for example, identification of the responsible group--divides the point process into several mutually exclusive processes, one for each group. Each one could, if desired, be further subdivided, for example, by nationality of the victim. The analyst therefore has the opportunity of studying not one but several point processes.

There are many different statistical techniques for analyzing such processes. One might start by considering the most general renewal process, characterized only by a fixed distribution of inter-event times. The hope would be that non-Poisson characteristics of some processes could be identified in order to provide a degree of predictability. This is most likely to be possible when large amounts of data are present, which argues against excessive decomposition of the original point process. On the other hand, it is well known that the union of many disparate processes tends, under fairly general conditions, to resemble a Poisson process, a fact that argues in favor of decomposition. Thus, there may be an optimal level of disaggregation, the determination of which must be a principal objective of the analysis.

Even if a process is demonstrably close to a Poisson process, there are still many analytical techniques that may prove helpful. In particular, one may investigate what factors--for example, time of year, political climate, precursor events, etc.--have a significant impact on the rate of a Poisson process or on the differences among several such rates. Techniques that have usually been applied to survival time data analysis are applicable by analogy to this problem. Here, the waiting time to a single event plays a role analogous to that of the survival time of a piece of equipment or a patient undergoing treatment. Various factors such as age, type of treatment, or operating environment, etc., may affect a failure rate or death rate in survival time analysis. Likewise, factors such as secular time, political climate, etc. may affect the occurrence rate of terrorist events.

FRAC (Failure Rate Analysis Code), developed at Los Alamos for analyzing failure rates of components in light water reactors, is one tool for these kinds of data analyses. Another is the Cox proportional hazards regression model (or simplified versions of it that may be more suitable for non-censored data). Both are specifically oriented toward identifying what factors, or combinations of factors, have significant effects on failure rates.

2. Correlational Studies of Terrorist Events

Each terrorist event may be thought of as representing a single observation in a large multivariate data set. Indeed, existing records of terrorist events are often coded exactly as a statistician would code multivariate data: for each event, columns in a file record are used to record such features as type of event, group (if any) claiming responsibility, victim's occupation, victim's nationality, etc. Many of the same problems that typically plague multivariate data, such as missing data in certain columns, are also likely to be found in the terrorism data sets.

The chief difference between these kinds of data and conventional multivariate data is that data on terrorist events will be almost entirely nominal (qualitative) and therefore not directly amenable to conventional techniques such as multiple regression, factor analysis, or discriminant analysis. Nevertheless, it is meaningful to speak of "correlations" among the various observables, which can in fact be defined quantitatively in terms of chi-square measures of association. For example, one terrorist group may have a disproportionate share of businessmen among its victims, while another attacks diplomats almost exclusively. Contingency-table analysis is most often a fruitful method for identifying and measuring such associations.

Quantities analogous to multivariate "factors" or "discriminant functions" may likewise be developed on the basis of qualitative data. For example, a discriminant function consisting of certain observables (analogous to the "MO" in conventional criminology jargon) can perhaps be developed that will permit classification of events for which the actual responsible group is unknown. Multivariate "factors" can be similarly identified: combinations of variables occurring together often enough to warrant their aggregation into single quanities, thereby effecting a reduction in the "dimensionality" or complexity of a decision problem. Although these kinds of statistical analyses are common in their application to inteval-scale (quantitative) data, the techniques are less familiar in nominal-data applications. There is, however, a sizeable body of literature in numerical taxonomy where methodologies have been developed for such special purposes as biological classification. The principal objective of this portion of the analysis would be the identification or, where necessary, development of procedures that can be readily adapted to the study of terrorist events.

M. C. Bryson/H. F. Martz

SCOPE OF WORK:

It is proposed that the following specific tasks be undertaken:

(1) Organize the incidents in the worldwide terrorism reports into a data base suitable for statistical analysis. This would be regarded as a pilot data base for use in identifying suitable analytical procedures, which would then be subject to modification depending on the outcome of the statistical analysis.

(2) Apply FRAC and the Cox proportional hazards analysis models in a pilot study to determine the feasibility of (a) identifying patterns in terrorist behavior and operating modes, and (b) predicting future terrorist trends from observed patterns.

(3) Investigate the applicability of correlational methods, such as those in the numerical taxonomy literature, for discovering patterns and structure in terrorism data. Discriminant analysis and factor analysis are expected to be given particular attention.

The primary deliverable will be a comprehensive report, inluding summary findings, regarding (1) the patterns inherent in observed terrorism data and (2) future short- and intermediate-range forecasts of terrorist behavior based on any observed pattern.

SPECIAL CAPABILITIES:

Los Alamos' experience with statistical analysis and computer code development is extensive. An example of relevant work is noted earlier under BACKGROUND. Access to and handling of terrorist-related data already exist at Los Alamos in connection with operational nuclear terrorism responsibilities.

M. W. Bitensky
(505) 667-2690

TITLE: IDENTIFICATION OF STRESSED INDIVIDUALS

OBJECTIVE:

To develop mechanisms to detect stressed individuals, both from a distance and close by.

BACKGROUND:

A potential assassin entering the White House for a tour or reception, or standing in a crowd waiting for a presidential appearance, or a terrorist going through airport security or passport control is likely to be under stress. The manifold symptoms of such stress may make such persons recognizable through the use of remote or other surreptitious equipment, the existence of which will not be apparent to them.

SCOPE OF WORK:

- Determine through literature searches the best delineators of stress.
- Develop a laboratory stress simulator as a model system for experimental purposes.
- Determine instrumental parameters for making the desired measurements.
- Perform preliminary experimental studies to provide a data base for more elaborate proposals.

SPECIAL CAPABILITIES:

The physiological knowledge available in the Life Sciences Division coupled with the Laboratory's well-recognized skills in instrumentation makes Los Alamos a logical place to carry out this program.

M. W. Bitensky
(505) 667-2690

TITLE: HUMAN PERFORMANCE ENHANCEMENT (OR DEGRADATION) IN A COUNTER-TERRORIST CONTEXT

OBJECTIVE:

To explore the possibility of inducing sleep by unobtrusive drug administration (inhalation or ingestion), while at the same time looking for other neurobiological levers that might be gainfully employed in counter-terrorist activities.

BACKGROUND:

Recent advances in neurobiology have transformed our knowledge of the substances controlling some aspects of human behavior. The discovery that some small peptides (molecules composed of, typically, a chain of a dozen or fewer amino acids) confer insensitivity to overwhelming pain, while others make experimental animals incapable of staying awake, offers the possibility of either spectacularly enhancing human performance to almost superhuman levels (a discipline Soviet scientists call "anthropomaximology") or, conversely, seriously degrading an adversary's response to threatening situations.

SCOPE OF WORK:

It is now known that morphine-like molecules produced in the body (endorphins and enkephalins) render it largely insensible to pain. It is also known that the blood of mice forcibly kept awake for long periods will, when injected into normally rested animals, cause them to fall instantly asleep. These latter experiments have led to the discovery of "sleep peptides" that are elaborated into the blood when an animal is kept awake and that emphatically convey the message: "Go to sleep!" Is there an "alertness" peptide that antagonizes this action, or is alertness simply the absence of effective levels of the sleep peptide? How is the synthesis and degradation of sleep peptide regulated? If its synthesis could be prevented, or its degradation accelerated it might be possible to keep someone, a crisis manager in a terrorist incident, for example, awake for very long periods without a serious decrement in performance. Conversely, it might be possible to make people fall quickly asleep by stimulating the synthesis (or inhibiting the degradation) of sleep peptide.

The peptide Angiotensin I is converted to Angiotensin II by the action of a known enzyme. Angiotensin II causes the increase in blood pressure that is an important part of the "fight or flight" response. Similar enzymes may lead to the production of "sleep peptide" from inactive precursors. The inhibition of such activating enzymes should result in enhanced alertness, while their stimulation should lead to an irresistible need to sleep.

For example, hostages and guards could be overwhelmed by sleep in a hostage-barricade situation by some substance in the air they breathed, the food they ate, or the water they drank. The hazards inherent in this situation could be quickly overcome without risk of injury or death. We do not, at present, know how to do this, but it is an exciting avenue to explore.

M. W. Bitensky

We would pursue the above-mentioned OBJECTIVE to explore the possibility of inducing sleep by unobtrusive drug administration initially by a literature search and later by some preliminary animal experiments. Our research would include other neurobiological levers that might be available to counter-terrorist advantage.

SPECIAL CAPABILITIES:

This information would be of interest not only to the counterterrorist community, but to many other sectors of the military and civilian communities as well. The Laboratory has the expertise, facilities, and equipment to do this work, which fits into its purpose of research and development of technologies to enhance US security. In addition, the Laboratory already has cooperative programs with the military and civilian communities and is well equipped to work on this program with its possible broad application.

S. D. Gardner/W. P. Fox
(505) 667-9242/(505) 667-4411

TITLE: RAPID ENTRY TECHNOLOGY DEVELOPMENT

OBJECTIVE:

To improve and make available rapid entry techniques and equipment involving specialized explosive charges and related devices.

BACKGROUND:

Explosive-shaped charges, breaching charges, and other rapid cutting devices are used to open or remove doors and breach walls or other barriers as a means for gaining rapid entry by SWAT teams. Generally, the use of such techniques requires minimum collateral damage, yet must be highly reliable with assured entry on the first attempt. The structural details of an enclosure can be extremely varied, such as the metal/insulation composite of an aircraft skin in which structural members are embedded, or a multi-layer wall in a modern building. Commercially available devices with the desired degree of flexibility and reliability are extremely limited.

SCOPE OF WORK:

- Reevaluate currently used explosive and related entry devices and techniques when applied to various likely barriers such as wooden and steel doors, aircraft fuselage sections, and building walls.
- Develop and test additional specialized breaching techniques and devices where deficiencies in available technology are identified.
- Maintain an assured supply of specialized devices where, because of economic or other considerations, they cannot be supplied by the commercial sector.
- Provide at Los Alamos a standing, secure test-range for use by law enforcement or Department of Defense (DOD) groups for test or training purposes or for modeling and testing in real time an entry plan. A variety of shaped charges and materials could be stockpiled to support this potential use.

SPECIAL CAPABILITIES:

Los Alamos has a large, ongoing research and development program in explosive and hydrodynamic phenomenology with numerous highly instrumented explosive/hydrodynamic test facilities. This technology base supports the Laboratory nuclear weapons program as well as non-nuclear ordnance development for the DOD.

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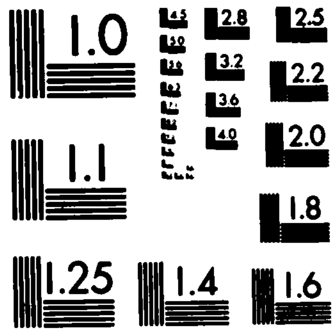

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

G. H. Kwei
(505) 667-5893

TITLE: PROTEIN MUTATIONS

OBJECTIVE:
To determine systematically the intracellular location of proteins observed in high resolution maps and to describe, index, and identify the functions of as many proteins as possible; and, ultimately, to establish the feasibility of using the protein maps for measurement of the effects of radiation and chemical mutagens and for unique identification of individuals.

BACKGROUND:
Most selectively disadvantageous mutations appear to produce an abnormal protein, cause a protein to be absent, or markedly change the amount of a protein present. The protein primarily affected may secondarily affect the expression of other structural genes, producing additional changes in the protein composition of cells. The effect of a point mutation or a small deletion varies, depending on which protein is affected, and, for point mutations, where an amino acid substitution occurs. If general conclusions regarding mutation rates are to be drawn, it is essential to examine mutations in as many different proteins as possible. The degree of variation compatible with survival may be estimated by looking for genetic polymorphisms in human proteins using high resolution, two-dimensional electrophoresis and computerized data reduction. This method enables observation of both single amino acid substitutions, which produce a charge change that occurs in about one-third of amino acid substitutions, and quantitative differences in the amount of protein produced. Additionally, some fraction of substitutions that do not produce charge shifts could be detected using peptide mapping of the proteins from single spots. Initially, a set of proteins has been distinguished whose map position (and therefore overall charge and molecular mass) is constant during vertebrate evolution. This suggests that mutations in the majority of proteins in this conserved set are lethal, and that if these proteins were used as mutation rate markers, very low mutation rates would result. Many more variants are observed for soluble cellular and plasma proteins than for those associated with cellular structures.

SCOPE OF WORK:
It has been suggested that the degree of observed heterozygosity in many and both short-term and long-term variations in gene expression and protein synthesis would be so large that high-resolution mapping for genetic studies might not be feasible. Extensive studies in this Laboratory and others demonstrate conclusively that this is not the case. For example, differences in protein spot positions are seen for approximately 1% of proteins when the patterns of two unrelated individuals are compared. Hence, it is feasible to begin to systematically identify charge variants of a large number of human proteins. To improve the certainty of association of two variants, methods for co-identification using specific antibodies and peptide

mapping have been devised. We are now beginning to list variants in normal populations, and to search for variants in 80 cell lines from individuals with known genetic diseases.

Our objectives are to (1) develop high resolution protein mapping and data reduction into a routinely useful tool, (2) map cells and tissues and make as many functional and intracellular location assignments as possible, (3) demonstrate that large numbers of variants may be found using the system, (4) demonstrate conclusively that the observed variants are genetic variants, (5) apply the system and data-base information to the problem of detecting and measuring the incidence of definable mutations in cell cultures exposed to ionizing radiation and chemical mutagens, and (6) determine the feasibility of applying the system for unique identification of an individual from small tissue samples or body fluids.

SPECIAL CAPABILITIES:

Los Alamos has a strong life sciences division comprised of five groups that focus on toxicology, genetics, pathology, and environmental studies. Also at Los Alamos is one of the largest computing capabilities in the world. This investigation of protein mutations would build on the existing expertise and projects in molecular and computer technology at the Laboratory.

R. A. Stutz
(505) 667-6342

TITLE: MICROWAVE RADIATION

OBJECTIVE:
To investigate microwave radiation effects on mammalian organisms.

BACKGROUND:
Considerable experimental evidence has been accumulated that shows a wide range of distinct effects on mammalian organisms due to exposure to microwave radiation. In the course of studying these phenomena, it was discovered by accident that certain experimental conditions caused laboratory animals such as mice to be stunned or killed. The phenomena are far from being understood and may involve field coupling interactions at critical resonance frequencies and amplitudes. Nonthermal phenomena seem to be key in the eventual understanding of the physics involved, where nonthermal effects are defined as those associated with radiation levels that are too low and/or too short in pulse duration to cause measurable tissue heating.

SCOPE OF WORK:
It is felt that the phenomena noted above needs to be explored and better understood. There are reports of Eurasian Communist countries performing research with combined fields of signals from several different microwave frequencies to produce at least perceptual distortion in humans. Research programs concerning cardiac arrest, RF hearing, and blood-brain-barrier enhanced permeability to toxins is also underway.

Past findings describe the experimental conditions as composed of single pulse, chopped CW microwave frequencies in the range of 2.2 to 2.7 GHz, with at least two amplitude settings that were sufficient to separate the stun from kill categories, although there appears to be a highly nonlinear relation between them.

We propose to replicate intentionally the accidental stun-kill effects on mice noted above and do some minimal exploration of the limits of the variables involved. At a minimum, two directional antennas will be required that can be operated in a CW, chopped mode for various width pulse, at frequencies between 2.2 and 2.7 GHz. Calculations of delivered energy will be required as well as field mapping measurements. Approximately 40 laboratory mice will be required, along with nonmetallic cages.

SPECIAL CAPABILITIES:
The proposed experiment would require minimal time and money to complete. Los Alamos has the expertise and facilities to do the work.

G. C. Saunders/A. Burris/
G. C. Seawright
(505) 667-8775/(505) 667-3993/
(505) 667-4462

TITLE: CONTRIBUTIONS TO THE CONTROLLING OF AGRICULTURAL TERRORISM

OBJECTIVE:

To utilize the capabilities of Los Alamos National Laboratory in countering and controlling terrorist attacks on United States' agricultural resources, including the introduction of disease organisms, exotic insects, and noxious chemicals.

BACKGROUND:

The potential for sabotaging US agriculture is real, and the economic and social impacts of these attacks has been documented. A well-coordinated, publicized attack involving both animals and crops would have devastating results and could lead to general lack of confidence in our political and military systsems if we no longer had available an uninterrupted supply of food. Planning of countermeasures to prevent, or at least minimize, the damage from possible attacks is important to national security.

SCOPE OF WORK:

Possible areas of Los Alamos' contributions to the resolution of the problem of agricultural terrorism fall into the following areas:

- Development of plant resistance to disease organisms and animal disease detection systems.
- Computer modeling of epizotics and epiphytotics and development of response scenarios appropriate to federal, state, and private sectors.
- Predicting the path of epiphytotics through the use of complex terrain and atmospheric dispersion modeling capabilities.

SPECIAL CAPABILITIES:

Current Los Alamos research in plant genetics, animal health monitoring systems, atmospheric and other modeling activities could readily be expanded or reoriented to respond to questions of agricultural terrorism.

M. D. McKay/R. J. Beckman
(505) 667-6227/(505) 667-1443

TITLE: COMPUTER MODEL FOR ANTI-TERRORIST TRAINING

OBJECTIVE:

The goal of this project is to develop a general computer model that allows a security force commander to practice his response to terrorist activities. An encounter between security force and terrorist commanders will be realistically simulated for trainees who oppose each other at two video display terminals.

BACKGROUND:

Recent terrorist activities have pointed out the necessity of increasing security at sensitive sites. While security forces at most of these sites have undergone anti-terrorist training, their commanders have had little or no continuing opportunity to test their responses to actual terrorist activities or to test the effects of security devices, such as fences and alarms. A basic game utilizing two Tektronics 4014 terminals running on a Digital VAX 11/780 has been developed at Los Alamos.

SCOPE OF WORK:

We propose adding the following to the basic sighting and movement model:

- Implement realistic engagement codes into the model, including different weapon types.
- Improve graphics by adding color.
- Perform a full-attack simulation at a Los Alamos site with the security force commander participating in subsequent refinement of the model.
- Enhance sighting and movement routines by including darkness and weather factors.

SPECIAL CAPABILITIES:

The Analysis and Assessment Division at Los Alamos has previously developed the base model with sighting and movement capabilities. Being a weapons laboratory, we have considerable familiarity with security needs and training.

G. P. Quigley
(505) 667-7121

TITLE: A DETECTOR FOR TOXIC CHEMICALS

OBJECTIVE:

To develop a universal detector that will give early warning of the contamination of the air and/or water supplies of a key government building or any site targeted by terrorists.

BACKGROUND:

Although the most likely potential threats have not been identified, there are a few obvious choices for terrorist groups to consider. For air supply contamination, one of these is a blood agent such as hydrogen cyanide (HCN) or cyanogen chloride (CNCl). Both of these can be procured commercially by the tank-car load or easily made in a clandestine factory (HCN from sodium cyanide and sulfuric acid). At high but readily achievable concentrations, their action (interfering with the use of oxygen by body tissues) can be rapid and devastating. The proposed detector would break up the HCN in a weak, electrical discharge (such as a Tesla coil) and produce electronically excited CN, which fluoresces strongly in the ultraviolet near 3880 Å. This distinctive fluorescence signature can be detected by a photodiode array giving an unequivocal identification of the presence of a CN-containing agent.

Likewise, other potential agents (such as the organophosphate nerve agents) contain molecular fragments that will fluoresce in a distinctive way (such as the emission from the excited PO from the nerve agents).

This device can be self-contained or connected, along with others, to a main computer that would perform the data analysis and identification. The stand-alone version of this device would occupy less than 1 cu ft of space and cost less than $30 K.

By constructing a probe that aerosolizes the water coming into the building, the same device could be used to analyze the water supply.

Also, it is likely that this technique can be used to determine the presence of biological agents. This can be done, for example, through the fluorescence from tryptophan, a fluorescing amino acid, and perhaps other, as yet unidentified fluorescing fragments.

SCOPE OF WORK:

- Identify the major potential threats.
- Obtain the spectral fingerprints of each in the electrical discharge.
- Determine the major background interferences and hence sensitivity for each agent detected (in real time).

- Construct a workable system from commercially available components to be used in a real world demonstration outside of the laboratory.

SPECIAL CAPABILITIES:

The development of the proposed device requires expertise and laboratory equipment to study the spectroscopy of fragments excited in an electric discharge. Since the proposed technique is really a blend of the techniques of laser-induced breakdown spectroscopy (LIBS) and metastable atom-induced fluorescence (MAIF), two areas where we have considerable experience, we will have no trouble in achieving the stated goals. Also, we are currently involved in a program funded by the Army's Chemical Systems Laboratory to develop techniques for detecting chemical warfare agents.

G. P. Quigley
(505) 667-7121

TITLE: DETECTION OF LIQUID COMBUSTIBLES

OBJECTIVE:

To develop a device that will detect the presence of vapors given off by liquid combustibles.

BACKGROUND:

Liquid combustibles, such as gasoline, for example, are highly volatile and contain substances that fluoresce strongly on being irradiated by a laser or other strong light source. The basis of this proposal is to develop this laser-induced fluorescence technique to detect parts-per-million (or better) levels of these vapors in air. Obviously, the background levels of these vapors will be a problem (particularly at airports, for example) and a significant effort will be expended in reducing this effect and enhancing the sampling of vapors from a particular location (luggage, for example).

SCOPE OF WORK:

- Identify the major liquid combustible threats.
- Obtain a spectral fingerprint from laser-induced fluorescence in these vapors.
- Determine the sensitivity levels.
- Study vapor sampling techniques.

SPECIAL CAPABILITIES:

We currently have ongoing programs in the detection of carcinogens from synfuel plant effluents (Department of Energy) and the detection of chemical warfare agents in the battlefield (Chemical Systems Laboratory). Thus, the expertise and hardware required to perform the proposed tasks already exists in the Chemistry Division of the Los Alamos National Laboratory.

G. P. Quigley
(505) 667-7121

TITLE: DETECTION OF NITRO COMPOUNDS IN EXPLOSIVES

BACKGROUND:

Many common explosives contain large quantities of nitro compounds such as TNT, DNB, and other nitro derivatives of aromatic compounds. These molecules do not fluoresce and hence a highly sensitive technique such as laser-induced fluorescence (LIF) cannot be used to detect them. There is a simple, well-known technique that can be used to convert these nitro compounds into an amine which fluoresces strongly. There are several ways in which this reduction of nitro compounds can be affected. One important way is by catalytic hydrogenation using molecular hydrogen. This can be done in the vapor phase on a platinum impregnated activated charcoal collector. The amines produced can then be irradiated with a suitable laser and the characteristic fluorescence of the amine will then indicate the presence of a nitro compound.

Based on our experience with LIF in amines, we can expect sensitivities to approach the parts-per-billion level in near real time.

The reduction of nitrate esters, such as nitroglycerin, will not, unfortunately, result in the production of fluorescing amines but will result in the production of the alcohol (glycerol) and ammonia if the reduction is complete. As an addendum to this proposal, we can consider the detection of the nitrate esters by detecting the reduction products. One possibility is to collect the ammonia gas and use a CO_2 laser/optoacoustic detection scheme. This is an extremely sensitive technique that has been shown to be useful in detecting trace quantities of the nerve agent GB.

SCOPE OF WORK:

- Investigate the collection and reduction of aromatic nitro compounds.
- Use LIF to characterize the fluorescence from the aromatic amines in terms of spectral content and sensitivity.
- Investigate the collection, reduction, and detection of nitrate esters.

SPECIAL CAPABILITIES:

At present, we have ongoing programs with the Department of Energy and the Army's Chemical Systems Laboratory to use LIF and optoacoustic detection techniques to detect trace quantities of carcinogens and chemical warfare agents. Thus, the expertise and hardware are already in existence and are being used on similar problems.

APPENDIX A. PREFACE

Appendix A contains material intended to provide information of a general nature about Los Alamos National Laboratory. Included are some informative pamphlets, two previous annual reports, and copies of viewgraphs emphasizing noteworthy aspects of Laboratory programs.

This Appendix further includes material designed to inform the reader of specific expertise within some of the Divisions represented by concept papers in this presentation.

Enclosed also are prospecti on three of the Laboratory's special organizations, the Institute of Geophysics and Planetary Physics, the Center for Materials Science, and the Center for Non-Linear Studies.

APPENDIX B. PREFACE

Appendix B contains specific technical material related to specific concept papers listed in the Table of Contents and included in this presentation. This material, which consists of Laboratory reports, Mini-Reviews, and reprints, is intended as supporting information for some of the papers herein presented. Each item in this Appendix is referenced to the particular paper it supports.

ENCLOSURE 2

Los Alamos

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

Earth and Space Sciences Division

DATE April 28, 1983
IN REPLY REFER TO ESS-DO
MAIL STOP D446
TELEPHONE 505 667 9005

Dr. James W. Kerr
Assistant Associate Director
Office of Research
National Preparedness Programs
Federal Emergency Management Agency
500 C Street, S.W.
Washington, DC 20472

Dear Dr. Kerr:

Enclosed is additional information on four of the topics that you requested in your January letter: Fire Modeling; Subsidence Monitoring; Volcanic Forecast, Hazards; Training and Communications. Information regarding the fifth topic, Drought - Legal and Institutional Options, has already been communicated directly to Mr. Morelli during a recent visit to Washington by the individuals involved.

This reply to your January request was delayed because we felt that the enclosed paper which was recently completed on volcanic hazards would provide you with the type of information that would be more useful to your present needs. I am also enclosing a copy of a letter to Mr. Morelli which discusses a recent concept that we believe could provide for an inexpensive means of monitoring for volcanic activity. Any suggestions you might have regarding how we might further pursue this concept would be greatly appreciated.

Some of us at Los Alamos have recently been having conversations with Strategic Air Command at Omaha regarding sensors, monitoring, and information management techniques for use during a nuclear attack. Similar concepts and techniques which can include applications of artificial intelligence could also be applied to FEMA's crisis management activities. For instance, they could be utilized in response to nuclear attack, chemical and biological releases, or a wide variety of unanticipated toxic emissions. These techniques can provide real-time information to the decision makers regarding what is happening in the environment and what is likely to happen in the future. They also enable present estimates of the environment and future predictions to be updated as additional real-time information becomes available. By utilizing recent concepts in management information systems and artificial intelligence, information which is of use to the decision maker can be made available. That is, information required in order for the crisis manager to make decisions can be made available, not just endless quantities of data from multitudinous sources.

If you would be interested in more information regarding these concepts, we would be happy to provide it. Also, if you could aid us by putting us in touch with other individuals at FEMA who may have interests in these areas, it would be greatly appreciated.

Thank you for the efforts you have been making with our work.

Sincerely yours,

Barbara G. Killian

BGK:cm

Enc: Los Alamos National Laboratory's FEMA Emergency Support Center
Application of Reactive-Flow Numerical Modeling Techniques to Predict the Dynamics and Damage Potential of Large-Scale Fires
Subsidence Emergency Management
Copy of 4/18/83 letter to Mr. Ugo Morelli, FEMA
LA-UR-83-1225

Cy: CRMO, w/enc. (A150)
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Los Alamos

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

Earth and Space Sciences Division

DATE April 28, 1983
IN REPLY REFER TO ESS-DO
MAIL STOP D446
TELEPHONE 505 667 9005

Mr. Ugo Morelli
Federal Emergency Management Agency
Natural Hazards Division - State & Local
500 C Street S.W.
Washington, DC 20472

Dear Mr. Morelli:

During our visit with you on February 17, you explained to us how FEMA interacts with other agencies and how some activities are developed. In particular, you explained how the Interior Department, as represented by US Geological Survey, has responsibility in the area of volcanic hazards. I believe that you also mentioned that if there were areas in which additional monitoring activities or other work were thought to be desirable, FEMA would approach the USGS and make recommendations for that work.

Los Alamos National Laboratory has been doing infrasound work for several years for the Department of Energy's Office of International Security Affairs. This work consists of deploying infrasound arrays, which are used to detect microbaric signals. The signals travel through the atmosphere, are recorded by the deployed arrays, and are subsequently transmitted to and analyzed at Los Alamos. We have recently deployed three permanent arrays at Los Alamos, New Mexico; Flagstaff, Arizona; and St. George, Utah. NOAA also has an array at Boulder, Colorado and cooperates with Los Alamos in the acquisition and analysis of data. These arrays have successfully detected signals generated by various disturbances at distances in excess of 1000 km.

In the, presently small, infrasound community there has recently been considerable excitement regarding indications that the microbarograph arrays have detected signals from Long Valley. The signals correlate in time with other measurements of energy release observed at Long Valley.

While we were in the Washington area in February, we also visited with Walter Hayes and Roy Bailey of the USGS at Reston. During our visit with them, they indicated that the USGS does not have infrasound capabilities.

The Earth and Space Sciences Division at Los Alamos has had close interactions with the USGS Astrogeophysical Laboratory at Flagstaff for many years. These interactions have included data integration of geochemical data, mapping, volcanoes, cratering, meteor impacts, air blast and debris lofting effects from explosions, and nuclear weapons effects. In fact, our interactions with the Flagstaff staff is a reason that one of our infrasound arrays is located at Flagstaff. In particular, Dr. David Roddy and Dr. Gene Shoemaker of Flagstaff have had a strong interest in the potential of our microbarographic measurements for some time; and we have interacted with them on numerous occasions in this mutual area of interest.

Both Los Alamos and Flagstaff think that microbarograph arrays can be rapidly deployed to provide a useful, inexpensive, automated, and technically exciting means of monitoring volcanoes. Such monitoring could cover large areas with just a minimal amount of equipment and could be utilized as a remote early warning system for indicating when more extensive measurements are warranted.

In recent conversations with Dr. Roddy, we have agreed upon the elements of a possible joint program for utilizing microbarograph arrays to monitor volcanic activity. As briefly described in the following, this effort would utilize the strengths of both laboratories.

In particular, there is significant technical expertise at Flagstaff regarding volcanic eruptions and associated phenomena. The staff at Flagstaff has been involved in studies related to Mt. St. Helens and its effects. They are presently studying Long Valley and Mono Craters. The Los Alamos staff has had about three years of experience in designing and deploying microbarograph arrays and in collecting and analyzing atmospheric microbarograph signals. In addition, we have a staff of volcanologists who have frequent interactions with the Flagstaff staff.

We envision several microbarograph arrays deployed in the western US for volcanic monitoring. The three arrays presently deployed for DOE studies would also be utilized for volcanic monitoring. Data from the deployed arrays would be telemetered to Flagstaff and to Los Alamos. Flagstaff personnel would be primarily involved with the data analysis and interpretation of volcanic activity. Los Alamos would design and install the arrays, provide some of the computer software, and participate in the analysis of atmospheric effects with Flagstaff.

Based on our conversations in February, the program that I have briefly outlined above seems to me to be the type of interagency activity that FEMA might wish to foster. We would be pleased to provide your offices with a more detailed description of the activities we envision, including costs. We seek your guidance regarding how we might best proceed in order to make the capabilities we envision usable capabilities for aiding FEMA in mitigating the effects of volcanic hazards.

Yours truly,

Barbara Killian

Barbara G. Killian

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TITLE: APPLICATION OF REACTIVE-FLOW NUMERICAL MODELING TECHNIQUES TO PREDICT THE DYNAMICS AND DAMAGE POTENTIAL OF LARGE-SCALE FIRES

OBJECTIVE:

Our initial objective is to apply existing reactive-flow numerical modeling techniques, supplemented by physicochemical submodels currently under development by FEMA and other agencies, to predict the evolution of nuclear explosive-induced, large-scale fires as a function of fuel source distribution, atmospheric conditions, terrain conditions, and other identified parameters. Our ultimate objective is to develop a numerical modeling capability to estimate fire damage from nuclear explosions as a function of the above parameters. The feasibility of accomplishing this objective will be addressed during the initial study period.

BACKGROUND:

Continuing developments in strategic-warfare technology toward more compact and accurate delivery systems have increased the likelihood of "surgical" nuclear scenarios where military and industrial facilities are considered as primary targets and the goal of achieving complete destruction of population centers via blast and shock effects becomes less significant. Under these conditions, a major consideration for civil defense preparedness and post-attack recovery concerns the collateral effects of such scenarios - namely fallout, and, of more significance to the present discussion, the spread over relatively large areas of nuclear explosive-induced fires.

Nuclear explosive-induced fires did occur after the Japanese events, and there is every reason to believe that they would be a factor in modern nuclear warfare. However, the variability in the extent of fire damage caused by uncertainties in atmospheric conditions, combustible-source distribution, multiburst effects, terrain effects, or other unknowns, and a lack of motivating factors in the past have precluded the use of fire damage predictions in present nuclear warfare civil defense planning.

SCOPE OF WORK:

During the past two years, researchers in the Energy (Q) Division at Los Alamos have developed a two-dimensional, time-dependent, hydrocode analysis capability for modeling turbulent, reactive, multiphase, multicomponent, compressible flows with convective and radiative heat transfer. We believe that this modeling effort and the associated code verification program have progressed to the point where realistic estimates of the reactive-flow phenomena of significance to energy conversion systems can be made with some confidence. We further believe that the major phenomena involved in large-scale fire growth and propagation are sufficiently similar to those in fossil-energy combustion processes that our existing capabilities, with minor modifications and inclusion of appropriate submodels, can be applied successfully to simulate such phenomena.

Task 1. Preliminary Analysis of Large-Scale Fires. We would identify the range of input, boundary condition, and submodel parameters of interest to this study. These parameters would include, but not be limited to, fuel source distributions, atmospheric conditions (including swirl), terrain variations, reaction rates of combustible materials and rate of firebrand production, initial fire ignition or radiative field distributions, blast/fire interactions, parameters describing the interaction of combustible fuel with the thermal radiation and the radiation transport process itself.

It appears that only one modification to our existing two-dimensional hydrocodes must be made so that large-scale fires can be modeled realistically. This would involve an extension of the heterogeneous combustion model (currently used to describe burning particles in motion) to describe the burning of stationary fuel sources. (An immobile structure field is an existing feature that can be used to describe these source materials.) Included in the extension would be the generation, transport, and burning/extinction of firebrands, and the effect of blast/fire interactions. We propose to use analytic results and experimental data generated by FEMA research programs (and related work) to effect this extension.

Task 2. Sensitivity Analysis. Before entering into a full-scale applications program, we believe that a careful examination of numerical constraints and limitations (such as zone size and time-step size stability requirements and the impact of numerical diffusion) are a necessity. Other important issues to be addressed include whether the required mesh size for physical accuracy conflicts with practical considerations of machine storage, run times, and cost. If so, modeling techniques must be developed to account for microscale features in an integral, more approximate fashion. In addition, the definition of appropriate far-field boundary conditions and their permissible distance from the active regions of the problem need to be established.

After numerical constraints have been firmly established, we would investigate the sensitivity of the model prediction to uncertainties in key input or submodel parameters, as listed under Task 1. This type of analysis is often useful in pinpointing areas where research activity should be concentrated.

Task 3. Scaling Studies/Experimental Support and Verification. We would assess the importance of scale size in experimental programs and provide assistance and guidance in the design of such experiments. Both large-scale and separate-effects experimental results will be used, as they become available, to determine model accuracy and to provide estimates of critical phenomenological parameters.

As results become available from related programs, we would update key model parameters or modeling techniques in a timely fashion. This should help ensure that the numerical modeling effort reflects up-to-date information and interacts with the overall program in an efficient manner.

Task 4. Feasibility Assessment of Fire Damage Predictions. We would make a preliminary feasibility assessment for hydrocode-based nuclear fire-damage prediction methodologies. Key problem areas will be identified and recommendations for future research programs will be made.

We believe that the above tasks could be completed within one year with a near-optional level-of-effort. Depending on the results of the first year's effort and FEMA's interest in pursuing additional studies in this area, two additional tasks appear to be natural extensions of the initial work.

Task 5. Integration of Reactive-Flow Techniques with Atmospheric Transport Capabilities. Assuming a positive outcome from Task 4, we propose to incorporate the reactive flow modeling framework, developed and exercised in the earlier work into a three-dimensional atmospheric transport code, such as those used in the Earth and Space Sciences Division at Los Alamos for pollutant transport studies. This description would incorporate complex terrain features, weather system models, and atmospheric boundary layer models. Tasks 3 and 4 would be continued in support of Task 5.

Task 6. Development and Application of Hydrocode-Based Fire Damage Methodology. We envision the final development and preliminary application of a predictive capability to assess nuclear explosive-induced fire spread and damage as a function of all identified parameters, including atmospheric conditions, fuel source distribution, terrain variations, and threat scenario. Task 3 would be continued in support of Task 6.

We anticipate that Tasks 5 and 6, with related support activities, could be completed within an additional two-year period, again with a near-optional level-of-effort.

SPECIAL CAPABILITIES:

The Los Alamos National Laboratory has an established reputation, the facilities, and the technical expertise to develop, verify, and apply large, transient, multidimensional, multiphase codes for modeling a variety of physical processes. Two examples of such codes are the TRAC (Liles, 1978) and SIMMER (Bell, 1977) codes used by the Laboratory's Energy Division to predict the response of nuclear reactors under emergency conditions. The latter code has been modified recently for turbulent, reactive-flow applications. The multifield methods used in these codes were developed by the Laboratory's Theoretical (T) Division, which has a long history of such innovative advances in fluid dynamics computational methods (Amsden and Harlow, 1974; Butler et al., 1980).

A. Related Work

More directly relevant to the proposed project, the Energy Division's Thermal-Hydraulics Group, Q-8, has applied and verified physicochemical models of coal combustion and gasification processes. Our approach has been to contribute to understanding the interactive nature of the turbulence, mixing, chemistry, and multiphase models and to assess their accuracy within the framework of our two-dimensional, time-dependent hydrocode, SIMMER, against analyses and experiments (Chapyak and Blewett, 1981; Chapyak et al., 1982).

Since October 1980, we have added to the SIMMER hydrocode models for turbulence stress, gas-phase specie and thermal diffusion, an improved Eulerian particle description, particle interaction with gas-phase turbulence, gas-phase chemistry, radiative heat transfer, particulate devolatilization, and heterogeneous reactions. Most of these models have been verified, to some extent, against experiments. Table I summarizes the scope of this project. Table II lists the main features of the basic SIMMER code structure.

B. Facilities

The Los Alamos Integrated Computer Network contains 12 major computers: five Cray-1s, four CDC 7600s, one CDC 6600, and two CDC Cyber-73s. They are supplemented by distributed processors, which are VAX computers produced by Digital Equipment Corporation. The total computing capacity of the Network exceeds that of any other computing center in the world. This computer network is managed and maintained by the Computing (C) Division, which has 120 staff members and 180 support members. The computing speed of the Cray is the highest, ranging from four times higher than that of the CDC 7600 for most commonly programmed codes to 10 times higher for codes optimally programmed for the Cray (for example, "vectorizing" the code).

TABLE I

MODELING FEATURES FOR TURBULENT REACTIVE FLOWS

Feature	Status
Turbulent Stress Closure	Available
Gas-Phase Specie Diffusion	Available
Gas-Phase Thermal Diffusion	Available
Gas-Phase Chemistry	Available
Particle/Turbulence Interactions	Available
Particulate Devolitalization	Available
Heterogeneous Chemistry	Available
Radiative Heat Transfer	Available
Swirl Flow	Available

TABLE II

BASIC FEATURES OF THE SIMMER-II CODE

Two-dimensional, Transient, Multiphase, Multicomponent, Eulerian

Semi-Implicit (Material Courant Condition)

Tunable Upwind-Centered Differencing

Flexible Boundary Conditions

Two Momentum Equations for Gas and Liquid Fields

Separate Energy Equations for Liquid Field Components

Interaction with Structure Field

Extensive Verification Program

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SUBSIDENCE EMERGENCY MANAGEMENT

Scientific Research Proposal

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February 8th,1982

SUBSIDENCE EMERGENCY MANAGEMENT

INTRODUCTION

A general description of the subsidence problem and its national extent is given in Appendix 1, which is a copy of section II.9 of the LANL concept paper of December,1982.

This report is an overview of technical aspects and recommends specific lines of investigation.

RECOMMENDED INVESTIGATIONS

Figure 1 shows the chain of circumstances which precede and follow a subsidence emergency, the response required of appropriate authorities and the knowledge needed to implement the response.

Study of column 3 shows that two key items of scientific knowledge are needed at this time. These are--

1)a stochastic (or engineering-geology) model capable of predicting the time, size and type of subsidence event in particular regions. For example, the prediction that Pittsburgh should expect 145 events between 1982 and 1987.

2)a deterministic (or geomechanical) model capable of determining whether a particular underground cavity will be stable in time, or if not, how to stabilize it. The same model could be used to design restoration measures after a collapse.

The stochastic model is of most use in long-range planning and design of long-range measures, such as legislation. The deterministic model is of most use in deciding response to particular emergency situations. However both are needed for an effective response to the problem.

		Emergency over ↑	
4. Emergency recovery & restoration	b. Restore longterm stability	Longterm habitility of region	.Areal stabilization methods
	a. Restore nonessential installations	Secondary economic disruption	.Site stabilization methods
3. Emergency reaction measures	c. Restore or bypass transportation routes	Economic and military disruption	.Emergency highway reconstruction
	b. Keep essential services operating	Secondary threats to life	.Emergency foundation engineering
	a. Save life	Loss of life	.Population size, location, emergency services
2. Nature of emergency		Damage to surface installations / Damage to underground installations	
		Sudden collapse of land surface / Sudden collapse of underground openings	
		Slow subsidence of land surface / Slow deterioration of underground openings	
1. Emergency prevention measures	c. Prevent surface construction	Construction of surface installations	. Mining history
	b. Change abandonment condition	Abandonment of mine or cessation of maintenance	. Cause and prevention of deterioration
	a. Change construction methods	Initial mining or underground construction	. Design of underground openings
	RESPONSE TO CONDITION	CONDITION	KNOWLEDGE NEEDED TO IMPLEMENT RESPONSE

Figure 1: The circumstances which precede and follow a subsidence emergency are shown, in time order, in the central column.

The response required of appropriate State and Federal authorities is shown in the left column.

The knowledge needed to implement this response is shown in the right column.

USE OF THE RESULTS

Figures 2 and 3 show how the results provide a foundation for a chain of investigations which would lead to a national assessment of the problem and design of a national response.

The proposed investigations are stage 1 of this scheme.

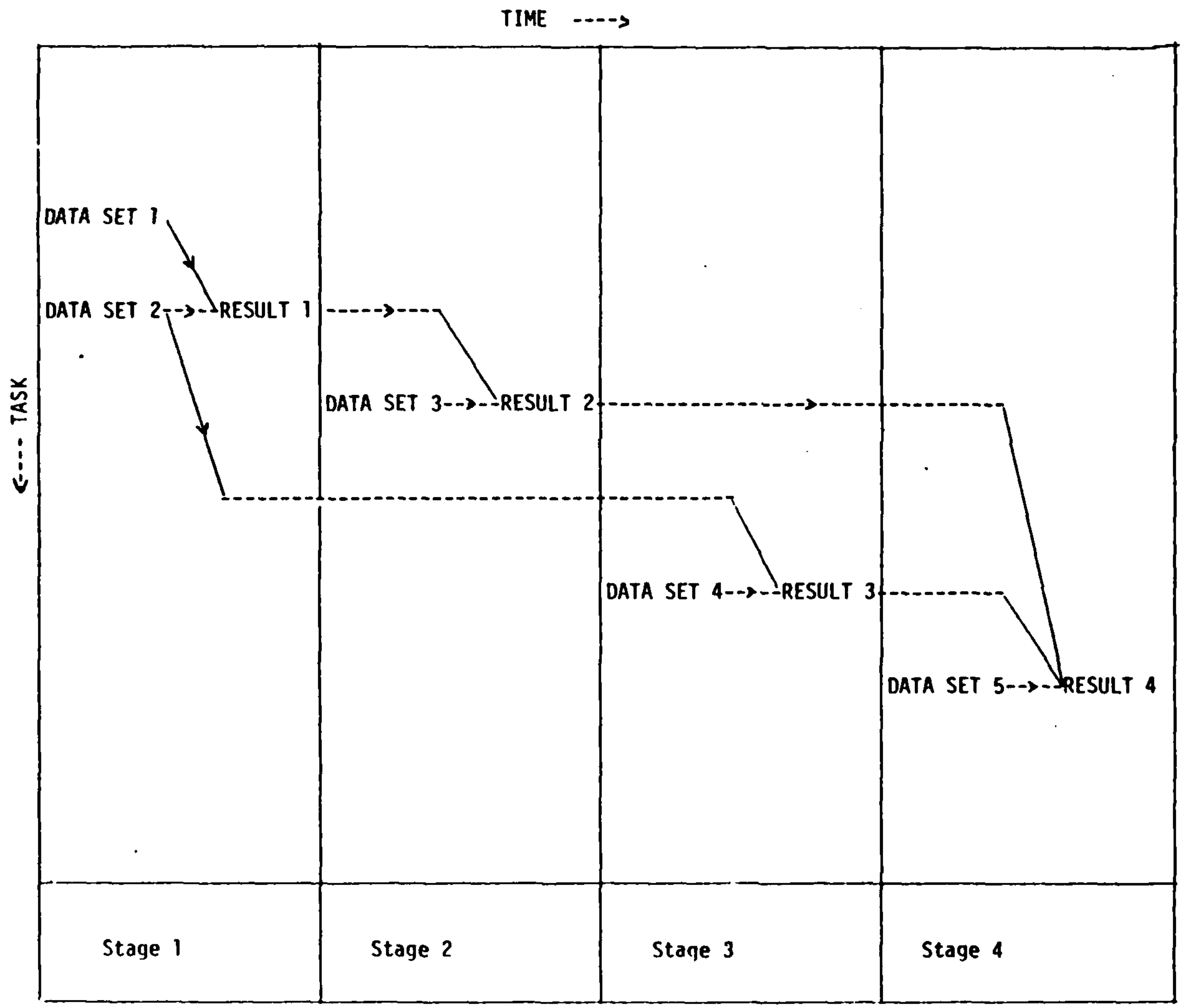

Figure 2: Chain of investigations leading to a national assessment and basis for planning a national response. Proposed investigations are Stage 1.

. LONGTERM INVESTIGATION STRATEGY

Stage 1: Collect data set 1: Mining or underground construction method in selected test areas

Collect data set 2: Subsidence effects in test areas

Result 1: Relationship of mining or construction method to time,type,size of subsidence effect.

Stage 2: Collect data set 3: Extent and timing of mining and underground construction,nationwide(stratified sampling procedures.)

Result 2: Use data set 3, result 1, to obtain a prediction of subsidence nationwide, in terms of timing,size,and location.

Stage 3: Collect data set 4: Location of population,surface construction, underground installations,in test areas

Result 3: Use data set 4, data set 2, to determine relation between subsidence and effects on human life and economic capability

Stage 4: Collect data set 5: Location of population, density,degree of urbanization,nationwide

Result 4: Use data set 5,result 2, result 3, to determine subsidence effects on the nation in terms of loss of life, disruption to economic activity. Locate areas of major concern and predict disaster scenarios for those areas.

Figure 3: Explanation of figure 2.

THE STOCHASTIC MODEL

A stochastic model is a computer program which is able to predict, for a given part of the United States, the probable number of subsidence events which will occur in that region in any particular time period in the future. It will also predict the type, size and severity of the events.

Stochastic models predict an average result over fairly large regions over intervals of time, and not specific events at particular times and places. Their main use is, therefore, in determining where the problem areas are and how bad the problem will be at any time.

Appendix 2 describes a stochastic model developed at LANL in 1982. This LANL 1982 model demonstrates that a useful stochastic model is feasible. The precision attainable is such that variations of this model should give acceptable accuracy for regions the size of four counties, for time periods of one year, for about 20 years into the future. Models for larger areas, longer time periods, should be even more accurate.

However the LANL 1982 model is a pilot study and needs upgrading if it is to be applied on a national basis. The additional work needed is described below.

REVISED STOCHASTIC MODEL

The LANL 1982 model was based on coal-mining excavations in the Pittsburgh seam in a four-county area of SW Pennsylvania, with the bulk of the data being from Allegheny County and the City of Pittsburgh.

The model predicts that subsidence should occur as a "wave" of events, some 50 years after mine abandonment. The current high rate of subsidence events, about 60 events per annum, is thus a delayed response to the years of peak coal production, 1920-1930, in the boom that preceded the Great Depression. This agrees with the opinions of the Pittsburgh foundation engineers that collected the data.

However the statistical studies that led to the creation of the computer program indicate that an alternative is possible. This alternative is that, instead of the Pittsburgh subsidence "wave" dying down in about 2020 A.D., so that events eventually cease, they would instead continue at a steady rate for an indefinite time into the future. A preliminary study of subsidence data from Illinois suggests that the "indefinite" model is a better fit in Illinois.

It is of the greatest importance to our understanding of the national impact of the problem to decide between these two alternatives. If the "wave" concept is correct, the problem, while serious at present, will die away over a human generation or two, at a finite cost. However if the process will continue indefinitely, the cost will accumulate to exceed the value of coal recovered and Pittsburgh may become economically uninhabitable, as are parts of Wales and Eastern

Pennsylvania at the present time, where no new industry dare locate in the region. The "indefinite" concept has geomechanical implications that allow the possibility of very substantial disasters at any time in the future. In support of that, it may be noted that while most subsidence events affect only a few acres at a time, there are two events in West Virginia in recent years that affected substantially larger areas, of the size of square miles.

The most effective method of deciding between the two concepts is to repeat the 1976 Pittsburgh data collection and conduct a statistical analysis to see what change has occurred in the rate of subsidence activity. The previous survey collected data up to the end of 1975, a re-survey some 8 years later should be sufficient to identify a trend.

The LANL 1982 model also needs revision to extend its capability to other rock types, other mining methods, than in Pittsburgh, if it is to be useful for other regions of the nation. This can be done fairly readily by collecting data from some other notorious areas in Illinois, Colorado, Wyoming, Kentucky, and from this determining the effect of regional changes.

THE DETERMINISTIC MODEL

A deterministic model is a computer program which is able to determine, for a specific underground opening, whether it will collapse as the rocks deteriorate with time, and if so, what engineering measures can be applied to prevent this happening.

The definition in the preceding paragraph is a statement of what we would like the model to do. In fact, no such model exists at the present time and the problem is to find out how to construct one. So this stage of the investigation would be a pilot study to determine how to construct such a model.

At present, deterministic models in underground engineering are of two main types. The first type is elastostatic, using methods such as finite differences, finite elements or integral equations to determine the ground stress that accompanies particular excavation designs and support procedures. The models predict whether a given design is stable or not. If it is unstable, the opening is re-designed for stability. There is no interest in determining what happens if the cavity fails, the design is to prevent failure.

The second type is displacement, using similar numerical methods, to determine what will happen around an unstable excavation. In this case, it is no longer of interest to confine attention to conditions of stability. Instead, failure is assumed and the interest is in what effect this has at the surface and whether operations can safely continue underground under these conditions.

Displacement models are the current frontier in design of undergroun openings, prompted by the introduction of complete-extraction mining methods in coal, particularly. There is still disagreement amongst various authorities of the most appropriate mathematical and numerical procedures.

For the past 6 months, LANL has been investigating methods of construction of displacement models and has decided to proceed with an approach which could be termed the vector potential method. The program is partially developed and some results have been obtained which confirm the validity of the method. It is particularly suited to analysis of the large ground displacements which accompany collapse of cavities and for assessment of the likely damage to surface roads, buildings and pipelines. A completed version of this model should have been tested against field observations in the very near future. It may be taken for granted that the mathematical and numerical problems will be disposed of, and that a functional computer model will be available for the start of these investigations.

The LANL deterministic(displacement) model will be able to determine the effect of mining method, at a particular site, on the damage that will ensue at the surface as the cavity collapses.

REVISED DETERMINISTIC MODEL

In any deterministic model there are a number of "undetermined parameters" which can only be established by calibrating the model against field observations. The reason is that there are some bulk material properties that cannot be measured in present laboratories because of the large size, complex boundary conditions or long times involved.

This is particularly the case in subsidence, where areas of square miles, inhomogeneous anelastic materials, and times of 50 years or more an involved.

It is therefore proposed to calibrate the model by examination of particular subsidence case histories. Several sites will be examined in detail to determine what actually occurred during subsidence, and material parameters will be adjusted till the model accurately predicts the observed behaviour. This will then provide an estimate of the appropriate bulk material properties over the long times involved.

It is proposed to select case histories from such examples as the following:

a)the uranium mines of central New Mexico, where a major subsidence disaster is in the making, to the point where some workings are becoming uncontrollable.

b)the abandoned coal mines in the city of Pittsburgh, Des Moines or Denver. These are particular problems because of surface urbanization and the community would welcome any new knowledge which contributes to disaster mitigation in their particular circumstances. There are technical reasons to expect better scientific results from Pittsburgh, such as the depth of background knowledge, intensity of the problem, and existence of excellent exposures in recent construction works.

c)An active mining region in the Kentucky-Pennsylvania area to examine the effect of abandonment procedures. A possible site is the Kitt Mine in West Virginia where some monitoring data has been obtained in recent years.

CONCLUSIONS

The proposed investigations are scientific studies designed to provide the foundations of knowledge needed to assess the national significance of the subsidence problem and plan response to emergency situations as they develop.

Present scientific understanding is limited by first, the very long time duration of the problem. With an average of 50 years between mining cause and subsidence effect, there is difficulty in relating cause to effect. By the time subsidence damage becomes apparent, the mining procedures which caused the problem have been forgotten. As a result, it is difficult to decide how to deal with the events as they occur.

The proposed investigations are designed to bridge the gap between cause and effect. The stochastic model will determine the relation between regional patterns of subsidence and general causes, and will be able to predict the type of disaster likely to occur as well as the severity at any particular date in the future. The deterministic model will provide a means of assessing the problem at any particular site and designing an appropriate response to particular emergencies.

Appendix 1
Appendix 2

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Appendix 1: General Review of the Subsidence Problem

APPENDIX 2

The LANL 1982 stochastic model

PREDICTION OF DELAYED SUBSIDENCE

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Contrary to active subsidence, which occurs concurrently with mining operations, or is completed within a few days following coal extraction, delayed subsidence may take many years to appear at the surface after coal mines are abandoned. There are two principal morphological types of delayed subsidence: troughs, which are shallow depressions, and sinks, which are steep-sided crown pits. Both types are damaging to surface structures, and a variety of methods have been introduced to deal with the problem, ranging from subsidence insurance to site restitution.

In planning insurance or restitution measures, a predictive model is of value in estimating the magnitude of the problem and the size of long-term budgetary commitments. Only one model is known, which was developed for the Bureau of Mines by GAI Consultants of Monroeville(1,2,3). The GAI model is presented in qualitative terms. This report develops a formal basis for the model and tests a numerical implementation on one of the best-described study areas, Allegheny County in Pennsylvania.

TERMINOLOGY

The terminology is illustrated in Figure 1. Let x, y, z be calendar dates: x the date of mine abandonment, y the date at which the mine structure looses stability, z the date at which subsidence first appears at the surface. Let a, b, c be intervals in years: $a = y - x$ is the lapse or hold-up time, $b = z - y$ is the travel or propagation time, $c = u + v = z - x$ is the delay time.

THE MODEL

Gray, Bruhn and Turka(3) portray the distributions of x, z, c and other derived variables. They describe the subsidence process as one in which subsidence events build up to a peak annual rate and then decrease. They suggest that current subsidence activity in southwest Pennsylvania may be the "crest of a wave" and that, after this passes, the annual frequency of subsidence events will decrease.

In order to construct a formal model, these statements are interpreted as asserting that x and c are two independent random variables and that z is dependent upon these as the sum, that is,

$$z = x + c$$

If N denotes a density function, so that, for example, $N_3(z)$ is the probability of a subsidence sink or trough appearing at time z, the distribution of z is the convolution of the distributions of x and c, that is, where * denotes the convolution operator,

$$N_3(z) = N_1(x) * N_2(c)$$

or, in terms of convolution integrals,

$$N_3(z) = \int_{-\infty}^{z} N_1(x)\, N_2(z-x)\, dx \qquad (1)$$

where the upper integration limit is dictated by requirements of cause and effect.

$N_3(z)$ is a probability density function. A subsidence prediction requires evaluation of the finite integral

$$M_3(z,u) = \int_{z}^{z+u} N_3(t)\, dt$$

which is the expected number of subsidence events in the period of u years starting at calendar date z.

To implement this model, we need the distribution of delay times, $N_2(c)$. An empirical distribution for Allegheny County is available from field work (Table 1), and we have also fitted some theoretical distributions to the empirical data.

We also need the distribution of mine abandonment dates, $N_1(x)$, and here some choices are possible. If we use the mine abandonment dates from subsidence field investigations the sample is completely biased towards those mines that have subsided. This reduces the utility of the model when we apply it to new areas in which only a small proportion the mines will give rise to subsidence events. If we use mine abandonment dates without taking account of mine size, we neglect the likely possibility that the probability of a subsidence event is a function of mined area. However the underground mine maps held at various repositories are generally incomplete and an integration of mine abandonment dates over worked areas would be a difficult task. Accordingly, we choose for $N_1(x)$ the coal production rate for the region. This has the advantage of being proportional to mined area. A possible disadvantage is that faces are maintained in operating mines for some time after production, so that production date is in advance

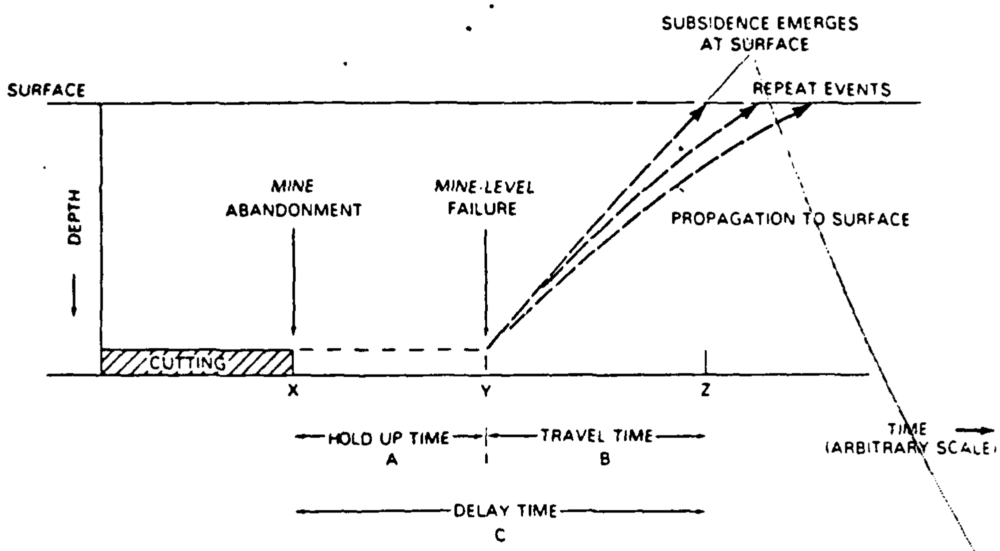

Figure 1: Random variables in delayed subsidence.

TABLE 1

Distributions of delay times, Allegheny County, PA. The empirical distribution is based on 132 delay times(3).

DELAY TIME Interval Years	CUMULATIVE FREQUENCY, % Empirical Distribution	Normal Distribution
0	0.000	0.037
10	0.000	0.337
20	0.758	2.048
30	6.818	8.401
40	18.182	23.785
50	51.515	48.090
60	73.485	73.153
70	89.394	90.021
80	97.727	97.430
90	97.727	99.552
100	99.242	99.948
110	100.000	99.996
120	100.000	100.000

of abandonment date. However operators close off completed sections and any difference will be only a few years. So little is known of the processes that initiate delayed subsidence that production date might, in any event, be a more relevant parameter than abandonment date.

The rate, $N_1(x)$ is not generally available, instead we have the finite integral

$$M_1(x,s) = \int_{x}^{x+s} N_1(t)\, dt$$

where $M_1(x,s)$ is the tonnage of coal mined in a period of length s years starting at calendar date x.

The model (1) can then be written

$$M_3(z,u) = \int_{t=z}^{z+u-s} \left(R\, M_1(t,s) \int_{c=z-t-s/2}^{z+u-t-s/2} N_2(c)\, dc \right) dt \qquad (2)$$

which treats the production as a delta function at the midpoint of each production period. The parameter R is a calibration constant with dimensions [number of subsidence events in period of length u/ millions of short tons of coal mined in period s]. The model is fit to the data by adjusting R, the only undetermined parameter.

FITTING THE MODEL

Results for Allegheny County, Pennsylvania, are shown in Table 2. Production for the county, $M_1(x,s)$, was assembled by searching Pennsylvania library sources. The production interval, s, was 10 years for the dates 1850-1870, 1 year thereafter. There are many missing years and these were estimated by a number of methods, including the estimation of county production as a proportion of state production of bituminous coal as tabulated by James(4) and including exponential interpolation for years that could not be determined by other means.

Recorded subsidence events, representing $N_3(z)$, were obtained from Gray, Bruhn, and Turka(3). Delay times, $N_2(c)$, were obtained from the same source.

The model was fitted to the observations for the period 1970-1975. The field survey apparently finished early in 1976, so data for the immediately preceding years is most complete. The low number of observations in 1976 is due to termination of the field survey, not to a sudden change in subsidence rate. The model was adjusted to fit the record for 1970-1975 by setting R to 1.612 for the empirical distribution of delay times, and to 1.893 for the normal approximation to the delay times.

Predictions are omitted for the years prior to 1910. This is because there is a truncation in $M_1(x,s)$ due to lack of production figures for the years 1780-1849. The model is valid only for the period starting about 60 years after the first production record. The figure 60 years is obtained from 4 standard deviations of c, that is, 4 times 15.03 years. Beyond 60 years, the effect of missing production figures is negligible.

TABLE 2

Subsidence predictions from 1910 to 1999 at 6-year intervals. The production data (column 3) is approximate. Recorded subsidence events (column 4) are from Gray, Bruhn, and Turka(3) for events classified as sinks, troughs and unknown, from Allegheny County, PA. Predictions based on model (2) are shown in columns 5 (empirical distribution with R = 1.612) and 6 (normal distribution with R = 1.893, mean 50.72 years, standard deviation 15.03 years).

Calendar Years First	Last		Production Millions of Short Tons	Number of Subsidence Events: Recorded	Predicted: Empirical Distribution		Predicted: Normal Distribution
1850	1855		5.00	0	—		—
1856	1861		5.96	0	---		---
1862	1867		7.88	0	---		---
1868	1873		10.70	0	---		---
1874	18[illegible]		12.10	0	---		---
1880	1885		16.21	0	---		---
1886	1891		24.74	0	---		---
1892	1897		29.34	0	---		---
1898	1903		36.88	0	---		---
1904	1909		47.89	0	---		---
1910	1915	M .	80.69	0	15		[illegible]
1916	1921	i P	83.48	0	20		21
1922	1927	n e	81.60	0	27		[illegible]
1928	1933	i a	84.20	0	36	.	[illegible]
1934	1939	n k	83.90	0	49		[illegible]
1940	1945	g .	90.70	0	61		61
1946	1951		66.50	0	77		[illegible]
1952	1957		48.12	13	[illegible]	.	[illegible]
1958	1963		35.89	10	117	.	[illegible]
1964	1969		25.90	28	129	P	[illegible]
1970	1975		20.85	139	136	e	[illegible]
1976	1981		15.45	2	143	a	[illegible]
1982	1987		11.09	---	145	k	[illegible]
1988	1993		8.28	---	133	.	[illegible]
1994	1999		6.17	---	117	.	[illegible]

DISCUSSION

The predictions of Table 1 illustrate the phenomenon that is the basis of the model. For example, there was a step upwards in production rate about 1910 and the subsidence effect appears as a delayed step at about 1960, many years after the cause. It is remarkable that mining activity about 1910 should have such unforeseen effects, some 50 years later.

However the model predicts many more subsidence events than have been recorded. The ratio of predicted to recorded numbers decreases backwards in time from the termination of the field survey. This can be explained by the method of collecting the field data, which depended upon interviews with residents and their memory of events in their neighborhood in the distant past. The rate of decrease is consistent with demographic data showing that the average residence time of urban citizens in the U.S. is about seven years. The probability of active recollection of subsidence events taking place more than 20 years prior to interview is negligible. Beyond this time, the only events remembered are catastrophes associated with active mining that were recorded in newspapers.

The lack of a comprehensive record of subsidence events makes precise calibration of the model a matter of speculation. The convolution integral (1) should probably contain another distribution for the "neighborhood memory" or sampling bias. Depending upon how this factor is assessed, there are large variations in the predicted subsidence.

It has been remarked, in discussions at this meeting, that active subsidence is potentially predictable, while delayed subsidence never will be. This may be true on a site-specific basis, but on a wide-area basis stochastic models of the type presented here are potentially capable of useful predictions as to the expected number of events in years following production.

The model (2) is simple to construct and can be run on a desk-top microcomputer in a few minutes. The construction of better models is not a computational problem but a problem in the experimental design of field surveys.

ACKNOWLEDGMENTS

I am grateful to Dr. Richard Gray, GAI Consultants, Dr, Phil Halleck, and Dr. Aaron Waters,

Los Alamos National Laboratory, for helpful discussions in the preparation of this report.

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BUDGETARY OUTLINE

1. Stochastic approach

a) Contract to GAI Associates of Monoroeville to repeat their 1976 survey and produce a data base of subsidence events since that time. Also to supply some missing coordinates from their 1976 survey.
Estimated $50,000

b) Contract to the Mine Repository Section, Bureau of Mines, Pittsburgh, to supply underground plans(for such events of the Pittsburgh data base for which mining plans are available).
Estimated $20,000

c) Contract to Illinois Geological Survey to provide their Illinois subsidence data as a data base in computer-compatible format.
Estimated $20,000

d) Contract to Mine Repository Section, probably at East St,Louis, Bureau of Mines, or to Engineering Department, University of Illinois, or to Illinois Geological Survey, to provide underground geological and mining data related to surface subsidence events.
Estimated $60,000

e) Equipment, digitizing, encoding, statistical analyses, programming, construction and calibration of stochastic model
Estimated $200,000

2. Deterministic approach

a) Contract to GAI Consultants of Monroeville or to Republic Steel to maintain intermittent monitoring over pillar-removal section at Kitt Mine,W.Va.
Estimated $ 20,000

b) Field work at Grants,N.M., and Pittsburgh
6 man-months Estimated $ 50,000

c) Equipment, programming, calibration of deterministic model
Estimated $200,000

$620,000

A wild guess for Barbara Killian only

LA-UR 83 - 1225

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36

TITLE: VOLCANIC HAZARDS: LOS ALAMOS NATIONAL LABORATORY CONCEPT PAPER

AUTHOR(S): Kenneth H. Wohletz, ESS-1

SUBMITTED TO: Informal Report for the Federal Emergency Management Administration (FEMA)

Los Alamos

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

FORM NO 836 R4
ST NO 2629 5/81

VOLCANIC HAZARDS: LOS ALAMOS NATIONAL LABORATORY CONCEPT PAPER

I. INTRODUCTIONS

The scope of this paper is that of an overview and therefore addresses the most general questions about volcanic hazards. The viewpoints established are those currently being pursued at the Los Alamos National Laboratory as well as those that have wide acceptability within the geologic community.

Three questions are: What are volcanic hazards and what have they been; what can be done to alleviate the problems of volcanic hazards, and in the present context, what needs to be done; how do we scientifically approach and study volcanic hazards? With these sort of questions in mind, this paper is aimed at giving a background outline to the study of volcanic hazards. In it we propose a methodology and attempt to describe how an interdisciplinary group, such as the Los Alamos National Laboratory where earth scientists work in close cooperation with those involved in state-of-the-art physical, chemical, and computation methods, can prepare hazard predictions, hazard precautions, and operate under stress-time (emergency) conditions. These objectives essentially fulfill a life-saving emphasis where prevention and mitigation coupled with response preparedness provide a minimization of volcanic hazards and emergencies, and allow restoration planning for long-range reconstruction in the wake of a volcanic disaster.

Volcanic Hazards - What Are They?

Volcanic hazards can best be evaluated by what they have been. On another level they can be likened to meteorological hazards such as tornadoes, floods, and droughts. With these respects they are inevitable, they are periodic in a complex way, they are predictable having magnitudes that can be evaluated on a 50 or 100 year interval, and they cause long-range environmental effects. Some specific aspects of volcanic hazards are:

Occurrence:

Direct effects of volcanic hazards are necessarily confined to volcanic areas. These areas are where volcanism has occurred within the last several million years and includes most of the western United States, Alaska, and Hawaii. The potential of the hazard increases around volcanoes that have had recent (in the last few centuries) activity. This area of risk includes much of Washington, Oregon, northern California, parts of other western states, Hawaii, and Alaska. The volcanic hazard of Cascade volcanoes of which over a dozen are imminently (within a century) active is obvious to many people. That of areas such as Mammoth Lakes, California; Yellowstone National Park, Wyoming; Clear Lake, California; San Francisco Peaks, Arizona; to name a few, is not so obvious. These not-so-well recognized areas present perhaps the greatest danger, due to the magnitude of possible eruptions (far exceeding those typical of the Cascades) and the lack of any existing preparations for the prediction of eruptions.

Mt. St. Helens (MSH) is one of the most active of Cascade volcanoes. Small-scale volcanic eruptions in general are typified by the 1980 explosions of MSH which ejected between 0.5 - 1.0 km^3 of ash. Those eruptions and their effects may be contrasted to large ones that have occurred at Yellowstone, Mammoth Lakes, and the Jemez Mountains in New Mexico, each of which have ejected several hundred to over one thousand km^3 of ash during single explosive phases. The devastation caused by an eruption of one of the large volcanoes compared with a smaller one such as MSH ($\sim$100 dead, tens of billion dollars total damages) is difficult to imagine. Likely the effects are comparable to those of a nuclear war in which not just a part of a state is immobilized, but maybe one-half of the United States would be immobilized by falling ash and other effects of the explosion.

Loss of Life:

Due to the explosive nature of some volcanoes, loss of life can be great because the eruptions happen quickly. Typically, eruptions in the past century have left hundreds to thousands dead in an instant. One only needs to read of the history of volcanism on Pacific Islands, Indonesia, Central America, and the Caribbean to realize the lethality of volcanoes. Their destruction, however, is just a pinpoint in time, and humanity exists without concept of the loss when compared to the long, drawn-out effects of warfare. Long range effects of volcanic eruptions are poorly understood; however, breathing volcanic dust can cause severe lung problems with infection and damage of tissue and this is just one effect to be considered.

Devastation:

Eruptions in the western United States have been shown to devastate areas of several tens of square kilometers to thousands of square kilometers during an eruption. By devastation, a complete removal of any life-form is meant. The effects of previous Yellowstone eruptions have been equivalent to that of hundreds to thousands of nuclear warheads. Those eruptions completely covered several western and midwestern states with over a meter of ash.

A small eruption such as MSH devastated timberlands with billions of dollars of wood lost. Imagine the effects of several or more states completely covered with a blanket of several feet of ash. A substantial portion of the

United States agriculture would be gone for several tens of years and hindered for the following century. This same blanket of ash would also stop all transportation in those states, stop all industry, and to a large extent require the evacuation of much of the area for years.

Even small ash clouds can prevent airplane transportation in and around them. Parts of the west coast of Washington were blocked during the Mt. St. Helens' eruptions. An ash cloud a thousand times larger would have stopped flights all over the western states for perhaps several weeks. Jets cannot fly in even the thinnest eruption clouds. Pilots flying 747 jet aircraft in seemingly clear air last year near the volcano Galunggung, Indonesia lost operation of their jet engines by microscopic dust.

A longer range effect of volcanic eruptions entails the problems due to water-shed instability. Areas devastated by eruptions and blanketed by ash are highly prone to flooding, avalanching, and slope instability. In many volcanic areas, ash deposits are unstable and quickly eroded. These deposits usually fill previous drainage systems so that in following years, creeks and rivers must recut their courses. As a result, much of the ash deposited by the eruption is moved to low-land areas in subsequent years. It will also fill rivers used for the purpose of water transport, terminating all barge traffic. This secondary process may devastate as much area as was during the primary deposition of the ash.

Social-Political Effects:

The economic impact and loss of transportation and communication during a small eruption may disrupt several communities directly and a state indirectly for a short period of a week or two. This effect has been demonstrated at

MSH. When billions of dollars of damages are assessed, the local and state political system must necessarily redirect its objectives to accommodate the affected populace. The effects are that of a small war. A large eruption can effectively cripple a total country. Due to a political campaign on Martinique in 1902 that required residents to stay in town for an election, 30,000 people lost their lives in an eruption. In short, the link between government and the individual is lost during a volcanic emergency and for a large eruption, this problem may persist for weeks or months.

Atmospheric/Climatic Effects

Perhaps the most important long-range effects of volcanic eruptions are only now being realized. This realization has grown from the study of the atmospheric effects by the small-scale eruption that occurred at El Chichon, Mexico. It is now evident that the ash cloud caused the unusually wet and cool spring weather experienced in the United States and Europe in 1983. This effect may last two or more years. The ash promoted temperature changes in the upper atmosphere and in the oceans that caused overall changes in storm circulation from the Pacific Ocean. Scientists now are studying the effects of very large eruption clouds and are beginning to realize that they may have been responsible for initiating ice ages and extinction of prehistoric life forms.

II. WHAT NEEDS TO BE DONE (SOFTENING THE BLOW)

The potential of volcanic hazards is understood for 50 year events such as MSH. Some ideas of hazard magnitude for 1000 year eruptions can be calculated. Still those of 5000 year eruptions can only be guessed and those have the potential to completely disrupt this country's economic and political system.

So preparation and mitigation plans need to be developed first for areas of volcanic hazards and then for country-wide effects. Hazard evaluation is not available for most areas of potential volcanic activity. Only since MSH has a large group in the U. S. Geological Survey been formed to deal with present hazards. It is only through scientific studies that disaster plans can be effectively made. Once we know the problem in detail we can plan in detail.

At present, since hazard evaluations are sparse, an organized group should be prepared to scientifically evaluate a hazard and have the ability to operate on short notice. Three stages of scientific study are necessary in evaluating volcanic hazards as outlined below. They are:

Evaluation of Historic Activity, eruptive types, and zones of devastation. This work allows a prediction of the type and magnitude of worst case and probable impending activity. It also defines the precursory volcanic signals that indicate the magnitude and type of an eruption.

Geophysical characterization requires an evaluation of regional seismic and geodetic (survey points) data. Set up of an array of seismographs and survey points allows moment by moment checks for underground movements that signal the timing of an eruption.

Atmospheric modeling considers present meteorological conditions that control the area that may be devastated by ash. The movement of ash is dependent on low and high altitude wind patterns, topographic features, and weather-front conditions. Models constructed for a specific area can show probable areas of devastation near the volcano and downwind for eruptions of various magnitudes. These models can generate maps that would direct the evacuation of people and establish zones of extensive danger.

III. HOW IS IT DONE

This section just gives a little more detail on the work involved in the preceding section. How do volcanologists, geophysicists, and meteorologists work together in preparation for volcanic hazards and during the event?

Volcanologists are familiar with all aspects of volcanoes and therefore can direct activities of physicists, chemists, and mathematicians toward an overall understanding of a hazard. In this way, scientists can employ the most sophisticated and accurate technical methods available in the study of the hazard.

Stratigraphy

When a volcanic hazard is first suspected, it can quickly be assessed by study of previous activity. The sequence of rocks and ash layers surrounding an awakening volcano can provide a detailed account of its character, patterns, and potential. The study of this history is called stratigraphy. The result of stratigraphic analysis is generation of a stratigraphic column (Fig. 1) which describes and illustrates the life history of a volcano in a time sequence of events. For example, history of explosive eruption is recorded in layers of pumice and fine ash. The structure of these layers describes the violence of the explosion and how the ash was deposited: by fallout of particles; by large avalanches or flows of cinders and blocks; by searing blasts of suffocating; incandescent gases and dust.

An effective method recently being developed for assessing various layers of volcanic materials uses the scanning electron microscope. This method evaluates the size and shape of ash particles as well as their chemical composition. By comparing particles in various layers to data on volcanic materials from historic eruptions all over the world, a quick assessment of the eruptive activity can be made. The sequence of particle samples - opening activity from lowest layers of ash, ending activity from top layers - gives information on the particular eruptive character of a volcano. Does it start out passive and become violent, or does violent activity commence with little warning? The sizes and shapes of volcanic particles are data that show the violence and eruptive mechanism. Their chemistry also allows assessment of harmful gases that are generated.

Modeling

Once the stratigraphic nature, the extent and volume of volcanic ejecta, and previous eruptive types are known, models of impending activity providing hazard zonation maps can be predicted from topographic and atmospheric conditions.

For deposits of ash resulting from fallout, the typical sizes, densities, and wetness of ash particles from previous eruptions are data for a computer model that calculates where ash will fall (Fig. 2). This model uses present wind conditions at different levels in the atmosphere and topographic controls to show amounts of ash fall to be expected downwind from the volcano for small-, medium-, and large-scale eruptions. This model is most important for far-field hazards, transportaiton, and communication effects.

For near-field hazards, where flows and hot gas blasts of volcanic ejecta occur (Fig. 3), topography is very important. From satellite images, a detailed array of topopgraphic data can be stored in a computer. The flow and lateral blast of particles emanating from a crater during explosive activity is primarily dependent on the height of the crater and eruption cloud in determination of how far the blast or flow will move from the volcano. This concept involves a potential energy surface which is high at the crater and decreases away from the crater intersecting the topographic surface at the furthest extent of devastation. Essentially, as a flow or blast cloud moves away from a crater it decreases in energy until it comes to a rest. In this way a flow may overtop ridges and other barriers until its potential surface is no longer higher than the topography. The distance to which ashes and lavas flow from a volcano is evident in old deposits and defines a typical energy surface for that volcano. This surface can be programmed in a computer with present day topography to produce maps of devastation in and around a volcanic area.

Geophysics:

Geophysical events such as small earthquakes, bulging, and collapsing of the ground level over large areas and even changes in the magnetic field and total gravity in and around a volcano occur before and during eruption. The change reflects the unseen movement of magma underneath a seemingly quiet volcano. These methods require sophisticated techniques to record and analyze data that show the tiny quiverings of the volcano and its slow "breathing." Much of the data is hidden in the background of normal seismic, tilting, and gravity changes in an area. To minimize the problem of background "noise," a volcanic area must be carefully analyzed from the standpoint of fault zones and unstable slopes. After specific, well-surveyed points have been established in a net-like fashion around and on the slopes of a volcano, permanent seismographs and tiltmeters can be installed. These devices continuously record earthquakes and tiny bulgings and settlings of the volcanoe's surface. The records are coded to radio signals that are received at a central station on magnetic tapes which can be used to generate graphs like those shown in Fig. 4. Volcanic earthquakes generate a specific signal that can be automatically recognized through computer analysis in order to alert personnel. Seismic and tilt records can be analyzed to calculate the amount, depth, and rate of magma movement towards the surface underneath a volcano.

Volcanoes, such as those in Hawaii, have been shown to generate characteristic geophysical warning signals of an impending eruption. Many volcanoes in the western United States, however, do not have geophysical arrays nor is the nature of geophysical precursors well-studied or characterized. Other geophysical techniques besides seismic and tiltmetry are still poorly developed, but may prove to yield important information on impending activity.

Atmospheric:

Day-to-day computer data on atmospheric conditions allow modeling of volcanic ash transport as mentioned earlier. Another important aspect of atmospheric study is plane flights near a volcano once activity has begun. These flights can be used to make infrared thermal maps of the volcanic area which pinpoint likely vent areas often in inaccessible regions where the ground heats up prior to an eruption. If mild acitivity precedes violent eruptions, sampling of the ash can give data for interpreting future events. Sampling during the eruption can give specific details on the distribution of ash and its abundance for use in air as well as ground transportaton rerouting. Some volcanic ash carries hazardous, corrosive, and often toxic materials which can be analyzed in the air prior to fallout downwind of the volcano.

One of the most promising aspects of atmospheric studies is that of LIDAR, a laser-type radar. This system can detect ash plumes that cannot be seen with the unaided eye, much as radar is used by meteorologists to detect rainfall. LIDAR gives information on the distance, height, and cloud particle density and is useful in charting the distribution of volcanic ash clouds.

IV. WORK APPROACH

The methods described above have all been tested and information on their cost, manpower demands, and completion time is available. This background provides the basis for an integrated plan-of-attack. In the advent of emergency conditions the scientific characterization and preparation can be implemented to several scales determined by the immediacy of the hazard. From previous studies, the work described can be completed on a one-week, month, or year basis. Generally, a one month warning occurs at quickly awakening volcanoes.

Once the time-level of scientific preparation is indicated, the before-eruption and during-eruption work activities can be set-up. These jobs are:

- I. Before Eruption
  - A. Identification of vents
  - B. Stratigraphy
    - 1. Volcano history
    - 2. Eruptive types and patterns
    - 3. Danger areas
    - 4. Ash and lava characterization
  - C. Modeling and hazard maps
  - D. Geophysical set-up
- II. During
  - E. Geophysical monitoring
  - F. Atmospheric surveillance and sampling
  - G. Ash characterication

Table 1 shows a matrix of operations that allows disaster mitigation on the scientific level. Without the operations preparedness, volcanic disasters tend to cause break-up of authority, poor scientific management, poorly conducted studies, and mismanagement of data. This table establishes a operations code which permits, on short notice, an efficient organized group effort with a minimum of chaotic conflicts. The work approach outlined also suggests an operations line of authority, a funding scheme, and a social/political interface.

The scientific work may also and should be extended to long-range effects analysis and restoration programs. The main volcanological effort involved in this phase involves characterization of the eruption deposits; their distributions and devastation; their effects on drainage systems; possibility of flooding, avalanching, and mud flows; and analysis of likely future activity. Much of the post-eruptive work involves that of a stratigraphic analysis described. Ongoing geophysical surveillance is very important to time future eruptions and their magnitude. Atmospheric sampling must be continued to follow the distribution of high altitude volcanic ash and assessment of its effects on climatic controls.

III. After

A. Devastation analysis

B. Flood and erosion prediction

C. Avalanching and mud flow hazards

D. Ash cloud dispersion and climate effects

E. Geophysical warning system of renewed activity

V. RESULTS AND DELIVERABLES

The primary objective of volcanic hazard assessment is formulation of a scientific basis for mitigation of the emergency and long-range planning. The tangible results of implementation of the work outlined above are listed below as deliverables.

- Historic behavior of a volcano and probability of future eruptions.
- Hazard maps based upon models that delineate areas of relative disaster and safety.
- Geophysical set-up for continuous monitoring of volcano status.
- Downwind atmospheric model outlining far-field hazards.
- Hazard preparation, prediction, and mitigation criteria.
- Social-economic impact for near-field and far-field effects.
- Rehabilitation limitations and long-range consequences.

Each of these deliverables may assume a report status for evaluation in government operations as well as the media interface. The relative importance of the above documents may be weighted for planning use. Due to the group effort approach and chain of authority, more control may be exerted on the release of qualified information to the media. The social effect of misinformation during emergency situations needs careful attention and the scientific/social interface appears to be another important facet of volcanic emergencies.

In the case of possible extreme social reaction to impending disasters, a teaching format is suggested for release of information. This method requires individuals capable of understanding scientific data and relating it to media sources.

VI. CONCLUSIONS

Natural hazards are a facet of all of our interactions with the environment, including dwelling safety, the economy, communications, and political/social welfare. Preparation and planning for the statistical occurrence of hazard emergencies are strong logical efforts that have both possible short- and long-range effects especially in saving lives and alleviating economic disruption.

The awakening of MSH, followed shortly by that of El Chichon, Mexico, has demonstrated the destructive behavior of small-scale volcanic eruptions. The devastation, loss of life, economic, and social problems of larger-scale eruptions likely increases exponentially, as do the studied associated geologic phenomena. Hazard preparations have not been made for most volcanic areas in the western United States. Although the U. S. Geological Survey has reports for several Cascade volcanoes, these do not offer a systematic plan for scientific evaluations in the advent of new activity.

The consequences of very large volcanic eruptions such as those that can occur at Yellowstone, Mammoth Lakes, and Clear Lake may be as devastating as a small-scale nuclear war centered in the United States (to draw an analogy), and the effects of such are not well-studied nor are any contingencies or plans available for quick implementation.

The main problem in disaster preparation in a state of emergency, from our experience, is that of organization of an efficient scientific effort which is designed to aid political, social, and economic decisions. For utmost confidence in emergency actions, decisions need to be made on a clearly defined state-of-the-art scientific effort which requires interdisciplinary organization and work, combined with modeling capabilities to quickly relate information as well as to provide a sound basis for prediction.

We have learned that the efforts outlined above are best-achieved by a close-knit effort using a team approach where groups of individuals concentrate on specific problems and report to the project authority.

In conclusion, a volcanic emergency is likely to occur in the United States on 50 year intervals with one of nation-wide consequences perhaps once in several hundred to one thousand years. A basis for preparation and mitigation as well as rehabilitation from such an event can be likened to a war-time state and the scientific effort needed is available at Los Alamos where we have organized science, experience, technical support, and stress-time preparedness.

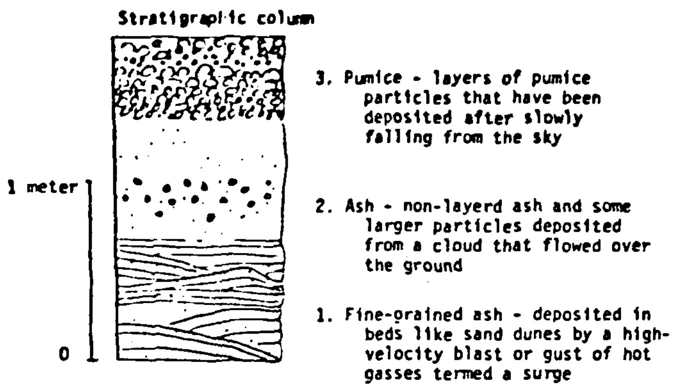


Fig. 1. An illustration of a stratigraphic section; the sequence of volcanic ash beds deposited by three phases of an eruption. The first phase was marked by a lateral blast (surge) of fine ash and incandescent gases which lasted only a few seconds; the second phase shows that ash and depbris flowed out of the volcano in a continuous manner for several minutes; the third phase was a rain of pumice that accumulated on the ground like hail stones.

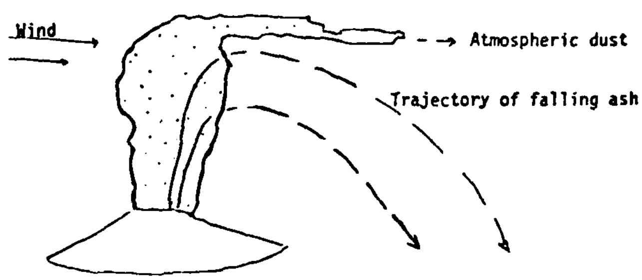


Fig. 2. Modeling of ash transport to far-field localities is based upon the wind velocity and ash partilce size to determine how far ash will be transported before it settles to the ground. High altitude dust may stay suspended for several months or years thereby causing changes in weather patterns.

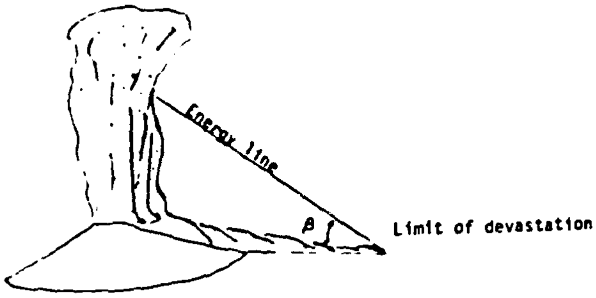


Fig. 3. Modeling of near-field lateral blasts (surges) and flows of ash uses the energy line concept which is a measure of gravity's affect upon flows and surges originating from different elevations above the crater. The distance from the crater that these volcanic clouds devastate is marked at the location where the energy line intersects the topographic contour (ground level).

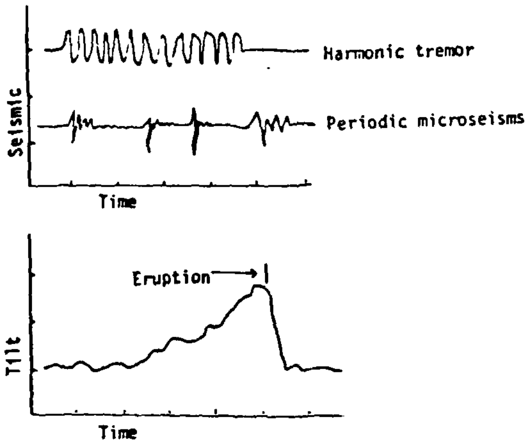
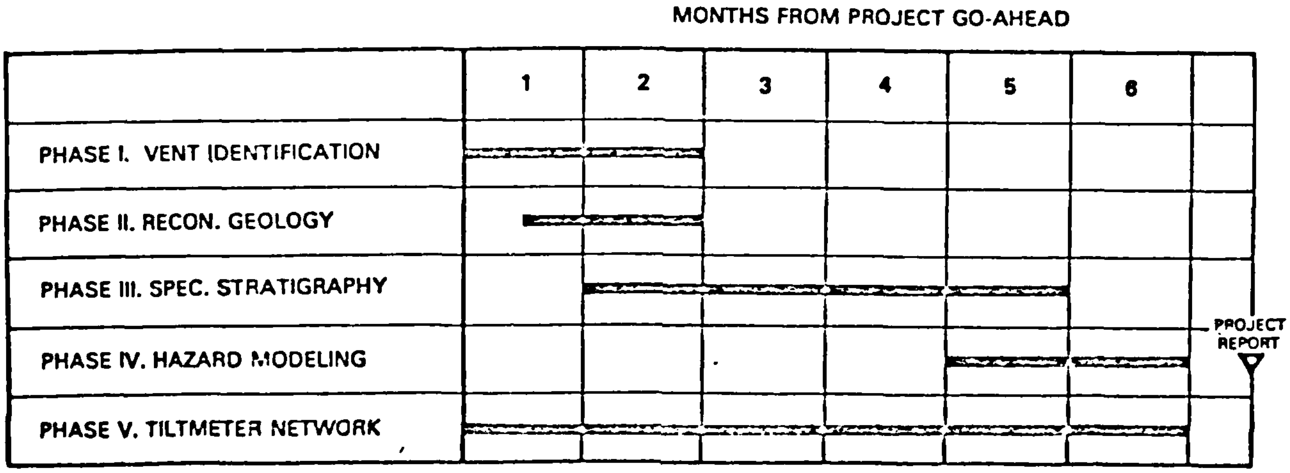


Fig. 4. Graphs of geophysical signals of volcanic activity. Harmonic seismic tremor indicates magma movement and steam activity below the ground surface; periodic microseisms show slow magma movement into cracks and fissures below the surface. These earthquakes often pass unnoticed, however, they signal an awakening volcano. Tilt records show the imperceptible change in ground level on or near a volcano before an eruption. Often these records indicate the inflation of the volcano with new magma and gases.

Table 1. Operations table for volcanic hazard analysis in the West Indies by Los Alamos National Laboratory.



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TITLE: LOS ALAMOS NATIONAL LABORATORY'S FEMA EMERGENCY SUPPORT CENTER

SCOPE: This multiyear program is designed to develop and provide a capability and resource to assist FEMA in its emergency management planning and training.

OBJECTIVE:

Establish a FEMA Emergency Support Center that would provide:

- Computer-based simulation of complex emergency situations and proposed responses. Such simulation products will access relevant data to provide rapid evaluation of proposed response scenarios and the training of individuals charged with managing emergency situations.
- Computer based simulation of power, communication, transportation, and other critical systems in order to identify and eliminate vulnerabilities before an emergency can occur.
- Low-cost simulations and systems that can be placed in the field to train local authorities charged with managing emergency situations.
- A support system to generate, maintain, and update software for FEMA computer network that will allow rapid promulgation of emergency management information and remote access to the more complex simulation programs.
- Other emergency simulation support to FEMA as needed.

BACKGROUND:

Anyone who has seen or played the modern video games must recognize the power of a well-designed computer simulation and especially its effectiveness in training. Computer simulations are also a very cost-effective way to evaluate the usefulness of a proposed response to a disturbance to the system being modeled.

A multipurpose simulation laboratory is planned for Los Alamos National Laboratory in support of national security interests. One of the primary purposes for developing this facility is to provide an interactive environment permitting real-time investigation of multivariate interactions and associated learning processes. Creation of an Emergency Support Center to service FEMA and the emergency management community could be developed peripherally to the proposed Los Alamos multipurpose simulation laboratory. Such a step would make the capability available to many more people and eliminate much duplication of effort. The existence of such a center, with its computing capacity and expertise, will provide new tools to managers of activities concerned with emergency preparedness and allow them to incorporate relevant data and procedures into their responses.

APPROACH:

This is a multiyear phased program that provides during the initial year for the design and development of an implementation plan for the proposed FEMA Emergency Support Center.

It is anticipated that the evolving plan will provide many desirable and useful capabilities including:

- Development of training packages and computerized training aids to support a variety of applications including terrorist countermeasures, response to emergency situations, civil defense actions, postemergency procedures, nuclear emergencies, and search team activities. Some of these simulations will be structured so as to be useful to location officials using inexpensive, portable microcomputers.

- Development and evaluation of methodologies, approaches, modifications of doctrine, and other complex issues by incorporating the theories of statistics and/or direct human involvement into the evaluation process. Associations and correlations can then be identified and used as a basis for proposing changes or making predictions concerning an existing situation.

- Investigation of "EXPERT" programs as a way to assist FEMA in evaluating and responding to emergency situations. The approach will be to develop artificial intelligence techniques and incorporate them into simulation products. This should lead to reduced human interaction in actual emergency situations and also ensure that the simulation tools developed can be more effectively used.

SPECIAL CAPABILITIES

The computing capabilities and experiences of the Laboratory range from the most modern CRAY supercomputer to the least expensive microcomputers such as the APPLE or TSR-80. In addition, Los Alamos computing systems can provide proper levels of security to protect classified, sensitive, or proprietary information. This wide range of secure computing capability, combined with decades of experience with the most complex computer simulations, make the Laboratory uniquely qualified to develop a FEMA Computer-based Emergency Support Center.

SCOPE OF WORK

Phase 1.

During the first year of this program, the Los Alamos National Laboratory will commit two staff members to the design and development of an implementation plan for a FEMA Emergency Support Center. This plan will define the data bases to be acquired and developed, design and data base management systems required, identify the initial computer-based simulation models and training aids which will best assist FEMA in its emergency management and planning functions, identify the hardware and software necessary to support the center, and in coordination with FEMA, develop a joint Los Alamos-FEMA staffing plan for the Center and potential users of the facility.

Phase 2 and Subsequent Phases.

Based upon the results of Phase 1 of this program, the specific products and capabilities identified will be developed during the subsequent phases based upon priorities developed in coordination with FEMA.

lyzed in the air prior to fallout downwind of the volcano.