



ENVIRONMENTAL  
RESEARCH INSTITUTE  
OF MICHIGAN

FORMERLY WILLOW RUN LABORATORIES, THE UNIVERSITY OF MICHIGAN

P.O. BOX 618 • ANN ARBOR • MICHIGAN • 48107

PHONE (313) 483-0500

TWX 810-223-7019

17 April 1973

IN REPLY REFER TO:  
ERIM-73-144-L1

National Science Foundation  
Contracts Branch, Room 630  
1800 G. Street, N.W.  
Washington, D. C. 20550

Attention: Mr. Barry D. Brown  
RFP 73-123

Subject: Technology Assessment of Geothermal Energy  
Resource Development

Reference: (a)/RFP 73-123

Enclosures: Volume I - Technical Proposal  
Volume II - Cost Proposal

The Environmental Research Institute of Michigan is pleased to submit the above subject proposal for your consideration. This proposal is being submitted in response to Reference (a) and is divided into two (2) volumes. Volume I provides a technical discussion while Volume II deals solely with the cost breakdown and contract representations.

It is anticipated that Dr. George Zissis, Research Physicist, will serve as Principal Investigator with Dr. Virginia Prentice, Associate Research Geographer, as Deputy Investigator for the proposed program. Biographical summaries are presented in the proposal for research personnel, consultants, and oversight committee who are expected to be available to participate on the program; however, the contract with Environmental Research Institute of Michigan should not specify an individual by name.

Present planning indicates that the proposed 12-month program could commence upon receipt of an executed contract. Because effective planning is dependent upon prior knowledge of commitments of manpower and facilities, it is requested that the Institute be advised as to the intent of the Sponsor at the earliest possible date. In the event a contract is not executed within four (4) months

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from the date of this proposal, the Institute reserves the right to assess its current work load to determine the availability of manpower and facilities for performance of the proposed work.

In the event that a contract is awarded to the Environmental Research Institute of Michigan as a result of this proposal, it is requested that a Cost Plus Fixed Fee type contract be granted.

If additional technical information is needed, please communicate with Dr. George Zissis (Area Code 313, 483-0500, extension 281), or Dr. Virginia Prentice (extension 313). Inquiries of a contractual or administrative nature may be directed to Messrs. Robert E. Lambert or Joseph R. Welch (extension 341).

Sincerely,

  
for Howard W. Courtney  
Contracts Manager

IMP:ns

PROPOSAL FOR TECHNOLOGY ASSESSMENT OF GEOTHERMAL ENERGY  
RESOURCE DEVELOPMENT

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## ABSTRACT

The Environmental Research Institute of Michigan (ERIM) submits this proposal in response to the National Science Foundation's RFP 73-123. This program is a recognition of the national importance of the systematic exploitation and development of energy resources, both in the short and the long run. Geothermal energy may supply an important portion of the solution to our energy needs.

Extraction of heat and generation of electricity from geothermal energy sources is not a new art. Schemes involving direct use of steam and hot water have been proposed with technology now at hand. In such cases economic issues and the considerations of social costs, environmental protection actions, legalities of ownership, and government regulatory policies are foremost. A significantly increased level of resource development has been envisioned if the technology for economical extraction from hot dry rocks can be achieved. In almost all of these cases the possibilities of mineral extraction and water treatment must be examined.

Energy policy considerations received considerable discussion prior to passage of the Geothermal Steam Act of 1970 during the 1970 hearings of the Committee on Interior and Insular Affairs. A brief review of some of the subsequent discussions and actions on energy policy is presented in this proposal. Recently introduced legislation would create a three-member Council on Energy Policy in the executive side of the government, a five-member Federal Power R&D Board, and a

multi-billion dollar federal research and development program involving five newly-created federally-funded resource development corporations. One of these is entitled "Geothermal Energy Development Corporation."

With the heavy involvement of at least eight major departments and agencies of the federal government, the desirability of and requirement for a policy study to prepare and present alternatives, options and strategies in the development of geothermal energy resources for decision-makers and the general public seems clear. A Technology Assessment is proposed to systematically analyze the full range of economic, social, environmental, political, institutional and other consequences of the development and introduction of geothermal energy resource technology.

An interdisciplinary team of University of Michigan faculty led by ERIM scientists was created less than a year ago to begin a technology assessment of remote sensing under NSF support. The philosophy and methodology of technology assessment developed by them for that study are used as the basis for design of the specific strategy proposed for this assessment program. This approach emphasizes the uses of scenarios and a value-oriented development of the structure of the impact space. Addition of a few experts in geothermal energy technology as consultants from the University and other organizations has strengthened the capability of the Technology Assessment Group to the level felt optimum for this assessment.

Five specific tasks are proposed:

- I. Develop a specific project philosophy and technology assessment methodology.
- II. Formulate an over-view of potential geothermal power technology.
- III. Identify and analyze impacts.
- IV. Formulate policy alternatives and research recommendations.
- V. Design dissemination and utilization of results.



For this final task it is suggested that the use of gaming-simulation may be a needed innovation if the critical coupling of the results of technology assessment to the policy-making elements of society is to be successfully achieved.

## NARRATIVE

## 2.1 Study Plan

As stated in the National Science Foundation Request for Proposal RFP 73-123, "The systematic exploitation and development of energy resources is an issue of national importance both in the short and the long run." This response from the Environmental Research Institute of Michigan presents a study plan which reviews the technology, matters of policy and impacts, the philosophy and methodologies of technology assessment, a preliminary specific methodology for the proposed effort and discussion of the dissemination and utilization of the anticipated results of the study.

### 2.1.1. Geothermal Energy: Resources and Technology

The legends of the goddess Pele are replete with instances of benevolence and malevolence on her part to the dwellers of the Hawaiian Islands. She often gave and often took. But no one disputed her power.

That power--potential source of large amounts of electricity, heat, and minerals--is one which has attracted many engineers and a few scientists. Now that the "energy crisis" has been recognized in the agendas of all parts of the United States government the use of the natural heat of the earth is beginning to be seriously examined.

Pursuit of this capability has been under way for many years. In 1904 a few electric lamps were powered by electricity from a natural-steam driven generator in Larderello, Italy. Since then plants providing tens to hundreds of megawatts have been built in New Zealand, Russia, Japan, Mexico and, in the United States, in California. Geothermal power has been obtained by use of "wet steam", i.e., steam occurring with hot water, and dry steam, that steam found without hot water. Naturally, such steam, with or without hot water, can and has been used for heating purposes. Iceland long has had homes heated in this manner. Here in the U.S. buildings and houses in Klamath Falls, Oregon, have been heated for many years by geothermal power.

In general, geothermal power from hot water or steam is cheap in operation; initial development of such systems, however, is quite costly. Further, the availability of geothermal sources for such power development is rather limited. Technology, which does not now exist, for extraction of power from dry "hot-rock" sources could radically change this situation.

The literature on geothermal energy presents a fascinating picture of rediscovery and popularization of a technological topic. Titles and subtitles reveal a growing awareness and the development of a theme -- the credo of a vast, untapped, natural source of energy.

For example, "Geothermal Energy - The Neglected Energy Option" by R. W. Rex includes the following summary: "A vast supply of natural steam, produced by heat within the Earth itself, exists in the United States as an energy source for generating electric power. Geothermal energy is clean and it is cheap." [1] Professor Rex, who was then (1971) at the University of California, Riverside, is now associated with the Pacific Energy Corporation working toward a realization of development of geothermal energy systems. Another example is J. Barnea's article in the January 1972 issue of Scientific American which begins, "An old source of power for man's work has begun to attract new interest." [2]

An Associated Press news story which appeared in March 1973 begins, "There is a treasure in California's weak earth. It's called geothermal energy and man increasingly is trying to harness it." The article goes on to speak about "...a vast store of energy that may be the cheapest, clean source of new power for some time to come," and states that "...it appears the bandwagon is beginning to roll." [3]

The article "Geothermal - Earth's Primordial Energy" published in 1971, contained the statements; "Only a fraction of the earth's interior heat may ever be available to man. But geothermal sources are now grossly underdeveloped; they hold the potential for a significant increase in U.S. energy resources." [4] Bowen and Groh go on to state "The pace of geothermal exploration and development has been slow in the United States for the last ten years because federal land

where most of the geothermal resources are believed to lie, were closed to development." They cite the federal leasing law (Geothermal Steam Act of 1970, Public Law 91-581, December 24, 1970) as reason to believe that this picture will now change.

In 1965, the USGS published Circular 519 entitled "Geothermal Energy".[5] This survey, prepared by Donald E. White, brief as it was, and "...hampered by a serious lack of data," contains several important judgmental statements about geothermal energy resources. White says that "Geothermal heat supplies only a very minor fraction of present (1965) domestic and world use of energy. Total utilization of geothermal energy in the world today is roughly equivalent to a production capacity of 1 million kw, and approximately half of this total has been developed in the past 15 years. In the future, geothermal energy is expected to be of considerable local significance and of much greater total quantity than now, but it is not likely to rank as one of the major sources of energy."

In USGS Circular 650, in 1972, the assessment is made that "The resources of heat in potential geothermal energy resources are poorly known. The total resource base for the United States is certainly greater than  $10^{22}$  calories of which only  $2.5 \times 10^{18}$  calories can be considered identified and recoverable at present."[6]

In May 1972, the summary report of the Cornell Workshop on Energy and the Environment, sponsored by the NSF/RANN Program and the Senate Committee on Interior and Insular Affairs, was published.[7] It contains a very interesting appraisal of the potential for geothermal energy development. The summary statement (pg.92) begins; "The surprise of the workshop was the very optimistic assessment of geothermal energy presented by Professor Rex." It concludes with; "Dispite these (environmental and deemed not intractable) problems, the panel was impressed by the necessity for investigating geothermal energy more seriously."

Indeed, S.1283, The National Energy Research and Development Act of 1973, introduced by Senator Jackson jointly with 27 co-sponsors in March 1973, seeks to establish for major activity in this field, a Geothermal Energy Development

Corporation as one of five resource development corporations.[8] International interest was most recently shown by a well-attended three-day seminar on geothermal energy held at the United Nations under sponsorship of the U. N. Department of Economic and Social Affairs with assistance from the Center for Energy Information.[9]

The advocates whose names appeared in the few documents just cited before, together with many others, contributed to the June 1972 hearings of the Senate Committee on Interior and Insular Affairs. The resulting publication, "Geothermal Energy Resources and Research"[10] contains the most complete and current summary of the state-of-the-art of geothermal energy technology and resources. Statements by Senators Bible, Fannin, and Goldwater, all indicated that geothermal power was an extremely promising and valuable resource calling for vigorous and immediate development. A somewhat different perspective was presented by Assistant Secretary John W. Larson, Department of Interior who said, "While the development of geothermal power is of importance to the nation and can supply additional source of relatively clean energy, it can at best only supply a small portion of the Nation's need on the basis of present scientific know-how."

The statement presented by Dr. R. W. Rex at those hearings included the following appraisal: "Now my main concern with the testimony that I have heard this morning is the extreme conservatism of the Department of the Interior in really pushing its own research efforts. I think it applies to really almost all of the Federal Agencies. Certainly it is true with the AEC, it is true with the National Science Foundation." Dr. Rex developed his thesis further in the afternoon, urging acceleration of geothermal energy development, adding; "My main point in being here today really is to point out that I think the various Federal agencies that are involved have taken almost a slowpoke pace in pursuing their R & D program, and the projections for the next few years for geothermal research are for lower, for example, than are projected for solar energy." Dr. Rex also spoke to the need for more scientific data as a basis for evaluation of proper consideration of the depletion allowance and his view that geothermal environmental impacts should be easily containable.

J. Hilbert Anderson gave his estimates of geothermal energy resources which were in good agreement with those by Dr. Rex. Anderson discussed his concept which entailed isobutane in a vapor turbine cycle and listed the advantages he saw in an isobutane hot water plant over a steam flashing cycle. The statement by Dr. A. J. Eggers, Jr. of NSF presented what he felt were the major challenges to be met in this field. Dr. Donovan, speaking for Dr. Eggers in his absence added, "We do know geothermal will work in a technical sense. The main question is whether technology can be developed which is sufficiently economical to make it usable on a much larger scale than we presently can."

Large scale production of geothermal energy remains the major technological issue in geothermal energy resource development. Economic considerations must include the costs of control of unfavorable environmental impacts. Some of these are reviewed in the Assessment of Geothermal Energy Resources, a substantive study prepared for the Committee on Energy Research and Development Goals, Federal Council for Science and Technology, by the Panel on Geothermal Energy Resources, September 25, 1972.[10]

Much more must be learned about the true nature of the geothermal process if utilization of this source is to contribute significant power. As mentioned before, much attention has been given to the naturally occurring but relatively rare geothermal steam sources near the surface [11]. Great economic gains can be made if ways can be found to tap the more prevalent hot dry rocks.

Two schemes have been proposed to extract energy from hot dry rock. Both depend upon the injection of water into rock which has been fractured artificially. Harlow and Pracht [12] made a theoretical study of geothermal energy extraction from deep drilled wells for the removal of natural heat energy in the absence of natural steam. They indicate that under favorable (but perhaps not unreasonably exotic) circumstances, the extraction of significant thermal power from each well can be expected to continue for many decades. An assessment of geothermal resources should take into account the potentiality of such less accidental sources.

#### 2.1.2. Energy Policy

In January 1973 Senator Hollings introduced, on behalf of himself and Senator Magnuson, Moss and Tanney, S.70, a bill entitled "Energy Policy Act

of 1973." Although this is the latest, extremely visible action in the discussion and creation of a national energy policy, as visible as was the first Presidential message devoted entirely to energy issues on 4 June 1971, perhaps the action of greatest potential in examination and formulation of a U. S. national energy policy was the establishment under Ford Foundation support of the Energy Policy Project.

The Energy Policy Project (EPP) was established in Washington, D.C. in May 1972 in response to the observation that, of the large number of energy studies underway, much of the work is limited to technical problems and stops short of policy analysis. The Energy Policy Project is an attempt to make a significant contribution to the totality of the energy policy problem. The Project hopes to serve as a focal point for researchers who wish to extend their work into the policy field. The major goal of this Ford Foundation effort is the creation of a comprehensive framework for policy analysis.

A specific study for the EPP is now underway at the University of Michigan. An interdisciplinary team has been formed to focus on the accurate determination of the total energy costs required to clean up the environment. These costs are to include the energy needed to operate the pollution control equipment and the energy required for its production. The study will also consider an environmental problem which could become an asset, i.e., it will examine the potentially beneficial uses of waste heat from power plants, uses such as residential heating and cooling, steam for industrial processes, and fuel production from agricultural and urban organic wastes. The Project Director of the University of Michigan study, Prof. Marc Ross, has agreed to serve as a consultant to ERIM on our proposed technology assessment. His expertise will be particularly useful in the areas of energy policy and alternative technologies. His participation will allow the assessment to build upon the EPP work at the University and will facilitate the influence of the research results on the formulation of a national energy policy.

S. David Freeman, former director of the Energy Policy Staff of the Office of Science and Technology, and now Director of the Energy Policy Project, recently noted that "...since New Deal days...government policy has been to try to keep energy costs as low as possible in order to stimulate ever-expanding use. This was right for the time, but now times have changed and the policy hasn't. The

time has come to change habits and begin practicing energy conservation, even energy frugality." [13]

The need for a national energy policy has been widely acknowledged. Federal legislation is pending in a number of bills such as S-70 the Energy Policy Act of 1973; S-357, the Federal Research and Development Act; and S-1283 the National Energy Research and Development Policy Act of 1973.

S-70 would create a 3-member Council on Energy Policy in the Executive Office of the President to advise him and Congress on all energy policy matters. The Council would be directed to formulate a long-range, comprehensive energy plan and make policy recommendations, coordinate all energy activities of the federal government, and serve as a central collection point for all energy information.

S-357 would create a 5-member Federal Power Research and Development Board to finance R&D programs to develop new clean sources of energy specifically including solar and geothermal. The board would also be directed to investigate more efficient methods of energy transmission and utilization and encourage implementation of energy conservation practices. Funding for the program would be obtained by imposing a 1% surcharge on consumer electric bills.

S-1283, introduced recently by Senator Henry Jackson and 27 co-sponsors, would establish a multi-billion dollar\* federal energy research and development program creating five federally funded, single-purpose corporations for development of geothermal, coal gasification, shale oil, advanced power-cycle, and coal liquifaction energy technologies. Mineral resources of the public lands would be available to the corporations whose goals would be to advance the potential energy technologies to the stage of commercial applicability.

S-70 and S-357 are almost identical to bills introduced in the 92nd Congress. S. David Freeman, frustrated with the slow pace of the legislative process in creating a central energy coordinating agency, suggested to the House Interior and Insular Affairs Committee in May 1972 that "...serious consideration should be given to taking action now to consolidate the significant

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\*"taken together, the program I propose...will increase Federal funding of energy R&D from the present level of less than \$800 million to about \$2 billion annually over a period of 10 years." Senator Jackson's statement [14]



energy R&D activities of the Federal Government into a single agency. AEC is the one Federal agency which has demonstrated the ability successfully to develop new energy technology. It has the technical talent and the laboratories. There is every reason to employ the AEC national laboratories on all aspects of energy R&D. The new agency would consolidate the many scattered R&D efforts in the Interior Department and the Environmental Protection Agency with the AEC's program. Its mission would be energy R&D, not any particular form". [15]

Freeman pointed out that funding for energy R&D is going to require a much larger financial commitment by the Federal Government as well as by the industry, but it is important that Government and industry both be involved especially as the technologies move closer to commercial reality.

In the same hearings, the late Dr. William T. Pecora, then Under Secretary, Department of the Interior, noted that President Nixon's proposed reorganization of the Executive Branch had "...recommended that the responsibility of energy and mineral resources be centralized in an energy and mineral resource administration within a new department of natural resources. Here, Federal energy policy will be integrated and will be developed...".[15]

The Jackson National Energy Research and Development Policy Act of 1973 (S-1283) represents a more aggressive approach to bridging the gap between R&D and defusing the energy crisis. As Senator Jackson noted when introducing the Bill, "Even if a favorable 'economic and regulatory climate' were achieved, I question claims that research and development efforts would improve. Quite the contrary, favorable economic climates in the past have encouraged complacency and neglect of potentially favorable technological alternatives. Whatever R&D is being done, has been forced by adversity." [14]

Although President Nixon's 1973 Energy message has not yet been delivered, and current administration policies have yet to be defined, the Fiscal Year 1974 Energy budget does indicate an increase in R&D funding for geothermal and solar energy from \$8 million in Fiscal Year 1973 to \$16 million in 1974 [16]. These are still minor expenditures in the total picture of \$772 million for energy research.

Further evidence of the current unsettled state of affairs regarding federal energy policy can be found in Congressional Hearings and proceedings of conferences such as Energy and Public Policy - 1972 held by The Conference Board in April 1972 [17]. The objective of The Conference Board Meeting was to attempt to define the complexities of the energy policy problem. The complexities were confirmed but, as noted by one participant, Harry Parry, an energy policy will not be easy to develop even if it could be decided in the absence of political issues that can be expected to influence energy policies in a very broad way. [17, p.218]

The Senate Committee on Interior and Insular Affairs is about to conclude a comprehensive study of national fuel and energy policy and will begin to deal with specific recommendations for legislation and administrative action. An assessment of the economic, environmental, social, political and legal implications of new energy technologies, especially as related to the total energy problem, would be of great value to the efforts of the committee.

### 2.1.3. Side Effects and Institutional Involvement

By and large the energy policy considerations discussed above are aimed at integration and expansion of efforts to attack the problems encompassed in the phrase, "The energy crisis." Typical of these problems are the conflicts posed by the desire to have freely available greater and greater amounts of energy per capita against the costs of resource depletion and degradation of the quality of the environment. Policy must eventually adjudicate between the many demands for the "good life" here and now, and the unspoken demands and need of future generations. Thus, although benefit-cost analyses are most commonly associated with an economic examination of a technological development, a comprehensive technology assessment will also focus on environmental and societal benefits and costs.

Geothermal power sources must be compared with alternative systems. For example, solar power has been considered to be in the long term an ideal source, being practically inexhaustible and seemingly pollution-free. However, potentially negative environmental impacts were identified by R. A. Cellarius in a paper entitled, "Will Solar Power Systems Really be Pollution Free?", presented at the 1972 International Solar Energy Society Meeting [18]. Prepared while he was at

the University of Michigan, this paper concludes that small scale rather than large energy systems are more desirable. As another illustration, we must consider the detrimental effects of the sulfur effluent accompanying the steam rising from a geothermal power system and compared it to the pollution factors associated with other alternative power sources. Environmental and health considerations enter as more than simple costs.

An examination of the social-psychology side effects inherent in the introduction of geothermal energy technology will reveal the need for action recommendations and a subsequent conveyal of scientific data to the general public. The perceptions and attitudes of the constituency toward proposed geothermal activities may create a rebellious attitude toward policy makers. Society may denounce what appears to be dangerous tampering with the earth's inner works. Traditional beliefs may conflict with modern technological activities which might prove hazardous to one's survival. An examination of the social-psychological effect of technology utilization may reveal a skeptical public reaction toward technology introduction.

The introduction of geothermal energy resource development may require changes in the institutional framework of society. This new energy technology may create a need for a new Federal agency just as did atomic energy.

An examination of the various governmental, industrial, and educational institutions (see Tables I and II) which are invoved in geothermal energy research suggests that most of the research and development promotional activities reside in governmental and educational institutions.

#### 2.1.4. Technology Assessment: Philosophy

Technology assessment has been defined as the "...systematic identification, analysis, and evaluation of the potential impacts of technology on social, economic, environmental, and political systems, institutions, and processes." [19] This analytical process intends to identify along with the obvious and direct consequences, those unintended consequences, whether detrimental or beneficial, of new technological developments through a consideration of the second and higher order impacts on society resulting from the utilization of new technologies or a significant change in the application of an existent technology. The desired results of a technology assessment include information on options, useful to decision makers.

TABLE I

Partial List of Existing Institutions which are now aware of  
or a Part of Programs in Geothermal Energy [1]

GOVERNMENT

Department of Interior  
 a. Bureau of Reclamation  
 b. U. S. Geological Survey  
 c. Office of Saline Water  
 d. Bureau of Mines

National Science Foundation  
 Advanced Research Projects Agency - DoD  
 National Aeronautics & Space Administration  
 a) Manned Spacecraft Center  
 b) Goddard Space Flight Center

Environmental Protection Agency  
 Naval Weapons Center  
 U. S. Air Force Cambridge Research Laboratory  
 Federal Power Commission

Atomic Energy Commission  
 a) Oak Ridge  
 b) Lawrence  
 c) Los Alamos  
 d) Argonne  
 e) Brookhaven

Nevada State Bureau of Mines  
 Oregon State Department of Geological  
 and Mineral Industries  
 California State Division of Mines  
 and Geology  
 State Departments of Public Works and  
 Commerce  
 State Department of Natural Resources  
 Other Organizations within state  
 governments of Utah, California, Oregon,  
 Nevada, Colorado, Arizona, New Mexico,  
 Wyoming, Idaho, Alaska, Montana,  
 Washington

INDUSTRIES

Big Chief Drilling Co.  
 San Diego Gas & Electric  
 Magma Power  
 Indian Oil Company  
 Signal Oil Company  
 Pacific Energy Corporation  
 Gulf Oil Company  
 Sun Oil Company  
 Getty Oil Company  
 Union Oil Company  
 Pacific Gas & Electric Co.  
 Battelle Northwest Laboratories  
 American Oil Shale Corporation  
 Thermal Power Company  
 Rogers Engineering Company, Inc.  
 Westinghouse Electric Company

UNIVERSITIES

Southern Methodist University  
 Arizona State University  
 University of California at Riverside  
 Virginia Polytechnic Institute  
 University of California  
 Stanford University  
 Colorado School of Mines  
 Johns Hopkins University  
 University of Houston  
 University of San Francisco  
 Oregon State University

TABLE II

GEOHERMAL ENERGY TECHNOLOGY ARRANGED BY INTERACTIONS  
WITH MAJOR GOVERNMENT AGENCIES

AGENCY	ROLE	GEOHERMAL ENERGY TECHNOLOGY
National Science Foundation	P	Research and Development
Department of Interior	R	Land Use
Environmental Protection Agency, Council of Environmental Quality	R	Environmental Impact
Federal Power Commission	R	Regulates Interstate Aspects of electrical power and gas industry network
National Aeronautical and Space Administration	P	Earth resources survey program
Department of Commerce, National Bureau of Standards	P,R	Research and Development
Atomic Energy Commission	P	Research and Development
Public Health Service, Department of Health, Education R and Welfare		Health hazards and standards

Role Code: P - Promotional  
R - Regulatory

There are many examples today of "partial" technology assessments, e.g., cost-benefit economic analyses and, as required by the National Environmental Policy Act, environmental impact statements. Society now realizes that it is necessary to evaluate not only the narrowly-defined primary effects of intended objectives, but also the secondary, or side effects, of those proposed actions. Technology assessment presents a "systems" approach for analysis of the societal implications of new technologies. A "systems" approach emphasizes that all of society's actions are interactive in nature and that it is impossible to isolate one factor of society from all others.

Yet, it must be remembered that a true technology assessment is very idealistic in nature. Although one may claim to have performed a very comprehensive technology assessment, it must still be a "partial" assessment since it is impossible to analyze the total interactive substance of society. Besides, because of changes in technological and social values, side effects judged inconsequential today may be considered significant in the future.

But is technology assessment only some new bureaucratic process that intends to harass industry and impede societal progress? During the past few decades of history, we have witnessed a vast increase in the rate of technological developments. Many consider technology the primary tool for solution of problems and have created influential innovations. With the advent of numerous and influential technologies, society has begun to feel the enormous impact of technology upon the quality of men's lives. This has led to the necessity for a much more thorough examination of the potential implications of new technologies so that policy makers may be more aware of the consequences of new policy formulations concerning technology.

There are many considerations which compel us to manage our technologies more efficiently. Joseph F. Coates relates that "...the growing complexity of society, the large scale of human enterprise, the throw-away society, and the shift in societal values." [20], among other societal trends, have made it necessary that our society develop "warning systems" as aids in decision making and consequent policy formulation. With proper planning the negative aspects of certain innovations such as the automobile and DDT might have been constrained or minimized. Much popular literature exists today that is concerned with the

proliferation and increasing severity of the unintended negative impacts accompanying new innovations, and society's inability to cope with these new difficulties. Social technologies such as legislation and new methods of litigation are now seen to be generally lagging behind physical technologies in their rate of development, introduction to, and acceptance by society.

Central to the philosophy of technology assessment is the concept that it is better to attempt an assessment than to let the technology go unharmed. The process is a positive decision-making tool which can be employed in order to organize certainty and uncertainty. It can play an important role in the management of societal affairs. The organization of what is known and not known helps facilitate policy-makers' evaluating of policy alternatives. Certainly, technology assessment will not prevent mankind from making mistakes. Yet, when decision makers have relevant scientific and social data at hand, policy making is more likely to be oriented toward the best interests of society.

Technology assessment is a technique which can present viable alternative action options in the form of policy recommendations derived through an examination of the impacts of technology upon society. Through the performance of these social impact analyses, policymakers will recognize the potential ability of certain action options to constrain the negative impacts and exploit the beneficial aspects of new technologies in as many different fashions as possible. Thus, technology assessment provides guidelines for the attainment of assumed societal values through an examination of social interactions. Although the narrowly defined primary effects of new technologies are usually well known, technological and social innovations may now be necessary in order to modify, block, establish controls, stimulate research and development, and/or maintain constant surveillance over new technologies whose utilization may have potential benefits or unwanted consequences on society. Nevertheless, it may be almost impossible to represent every varied interest in the society while performing these assessments. A technology assessment study would never be the last word or final study conducted on the technology in question, but it certainly would influence the course of technological development.

Important considerations which should be examined in any technology assessment include questions such as: who are the decision makers and/or influencing groups in the decision and assessment making process?; who are the affected groups not represented in the policy making process?; how can the technology assessment avoid being simply a form of technology harassment?; who should perform the assessment and what should be their relationship to the technology involved?; how should one limit the scope of the technology?; how reliable are the forecasts made?; and finally, how valid are our basic societal assumptions? The answers to these questions are difficult and controversial. Yet, responses must be attempted in order to integrate the process of technology assessment into the socio-political system. If the concept of technology assessment can be of substantive aid, technology assessment will take root and contribute to society in a time when some people feel that we should abandon technology altogether.

In response to the philosophic questions above, it has been demonstrated that, in order for technology assessment to be believable to the general public, and thus, useful to policy makers, it should provide a "...balanced look at all alternatives, options, and possible outcomes." [20] Technology assessment must be a neutral analysis of the future outcomes and alternatives of the technology in focus. For "...if an assessment is not even-handed, it becomes merely another weapon in a rancorous dispute." [20] Institutionally ERIM would seem to satisfy the criterion of neutrality in the proposed project for it has no vested interests in the areas of development of any one system for geothermal energy. Yet, it does have expertise in the areas of the related physical sciences and in technology assessment.

The formation of an adequate technology assessment capability is difficult, because society is ill equipped to handle the problems of conflicting interests and few analytical methods have been developed. Scientists and engineers who have committed a great deal of their time to development of a specific technology tend to be psychologically biased toward technology and are inclined to overlook its detrimental side effects. Those who have not made such a commitment are not likely to know enough about the technology to assess it. The mixture of both kinds



of scientific personnel is important for a good technology assessment project. The proposed ERIM project team can present such a mix and therefore should alleviate the problems of conflicting interests that are generally inherent in an assessment task.

#### 2.1.5. Technology Assessment: Methodologies

The MITRE Corporation report on their methodology of technology assessment is generally recognized as the first attempt to develop an analytical method to determine the impacts of technology on society.[21] Although the MITRE Corporation report presents a rather exhaustive analytical technique for the generation of the second and third order consequences sought in an ideal technology assessment, its approach is too structured and sterile, tending to "turn off" a policy maker to the results of the study. The long tedious tasks of answering checklists would also remove the excitement inherent in the research aspects of technology assessment. Nevertheless, the MITRE corporation's report is a valuable tool which can be used as a reference guide to insure the assessors of a technology that the areas of important consideration have been covered. The National Academy of Engineering study in technology assessment employed a methodology closely resembling that of MITRE, and the NAE report did show the utility of its methodology in deriving useful data.[22] Keeping in mind the two reports mentioned above, ERIM will attempt to integrate some new and potentially useful tools for inquiring into the impacts of geothermal energy on society.

ERIM has gained experience in such tasks during its Technology Assessment of Remote Sensing project, and Professor Kan Chen of the Electrical and Computer Engineering Department of the University of Michigan has introduced the project team to the various methodologies available for use in a technology assessment [23]. He has suggested in his taxonomy that there are two basic types of methodological structures: scanning methods, which employ a direct, intuitive single-stage approach to the problem; and tracing methods, which use an indirect, multi-stage structural approach. Each of these two types of methods can be used by either single experts or groups of experts. There are five basic techniques available for scansion analyses.

First, one may analyze the impacts of technology by examining the ability of a specific technology to generate some type of tremendous impact. Second, one could explore the various societal problems, and the effects of directing technology to solve these problems. Third, impacts could be determined by analysis using as a point of departure the various disciplines, including economic, environmental, social, political, and legal analyses. Fourth, there is the MITRE checklist approach.

ERIM will attempt to focus a significant portion of this effort on the fifth scansion technique. This technique entails an examination of the significant contributions of new technologies through a portrayal of the effects of technology on societal values. If, through a value oriented approach to technology assessment, we can identify families of important values which may be affected by particular policy options, if we can suggest indicators and feedback mechanisms for controlling those impacts, and if we can sensitize those involved in the development and use of geothermal power technology to the latent value implications of their action, then we can consider the value oriented approach to be a useful contribution to our technology assessment project.

Our choice of a social value oriented approach to technology assessment is not simply the result of a desire for a novel methodology (although, they are badly needed), nor is it based on a utopian image of the ideal policy making process. Rather, it is to a large degree the result of the desire to make explicit the value judgments and value impacts inherent in the process of policy making implementation and evaluation. As difficult policy decisions involve ultimately a balance between conflicting values, we believe that the value-oriented approach provides a framework for integrating results from other technology assessment approaches and provides most useful results at the end to help make policy decisions.

We suggest that the exhaustive approach to technology assessment may indeed be endless, and perhaps, also foolish. Whether or not a value impact analysis can be done is yet to be determined, and thus, other methods of describing the impact space are necessary. Since the assessment of the impact of technology on society is a new field, the recognized tools of scientific inquiry have not yet been applied widely or with confidence in this field. Many powerful tools potentially have

application to technology assessment, but so far their contribution is unproven.

The analytical tracing technique methods, those in the second category of methodologies identified before, are potentially powerful tools which can also be used in this work. Relevance tree structuring techniques are used in operations research for decision analysis. This technique stems from a rational derivation of technological applications to perceived impacts, unlike the scanning techniques which derive their outcomes from "bolts of genius." A selective sequence technique may isolate one branch of the tree structure for a more complete examination. ERIM has examined and extended a decision-tree analysis originated by MATHEMATICA, Inc. for a Kentucky strip mining decision model in a cost-benefit analysis of remote sensing technology.

Dynamic systems modelling and input-output analysis are two other tracing tools which could be utilized in a technology assessment analysis. In our remote sensing technology assessment project ERIM has begun to examine the input-output matrix analysis technique in order to determine the interactive nature of society and the reciprocal effects of possible actions. This matrix has the following form:

	Technology	Environ.	Econ.	Pol.Soc.
Technology				
Environment				
Economic				
Political/ Social				

After identifying the intended, primary effects of remote sensing technology, we would attempt to discern the impacts of an existent remote sensing technology on the technological, environmental, economic, and political-social spheres of

society, the impacts of a perceived improved environment on the various aspects of society, the impacts of the proposed cost-benefit economic analysis on society, etc.

There are many other tracing tools which we are examining for their feasibility in our NSF-sponsored technology assessment. Simulation modelling is a tool for investigating the interactions in a complex multilevel feedback system--a good characterization of societal interaction. Morphological analysis is a powerful tool for stimulating the imagination and minimizing the probability of overlooking new alternatives. It comprises listing all important dimensions of a situation (or problem) and listing all possible outcomes along each dimension. All combinations are then examined for feasibility, plausibility, and desirability. The examination of remote sensing policy impacts through the generation of scenarios has been found to be of major importance in this work.

This growing ERIM experience in technology assessment involves development and use of many types of study tools to perform a social impact analysis.

#### 2.1.6. Specific Methodology for the Proposed Project

In order to attempt a technology assessment, one must first structure the problem, set up boundary limits and define criteria to measure system performance. Technology-initiated assessments suggest many varied cause-effect relationships, and thus, the number of consequences becomes enormously multiplied by the potential number of policy strategies. Sometimes it becomes necessary to modify the study by focusing the technology toward one or at most a few areas of social concern or application that might be critically affected by the subject technology. It may even become necessary to limit the assessment problem to a problem-initiated assessment.

Most technology-initiated studies begin with a period of data base accumulation, considered important since an assessment is no better than the data base on which it is made. Although the participants in the project may have a general knowledge on the subject, project participants must formulate a common language in order to dissolve interdisciplinary barriers. Words such as institution, philosophy, and primary and secondary effects must convey the same meaning to all members of the project team if the team is to be effective. Most members

of our proposed project team have gone through this difficult process of developing a common language and have learned to "initiate" new members joining our team.

On July 16-20, 1973, the short, intensive course in "New Approaches to Low-Pollution and Resource-Conserving Power Generation" will be offered as one of the Engineering Summer Conferences at the University of Michigan. During this course Profs. George I. Haddad and Dale M. Grimes with several visiting lecturers will discuss topics including dry-well geothermal sources, large solar arrays, direct solar house heating and air conditioning, and other concerns with the world energy problem (see Section 4.1 in the Appendices for details of this course). The course would serve as a logical introduction to a seminar series conducted at the beginning of this project to give all task members a general appreciation of the technologies involved. This seminar series would help establish a working vocabulary between the various disciplines represented on the team.

The ERIM staff is aware of the literature in technology assessment, and consultants such as Prof. Ross and the social scientists of our team will add awareness of the energy policy issues discussed earlier. The ERIM team professes the ability to deal with all the concerns found in these policy issues, for our task force is composed of environmental, legal, economic and social-political experts.

ERIM proposes to follow a specific strategy including the tasks below.

- I. Develop a specific project philosophy and technology assessment methodology
  1. Study the recent and imminent governmental actions (policy directives, legislation, etc.) that impinge on the development of geothermal power technologies.
    - a. Identify decision making agencies and individuals
    - b. Identify parties of interest
  2. Define scope, function, and limitations of tools for the study problem.
    - a. Use scenarios to illustrate potential decision-making alternatives and their consequences

- b. Use gaming simulation similarly
  - c. Develop the value-oriented approach
  - d. Perform preliminary selection of approach and tools  
(Review with NSF)
- II. Formulate overview of potential geothermal power technology
- 1. Determine present status and usage of geothermal power technology
  - 2. Delineate the various feasible technologies
  - 3. Carry out preliminary assessment of technical costs  
(i.e., capital, operational and R&D)
  - 4. Examine relevant social technologies and interactions
- III. Identify and analyze impacts
- 1. Delineate and consider discipline-structured side effects
    - a. Economic
    - b. Environmental
    - c. Institutional
    - d. Social
    - e. Others
  - 2. Obtain value-oriented classification of impacts
  - 3. Carry out quantification of side effects
    - a. Positive, negative, uncertain
    - b. Controllable versus uncontrollable
    - c. Risk versus non-risk
- IV. Formulate policy alternatives and research recommendations.  
Structure a comprehensive technology assessment as found appropriate (Review with NSF)
- V. Design dissemination and utilization of results
- 1. Structure the use of gaming simulation for communication with policy makers
  - 2. Define the optimum role of modern communications media
  - 3. Review briefing, presentation and report strategies

ERIM will focus much of its attention on the generation of scenarios. Scenarios provide an excellent mechanism for investigating the consequences of decisions and the reactions of decision makers in realistic situations. Through the generation of scenarios, ERIM will be able to locate the points of impact for policy makers and the effects of their possible decisions on future events. Since the utilization of future energy sources rests so heavily on policy formulation, it would seem logical that a technology assessment of geothermal energy be concerned with scenario writing. Since futures are probabilistic not deterministic, one must evaluate the role of technological forecasting in technology assessment. Technological forecasting tools can help evaluate many alternative futures in order to place emphasis on those futures which seem most significant. Thus, we will concentrate our efforts on those figures which seem most feasible and analyze the resultant societal structure in terms of national goals and values. Forecasting techniques involving scenario writing should be utilized to a large degree in our scientific inquiry.

Other potentially useful tools in assessing the impact of a technology are in an embryonic form for predicting societal consequences, but progress is being made. Three group methods of impact analysis appear to provide useful contributions; the Delphi technique; structured brainstorming; and gaming simulation. The Delphi technique is one means for tapping expert knowledge and providing numerical estimates about specific events. It uses experts from appropriate disciplines and extracts their individual opinions separately and in quantitative terms. Although our experience in this field is limited, we may utilize the questionnaire format to obtain technical consensus.

In our technology assessment of remote sensing, the ability of gaming to locate areas of impact remains, for the present, hypothesis and not fact. But we are exploring gaming theory and hope to derive a working and effective game that could be extended to a technology assessment of the development of technologies for applications of geothermal energy.

ERIM will attempt to create a mix of scenario writing, gaming simulation, and hopefully a value-oriented methodology in a manner which will reflect the

importance of policy formulation energy technology. These techniques will be helpful in analyzing the technological and societal changes and interactions accompanying geothermal energy technology application and in suggesting alternative future and policy options.

Much can be learned about the impact of technology from an economic analysis. In the early stages of the technology development, it is difficult but important to identify many of the potential benefits and detriments, and to obtain qualitative estimates of the magnitude of these effects. This specific technology assessment project encounters the problem of the economic feasibility of the technologies involved. If the major features of the proposed geothermal energy system are specified, capital investment and operating costs can be determined with a fair amount of precision.

We expect to extend existing economic analyses to a cost-benefit-detriment analysis of geothermal power development as early as possible and to utilize such economic analyses wherever they can be effectively applied to the problems of this technological assessment. The problems of the uncertain nature of the technology, the economies of scale, market receptivity, the balance of payments, research and development cost recovery and opportunity cost, and the magnitude of capital problems are among the factors which must certainly be explored.

A technology assessment must consider whether or not a new energy technology will make sufficient inroads on the economic market structure. Competing energy conversion techniques may render a new energy technology superficial or unworthwhile. The proposed project must attempt to assess whether the opportunity costs of geothermal energy research are worthwhile. In any technology assessment alternative and complementary technologies must be examined. Various types of support technologies and even alternate energy sources must be considered along with hybrid and multiple-use systems. Energy policy may even consider systems design and implementation for many simultaneous uses, such as technology developed for both heat and electrical power generation.

The economic analysis techniques as formulated and used in the design of a cost-benefit study [24] conducted by ERIM with MATHEMATICA, Inc. and System Planning Corporation will be restructured and expanded for use in this assessment.



Dr. Klaus Heiss, a senior economist internationally known for his leadership in the cost-benefit study of the Space Shuttle [25], will play a major role in this portion of our effort.

## 2.2 Design for Dissemination and Utilization of Results

An important facet of technology assessment is its utility. The research team must not only perform the impact analysis in a proficient manner, but of equally importance, they must be able to disseminate the final results in an effective way. Decision makers should find the advice of a technology assessment to be useful if the study itself is to be judged worthwhile in a benefit-cost sense. Most assessment studies performed to date have disseminated their results merely by means of briefings and written reports. These reports usually consist of a summary and extensive technical publications, sometimes a layman's or popularized version as well. "...Communicating the assessment results and their importance to the public, the specially affected groups, and the government decision makers...takes more than issuing reports," [26] according to Chauncey Starr, who suggests a variety of dissemination techniques including public debates, articles in popular journals, Congressional hearings, and formal, official presentations.

ERIM's experience in reviewing assessment studies suggests that an additional dimension of dissemination is needed and should be sought. We suggest that gaming simulation may provide an effective means of communicating the project results to decision makers and stakeholder groups. Through a gaming simulation procedure, political realities may be introduced to determine the feasibility and desirability of the technology assessment recommendations. The roles and functions of the decision makers may be more sharply delineated in a gaming simulation dissemination procedure in order to accurately reflect on the results of the technology assessment policy recommendations. Although we are not sure, at present, whether gaming can be an effective mode for disseminating data, other studies have suggested its utility in this manner. In their report An Experiment in Simulation Gaming for Social Policy Studies, T. J. Gordon, et.al., concluded that a "...game did demonstrate that the (game) format could serve as a teaching tool, promote communication between players (whom we hope would be decision makers), provide

an orderly framework for the consideration of alternative potential political actions, and spark debate on issues of concern to various sectors of society... the game is a forum in which planners and forecasters can learn a great deal about how they can support each other in pursuing a brighter society." [21]

Still another reason for examining gaming simulation is the great variation of decision makers and institutions involved, and the resulting wide range of options to be presented. Conceptually these range from educational support to industrial contracts and municipality zoning and land use changes. The options must be addressed to a highly "disaggregated" set of decision makers.

We would attempt to structure a dissemination plan to include the conventional means of popular and technical reports, briefings, presentations, and the like, but which would go beyond into press conferences and TV/radio programs. The Environmental Law Society of the University of Michigan, a group of law students interested in legal aspects of environmental protection (see Section 2.3), has shown innovative creativity in communications with many decision-maker communities. They will be interested in seeing that appropriate attention is paid at all levels to the results of the proposed assessment.

In addition, ERIM plans to examine the uses of gaming simulation for information transfer in the remote sensing technology assessment project. If some success is forthcoming, derived but similar structure could be attempted for the results of this assessment. Our interest in this approach stems from the view that the results of technology assessments are not static but dynamic, and can not be communicated effectively except in an interactive, dynamic mode. For some assessment the results might best reach the public via community cable TV providing a real-time return link could be implemented, at least partially. We are keenly aware of the dangers in such real-time two-way communications, not the least of which is the vulnerability to establishment of propagandizing. The distance from communication through the domain of instruction and into proselytism is uncomfortably short, yet the importance of using innovative methods for dissemination of results to the general public as well as to the decision makers can not be overemphasized.

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## 2.3 Program Management

### 2.3.1 The ERIM Organization

As a result of a cooperative effort between the State of Michigan and the University of Michigan, the Environmental Research Institute of Michigan (ERIM) was established in June 1972 as an independent not-for-profit corporation to carry on the research activities of the University's Willow Run Laboratories. ERIM's activities cover a broad range of scientific and technical disciplines, with emphasis on the physical sciences, earth sciences, computer sciences, engineering and mathematics, and in the application of these disciplines to the solution of a variety of broad problems facing our society.

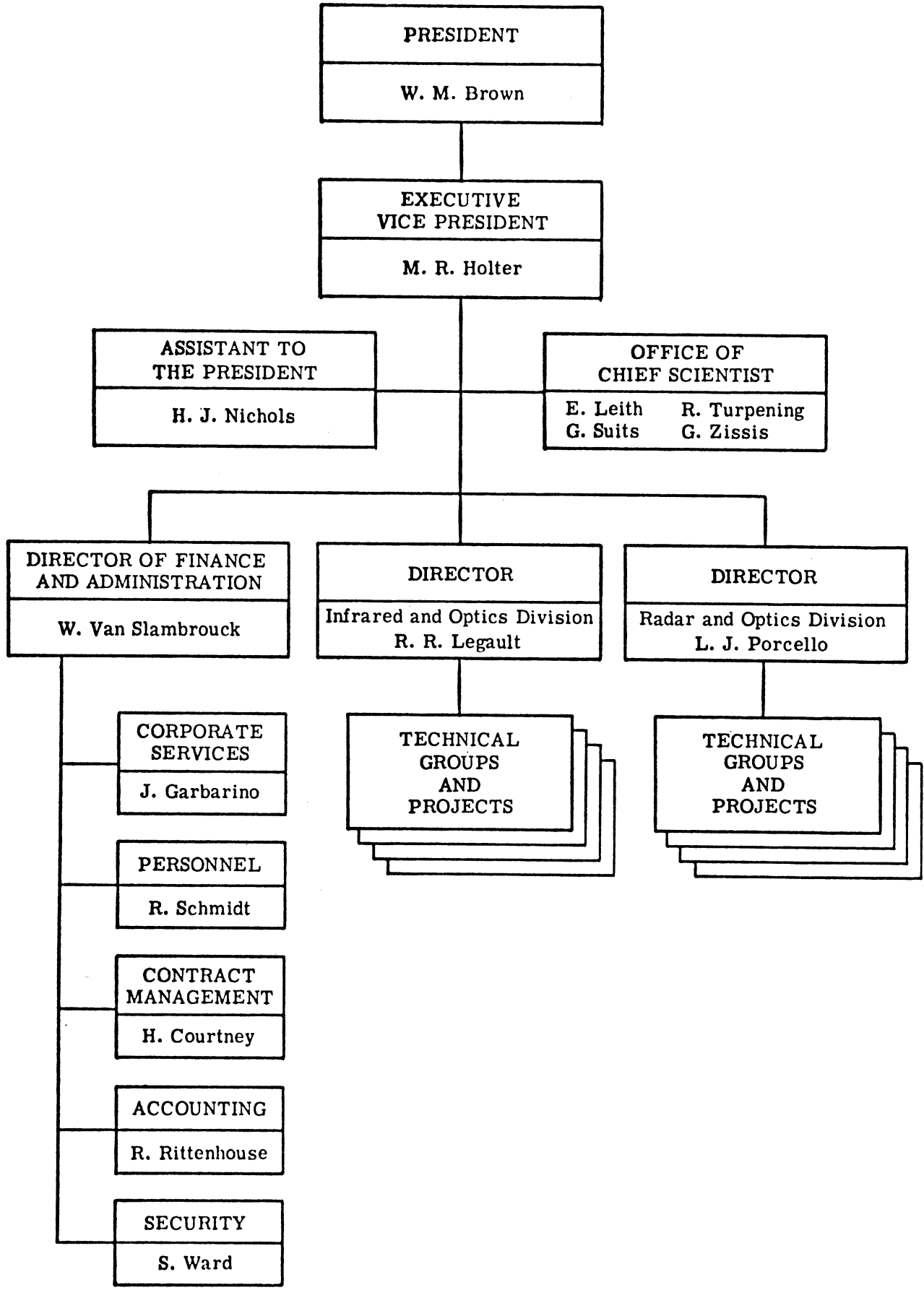
ERIM's organizational structure is shown in Figure 3-1. All key personnel identified in the ERIM structure held comparable positions in the organization while under University auspices, and hence are well experienced in the management and conduct of both large and small research activities. ERIM's current level of research business is approximately \$7 million per year.

### 2.3.2 Program Organization

The geothermal energy technology assessment program will be directed from ERIM's Infrared and Optics Division, headed by Richard R. Legault. This Division contains ERIM's prime technical capabilities in both thermal and geophysical disciplines and normally directs such related research. A major portion of ERIM's technology assessment studies are also conducted from the Infrared and Optics Division.

The Principal Investigator for this program will be Dr. George J. Zissis, Chief Scientist for the Infrared and Optics Division and Scientific Advisor for all of ERIM. Dr. Zissis is ERIM's most qualified manager for conducting this research. He has 20 year's experience in conducting and supervising multidisciplinary programs in the field of infrared and thermal research, and is nationally recognized for his achievements. He has served on numerous

FIGURE 3-1. ORGANIZATION OF THE ENVIRONMENTAL RESEARCH INSTITUTE OF MICHIGAN



government advisory committees (see Vita). His primary responsibilities at ERIM are to direct IRIA (Infrared Information and Analysis Center) and to organize and direct special projects notable for their interdisciplinary aspects. He is currently Principal Investigator for an NSF Grant on the Technology Assessment of Remote Sensing which extends through September 1973.

As Principal Investigator, Dr. Zissis will be responsible for the overall direction of the program and the coordination of all participants. Specifically his functions will include:

- a. Definition of Program Plans, Organization and Schedules
- b. Program Staffing, both internal and consultants
- c. Technical Guidance
- d. Coordination and Liaison
- e. Cost Control
- f. Deliverable Items

It is anticipated that Dr. Zissis will devote approximately 35% of his time to this program over the 12 month performance period.

Key personnel for the program will be drawn from the ERIM staff, primarily from the Infrared and Optics Division, and from the University of Michigan. No subcontract efforts are planned. The nucleus of this working team is already in existence under Dr. Zissis' direction, addressing economic benefit problems on other contracts. The close proximity of ERIM and the University, coupled with the historic tie which exists between the two organizations, contribute to the ease of such a working arrangement. University personnel cooperate with ERIM under two established working arrangements: 1) as consultants to ERIM or 2) as temporary hourly ERIM employees. The specific arrangement for each "consultant" depends on their position in the University and on their personal preference. Either way, considerable flexibility exists in acquiring and scheduling the great depth of expertise available from the University staff.

It is also planned to employ consultants from other organizations under usual consulting agreement contracts. The specific personnel, their capabilities and specific roles are discussed in a subsequent section. These, as well as all other key personnel employed on the program will work under the supervision of the Principal Investigator.

The Overview Committee suggested in the RFP will be established early in the program. Although their expenses will be covered by the Project budget, they are to operate as an independent group and are free to make their recommendations to either the Principal Investigator or directly to NSF. The responsibility for providing this Committee with timely information on the purpose, scope and progress of the program lies with the Principal Investigator.

A graphical illustration of the program organization as outlined above is given in Figure 3-2. The salient features of the organization are:

- a. A well qualified and established technology assessment team of great technical depth
- b. A close knit organization providing maximum flexibility and communications
- c. A working management directly involved in the technical effort

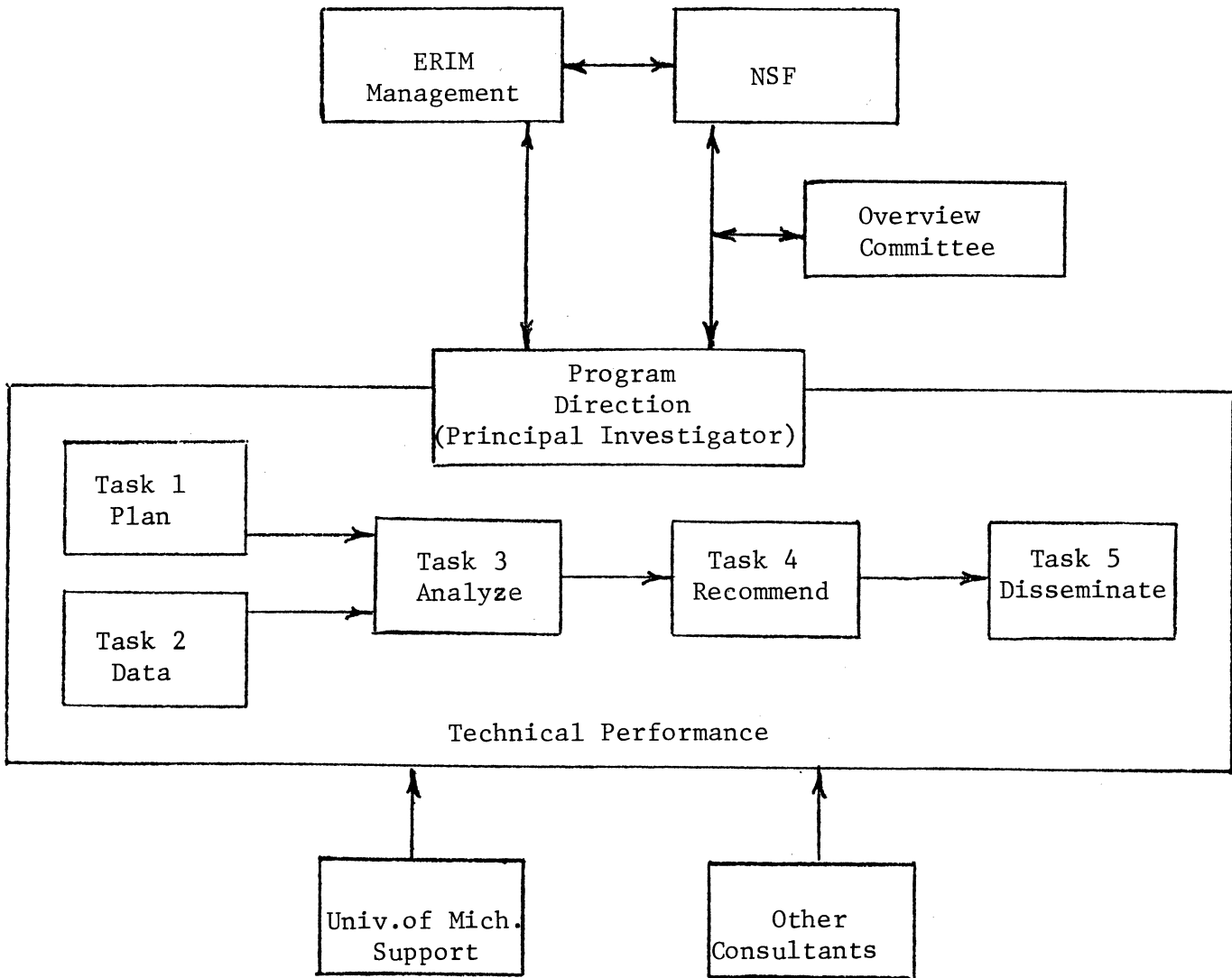
### 2.3.3 Program Outline

Five basic tasks have been identified as encompassing the technical effort required for this program. These tasks are:

- Task 1. Develop a specific project philosophy and technology assessment methodology. This creates a detailed plan to define the activities required, their scope, and interrelationships. The material presented in this proposal represents an overview of the plan; further details will be developed after contract award and



Figure 3-2  
Program Organization



consultation with the sponsor and the oversight committee. The development of the plan is an evaluation study in itself, as it seeks to identify the parties of interest and their weighted value; the analytical tools available and their relative capabilities and confidence factors, and the extent of the technology to be encompassed, as well as the time frame to which the study should be addressed.

- Task 2. Formulate overview of geothermal energy technology. Summarize the salient features of the applicable technology relating to geothermal energy utilization. Emphasis will be on the practicality and economics of the engineering aspects, to be drawn mainly from pilot operations now in existence, but will also include social technology aspects relative to mass media, government participation, etc.
- Task 3. Identify and analyze impacts of large scale geothermal energy utilization. This task is the real meat of the program and includes not only the trade-off study of the basic factors defined in Task 2, but also includes the definition and evaluation of side effects which can have economic and social impact.
- Task 4. Formulate policy alternatives and research recommendations resulting from the Task 3 analysis. This basically involves the interpretation of the analytical results and requires the present talent which can be brought to bear on the problem.

Task 5. Design dissemination and utilization of results.

Reports will be prepared, but realizing the shortcomings of a printed document in conveying the intricacies of a multi-variant problem, we plan to explore less orthodox means of conveying the results of this study to interested parties. One possible method to be explored is to convey the results in the form of a game which can be manipulated in accordance to mathematical game-theory concepts. In this way, the myriad of variables can be explored to whatever length deemed necessary by interested participants.

The time-phase relationships of these tasks, and their associated milestones are depicted in Figure 3-3. The technical manpower expected to be utilized on each task is also indicated.

#### 2.3.4 Program Control

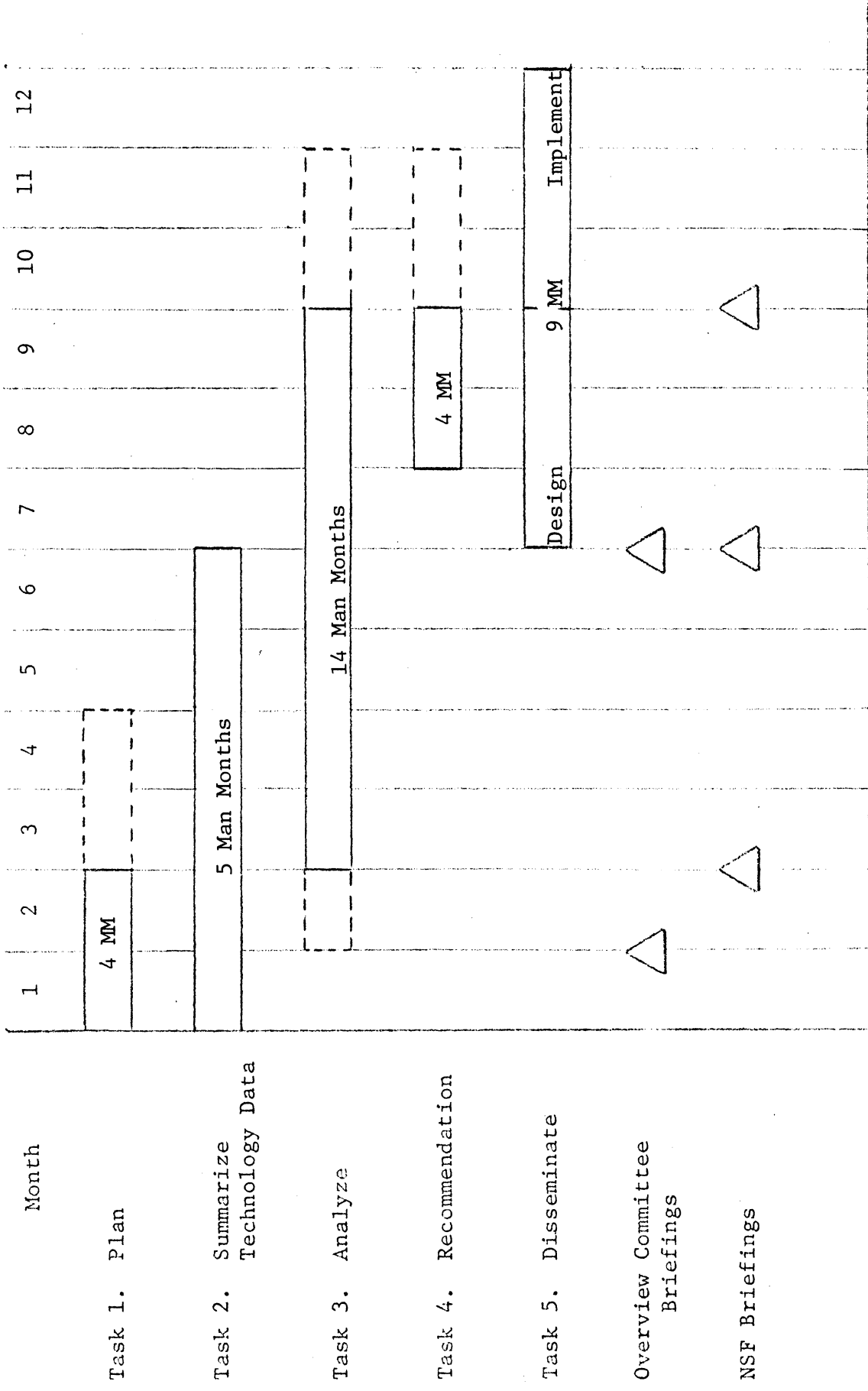
Program control rests with the Principal Investigator. To assist him, ERIM provides the necessary tools and support for handling administrative matters such as contract and subcontract negotiations, purchasing, cost accounting and reporting (to the Sponsor and to the Principal Investigator). ERIM administrative and control procedures are the same as those used for many years while associated with The University of Michigan.

For the work performed within ERIM, the Principal Investigator has direct control over job assignments, budgets, and expenditures, so that immediate response is possible in making any necessary changes in the conduct of the program. Formal paperwork for the technical direction of the program is purposely held to a minimum.

Upon contract award, the Contract Administration Group authorizes work to begin by assigning an account number against a budget consistent with

Figure 3-3

PROGRAM SCHEDULE



the cost/task structure of the negotiated contract. Where necessary or desirable to identify costs against separate tasks of a highly complex project, (such as our AMOS, BAMIRAC or NASA Multispectral Imaging projects) multiple subaccounts may be established, each treated as a separate cost center. The Principal Investigator provides a list of personnel authorized to commit funds on each account and no service unit will honor financial commitment orders lacking the required authorized signature. Cost accounting within ERIM is performed on a weekly basis to provide the Principal Investigator with the timely information needed to make sound decisions on cost control.

Program staffing and personnel assignments are made by the Principal Investigator in concert with the Division Head and the second tier managers. Technical personnel and specialists will be phased in and out as the need arises and will not be carried over periods of time when their expertise is not required. Biographies of personnel expected to be employed on this program are presented in an appendix.

## 2.4 Personnel

It is ERIM's intent to staff this technology assessment program from three principal sources:

- a) Existing ERIM technical staff
- b) University of Michigan consultants
- c) Other consultants

As explained in Section 2.3.2, the nucleus of the desired staff already exists as a working group engaged in the Technology Assessment of Remote Sensing Study for NSF. With the scheduled reduction in level of effort on this program in September, this group can readily divert to this very similar program described herein. The group will be augmented to provide the additional technical expertise and level of effort required. Biographies of key personnel planned for this program are presented in an appendix.

### 2.4.1 Overview Committee

Three element personages with backgrounds ideal for this purpose have agreed to form the Overview Committee for this proposed program:

Professor Harlan Hatcher, humanist and scholar, and President Emeritus of The University of Michigan. Since his retirement as President, his interest in sociological problems have led him to become President of The Developing Great Lakes Magalopolis Research Project.

Dr. Paul W. McCracken, Professor of Business Administration at The University of Michigan, former economic advisor to President Nixon and former Chairman of the Committee of Economic Administration. Dr. McCracken is clearly qualified to address the economic factors of such a technology assessment program.

Professor David Gates, nationally known ecologist and physicist, Director of The University's Biological Station. Dr. Gates provides the Committee with required technological competence (in energy conversion) and his extensive experience on numerous national advisory boards.

### 2.4.2 The ERIM Staff

The ERIM Staff consists of full-time researchers, part-time employees

who are graduate or undergraduate students at various Universities, and a few faculty members from neighboring Universities who choose to pursue a portion of their professional activities within the framework of this institute. ERIM has an overall staff approaching 400 employees. Of this total, the technical staff consists of approximately 190 full-time employees and 75 part-time employees. This distribution of personnel and the disciplinary depth is depicted in Figure 4-1. The figures shown relate to all of ERIM; within the Infrared and Optics Division, where this technology assessment work would be performed, there is a much larger percentage of Environmental Science personnel and a much lower percentage of Electronics personnel.

The organization and personnel of this Division are shown in Figure 4-2. The structure shows the nominal home-base for each employee, but they are readily and informally assigned to the particular project location where their expertise is needed.

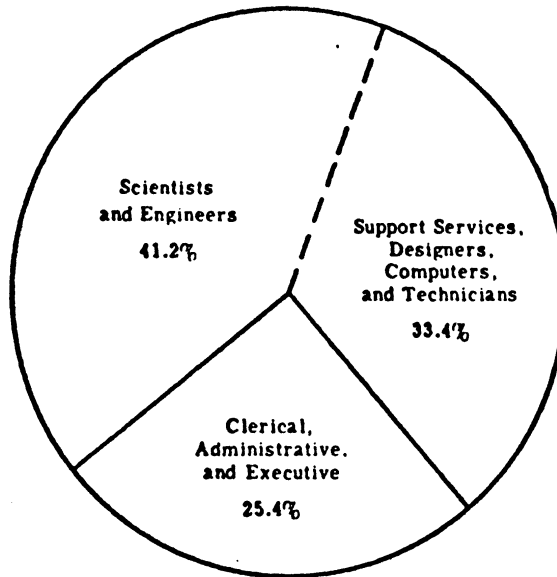
Dr. George Zissis will direct the program as Principal Investigator. Specific comments on his qualifications, and position in the ERIM organization were made in Section 2.3.2. Dr. Zissis will devote approximately 35% of his time to this program.

Because it is planned that the Principal Investigator play such an intimate role in the technical performance of this study, Dr. Zissis plans that Dr. Virginia Prentice shall serve as his Deputy Principal Investigator. This arrangement makes explicit the responsibility that Ms. Prentice will carry in the overall conduct of the program, and assures that one of the programs architects as always available for guidance and coordination of the participants. Dr. Prentice has over fifteen years experience in the fields of geography, natural resources and ecology, and is active in numerous related civic and service organizations. She is a key participant in our existing technology assessment efforts. She will devote approximately 40% of her time to this proposed program, primarily on Tasks k, 3 and 4.

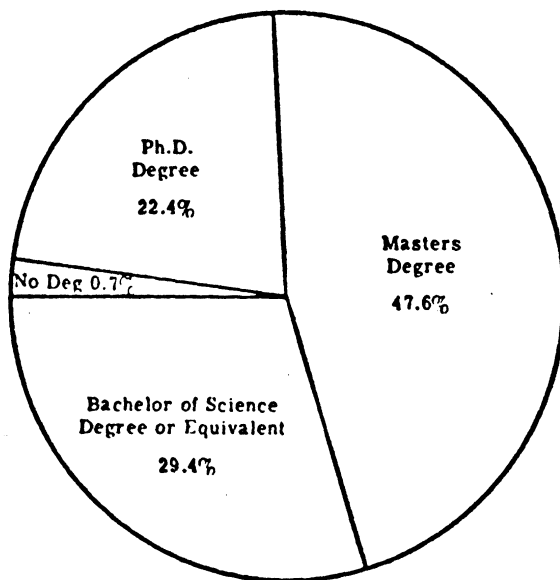
In addition to the Principal Investigator and his Deputy, other key ERIM personnel to be used on this program are:

Mark Berg	Task 1, 3, 4
Dan Steinway	Task 1, 3, 4
Tom Feagan	Task 2, 3

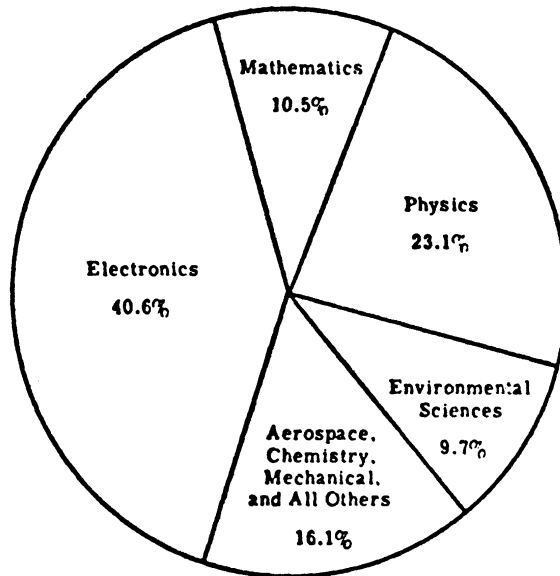
**Figure 4-1  
DISTRIBUTION OF PERSONNEL**



**DIVISION OF ALL PERSONNEL EMPLOYED BY ERIM**



**DIVISION OF SCIENTISTS AND ENGINEERS BY DEGREES HELD**



**DIVISION OF SCIENTISTS AND ENGINEERS BY FIELD OF HIGHEST DEGREE**



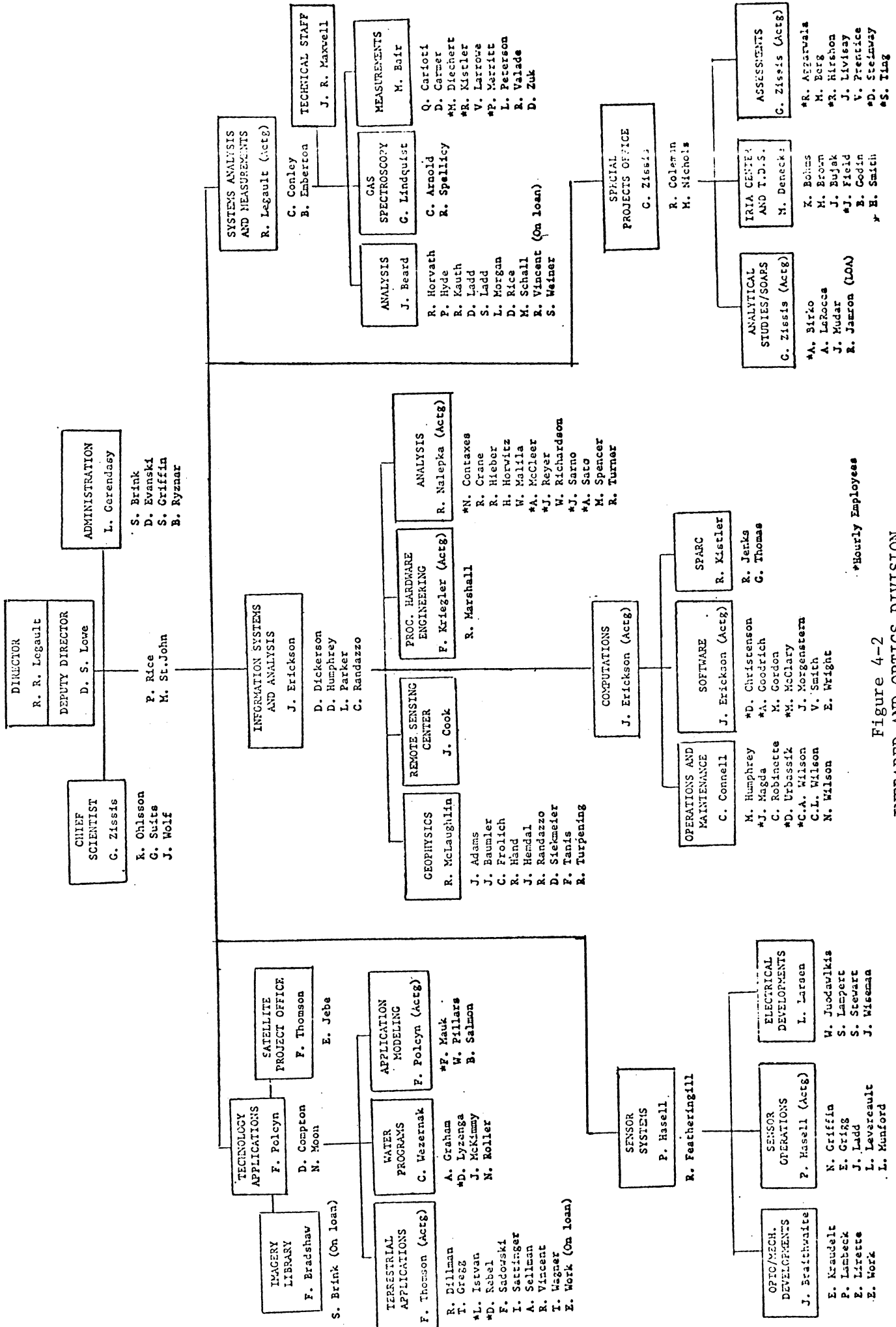


Figure 4-2  
INFRARED AND OPTICS DIVISION

\*Hourly Employees

Robert Vincent	Task 2, 4
Dr. Gwynn Suits	Task 2
Irvin Sattinger	Task 2, 4
Sheldon Weiner	Task 5

Messers. Berg, Steinway and Feagan, like Drs. Zissis and Prentice, are part of our established Technology Assessment team. Messers. Vincent, Suits, and Sattinger have the necessary background to provide and evaluate the technological state of the art required in this program.

Sheldon Weiner, currently completing his PhD thesis in Physics, is also a professional writer with experience in movie script writing at Tom Handy, and is eminently qualified to prepare the final documentation of this program.

#### 2.4.3. University of Michigan Consultants

University staff, who are presently members of our Technology Assessment team, and will continue on this proposed program include:

Professor Kan Chen, College of Engineering, specializing in Social Engineering (Primarily Tasks 1 and 3).

Professor Sam Estep, Law School, specializing in legal aspects of technological advances (Primarily Task 1 and 5).

Professor Lou Kasda, College of Engineering, specializing in decision theory and modeling (Primarily Task 1 and 3).

Professor William Bentley, School of Natural Resources, Resource Economist familiar with gaming simulations (Primarily Tasks 3 and 5).

To augment our capability in energy conversion technology, Dr. Marc Ross, Professor of Physics, will be added to the project as a Faculty Consultant. Dr. Ross will bring his experience as Project Director of The University of Michigan's Energy Policy Program, and will participate largely in Tasks 1 and 2.

It is planned that in the conduct of this technology assessment program, efforts will be made to involve the Environmental Law Society (ELS) of the University of Michigan. This is a group of law students interested in the legal aspects of environmental protection. While the society has existed only a few years it has established itself as a vigorous and active organization. The society concerns itself with three major types of problems - litigation, legislation and trouble shooting.

In the litigation area, the society has written and submitted several amicus curiae briefs. Usually, these briefs have been limited to fairly technical legal issues, at the heart of sound law, but usually not the focal point of the controversy. For example, recently ELS submitted a brief in Federal District Court supporting the constitutionality of the Michigan Environmental Protection Act in a suit against a sand removal operation. ELS is presently planning to institute suit against a federal agency for violation of its duties to the public under S102(c) of the National Environmental Policy Act.

Legislation writing and testimony to legislative committees occupy a major place in ELS activity. The society has had a great deal of success in writing legislation for state, regional and local governments. Usually these efforts are undertaken at the behest of a legislature. Most recently ELS has been requested to draft a comprehensive wetlands planning statute for the State of Michigan. A less visible, though by no means less important function is the testimony given by ELS on proposed legislation and agency action. There is a great need for informed legal and environmental advice.

Third, ELS does some trouble-shooting. Many citizens in the southeast Michigan area call ELS seeking either direct legal aid or referral to attorney agencies able to help them with their problem. ELS regularly has more requests for its services than it can efficiently handle. The result is that ELS has become skilled in referring these sorts of problems.

ELS performs one other type of work - Special Projects. These projects are usually long-term major efforts undertaken by individual members of the society. For example, one member of ELS will be working in the Office of the



Wayne County Air Pollution Control Commission.

It is possible that ELS participation in the ERIM technology assessment program could be secured as part of its special projects committment. To achieve a full integration of efforts, it may be desirable to augment our Technology Assessment staff with one of these students on a part time hourly basis.

Another University innovation of potential value to the Technology Assessment program is the newly instituted Course Mart Program. This program includes a variety of courses taught by non-regular faculty, or by regular faculty members wishing to teach outside their own field of specialization. Undergraduate students receive academic credit for these courses, although most of the courses are required to be offered on a pass-fail basis only. The program has been successful in large part because the courses deal with timely subject matter which cannot always be integrated into the normal cirriculum.

One of the proposed project members, Robert Abrams, has taught environmental law in the Course Mart program for the last year and one-half. He had indicated that he believes that there would be significant student interest in both technology assessment and energy problems. It is possible that this student interest in these fields could be served by the presence of this project at ERIM. There may be anticipated some reciprocal benefits to the project arising from the involvement of these particular university students. One example is preliminary research of some tangential issues which might arise, for example a study of the historical use of patents in the energy industry.

#### 2.4.4 Other Consultants

One key consultant in the area of economic studies will be Dr. Klaus P. Heiss, formerly Director, Advanced Technology Economics of MATHEMATICA, Inc. Dr. Heiss will contribute his expertise in economics and game theory to Tasks 1 and 3, and 4. His enclosed biography clearly shows the extent of his previous participation in economic studies of national importance.

Technological expertise in the area of power generation and conversion will be obtained from J. H. Anderson, Consulting Engineer, York, Pa. The Andersons (Father and Son) specialize in the field of geothermal hot-water exploration. Reportedly, their designs avoid most of the adverse environmental

effects of previous geothermal technology. Their expertise extends to solar power conversion as well. They have given testimony to Senate Committee hearings on the subject of Geothermal Energy Resources and Research (1972).

One other consultant whom we wish to participate in our Technology Assessment Program is Dr. Alden Meinal, formerly with The University of Arizona, and now forming Helio Associates with a small group of associates from The University's Optical Science Center. Dr. Meinal has expressed a willingness to cooperate in our work, but to avoid a conflict of interest, it must be on a subcontract basis with their new company, which is not yet in a position to negotiate business. Resolution of this impasse cannot be achieved until after the submission date of this proposal, and so Dr. Meinal can only be listed as a "potential consultant."

The time available to prepare this proposal did not allow completion of all feasible arrangements for consultants and advisors. Discussions were held with members of the U.S. Geological Survey and by means of requests to the Director of U.S.G.S. it should prove possible to have the active if limited participation of Dr. R. Williams on IR Remote Sensing and inventoring of geothermally rich regions, as well as experts in Menlo Park and Denver on power extraction techniques.

## 2.5 Related Programs and Activities

Through its status as a not for profit research organization, ERIM has amassed a wealth of experience to qualify for performing this proposed study. We have worked cooperatively with many government agencies including: National Science Foundation; U.S. Department of Agriculture; U.S. Geological Service; National Aeronautics and Space Administration; many agencies of the U.S. Air Force; U.S. Coast Guard; Naval Oceanographic Office; and many other defense and non-defense related offices and projects. The central focus of most of these efforts has been to study the feasibility of solving problems with remote sensing systems. We have also worked with private corporations and foreign investigators seeking to apply remote sensing data collection and processing techniques. We have developed, and are continuing to develop, data processing techniques for satellite and aircraft data. We have an acquaintance with about fifty investigations now proposed for ERTS-1, a direct involvement in nine investigations, a good working relationship and free information exchange with many of the investigators and an excellent background of experience which will be invaluable when trying to assess the likelihood of a successful outcome of the experiments and of the impact of results of sensor performance.

ERIM (formerly Willow Run Laboratories) has long been known as a pioneer in techniques and procedures for the accumulation, processing and analysis of multispectral data. It was here that the first multispectral scanner was invented, designed and built. It was here that both digital and analog techniques for the processing multispectral data were first established. Moreover, the application of remote sensing techniques to specific applications has been a long standing activity of the organization. In addition to furthering vital aspects of infrared and remote sensing technology, ERIM is widely recognized as a center for the exchange and dissemination of information relative to all aspects of remote sensing. This recognition results from our well known data banks, information centers and symposia sponsorship. The following sections describe two current Technology Assessment Programs followed by a more general description of ERIM's overall capabilities.

### 2.5.1 Project Summary: "Assessing the Impact of Remote Sensing of the Environment"

This technology assessment program is being conducted by ERIM under Grant No. G1-34899 from the National Science Foundation. The program covers

the period from July 1972 through September 1973. Dr. George Zissis is the Principal Investigator.

This project was undertaken to explore and evaluate the social, economic, political and environmental impacts of remote sensing of the environment on both national and international scene. This project aims to develop a technological assessment methodology that can be used to indicate alternatives and influence policy making decisions concerning the application of this new technology. Through analyse of the economic effects, political feasibility, and social acceptability of remote sensing applications, both beneficial and detrimental consequence will be identified or predicted, thus permitting timely remedial or preventative action.

These studies involve the determination of the current status of remote sensing technology, and today's use of remote-sensing information. An examination is being made to identify current economic, legal, and political ramifications. In parallel with these efforts is an exploration of predictive technique available for impact assessment. Those found to be valuable will be applied.

The methodology of this current program closely parallel the work proposed herein. Specific references to the applicability of this work have been made in the technical section of this proposal.

#### 2.5.2 Project Summary: "Application of Remote Sensing Technology to Local Environmental Planning and Public Policy"

The project is sponsored by the National Science Foundation through its program for Research Applied to National Needs (RANN). Other participants include personnel from the Program in Urban Studies and the Department of Geography, both from the Flint College, The University of Michigan, and members of the Department of Urban Planning of the Ann Arbor campus, and the Genesee County Metropolitan Planning Commission (GCMPC), Flint, Michigan. The contract period is June 1971--June 1974.

The objective is to assist in increasing the effectiveness of public planning agencies to be achieved by a three-part program: (1) continue to introduce the information gathering and processing capabilities and potentials of remote sensing systems to selected planning agencies; (2) determine the present information flow within and between selected agencies; and (3) measure the changes and improvements in information utilization in public decision making brought about by the remote sensing information system. The resources

and methodology being employed include: (1) infrared, optical, multispectral, and imaging radar remote sensors, automatic spectral recognition and data interpretation, basic cartographic analysis and presentation, and information formatting to agency specifications; (2) determination of the present data needs, the utilization and assessment of available data, and the transformation of information by decision processes into agency policy, identification of anomalous or disadvantageous information utilization, and identification of unmet or unrecognized data needs for which remote sensing technology would be potentially suitable; and (3) use of the descriptive model of information utilization and decision making developed in (2) to measure changes in the agencies, use of corporative cost accounting and where feasible, cost benefit analyses to measure relative costs and benefits of remote sensing information systems, and development of normative models that would increase the effect of comprehensive planning guidelines on the formation of public policy and decisions.

The subtasks in support of this objective include three specific topical investigations, a bibliographic task, and supporting analysis. These are summarized below. The principal investigator for this project is Dr. R. Keith Raney.

#### HIGHWAY CORRIDOR LOCATION

Objective: Determine the extent to which information derived through remote sensing can assist location of major highway corridors.

Preliminary Results: Two problems are perceived by highway planning personnel in the State Agency for corridor location: (1) generalized corridor and corridor selection, and (2) preparation of Environmental Impact Statements pertaining to corridor selection and the eventual highway alignment. Remotely sensed information has been judged by Agency personnel as being potentially helpful in addressing these problems. The capability to automatically classify and calculate the extent of certain physiographic features and land use, and the capability to gather data not readily available by other means (such as being particularly pertinent to help meet these problems.

Future Work: Cooperate with highway planning personnel in the Department of State Highways in gathering and interpreting information for alternate corridors in a generalized corridor to be specified, and to evaluate the impact of said information on the means employed to meet the two problems cited above.



## LAND USE POLICY DECISIONS IN INLAND LAKE AREA

Objective: Determine the impact of information derived from Remotely Sensed data and other technological sources on the formulation of land use, policy and practice for an inland lakes region being subjected to urbanization pressures.

Preliminary Results: Residential development and other aspects of urbanization in a once rural and recreational inland lakes region is proceeding subject only to piecemeal policies. The region is politically and socially disaggregate, yet the environmental consequences of the accelerated eutrophication of subject lakes as a function of land use and development is a problem common to (if not yet perceived by) all regional residents. The role of technology is to (1) help focus local concern for the problem, (2) provide quantitative data on the extent of the problem, and (3) suggest more technically desirable alternatives. Locally in the test area, bonding issues for additional sewerage have been challenged in spite of the closure to "partial body contact" by the health department last season of one of the lakes.

Future Plans: Complete identification of local opinion leaders, inform them (through GCMPC) of the consequences of action or inaction on land uses policies and consequential water quality, and observe the effect of this information on problem perception and land use and development policy formulation.

## TECHNOLOGY/AGENCY LINKAGE

Objective: To formulate methodological conclusions pertaining to the coupling of remote sensing technology to public decision making.

Sub-Objective: To create interactive linkage between this project and the Genesee County Metropolitan Planning Commission (GCMPC) to study the flow of innovative information (derived from remote sensing) into the decision making process. To respond to particular data needs of GCMPC, specifically in the preparation of a township master plan, using as appropriate remotely sensed data.

Preliminary Results: The interface between technology resources and public agencies is difficult. More blockages to linkage exist for less specialized and for less mission oriented agencies than for the converse. E.G., it is

easier to establish and maintain linkage between technology and an agency if the agency is "water resources" rather than "county planning". One methodology to improve the interface is to concentrate on one topical problem of concern to the planning agency, e.g., "township land use and land capability" for a specific township, in concert with the township's policy makers. Linkage is slowly developed, and is within its growth, cyclical. Linkage between this Project and GCMPC has grown to the working level of problem formulation and participatory interaction on data utilization.

Future Work: Continue to deepen and utilize the linkage between the Project and GCMPC. Provide remotely sensed land use inventory of Vienna Township. Evaluate the impact and cost of that output on GCMPC, and on the township planners. Cooperate in evaluation of the utility and cost of remote sensing information for problems of county planning. Formulate linkage methodological conclusions.

## ANALYSIS

Objective: To formulate evaluative conclusions regarding the costs, utility, and impact of remotely sensed information in meeting the needs of public planning and decision making.

Preliminary Results: Cost accounting for the collection, processing, and dissemination of selected remotely sensed information has been completed. Flow of information within GCMPC for sample planning tasks has been described. Specific analyses are proceeding in the three topical investigations noted above.

Future Work: Continue to monitor and interact with the three tasks to assure experiment progress that should facilitate analysis, and to complete said analyses.

## BIBIOGRAPHY

Objective: Perform literature search to determine state of knowledge of (1) technology utilization in public decision making; (2) technological innovation in local and regional governmental jurisdictions; (3) role of remote sensing in planning and public policy formulation; and (4) remote sensing technology.

Preliminary Results: Very little has appeared in the literature on the first three topics. Research to date has emphasized points (2) and (3) above. Under point (2), many articles have appeared dealing with the theory or intent of such innovation, but very few studies are reported dealing with results, either as case studies or as broader but empirically based conclusions. Under point (3), many articles have appeared dealing with aspects of the technology, some articles report pilot studies with operational agencies, many articles exist that discuss aerial photography in the planning process, but no papers have been discovered that report results of the application of more comprehensive remote sensing to meet planning data needs in an operational or quasi-operational sense. There is a large literature on remote sensing technology. The bibliographic task is concentrating on listing bibliographies, compendia, and relatively unusual selected articles.

Future Work: Continue to search the literature in the cited areas, prepare a bibliographic summary report, and use the findings in continually updating Project research.

### 2.5.3 Overall ERIM capability

#### Remote Sensing Technology

ERIM, as Willow Run Laboratories, has been active since 1960 in pioneering the application of remote sensing equipment and methods to the solution of problems in earth resources management and control of the environment. Growing out of its extensive research and development background in military airborne reconnaissance, this broad program has been directed toward investigations of remote sensing from both aircraft and spacecraft, and includes the following major activities:

- Development of new remote sensing concepts, techniques and equipment
- Research on physical and biological phenomena related to remote sensing analysis and interpretation
- Collection and analysis of remote sensing data and imagery
- Systems analysis in support of remote sensing applications
- Dissemination of information

#### Development of New Concepts, Techniques and Equipment

The capabilities of remote sensing, originally limited to the use of aerial photography, have been greatly expanded by the development of new

types of sensors, such as infrared and multispectral optical-mechanical scanners and fine resolution synthetic aperture radars. New developments of these types of sensor equipment at WRL for military purposes have been adapted to civilian applications, and the problem of reducing classification of scanner and radar imagery has been given major attention as an important means of increasing the availability of remote sensing for peaceful uses. As a part of the development of the sensory devices, new methods have been developed for processing sensor data, including optical methods for processing radar data and analysis of imagery and spectral pattern recognition methods used with multispectral sensing.

The development of the multispectral scanner concept has provided a sensor capable of reliable discrimination and identification of many types of natural surface materials and man-made structures through the use of fine resolution and quantitative analysis of spectral data. The electrical form of the scanner signal output and the inherent solution of the registration problem for multiple channels make it possible to adapt the process to automatic processing of large amounts of data.

As multispectral sensing moves to becoming a practical tool with operational applications current tasks at ERIM devoted to advancing the state of the art of multispectral processing and interpretation include the continued measurement and analysis of optical reflectance, emittance, and transmittance spectral for addition to the NASA Earth Resources Spectral Information System, modeling for atmospheric effects on scene illumination, radiation transfer in the atmosphere, classification accuracy through preprocessing schemes, signature extension methods away from known areas on the ground and estimation of sub-resolution mixtures of proportions of materials by spectral means, and analysis of advanced types of multispectral processing equipment for high-throughput rates using hybrid computers. Applications to geologic compositional mapping of silicate and iron rock types and water depth determination in shallow water areas are noteworthy developments.

#### Research on Physical, Chemical and Biological Phenomena

The interpretation and analysis of remote sensor outputs requires a fundamental knowledge of the relationship of physical, chemical, and biological phenomena to the electromagnetic signatures produced by various types of target and background materials observed by the sensors. WRL is conducting a major

program in target signature analysis designed to collect signature data through laboratory and field measurements as well as through the collection and analysis of data reported by other investigators. The Target Signature Analysis Center is responsible for the experimental and analytical investigation of electromagnetic signature data, for maintaining a computerized data bank, and for disseminating the resulting information to potential users. Research in the earth sciences and life sciences to relate remote sensing results to natural phenomena is conducted in cooperation with faculty members in teaching departments of the University.

#### Airborne Data Collection and Analysis

A large and varied program supported primarily by NASA is conducted to collect remote sensing data and imagery from airborne platforms, and to analyze and interpret the data as an important aid in solving many current problems in earth resources inventory and environmental pollution. Flights have been made over lakes and rivers, urban and agricultural areas, geothermal areas, tropical forests, and snow and ice covered regions. Ground truth collected at the time of the overflights is used to validate the remote sensor outputs and to perfect the processes of identifying crops, detecting pollution or plant disease, measuring areas, and mapping the surface cover of urban areas and natural habitats, as well as subsurface phenomena.

#### Systems Analysis

Special studies have been conducted to determine the role of remote sensing in many application areas, with considerable emphasis on investigating the role of earth resources satellites. Satellite studies, beginning in 1965, have been concerned with present and future capabilities of specific sensors, with surveys of potential satellite applications, and with contributions to economic and operational studies. Members of the technical staff have participated as individual consultants to NASA and other government agencies, and as members of special study groups in defining the objectives and program of future research leading to the full development of satellite capabilities. WRL has at various times been represented on the Committee on Remote Sensing of the Environment of the National Academy of Sciences (including its Subcommittee on Declassification), the Woods Hole Summer Study, and several of the Instrument Teams formed by NASA to study the application of specific types of sensors to satellite platforms.

### Economic and Application Analysis

ERIM, as Willow Run Laboratories, has participated in studies to identify and quantify the benefits to be derived from a wide variety of applications of remote sensing, such as the detection and control of plant disease, improved forecasting of crops, location of natural resources and monitoring of pollution. Several cost-benefit analyses have been based on detailed studies of particular cases involving for example, the use of remote sensing for plant disease detection or hydroelectric power system control. (This case in point was part of a project undertaken in cooperation with Planning Research Corporation).

Another example was an application study in which Willow Run Laboratories participated with IBM in a detailed survey of potential applications for earth resource satellites in various scientific and economic areas. This included a definition of the state of the art of major types of sensors available.

The investigation included recommendations for types of sensors and experiments to be included in an orbiting research laboratory program and schedules for implementing a suitable series of experiments.

### Dissemination of Information

A vital function of ERIM is the dissemination of scientific and technical information in those fields in which it is actively engaged. This information is presented to many audiences in many forms.

#### Information Centers

ERIM has a contractual responsibility for operating several national information centers sponsored by various agencies of the Federal Government for the purpose of collecting, analyzing, and disseminating information in broad technical areas of major importance to the national defense. Organizations and individuals with necessary security clearance have access to comprehensive collections of technical documents and data files maintained by these centers, including state-of-the-art reports published on many specific topics, as well as general and special bibliographies.

ERIM maintains and operates the following centers:

The Infrared Information and Analysis Center (IRIA), sponsored since 1955 by the Office of Naval Research.

The Target Signature Analysis Center, which is responsible for collecting and analyzing data on the reflective and emissive characteristics of many types of natural and cultural targets and backgrounds.

### The Center for Remote Sensing Information Analysis

This center was initiated at The University in 1968 to serve as a focal point for information handling and related functions within the University's extensive and long standing programs of research, education and service in the varied aspects of remote sensing. The objectives of the Center are to maintain a library of literature and data along with evaluation of these materials, to prepare and publish document accessions lists, annotated special and general bibliographies and research reviews. It will conduct state-of-the-art reviews and other special studies and analyses, and prepare and publish the results. Consultation, advisory services, and technical guidance in this field are to be provided, drawing upon the substantial experience of the Willow Run Laboratories and other University units involved in remote sensing.

### Conference and Symposia

ERIM conducts a series of Symposia on Remote Sensing of the Environment, the first one being held in 1962. The most recent meeting, the eighth held in October 1972 was attended by 825 natural scientists, physicists and engineers. This was an unclassified symposium devoted to an examination of technical sensory methods, developed originally in defense contexts, but now being adapted to civilian applications in such fields as agriculture, forestry, geology, oceanography, volcanology, and the like. This series of symposia has had a major national impact in developing the interest of natural scientists in the potential of remote sensing and in providing for the exchange of information among equipment designers, natural scientists and government representatives.

Since 1955, Willow Run Laboratories has been responsible for arranging and conducting an Annual Radar Symposium. These classified meetings are attended by an average of 500-700 specialists from government, industry, and universities to exchange information concerning the most recent advances in radar technology.

Also, as a part of its IRIA program, WRL published the classified Proceedings of IRIS, the Infrared Information Symposium.

3

COST PROPOSAL

This Section is Presented  
as Volume II to This Proposal



4  
APPENDICES

APPENDIX 4.1 UNIVERSITY OF MICHIGAN  
COLLEGE OF ENGINEERING SUMMER CONFERENCE

7312—NEW APPROACHES TO LOW-POLLUTION AND  
RESOURCE-CONSERVING POWER GENERATION

July 16-20 Fee: \$250

George I. Haddad and Dale M. Grimes, Co-Chairmen

Pollution-free, resource-conserving power generation is becoming one of our most important needs. It is also becoming quite obvious that in order to accomplish these objectives man must apply technologies and systems which in the past have appeared too expensive to be practical. This course will be concerned with nonconventional methods of power generation which include, dry-well geothermal sources, ground-based solar-cell arrays and also direct solar house heating and air-conditioning.

In particular a detailed consideration of the concept, proposed by Dr. Peter E. Glaser, of utilizing a space satellite power station will be presented. In this concept a space station is utilized to convert the sun's energy through solar cells to DC power which in turn can be employed to generate microwave power which can be transmitted to the earth and reconverted into usable electric power.

**PREREQUISITE**

Applicants should have a bachelor's degree in either engineering or a physical science or the equivalent experience.

**COURSE CONTENT**

Topics to be covered include:

- The World Energy Problem: Pollution and Resource Depletion
- Dry-Well Geothermal Sources
- Ground-Based Solar Arrays
- Direct Solar House Heating and Air-Conditioning
- A Space Satellite Power Station Concept
- Solar Cell Technology
- Microwave Power Generation, Transmission, Reception and Rectification
- Atmospheric Phenomena (Attenuation, Scattering and Diffraction)
- Other Alternatives for Low-Pollution and Resource-Conserving Power Generation
- Biological Effects and Radio Frequency Interference
- Transportation and Assembly of Space Station, Overall System Consideration, Alignment and Tracking Problems
- Integration into National Power Grids
- Economic Trade-Offs

- Implementing Integrated Circuit Systems
- Automotive Applications
- Environmental Applications
- Medical Applications
- Specifications for Integrated Circuits
- Reliability Specifications
- Failure Analysis
- Future Capabilities

**STAFF**

**From the University of Michigan:**

- Professor N. A. Masnari, Electron Physics Laboratory, Department of Electrical and Computer Engineering, chairman of the course
- Professor L.C. McAfee, Department of Electrical and Computer Engineering

**From Industry:**

- V.R. Brown, President of Environmental Metrolog, Corporation
- I.A. Lesk, Director of Central Research Laboratories, Semiconductor Products Division, Motorola Incorporated
- H.C. Lin, Professor of Electrical Engineering, University of Maryland, and Senior Advisory Engineer, Westinghouse Electric Corporation, Aerospace Division
- R.A. Stehlin, Manager of Integrated Circuits Design, Semiconductor Research and Development Laboratory, Texas Instruments, Incorporated

TECHNOLOGY ASSESSMENT OF GEOTHERMAL  
ENERGY RESOURCE DEVELOPMENT

4.2 BIOGRAPHICAL SUMMARIES

TECHNOLOGY ASSESSMENT OF GEOTHERMAL  
ENERGY RESOURCE DEVELOPMENT

BIOGRAPHICAL SUMMARIES  
OVERSIGHT COMMITTEE

Dr. David Gates

Dr. Paul McCracken

Dr. Harlan Hatcher

Dr. David M. Gates

Professor of Botany and Director, Biological Station, The University of Michigan, Ann Arbor, Michigan 48104 1971-

Academic Training

Ph.D. (Physics) The University of Michigan 1948  
M. S. (Physics) The University of Michigan 1944  
B. S. (Physics) The University of Michigan 1942  
Kansas State University 1940

Director, Missouri Botanical Garden, St. Louis, Mo. 63110  
1965-1971.

Professor of Biology, Washington University, St. Louis, Mo. 63130  
1965-1971.

and

Senior Fellow, Center for the Biology of Natural Systems,  
Washington University, St. Louis, Mo. 63130  
1965-1971.

Chairman, Environmental Studies Board, National Academy of Sciences,  
National Academy of Engineering, Washington, D.C.  
1970-

Member, National Science Board. A Presidential Appointment.  
The policy board of the National Science Foundation.  
1970-

Member, Panel of Science and Technology, Committee on Science  
and Astronautics, U. S. House of Representatives.  
1970-

Member-at-Large, Governing Board, American Institute of  
Biological Sciences. 1970-

Member, National Science Foundation Advisory Committee for  
Biological and Medical Sciences.  
1967-1970.

Member, National Air Quality Criteria Advisory Committee for  
Clean Air Standards. U. S. Public Health Service,  
Department of Health, Education and Welfare.  
1968-1970.

### Advisory Committees

Board of Advisors to Thorne Ecological Foundation. Boulder, Colorado. 1969-

Committee on Resources and Needs of the Major Systematic Biology Collections of the United States. 1969-

Council Member, International Association of Botanic Gardens. 1969-

Member, Board of Trustees of The Academy of Science of St. Louis. 1971-

Dr. Gates originated a new subdiscipline in science known as biophysical ecology. It is a combination of autecology, biometeorology, and biophysics, but in essence represents a strong analytical approach towards understanding the interaction of organisms and their environment.

Dr. Gates was the first person to observe the infrared spectrum of the sun and the molecular composition of the stratosphere using skyhook balloons as vehicles to transport infrared spectrometers into stratosphere. The first successful flight of instruments designed and launched by Dr. Gates was in 1955. It was from this flight that one of the earliest direct measurements of stratospheric water vapor was achieved. Dr. Gates lead theoretical studies concerning the molecular structure of the atmosphere and in particular worked out the details concerning the emission and absorption of infrared radiation by the atmosphere, which are important in heat budget considerations of the Earth. He made some of the first spectral measurements concerning the composition of smog in Los Angeles and demonstrated the presence of hydrocarbons in the polluted air.

His interests in science have spanned the physical and biological sciences. During recent years he has devoted himself to understanding ecosystems and in particular towards understanding the adaptation, behavior, and response of individual species within ecosystems.

## Professional Memberships

American Meteorological Society  
Botanical Society of America  
The Ecological Society of America  
Optical Society of America  
American Association for the Advancement of Science  
American Institute of Biological Sciences

## Advisory Committees

National Academy of Sciences, National Research Council.  
Committee on Remote Sensing of the Environment. 1967-1970.

National Academy of Sciences, Ex-Officio Member of Committee for  
International Environmental Programs. 1970-

American Institute of Biological Sciences, Environmental Biology  
Advisory Panel for National Aeronautics and Space Administra-  
tion. 1964-1969.

American Institute of Biological Sciences, Chairman Steering  
Committee, Flora of North America Project. 1966-

American Institute of Biological Sciences, Ad Hoc Committee  
on Public Responsibilities. 1969.

Task Force of the Study Committee for the conduct of Feasibility  
Study of a National Institute of Ecology, The Ecological  
Society of America. 1969-

Ad Hoc Advisory Committee to Smithsonian Institution Office of  
Ecology. 1968.

Satellite Sub-Committee of the Research Committee of The Arctic  
Institute of North America. 1967-

Environmental Sciences Institute (ESI) Board of Councillors,  
San Jose College, San Jose, California. 1968-

Scientific Advisory Committee to the Institute of Arctic and  
Alpine Research (INSTAAR). Boulder, Colorado. 1968-

Chairman, Ad Hoc Committee on the Environment. Environmental  
Clearinghouse Inc., Washington, D.C. 1968-1970.

PAUL W. McCracken

Paul W. McCracken, Edmund Ezra Day University Professor of Business Administration and past Chairman of the President's Council of Economic Advisers, was born in Richland, Iowa, in 1915. He holds an A.B. degree from William Penn College, Oskaloosa, Iowa, and an M.A. and Ph.D. in economics from Harvard University. Additionally, he holds an honorary L.H.D. from William Penn College, and honorary L.L.D. degrees from Albion and Huron Colleges. \*

McCracken taught on the faculty of the Foundation School, Berea College, Ky., 1937-40. He worked as an economist in the U.S. Department of Commerce, Washington, D.C., 1942-43, and then as a financial economist and director of research at the Federal Reserve Bank of Minneapolis, 1943-48.

From 1948 through 1965 he served on the faculties of the School of Business Administration and the Graduate School of Business Administration at the University of Michigan. In 1966 he assumed the title of Edmund Ezra Day University Professor of Business Administration at the University of Michigan.

McCracken was on leave from the University, 1956-59, while he served as member of the President's Council of Economic Advisers. He returned to the Council to serve as chairman in 1969 for three years.

Winner of awards and author of many papers and monographs on economic and financial policy, McCracken is a member of several professional societies and a director on several boards.

He has lectured throughout the world and participated on national economic commissions, task forces, and advisory boards. He is listed in "American Men of Science" and "Who's Who in America."

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\* Honorary Doctor of Literature degree, Iowa Wesleyan College.



HARLAN ( HENTHORNE) HATCHER

Born September 9, 1898, at Ironton, Ohio. A. B., 1922, A. M., 1923, Ph. D., 1927, Ohio State University. He is the recipient of the following honorary degrees: Doctor of Laws (LL.D.) -- Bowling Green State University (1948), University of Michigan (1951), Ohio State University (1952), University of Cincinnati (1952), Wesleyan University (1953), University of Akron (1953), Michigan State University (1955), Butler University (1955), University of North Dakota (1956), Northwestern University (1956), Kalamazoo College (1958), and University of California (1966); Doctor of Humane Letters (L. H. D.) -- College of Wooster (1954), New York University (1956), and Lawrence Institute of Technology (1958); Doctor of Letters (Litt. D.) -- Miami University (1947), University of Toledo (1952), Albion College (1952), University of Kentucky (1955), University of Pittsburgh (1955), Waseda University at Tokyo (1962), Northern Michigan University (1964), and Pennsylvania Military College (1968); Doctor of Education (Ed. D.) -- Hillsdale College (1961), and Southern Illinois University (1966).

Moving from an instructor at Ohio State University in 1922 to professor of English from 1932-1944, he served as dean of the College of Arts and Sciences from 1944-48 and as vice president of the University from 1948-51. He then served as president of The University of Michigan from 1951 until 1967. Since 1968 he has been president of the Developing Great Lakes Megalopolis Research Project, Inc. The Harlan Hatcher Graduate Library Buildings at The University of Michigan are named in his honor.

He was president of the Association of American Universities. During World War II he received decorations from The Netherlands, Thailand, Italy, and Japan.

H. H. HATCHER ( Cont. )

He is the author of many articles and books, including, "The Versification of Robert Browning" (1928), "Creating the Modern American Novel" (1935), "The Great Lakes " (1944), "Lake Erie" (1945), "A Century of Iron and Men" (1950), and "A Pictorial History of the Great Lakes" (1963).

TECHNOLOGY ASSESSMENT OF GEOTHERMAL  
ENERGY RESOURCE DEVELOPMENT

BIOGRAPHICAL SUMMARIES  
ERIM PERSONNEL

Presented on the following pages are biographical summaries for key personnel who are expected to be available to participate directly on the proposed research program. Their names and titles are listed below.

Dr. George J. Zissis	- Research Physicist
Dr. Virginia L. Prentice	- Associate Research Geographer
Dr. Mark R. Berg	- Graduate Research Assistant
Mr. Daniel M. Steinway	- Research Assistant
Dr. Robert K. Vincent	- Associate Research Engineer
Ms. Bette C. Salmon	-
Dr. Gwynn H. Suits	- Research Physicist
Dr. Sheldon R. Weiner	- Associate Research Physicist
Mr. Thomas B. Feagans	- Graduate Research Assistant
Mr. Irvin J. Sattinger	- Research Engineer
Mr. Robert H. Abrams	- Graduate Research Assistant

ZISSIS, GEORGE J.

RESEARCH PHYSICIST, OFFICE OF  
CHIEF SCIENTIST & TECHNICAL MANAGER  
INFRARED AND OPTICS DIVISION

#### EDUCATION

BS	Physics	Purdue University, 1946
MS	Physics	Purdue University, 1950
PhD	Physics	Purdue University, 1954

#### EMPLOYMENT

Meteorology Officer and Photo Intelligence Officer, U. S. Army Air Force, 1943-1946  
Instructor in Sophomore Engineering Physics, Research Fellow, Graduate Assistant and Graduate Research Assistant, Purdue University, 1946-1954  
Senior Scientist, Westinghouse Atomic Power Division, 1954-1955  
Research Associate, The University of Michigan, IST, 1955-1956  
Member of Special Air Defense Study, Office of Naval Research, Summer 1957  
Associate Research Physicist, The University of Michigan, IST, 1956-1958  
Research Physicist, The University of Michigan, IST, 1958-  
Alternate to the Head of the Infrared Laboratory, The University of Michigan, IST, 1957-1964  
Visiting Lecturer, Department of Aeronautical and Astronautical Engineering, The University of Michigan, 1961-1962  
(On Leave of Absence - September 1962 to July 1964) Staff Member, Research Engineering Support Division, Institute for Defense Analyses, 1962-1964  
Associate Head, Infrared Laboratory, The University of Michigan, IST, 1964  
Head, Infrared Physics Laboratory, The University of Michigan, IST, 1964-1969  
Lecturer, Department of Electrical Engineering, The University of Michigan, 1969-1970  
Chief Scientist, Infrared and Optics Laboratory, The University of Michigan, IST, 1969-1970. Technical Manager, 1971.

#### EXPERIENCE

Chairman of the National Academy of Sciences (NAS) Committee on Remote Sensing Programs for Earth Resource Surveys, 1969-1972; member since 1966. Member of following National Academy of Sciences and National Academy of Engineering Committees and Panels: Chairman of Panel 232.00-Photometry and Radiometry of the NAS/NAE/NRC Evaluation Panels for the National Bureau of Standards (1970-1972). Panels Advisory to National Bureau of Standards Metrology Division, 1967-1970 and to National Bureau of Standards, Heat Division, 1969-1970; Committee on Remote Sensing of Environment, 1968-1971;

ZISSIS, GEORGE J.

11/72

ZISSIS, GEORGE J.

RESEARCH PHYSICIST, OFFICE OF  
CHIEF SCIENTIST & TECHNICAL MANAGER  
INFRARED AND OPTICS DIVISION

EXPERIENCE (continued)

Panel on Systems for Remote Sensing Information and Distribution, NAS/NRC Study on Useful Applications of Earth Oriented Satellites (1968); Earth Working Group, Space Priorities Study of Space Science Board (1970); NAE Organizing Committee for the Space Applications Board (1972). Recipient of the Public Service Award by Department of Interior (1972); Editor-in-Chief, American Elsevier Publishing Co., journal "Remote Sensing of Environment," 1971-; Member, Honorary Editorial Advisory Board for Infrared Physics, Pergamon Press. Project Director for the Ballistic Missile Radiation Analysis Center, Project AMOS (the Mt. Haleakala Observatory), Projects AMPIRT and Compass Eagle, and the Night Vision Aids research program until 1969. Director of the Infrared Information and Analysis (IRIA) Center, Executive Secretary of the IRIS Specialty Groups, and Editor, Proc. IRIS. Scientific direction of programs involving studies of target and background characteristics; radiometric calibration standards and techniques; infrared systems for military and civilian applications; optical properties of materials; atmospheric propagation; and measurements and analyses of radiation from ballistic and guided missiles, aircraft and ground targets, sky and ground backgrounds. Former Project Leader for Institute for Defense Analyses RESD Project AGILE Counterinsurgency Task, Chairman of Counterinsurgency Research and Development Symposia, and member of IDA/ARPA DEFENDER Panel on Optical Discrimination (1963-1968). Past Chairman of Optical Society of America Radiometry and Photometry Technical Group, and IRIS Specialty Group on Target Measurements. In charge of critical facility for pressurized water reactor core studies and mockup; experiments concerned partial construction of facility, approach to critical with various core designs. Emission atomic beam light sources for studies of hyperfine structure, isotope shift and precision absolute wavelength measurements. Experimental and theoretical studies of Perot-Fabry interferometry. Overseas duty as photo interpreter at RAF Medmenham, Central Intelligence, specializing in third phase analysis of radar, wireless and unknown objects.

PROFESSIONAL AND HONORARY SOCIETIES

Fellow, American Association for the Advancement of Science  
Member, Sigma Xi  
Member, Sigma Pi Sigma  
Fellow, Optical Society of America  
Member, American Society of Photogrammetry  
Member, Ann Arbor Section of Optical Society of America  
Member, Science Research Club, The University of Michigan  
Member, American Geophysical Union  
Member, Research Club, The University of Michigan

ZISSIS, GEORGE J.

RESEARCH PHYSICIST,  
TECHNICAL MANAGER,  
INFRARED & OPTICS LABORATORY

LISTED IN:

American Men of Science  
Marquis - Who's Who in the Midwest  
Dictionary of International Biography

PUBLICATIONS

- "Hyperfine Structure of the Resonance Lines of Indium ( $In^{115}$ ), Co-author, Physical Review, 91, 297-299, July 15, 1953.
- "Selections of Optimal Spacers in Perot-Fabry Interferometry," Co-author, Journal of the Optical Society of America, 43, 673-680, August 1953.
- "Isotopic Shift of Germanium Lines (GEL)," Technical Report No. 1, Spectroscopy Research, Purdue University, Department of Physics, Contract N7ONR 39421, NR 019-127, January 1954.
- "Precision Wavelength Measurements of Germanium Lines (GEL) Produced in an Atomic Beam Light Source," Technical Report No. 2, Spectroscopy Research, Purdue University, Dept. of Physics, on Contract N7ONR 39421, NR 019-127, January 1954.
- "Precision Wavelengths and Isotopic Shift Measurements of Germanium Arc Lines," Co-author, Physical Review, 95, 1463-1468, Sept. 1954.
- "Critical Experiments on Slightly Enriched Uranium-Zirconium Assembly," 11, 1955, on AEC Pressurized Water Reactor Contract.
- "Preliminary Data on Air-to-Ground Background Measurements Program," delivered at the Infrared Information Analyses Symposium, March 1956.
- "Measurements of Ground Backgrounds at IRMP 1956," Co-author, delivered at the IRMP 1956 Symposium at Wright-Patterson Air Force Base.
- "Preliminary Data on Air-to-Ground Background Measurement Program," The Proceedings of the Symposium on Infrared Backgrounds, University of Michigan Report No. 2389-2-S, March 1956. (CONFIDENTIAL)
- "Measurements of Ground Backgrounds at IRMP 1956," Proceedings of IRMP Symposium 1956, 57 WCLR 2647, May 1957.
- "Final Report on NONR 2384(00)," September 1957.
- "A Slide Rule for Radiance Calculations," Co-author, The University of Michigan Report No. 2144-247-T, May 1958.
- "Reduction of S/N Ratio with Range for PbTe and Thermistor Detectors," Co-author, The University of Michigan, Report No. 2144-246-T, June 1958.
- "Field Sources of Blackbody Radiation," Co-author, The University of Michigan, Report No. 2144-264-T.
- "Infrared Measurements of Ballistic Missiles During IRMP 1958," delivered at the February 1959 meeting of IRIS.
- "Field Sources of Blackbody Radiation," Co-author, Review of Scientific Instruments, 30, 200 (1959).
- "Infrared Measurements of Ballistic Missiles During IRMP 1958," Co-author, Proceedings of IRIS, Vol. 4, No. 2, 291-340, May 1959.
- "Infrared Measurements of Ballistic Missiles During IRMP 1958," Co-author, The University of Michigan Reports No. 2900-10-T & 2144-410-J, June 1959.

ZISSIS, GEORGE J.

RESEARCH PHYSICIST,  
TECHNICAL MANAGER,  
INFRARED & OPTICS LABORATORY

PUBLICATIONS (continued)

- "Characteristics of a Ground Infrared Range," Co-author, The University of Michigan Report No. 2849-6-F, June 1959. (SECRET)
- "State-of-Knowledge - Concerning Phenomenology of Ballistic Missiles in the Launch Phase," presentation given on behalf of ARPA to the Director of Defense Research and Engineering, July 1960.
- "Ballistic Missile Radiation Analysis Center," Presentation given at Anti-Missile Research Advisory Council Meeting of 21-22 July 1960.
- "Measurements of Radiation from Missiles in the Powered Phase," Co-author, The University of Michigan Report No. 2389-38-T, October 1960 (SECRET).
- "First Annual Report of Ballistic Missile Radiation Center," Co-author, The University of Michigan Report No. 2950-19-F, July 1960. (SECRET).
- "Ballistic Missile Radiation Analysis Center," Co-author, The University of Michigan Report No. 2950-22-S, July 1960. (SECRET)
- "Transactions of the BAMIRAC 1960 Summer Study - State of Knowledge of Missile Phenomenology for Ballistic Missile Defense," Editor, The University of Michigan Report No. 3768-6-X, October 1960. (SECRET)
- "Semi-Annual Report of Ballistic Missile Radiation Analysis Center," Co-author, The University of Michigan Report No. 3768-12-T, three volumes, January 1961. (SECRET)
- "Ballistic Missile Radiation Analysis Center," Co-author, Proceedings of IRIS, Vol. 6, No. 2, 29-30 May 1961.
- "Infrared Techniques in Astrophysics," paper given at the Summer Conference for College Professors on Physics and Astronomy, Georgetown University, Washington, D. C., Summer 1961.
- "Second Annual Report of Ballistic Missile Radiation Analysis Center," Co-author, The University of Michigan Report No. 3768-29-F, July 1961. (SECRET)
- "Final Report of Ballistic Missile Radiation Analysis Center, IRMP 59/60," Co-author, The University of Michigan Report No. 3768-34-F, October 1961. (SECRET)
- "Second Semi-Annual Report of Ballistic Missile Radiation Analysis Center," Co-author, The University of Michigan Report No. 4613-9-P, December 1961. (SECRET)
- "Ballistic Missile Radiation Analysis Center Summer Study, 1961," Editor, The University of Michigan Report No. 4613-11-X, December 1961. (SECRET)
- "State-of-the-Art of IR Targets: An IRIS Briefing for J. Bridges," Office of Electronics, ODDR and E, 1962. (SECRET)
- "Fundamentals of Infrared Technology," Co-author, The Macmillan Co., 1962.
- "Third Annual Report of the Ballistic Missile Radiation Analysis Center," Co-author, The University of Michigan Report No. 4613-21-F, Vols. I and II (1 July - 30 June 1962), September 1962. (SECRET)
- "Calibration of Missile-Radiation Measuring Instruments: Final Report," Co-author, The University of Michigan Report No. 4624-14-F, Sept. 1962.

ZISSIS, GEORGE J.

RESEARCH PHYSICIST,  
TECHNICAL MANAGER,  
INFRARED & OPTICS LABORATORY

- "Methods of Radiometric Calibration," Co-author, The University of Michigan Report No. 4613-20-R, September 1962.
- "Infrared Technology and Ballistic Missile Defense," an invited lecture at the Purdue University Aeronautical and Engineering Science Colloquium, 11 January 1963.
- "Spectral Responsivity of Radiometers," Co-author, presented at Optical Society of America Meeting, March 1963.
- "Infrared Considerations Affecting the Survivability of Tactical Aircraft," IDA Study S-105, April 1963. (SECRET)
- "Infrared Target and Background Radiometric Measurements-Concepts, Units, and Techniques," Co-author, Infrared Physics, Vol. 3, No. 3, p. 139, September 1963.
- "Counterinsurgency: A Briefing for the Board of Trustees of IDA," April 22, 1964. (SECRET)
- "Review of "Light and Heat Sensing," Applied Optics, Vol. 3, No. 8, p. 914, August 1964.
- Contributor to various IDA reports on Ballistic Missile Defense, Limited Warfare, and Space Sciences.
- AMOS Study of Ground-Based Photography of Space Objects (U), Co-author, July 1965, (5900-32-X).
- "Avionics Problems in the Special Applications of Counterinsurgency," May 1965. (6400-23-R).
- "Instruments-Radiometers, Spectrometers and Interferometers," Three Lectures given at the Fundamentals of IR Technology, University of Michigan Engineering Summer Conference (1963-present).
- "Review of Thermal Radiation Laws; The Effect of Cavity Shape on Emissivity; Calibration Standards;" Three lectures given as Chairman of Infrared Radiometry - Calibration and Measurements, University of Michigan Engineering Summer Conference (1965-present).
- "Radiometry for Remote Sensing," Lecture given at NSF Sponsored Course for College Teachers in Optics, 1967, and Advanced Infrared Technology, University of Michigan Engineering Summer Conference (1967-present).
- "Radiation Sources," invited lecture at Northeastern University's NASA/ERC Seminar on Infrared Techniques (August 1965).
- "Closing Comments," presented at the 5th Symposium on Remote Sensing of Environment, April 1968, and published in Proceedings of Remote Sensing, September 1968.
- "Radiometry for Remote Sensing," Lecture given at NASA Manned Space Center, Houston, Texas, and published as University of Michigan Report No. 01672-1-X, "Notes for a Program Study in Remote Sensing of Earth Resources," November 1968.
- "Counter-infiltration and Surveillance Systems," a secret presentation at ITT Defense-Space Group National Security Seminar (December 1968).

ZISSIS, GEORGE J.

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ZISSIS, GEORGE J.

RESEARCH PHYSICIST, OFFICE OF  
CHIEF SCIENTIST & TECHNICAL MANAGER  
INFRARED AND OPTICS DIVISION

- "Infrared Image Recording Systems," presented at the Optical Telescope Technology Workshop, NASA Marshall Space Flight Center, 29 April-1 May 1969, published in Optical Telescope Technology, NASA SP-233, 1970.
- Contributor to "Systems for Remote-Sensing Information and Distribution," Report of Panel 8 of the NAS/NRC Summer Study on "Useful Applications of Earth-Oriented Satellites," for NASA (1969).
- "Force Fields; Wave Motion; Radiometric Nomenclature and Geometry; Spectral Quantities; Reflectance and Transmittance; Absorption and Emission of Radiation;" Ten lectures given as Co-chairman of Fundamentals of Remote Sensing, Engineering Summer Conference (1969).
- "Techniques for Remote Sensing of Environment," invited lecture at the National Youth Conference on the Atom, October 1969.
- "Contribution to Working Group Report, 'The Earth' for the Space Priorities Study of the NAS Space Science Board (1970).
- "IR Technology for Civilian Applications," paper presented at Symposium on Applications of Reconnaissance Technology to Monitoring and Planning Environmental Change, Rome Air Development Center, Rome, N. Y., June 1970.
- "Training and Education: The Need and The Prospect", A Panel Discussion, Proceedings of the Seventh International Symposium on Remote Sensing of Environment, Report 10259-1-X, pp. 1597-1598, (1971).
- Lectures under auspices of AAPT and American Institute of Physics "Visiting Scientists Program in Physics", at Augustana College, Sioux Falls, South Dakota, February 24-25, 1971; University of Wisconsin, Eau Claire, Wisconsin, February 1972; and Ellsworth Community College, Iowa Falls, Iowa, April 1972.
- Invited paper "Remote Sensing Techniques for Oil Slick Measurements," G. J. Zissis, et al, presented at the International Symposium on Identification and Measurement of Environmental Pollutants," Ottawa, Canada on June 16, 1971, published in Proceedings, pp. 265-270, (1972).
- Invited lecture "Remote Sensing of the Environment," at Wayne State University, Department of Physics, NSF-sponsored course on Environmental Sciences, July 8, 1971.
- "Meeting Review: Seventh International Symposium on Remote Sensing of Environment, May 17-21, 1971", Icarus 16, 401-403, (1972).
- "The Development of Remote Sensing of Earth Resources," paper presented at the 13th Meeting of the Panel on Science & Technology, Committee on Science & Astronautics, U. S. House of Representatives and published in Proceedings No. 13, January 1972, and in Remote Sensing of Earth Resources, 1972.
- "Design of a Study to Evaluate Benefits and Cost of Data from the First Earth Resources Technology Satellite (ERTS-A)", Final Report 11215-F, University of Michigan, Willow Run Laboratories, July 1972 with co-authors K. P. Heiss, MATHEMATICA, Inc. and R. A. Summers, System Planning Corporation.

PRENTICE, VIRGINIA L.

ASSOCIATE RESEARCH GEOGRAPHER

EDUCATION

BA	Geography	Michigan State University, 1944
MA	Geography	Northwestern University, 1947
Ph.D	Geography	The University of Michigan, 1972

EMPLOYMENT

Engineering Aide, U. S. Geological Survey, Washington, D.C., 1944-1945  
Graduate Assistant & Library Assistant, Northwestern University,  
Evanston, Illinois, 1945-1947  
Instructor, Michigan College of Mining & Technology, Houghton, Michigan,  
1948  
Geographer, Central Intelligence Agency, Washington, D.C., 1948-1949  
Instructor (part-time), University of Denver, 1950  
Military Pay Clerk, U. S. Army, Ft. Sheridan, Illinois, 1950-1953  
Clerk-Typist, U. S. Snow Ice & Permafrost Res. Establishment,  
Wilmette, Illinois, 1953-1955  
Geographer, USA Cold Regions Res. & Engineering Lab., Hanover, N. H.,  
1955-1964  
Research Associate, The University of Michigan, IST, 1964-1968  
Associate Research Geographer, The University of Michigan, IST, 1968-1972  
Associate Research Geographer, Environmental Research Institute of Michigan  
1973-

EXPERIENCE

Miss Prentice is assigned to the Infrared and Optics Laboratory. A major responsibility is in the collection and analysis of digital ground measurement data extracted from infrared and other imagery. Current projects include developing a methodology for assessing the impact of remote sensing technology on society. She is involved in the remote sensing programs of the laboratory, and has been coordinator and co-director respectively, of the 1966 and 1967 NSF Summer Short Courses on Remote Sensing of Environment for College Teachers, and coordinator of the 1968 and 1969 Institutes on Geographic Applications of Remote Sensing. Miss Prentice has also participated as an instructor in the University Center for Adult Education. She is a member of the Ottawa National Forest Multiple Use Advisory Committee at request of U. S. Forest Service. She has testified at U. S. House of Representatives hearings on Sleeping Bear Dunes National Lakeshore and at numerous other national and state level hearings on conservation and environmental issues.

PRENTICE, VIRGINIA L.

10/72

PRENTICE, VIRGINIA L.

ASSOCIATE RESEARCH GEOGRAPHER

PROFESSIONAL AND HONORARY SOCIETIES

Association of American Geographers -

Member, Commission on Geographic Applications of Remote Sensing 1967-70  
Sigma Xi

American Society of Photogrammetry

President, Great Lakes Region, 1969

Chairman, Remote Sensing Committee, Remote Sensing & Interpretation  
Division, 1970

Society of Women Geographers

American Association for the Advancement of Science-Fellow

Graduate Women in Science (formerly Sigma Delta Epsilon)

Glaciological Society

Michigan Academy of Science, Arts & Letters

The University of Michigan Women's Research Club-President 1969-1970

CIVIC AND SERVICE ORGANIZATIONS, ETC.

Sierra Club - National Bulletin Advisory Committee 1969-1970

Nominating Committee 1970-1971

Chairman, Mackinac Chapter 1967-1970

Michigan Natural Areas Council -

Board of Directors, 1972

McCormack Tract Ad Hoc Citizens Advisory Committee - 1970

Ottawa National Forest Multiple Use Advisory Committee 1972-1973

HONORS

Presidential Citation for Meritorious Service - American Society  
of Photogrammetry, March 1967

Meritorious Service Award - Sierra Club - 1971

LISTED IN

American Men of Science

PRENTICE, VIRGINIA L.

ASSOCIATE RESEARCH GEOGRAPHER

PUBLICATIONS

- "Photo Interpretation of Vegetation. Literature Survey and Analysis",  
Technical Report 69, USA Snow Ice and Permafrost Research Establishment,  
Corps of Engineers, Wilmette, Illinois, 1960.
- Background Study of Puerto Rico. Briefing Report for use in Aerial  
Sensing Studies of Tropical Areas. USA Cold Regions Research and  
Engineering Laboratory, Special Report 71, 1965, 75 pp., Hanover,  
New Hampshire.
- "General Description of Raytran Study Sites", USA Cold Regions Research  
and Engineering Laboratory, Technical Note, 1964, Hanover, New Hampshire,  
(not for general distribution).
- "Airphoto Analysis of Willmar, Minnesota", USA Cold Regions Research and  
Engineering Laboratory, Technical Note, 1964, Hanover, New Hampshire,  
(not for general distribution).
- "Air Photo Interpretation", The Professional Geographer, Vol. XVI, No. 2,  
March 1964, Review Article.
- "Comparison of Terrain Analysis from Side Looking Radar with Visual Aerial  
Photography", co-author, USA Cold Regions Research and Engineering  
Laboratory, Technical Report (SECRET).
- "Aerial Photographs as Basic Source Materials in Geographic Research: An  
Example from the Grand Coulee Area", paper read at the Annual Meeting  
of the Association of American Geographers, Santa Monica, California,  
1957, Abstract published in the Annals of the AAG, Vol. 48, 1958.
- "Contributions of Air Photo Interpretation to the Study of the History  
of Man", Paper read at the Annual Meetings of the American Society of  
Photogrammetry, Washington, D. C., March 7, 1967.
- Remote Sensing of Environment, Report No. 4864-12-P, Institute of Science  
and Technology, Willow Run Laboratories, The University of Michigan,  
April 1967, 22 pp.
- "Scale, Detail and the Fine Art of Generalization", Paper presented at  
the Ninth Annual Meeting of the American Institute of Aeronautics and  
Astronautics, Anaheim, California, October 1967, 11 pp.
- "Multisensor Aerial Reconnaissance of Salmon Event Underground Nuclear  
Explosion", co-author, USNRDL-TR-67-131, U. S. Naval Radiological  
Defense Laboratory, San Francisco, California, 20 October 1967, 182 pp.,  
(CONFIDENTIAL).
- "Selected Bibliography of Remote Sensing", co-author, Inter-agency Report  
NASA-129, U. S. Department of the Interior, Geological Survey, 1938,  
34 pp.
- "Time Periods and Spectral Regions: Implications for Geographic Investi-  
gations Utilizing Infrared Imagery," co-author, Paper prepared for the  
International Geographic Union Meetings, New Delhi, India, December 1968,  
Report No. 4864-15-Sa, The University of Michigan, Willow Run Laboratories.

PRENTICE, VIRGINIA L.

ASSOCIATE RESEARCH GEOGRAPHER

PUBLICATIONS (continued)

"Progress in Remote Sensing and Its Application to Highway Engineering and Research", Remote Sensing and Its Application to Highway Engineering, co-author, Highway Research Board, National Research Council, Washington, D. C., Highway Research Board Special Report No. 102, pp. 38-48, 1969.

"Sleeping Bear Dunes....A National Lakeshore for Michigan", Sierra Club Bulletin, Vol. 54, No. 6, June 1969, pp. 8-11.

Infrared Survey for Kimberlite Deposits in Botswana, co-author, Report No. 3047-1-L, Willow Run Laboratories, Institute of Science and Technology, The University of Michigan, December 1969.

"Multispectral Remote Sensing Techniques Applied to Salinity and Drainage Problems, Columbia Basin, Washington", PhD Dissertation, 1972.

"Effective Environmental Action," Sierra Club Council Newsletter, Vol. IV, No. 2, 1972, pp. 4-5, 8.

PRENTICE, VIRGINIA L.

-4-

10/72

BERG, MARK R.

GRADUATE RESEARCH ASSISTANT

#### EDUCATION

BSE, Mechanical Engineering, University of Michigan, 1967  
MSE, Mechanical Engineering, University of Michigan, 1968  
Special Student Status, Rackham Graduate School, University  
of Michigan, 1970-71  
Ph.D., Program in Urban & Regional Planning, University of  
Michigan, 1972-Present

#### EXPERIENCE

Student Research Assistant, Biomechanics Research Center,  
Wayne State University, Summers 1964, 65, and 66.

Research Associate, Highway Safety Research Institute,  
University of Michigan, 1967-68.

Project Engineer, General Motors-Safety Research and  
Development Laboratory, 1968-1971 (part time, 1971-72).

Research Associate, Project PROPE, NSF-#GS 31522, University  
of Michigan, 1971-72.

Graduate Research Assistant, Technology Assessment of Remote  
Sensing of the Environment, Environmental Research Institute  
of Michigan, 1972-present.

#### HONORARY SOCIETIES

Pi Tau Sigma Society

#### PUBLICATIONS

Growth Policy: Population, Environment, and Beyond, Chen, Lagler,  
Berg, et.al., University of Michigan Press, 1973

Growth, Resources and Environment, PROPE working paper, Mimeo,  
1972.

"Paradigms and the Growth of Knowledge," The Philosophy Forum,  
Vol.XII, No.2, December 1972.

STEINWAY, DANIEL M.

RESEARCH ASSISTANT

#### EDUCATION

BSE, Engineering Science, University of Michigan, 1972

#### EMPLOYMENT

Research Assistant, Willow Run Laboratories, Environmental  
Research Institute of Michigan, 1972-Present

#### EXPERIENCE

Writing of articles for the Michigan Technic, a University of  
Michigan College of Engineering publication.

Writing of reports and proposals for Willow Run Laboratories  
of the University of Michigan and the Environmental Research  
Institute of Michigan.

Analysis of feasible automobile pollution controls.

#### HONORARY SOCIETIES

Cum Laude Society

#### AWARDS

Rensselaer Polytechnic Institute Medal of Science  
Dean's List, The University of Michigan, 1971-72

#### PUBLICATIONS

The Feasibility of a Nitric Oxide Catalytic Afterburner, Steinway,  
Hartstein, et.al., Report on senior-year independent project, The  
University of Michigan, 1972.

The Ideology of Mark Twain, Report on senior-year independent project,  
The University of Michigan, 1972.

Contractors of Port Huron Water Tunnel Versus City of Detroit, Steinway,  
et.al., Presentation of plaintiffs brief in the Port Huron water tunnel  
explosion lawsuit, The University of Michigan, 1972.

VINCENT, ROBERT K.

ASSOCIATE RESEARCH ENGINEER

Born 6 February 1941, Bunkie, Louisiana

Married - 3 Children (Derek born 12 January 1967 and David and Heather born 14 April 1969)

**EDUCATION:**

BA Louisiana Tech University, 1963, Math, (Cum Laude)  
BS Louisiana Tech University, 1963, Physics (Cum Laude)  
MS University of Maryland, 1966, Physics  
PhD The University of Michigan (currently pursuing), Geology

**EMPLOYMENT**

1961 (summer) - United Gas Research Lab. - Engineering Asst.  
1963 - 1965 (summers) - Texas Instruments, Inc. - Engineer  
1966 - May 1970 - Air Force Cambridge Research Labs. - Capt. USAF,  
General Physicist, Lunar-Planetary Research Branch,  
Space Physics Laboratory  
1970 - 1972 - The University of Michigan, Institute of Science and  
Technology, Willow Run Laboratories  
1973 - Present - The Environmental Research Institute of Michigan  
(formerly Willow Run Laboratories).

**EXPERIENCE:**

**Air Force Cambridge Research Laboratories:**

While at Air Force Cambridge Research Laboratories Mr. Vincent was actively engaged with infrared imaging of the moon and planets via earth-based telescopes. He conducted both experimental and theoretical investigations pertaining to the infrared spectra of particulate surfaces, in order to determine what effect surface roughness has on infrared remote sensing data. The theoretical work was based on Mie scattering theory as applied to particulate media which have complex indices of refraction.

**The University of Michigan:**

At The University of Michigan, Mr. Vincent has primarily performed research connected with a NASA Earth Resources contract. He has conducted analytical studies to relate laboratory emissivity data of various rocks and soils to the actual radiance data collected by detectors on-board airplanes and satellites and has studied emission polarization properties of various natural and man-made materials. In October 1970 he became principal investigator for a NASA multispectral data-taking flight over Pisgah Crater, California, for the purposes of improving a technique he devised earlier in 1970, for recognizing gross differences in silica content among silicate targets, and creating a new technique for discrimination of iron oxides. He has had contrac-



VINCENT, ROBERT K.

ASSOCIATE RESEARCH ENGINEER

**EXPERIENCE (cont):**

tual responsibilities for the creation and maintenance of the Earth Resources Spectral Information System of the NASA Manned Spacecraft Center in Houston, Texas. In 1972 he became a principal investigator on an accepted Earth Resources Technology Sattelite (ERTS) proposal entitled "Mapping of Exposed Ferric and Ferrous Compounds," which will be completed in late 1973. He has also been named a principal investigator on a SKYLAB proposal, on which work will start in July 1973. In 1972, Mr. Vincent was named to an ad hoc committee to advise the NASA Planetology Chief, Mr. Steve Dwornik, on geological remote sensing in the solar system.

**PROFESSIONAL SOCIETIES:**

American Institute of Physics (1963)  
Optical Society of America (1968)  
American Geophysical Union (1968)  
American Association for the Advancement of Science (1971)

**PUBLICATIONS:** (see attached sheets)

VINCENT, ROBERT K.

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VINCENT, ROBERT K.

ASSOCIATE RESEARCH ENGINEER

Non-Report Publications

"Infrared Reflectance from Mat Surfaces," R. K. Vincent and G. R. Hunt, Applied Optics, v. 7, pp. 53-59, 1968.

"Modification to the Perkin-Elmer Reflectance Attachment for Studying Powders," G. R. Hunt and R. K. Vincent, Journal of Scientific Instruments, v. 1, pp. 470-471, 1968.

"The Behavior of Spectral Features in the Infrared Emission from Particulate Surfaces of Various Grain Sizes," G. R. Hunt and R. K. Vincent, Journal of Geophysical Research, v. 73, pp. 6039-6046, 1968.

"Lunar Eclipse: Infrared Images and an Anomaly of Possible Internal Origin," G. R. Hunt, J. W. Salisbury and R. K. Vincent, Science, v. 162, pp. 252-254, 1968.

"Infrared Images of the Eclipsed Moon," G. R. Hunt, J. W. Salisbury, and R. K. Vincent, Sky and Telescope, v. 36, pp. 223-225, 1968.

"Lunar Thermal Anomalies and Internal Heating," G. R. Hunt, J. W. Salisbury and R. K. Vincent (comments on), Astrophysics and Space Science, v. 4., pp. 370-372, 1969.

"Bibliography of Lunar-Planetary Research - First Quarter 1969," J. E. Adler, S. R. Balsamo, J. P. Dybwad, G. R. Hunt, L. M. Logan, J. S. Salisbury, R. K. Vincent, and K. P. Zinnow, Icarus, v. 11, pp. 118-138, 1969.

"Infrared Emissivity of Lunar Surface Features: Part II. Interpretation," J. W. Salisbury, R. K. Vincent, L. M. Logan and G. R. Hunt, Journal of Geophysical Research, v. 75, pp. 2671-2682, 1970.

"Infrared Emissivity of Calcite Powders as Calculated from a Cloudy Atmosphere Model and Compared with Experimental Results," (Abstract), R. K. Vincent, Transactions of the American Geophys. Union, v. 51, No. 4, p. 337, 1970.

"Discrimination of Basic Silicate Rocks by Recognition Maps Processed from Aerial Infrared Data," R. K. Vincent and F. Thomson, Proceedings of the Seventh International Symposium on Remote Sensing of Environment, pp. 247-252, 1971.

"Infrared Recognition Maps of Silicate Rock Types - A New Tool for Mineralogical Exploration," R. K. Vincent, Abstract only, ABSTRACTS, 1971 Annual Meeting of the Geological Society of America in Washington, D. C., p. 739, 1971.

VINCENT, ROBERT K.

ASSOCIATE RESEARCH ENGINEER

Non-Report Publications (cont)

"Discrimination of Iron-Rich Zones Using Visible and Near-Infrared Spectral Analysis," L. Rowan and R. K. Vincent, Abstract only, ABSTRACTS, 1971 Annual Meeting of the Geological Society of America in Washington, D. C., p. 691, 1971.

"Rock Type Discrimination from Ratioed Infrared Scanner Images of Pisgah Crater, California," R. K. Vincent and F. Thomson, Science, v. 175, pp. 986-988, 1972.

"Recognition of Exposed Quartz Sand and Sandstone by Two-Channel Infrared Imagery," R. K. Vincent, F. Thomson, and K. Watson, Journal of Geophysical Research, v. 77, pp. 2473-2477, 1972.

"Spectral Compositional Imaging of Silicate Rocks," R. K. Vincent and F. Thomson, Journal of Geophysical Research, v. 77, pp. 2465-2471, 1972.

"Experimental Methods for Geological Remote Sensing," R. K. Vincent, Fourth Annual Earth Resources Program Review Proceedings, NASA Manned Spacecraft Center, Houston, Texas, 1972.

"Emission Polarization Study on Quartz and Calcite," R. K. Vincent, Applied Optics, v. 11, pp. 1942-1945, 1972.

"An ERTS Multispectral Scanner Experiment for Mapping Iron Compounds," R. K. Vincent, Proceedings of the Eighth International Symposium on Remote Sensing of Environment, Ann Arbor, Michigan, to be published in 1972.

VINCENT, ROBERT K.

9/72

VINCENT, ROBERT K.

ASSOCIATE RESEARCH ENGINEER

PUBLICATIONS (cont)

Technical Reports

J. E. Adler, W. E. Alexander, J. P. Dybwad, G. R. Hunt, J. W. Salisbury, and R. K. Vincent, "Bibliography of Lunar and Planetary Research Supplement No. 3-1967," U. S. Air Force Cambridge Research Laboratories, Bedford, Mass., 1968.

J. E. Adler, S. R. Balsamo, J. P. Dybwad, G. R. Hunt, L. M. Logan, J. W. Salisbury, R. K. Vincent, and K. P. Zinnow, "Bibliography of Lunar and Planetary Research Supplement No. 4-1968," U. S. Air Force Cambridge Research Laboratories, Bedford, Mass., 1969.

R. K. Vincent, "Geological Remote Sensing in the Thermal Infrared Wavelength Region," Notes for a Short Course in Advanced Infrared Technology, Institute of Science and Technology, The University of Michigan, Ann Arbor, 1971.

V. Leeman, D. Earing, R. K. Vincent and S. Ladd, "The NASA Earth Resources Spectral Information System: A Data Compilation," The University of Michigan Technical Report 3165-24-T, NASA Contract NAS 9-9784, 1971.

R. K. Vincent, "Data Gaps in the NASA Earth Resources Spectral Information System," The University of Michigan Technical Report 3165-25-T, NASA Contract NAS 9-9784, 1971.

R. K. Vincent, R. Horvath, F. Thomson, and E. Work, "Remote Sensing Data-Analysis Projects Associated with the NASA Earth Resources Spectral Information System," The University of Michigan Technical Report 3165-26-T, NASA Contract NAS9-9784, 1971.

R. K. Vincent, "Rock-Type Discrimination from Ratio Images of the Pisgah Crater, California Test Site," The University of Michigan Report 3165-77-T, NASA Contract NAS9-9784, 1972.

R. K. Vincent, G. Suits, H. Horowitz, and J. Erickson, "Investigation of the Theoretical Methods for the Optical Modeling of Agricultural Fields and Rough-Textured Rock and Mineral Surfaces," The University of Michigan Report, 3165-78-T, NASA Contract NAS9-9784, 1972.

T. Wagner, R. K. Vincent, B. Drake, R. Mitchell, and P. Jackson, "Tunnel-Site Selection by Remote Sensing Techniques," The University of Michigan Technical Report 10018-13-F, U. S. Bureau of Mines Contract H0210041 (ARPA Order No. 1579, Amendment 2, Program Code IF10), 1972.

SALMON, BETTE C.

Born 17 February 1948, Mount Holly, New Jersey

EDUCATION:

Pitman High School, Pitman, New Jersey, Class of 1966

BS Juniata College, Huntingdon, Pennsylvania, 1969, Geology  
MS The University of Michigan, Ann Arbor, 1972, Structural  
Geology

SCHOLARSHIPS AND AWARDS:

1966, valedictorian of Pitman High School, Pitman, New Jersey  
1966, Rotary Club Scholarship for Community Service,  
Pitman Rotary Club, Pitman, N. J.  
1969, Anna Blaisdell Memorial Award in Geology and Mathematics,  
Juniata College, Huntingdon, Pennsylvania  
1969, 1970, National Science Foundation Traineeship, The  
University of Michigan, Ann Arbor.

EMPLOYMENT:

1968-69 - Juniata College, Teaching assistant  
1971 - The University of Michigan, Department of Materials  
and Metallurgy, Technician (part-time)  
1971-72 - The University of Michigan, Department of Geology  
and Mineralogy, Research Assistant and teaching Fellow  
1972-present - Environmental Research Institute of Michigan

EXPERIENCE:

Juniata College:  
Miss Salmon was a teaching assistant for introductory Geology at  
Juniata College.

The University of Michigan:  
At the University Miss Salmon has been a part-time technician on  
the transmitting and scanning electron microscope in the Department  
of Materials and Metallurgy, a research assistant in rock mechanics-  
ore deposits research under Prof. William C. Kelley and Prof.  
Bruce Clark of the Department of Geology and Mineralogy, and a  
teaching fellow for introductory geology. Her Masters thesis was  
concerned with deformation in sulfides. Since the Environmental

SALMON, BETTE C.

EXPERIENCE (Cont)

Research Institute of Michigan (formerly Willow Run Laboratories)  
she has been assisting in research in geological remote sensing,  
including examination of ERTS-A data over the Wind River Range,  
Wyoming, for structural and mineral resource information.

PROFESSIONAL SOCIETIES:

Student associate of SEPM  
Student member of GSA

SUITS, GWYNN H.

RESEARCH PHYSICIST

EDUCATION

BS	Physics	The University of Michigan, 1947
MA	Physics	The University of Michigan, 1948
PhD	Physics	The University of Michigan, 1955

EMPLOYMENT

Teaching Fellow, The University of Michigan, 1947-1951  
Research Assistant, The University of Michigan, IST, 1951-1954  
Research Associate, The University of Michigan, IST, 1954-1958  
Research Physicist (Head, Infrared Laboratory), The University of Michigan, IST, 1958-1964  
(Leave of Absence, to serve on the staff of the Institute for Defense Analyses, Arlington, Virginia, 1964-1965)  
Research Physicist, Program Planning Staff, Willow Run Labs, IST, The University of Michigan, 1965-1973  
Professor of Remote Sensing, Forestry, School of Natural Resources, The University of Michigan, 1968-1973  
Research Physicist, Environmental Research Institute of Michigan, 1973 -  
Adjunct Professor of Remote Sensing, School of Natural Resources, The University of Michigan, 1973 -

EXPERIENCE

Dr. Suits has worked in electronics (high-frequency) and pulse techniques, (electrical noise study in semiconductors); in solid state-physics (preparation of high-purity, single-crystal semiconducting material, preparation and study of thin evaporated metal and insulating films); in physical optics and optical spectroscopy; and laboratory administration. He prepared and presented lectures on quantum detectors for the course on Fundamentals of IR Technology, The University of Michigan Engineering Summer Conferences, and conducted courses dealing with the subject of Remote Sensing. He has done research in remote sensing for both military and civilian applications.

PROFESSIONAL AND HONORARY SOCIETIES

American Physical Society  
Sigma Xi  
American Society of Photogrammetry

SUITS, GWYNN H.

1/73

SUITS, GWYNN H.

RESEARCH PHYSICIST

LISTED IN

American Men of Science

PUBLICATIONS

- Doctoral Dissertation: "Metal-Insulator-Metal Junction," University Microfilms, Ann Arbor, Michigan 1955. 80 pages. The official publication of the doctoral dissertation.
- "Excess Noise in InSb," Co-author, J. of Applied Physics, Vol. 27, November 1956.
- "A Single-Crystal Photoconductive Tellurium Detector," Co-author, 2144-240-T, February 1958.
- "Atmospheric Absorption Effects on Radiometer Response," Co-author, 2144-380-T, 1958.
- "Exact Current-Voltage Relation for the Metal-Insulator-Metal Junction with a Simple Model for Trapping of Charge Carriers," J. Appl. Phys., April 1957.
- "Notes on Methods of Obtaining Resolution Finer than the Instantaneous Field of View of a Scanning Device," with M. Holter, Proc. IRIS, Vol. 4, No. 4, October 1959. (SECRET)
- "The Nature of Infrared Radiation and Ways to Photograph It," The University of Michigan, Report No. 36943-9-S, February 1960, published in Photogrammetric Engineering, December 1960.
- "Report on Scan Correction," Co-author, The University of Michigan, Report No. 2900-256-S/Sa, March 1961, Proc. IRIS, Vol. 6, No. 2, (CONFIDENTIAL)
- "Fundamentals of Infrared Technology," Co-author, 1962, MacMillan Co.
- "Foliage Penetration Experiment," 2900-430-I.
- "Spectrum Matching and Imaging Device," Co-author, IRIS paper, 2900-448-J.
- "Infrared Study of Lunar Surface Details," The University of Michigan, Report No. 6194-1, March 1964, Co-author.
- "Air Launched Anti-Tank Weapons," 1965, Co-author. (SECRET)
- "Theoretical Comparison of Visual Aid and Night Vision Equipment, 1965. (CONFIDENTIAL)
- "Considerations for Declassification of Airborne Infrared Remote Sensing Devices," The University of Michigan, Report No. 36943-75-S, February 1966, Paper No. 252, ACSM-ASP Convention, March 6-11, 1966.
- "Declassification of Infrared Devices," Photogrammetric Engineering, November 1966.
- "Remote Sensing of Southern Corn Leaf Blight," G. R. Safir, G. Suits, A. Ellingboe, American Phytopathological Society Meeting, 1971.



SUITS, GWYNN H.

RESEARCH PHYSICIST

PUBLICATIONS (continued)

- "Introduction to Sensors," International Workshop on Remote Sensing, Ann Arbor, Michigan, 1971.
- "Remote Sensing Interpretation," North Central Regional Meeting, American Phytopathological Society, E. Lansing, Michigan, 1971.
- "Remote Sensing Techniques for Oil Slick Measurements," R. Horvath, W. Morgan, F. C. Polcyn, and G. H. Suits, International Symposium on Identification and Measurement of Environmental Pollutants, Ottawa, Canada, 1971.
- "Spectral Reflectance and Transmittance of Blighted and Healthy Corn," G. Safir, G. Suits, and A. Ellingboe, *Phytopathology*, 62, 1210, 1972.
- "The Calculation of the Directional Reflectance of a Vegetative Canopy," G. Suits, *Remote Sensing of Environment*, 2, 117, 1972.
- "Infrared Fluorescence of Corn Leaves Infected by Southern Corn Leaf Blight," G. Suits and co-authors, submitted to *Photogrammetric Engineering*, 1971.
- "Directional Reflectance of Vegetative Canopies," G. Suits, G. Safir, presented at Optical Society of America, Ann Arbor Section, 20 January 1972.
- "Prediction of Directional Reflectance of a Corn Field Under Stress," G. Suits, G. Safir, A. Ellingboe, 4th Annual Earth Resources Program Review, NASA, MSC, Houston, January 17-21, 1972.
- "The Cause of Azimuthal Variations in Directional Reflectance of Vegetative Canopies," G. Suits, *Remote Sensing of Environment*, 2, 175, 1972.
- "Verification of a Reflectance Model for Mature Corn with Applications to Corn Blight Detection," G. Suits and G. Safir, *Remote Sensing of Environment*, 2, 183, 1972.
- "Application of a Directional Reflectance Model to Wheat Canopies under Stress," G. Safir, G. Suits and M. Wiese, presented at International Conference on Remote Sensing in Arid Lands, Tucson, Arizona, November 1972.
- "The Nature of Electromagnetic Radiation," G. Suits, Chapter II, *Manual of Remote Sensing*, American Society of Photogrammetry (in publication).

SUITS, GWYNN H.

1/73

WEINER, SHELDON R.

ASSOCIATE RESEARCH PHYSICIST

#### EDUCATION

BA, Journalism, Wayne State University, 1949  
BS, Mathematics, Wayne State University, 1961  
MS, Physics, Michigan State University, 1967  
PhD, Physics (expected) University of Michigan 1973

#### EMPLOYMENT

Writer, The Jam Handy Organization, 1962-1967  
Writer, Free Lance, 1967-1969  
Technical Writer, University of Michigan, IST, 1969-1972  
Teaching Fellow, University of Michigan, 1971-1972  
Associate Research Physicist, University of Michigan, IST (ERIM)  
1972-present

#### EXPERIENCE

Writing of reports, films, promotional and technical presentations for industrial clients including: Ford Motor Company, General Motors Corporation, Dupont, Eastman Kodak, GAF and Armco Steel.

Writing of reports and proposals for Willow Run Laboratories of The University of Michigan

Measurement and analysis of radioactive isotope nuclear energy levels and their spin assignments. Investigation of high energy interactions of cosmic ray primaries with nuclei of atmospheric constituents, including primary energy spectrum, neutral-to-charge ratio and proton-nucleus inelasticity.

Bidirectional reflectance modeling of visible and infrared radiation from rough surfaces. Evaluation of methods used to monitor atmospheric constituents.

#### PROFESSIONAL SOCIETIES

American Physical Society  
American Association of Physics Teachers

#### SCIENTIFIC PUBLICATIONS

Energy Dependence of the Neutral-to-Charged Ratio at Chacaltaya,  
Proceedings of the 12th International Conference on Cosmic Rays, The  
University of Tasmania, Hobart, Australia, 1971.

Bidirectional Reflectance Model Validation and Utilization, Environmental  
Research Institute of Michigan, Report No. 196400-1-T (with J. Beard,  
J. R. Maxwell, D. Ladd and S. Ladd), 1973.

Polarized Radiance, Environmental Research Institute of Michigan, Report  
No. 192500-1-T(I) (with J. R. Maxwell), 1973.

Evaluation and Recommendations for Methods of Environmental Monitoring by  
Remote Sensing, Chapter III (with D. Anding), Unpublished report to the  
Environmental Protection Agency.

FEAGANS, THOMAS B.

Graduate Research Assistant

**EDUCATION**

West Virginia University 1959-63 BA degree in Mathematics  
West Virginia University 1963-64 MA degree in Mathematics  
Massachusetts Institute of Technology 1965-68 Philosophy of Science  
and Logic, no degree to date  
University of Michigan 1969-70 Mathematical Economics,  
1971-present no degree to date

**EMPLOYMENT**

Graduate Assistant in Mathematics, West Virginia University, 1963-64  
Instructor of Mathematics, West Virginia University, 1964-65  
Research Assistant, Facilities Inventory Research, Cambridge, Massachusetts,  
1968-69  
Student Administrative Assistant, University of Michigan Parking Office,  
1969-70  
Student Assistant (Analysis Section), Willow Run Laboratories, 1970-71  
Research Assistant, Institute for the Study of Mental Retardation,  
U. of M., 1971

**AWARDS**

Claude Benedum Undergraduate Scholarship, West Virginia University, 1959  
NDEA Fellowship for the Study of Philosophy of Science, MIT, 1965-68

**PROFESSIONAL SOCIETIES**

American Mathematical Association  
Association for the Study of Symbolic Logic  
American Economic Association

**RESEARCH REPORTS**

"A Study of the Feasibility of Introducing PPB Methods into the Boston  
Public School System" (unpublished)  
"An Economic Analysis of the Future of The University of Michigan Parking  
System" (unpublished)  
"Theoretical Approaches to the Study of Mental Disturbance; A Philosophy  
of Science Overview" (To be published as an ISMR Monograph, University  
of Michigan, 1972)

SATTINGER, IRVIN J.

RESEARCH ENGINEER

#### EDUCATION

BS Electrical Engineering The University of Michigan, 1933  
MS Electrical Engineering The University of Michigan, 1935

#### EMPLOYMENT

Junior Engineer, Central Ohio Light & Power Company, 1936-1937  
Electrical Draftsman, Commonwealth & Southern Corp., 1937-1938  
Electrical Draftsman, Loup River Public Power Dist., 1938-1939  
Assistant Engineer, Indiana Service Corp., 1938-1941  
Electrical Designer, Basic Magnesium, Inc., 1941-1943  
Instructor (part time), Ohio Northern University, 1944-1945  
Design Engineer, Lear, Inc., 1943-1948  
Research Engineer, The University of Michigan, IST, 1948 -

#### EXPERIENCE

Design of electric power distribution systems. Development of aircraft temperature and flight controls. Development of guided missile control systems. Analysis of guided missile and air defense systems. Research on military ground vehicles (computer studies of suspension and fire control subsystems; development of terrain measurement systems). Studies of automatic checkout systems for guided missiles. Analysis and design of data-conversion systems. Studies of space vehicle navigation and attitude control systems. Definition of manned earth orbiting experiments in earth observation. Technical, operational and economic studies of remote sensing applications to agriculture, forestry, hydrology, oceanography, and urban problems.

#### PROFESSIONAL AND HONORARY SOCIETIES

Member, Tau Beta Pi  
Member, Phi Kappa Phi  
Senior Member, Institute of Electrical & Electronics Engineers

SATTINGER, IRVIN J.

12/71

**SATTINGER, IRVIN J.**

**RESEARCH ENGINEER**

**PUBLICATIONS**

- "Application of the Analog Computer to the Design of Military Vehicles," with E. B. Therkelsen, C. Garelis, H. T. Nay, S. R. Lampert, Report No. 2023-1-T, WRL, The University of Michigan, Ann Arbor, Michigan, 1954 (CONFIDENTIAL).
- "Application of Analog Computers to Automotive Design," Report No. WRR-1-S, 15 January 1954.
- "Analysis of the Suspension System of the M47 Tank by Means of Simulation Techniques," with E. B. Therkelsen, C. Garelis, and V. H. Geyer, Report No. 2023-2-T, WRL, The University of Michigan, Ann Arbor, Michigan, June 1954.
- "Simulation of Military Vehicle Suspension Systems," with E. B. Therkelsen, Proceedings of IRE National Simulation Conference, January 19, 21, 1956, pp. 1.1-1.6.
- "Design of a Shock Absorber Mechanism for the Gun Elevating System of a Military Tank," with S. R. Lampert, Association for Computing Machinery Conference, June 23-25, 1954.
- "Application of Electronic Computers to Scientific Problems," Proceedings of the Conference on Ships and Waves, October 25-27, 1954.
- "Methods of Evaluating the Effects of Terrain Geometry on Vehicle Mobility," Proceedings of the Interservice Vehicle Mobility Symposium, April 18-20, 1955.
- "Scope Visualizes Computer Results," Control Engineering, pp. 109, 111, 113, October 1956.
- "Navigational Techniques for Interplanetary Space Flight," with W. R. DeHart and others, Report No. 2752-15-F, WRL, The University of Michigan, Ann Arbor, Michigan, May 1959.
- Book "Applying Computers," June 1959.
- "An Instrumentation System for the Measurement of Stress-Strain Relationships of Soil," American Association for the Advancement of Science, December 26-31, 1959.
- "Analysis of a Falling-Sphere Experiment for Measurement of Upper-Atmosphere Density and Wind Velocity," with J. Otterman and D. F. Smith, Report No. 2873-5-F, WRL, The University of Michigan, Ann Arbor, Michigan, April 1960.
- "Computer Simulation of Vehicle Motion in Three Dimensions," with D. F. Smith, Report No. 2901-10-T, WRL, The University of Michigan, Ann Arbor, Michigan, April 1960.
- "Final Report on Development of Vehicle Computation Methods," with D. F. Smith, Report No. 2901-11-F, WRL, The University of Michigan, Ann Arbor, Michigan, April 1960.

SATTINGER, IRVIN J.

RESEARCH ENGINEER

PUBLICATIONS (continued)

- "Automatic Checkout of Missile Electronic Circuits by Digital Computer Methods," with W. H. Lawrence and J. S. Rogaczewski, The University of Michigan, Report No. 3465-18-F, August 1960.
- "Human Reaction to Military Vehicle Ride," with S. Sternick and D.T. Stimmel, The University of Michigan, Report No. 2889-17-F, Jan. 1961.
- "Analysis of a Falling-Sphere Experiment for Measurement of Upper Atmosphere Density and Wind Velocity," Journal of Geophysical Research, March 1961.
- "Feasibility Study of a Pavement-Deflection Measurement System," with W. H. Lawrence and L. H. Thomas, The University of Michigan, Report No. 3742-5-F, November 1960.
- "A Digital Impedance Comparator for Use in Automatic Checkout of Electronic Circuits," with W. H. Lawrence and J. S. Rogaczewski, The University of Michigan, Report No. 3465-43-F, May 1961.
- "An Instrumentation System for the Measurement of Terrain Geometry," with S. Sternic,, Report No. 2948-20-S, Paper presented at 1st International Conference on the Mechanics of Soil-Vehicle Systems, IST, The University of Michigan, 12-16 June 1961.
- "Instrumentation System for Measuring Stress-Strain Relationships of Soils," The University of Michigan, Report No. 2948-35-F, December 1961.
- "Instrumentation System for Measurement of Terrain Profile," The University of Michigan, Report No. 2948-36-F, December 1961.
- "Techniques for Determining Center of Mass of a Space Vehicle," with W.H. Lawrence, S. C. Black, and D. A. Siekmeier, The University of Michigan, Report No. 4449-8-F, December 1962.
- "Study and Analysis of Selected Long-Distance Navigation Techniques," with J. O'Day, R. Scott, and J. Sullivan, The University of Michigan, Report No. 4761-10-F, December 1962.
- "System Analysis in Development Programs," International Development Review, Vol. V, No. 3, September 1963.
- "Manned Earth Orbital Program in Earth Sensing," Co-author, Proceedings of the Symposium on Post-Apollo Space Exploration, American Astronautical Society, Chicago, Ill., May 1965.
- "Peaceful Uses of Earth-Observation Spacecraft," with D.S. Lowe and F.C. Polcyn, The University of Michigan, Report No. 7219-1-F, February 1966.
- "Methods of Feasibility and Economic Analysis of Remote Sensing Application," Co-author, Proceedings of the Fifth Symposium on Remote Sensing of the Environment, Ann Arbor, Mich., 16-18 April 1968.
- "Water Depth Determinations Using Remote Sensing Techniques," Co-author, Proceedings of the Sixth Symposium on Remote Sensing of the Environment, Ann Arbor, Michigan, 13-16 October 1969.
- "The Measurement of Water Depth by Remote Sensing Techniques," F. C. Polcyn, W. L. Brown, I. J. Sattinger, Report No. 8973-26-F, Willow Run Laboratories, The University of Michigan, Ann Arbor, October 1970.

SATTINGER, IRVIN J.

RESEARCH ENGINEER

LISTED IN:

American Men of Science

Patents

Patent 3,319,162

May 9, 1967

"Computer Controlled Alternating-Current Bridge-Type Impedance  
Measurement System for Electrical Circuit Components."

ABRAMS, ROBERT H.

GRADUATE RESEARCH ASSISTANT

#### EDUCATION

AB, Philosophy, University of Michigan, 1969  
Stanford Law School, 1969-1971  
University of Michigan, 1971-present

#### EMPLOYMENT

University of Michigan Law School, 1970-71  
Construction, Yarmouth, Maine, 4/71 to 8/71  
Drummond Wescott & Woodsum, 5/72 to 8/72

#### HONORS AND PROFESSIONAL SOCIETIES

Winner Hilmer Oehlman, Jr. Legal Writing Award, 1969-70  
Member Stanford Law Review, 1970-71  
Editor-In-Chief Stanford Law School Yearbook, 1970-71  
Chairman, University of Michigan Environmental  
Law Society, 1972-73  
Instructor, Undergraduate Environmental Law, 1973-present

#### EXPERIENCE

Since coming to the University of Michigan Law School, have been attempting to specialize in environmental law. Three legal areas have been of particular interest; traditional property law; government regulation of resource use; and recent substantive environmental legislation. Experience at Michigan has been enhanced by several unique circumstances. Most important, have been able to study extensively under Prof. Joseph Sax, the leading authority in the field of environmental law. Second, able to spend a year as chairman of the Environmental Law Society. Finally Michigan has a program which has allowed teaching of an undergraduate course in Environmental Law for the last three semesters. Seminar in energy policy, responsible for planning the portion devoted to the study of nuclear power. Purpose of the seminar was to inquire into the dimensions of the present energy shortage and attempt to devise a coherent energy policy in light of detailed study of the various energy sources.



TECHNOLOGY ASSESSMENT OF GEOTHERMAL  
ENERGY RESOURCE DEVELOPMENT

BIOGRAPHICAL SUMMARIES  
CONSULTANTS

Dr. Kan Chen

Dr. Marc Ross

Dr. Klaus Heiss

Dr. Samuel Estep

Dr. William Bentley

Mr. J. Hilton Anderson

KAI CHEN

Paul G. Goebel Professor of Advanced Technology  
Professor of Electrical and Computer Engineering,  
University of Michigan

EDUCATIONAL BACKGROUND

BEE	Cornell University	1950	(Power Systems)
SM	Massachusetts Institute of Technology	1951	(Power Systems)
ScD	Massachusetts Institute of Technology	1954	(Automatic Control Systems)

RELEVANT BACKGROUND

Consultant, Environmental Research Institute of Michigan, working on a current project on the technology assessment of remote sensing.

Director, Project PROPE (Policy Research on Population and Environment), an interdisciplinary project at the University of Michigan, supported by the National Science Foundation (1971-73).

Teaching courses in Macro Societal Systems Engineering, and Social Decision making at the University of Michigan, including technology assessment as a topic.

PAST EXPERIENCE

Professor of Environmental Systems Engineering  
University of Pittsburgh, Pittsburgh, PA (1970-71)

Director, Institute-wide Program on Urban Development  
Stanford Research Institute, Menlo Park, CA (1966-70)

Manager, Systems Technology Research and Development  
Westinghouse Electric Corporation, Pittsburgh, PA (1954-65)

Trainee, Detroit Edison Co., Detroit, Mi (1950)

PROFESSIONAL SOCIETIES

Institute of Electrical and Electronic Engineers (IEEE)  
President, IEEE Systems, Man and Cybernetics Society (1973)  
IEEE Fellow

KAN CHEN

PUBLICATIONS

Books

National Priorities, San Francisco Press, 1970

Urban Dynamics: Extensions and Reflections, San Francisco Press, 1972

Growth Policy: Population, Environment, and Beyond, with K. F. Lagler, et. al., (in press), University of Michigan Press, 1973

Technical articles (see attached list)

PUBLICATIONS

1. "Testing of D.C. Interrupters on A.C. Test Circuits," (co-authored with E.W. Boehne), AIEE Transactions, 1955.
2. "Quasi-Linearization Techniques for Transient Study of Nonlinear Feedback Control Systems," AIEE Transactions, 1956.
3. "A Single-Transistor Magnetic-Coupled Oscillator," (co-authored with A. J. Schiewe), AIEE Transactions, 1956.
4. "Analogue Multiplying Circuits Using Switching Transistors," (co-authored with R. O. Decker) IRE Convention Record, 1956.
5. "Analogue Logarithmic and Antilogarithmic Circuits Using Switching Transistors," (co-authored by A. J. Schiewe), Proceedings of Western Joing Computer Conference, 1957.
6. "A Quick Method for Estimating Closed-Loop Poles of Control Systems," AIEE Transactions, 1959.
7. "A Standard Transistorized Optimum Response Controller," (co-authored with D.R. Little), AIEE Transactions, 1959.
8. "Analysis and Design of Feedback Control Systems with Gain and Time Constant Variations," IRE WESCON Record, 1960.
9. "Design of Non-Interacting Control Systems Using Bode Diagrams," (co-authored with R.A. Mathias and D.M. Sauter), AIEE Transactions, 1961.
10. "Process Optimization by Combining the Model and Experimental Approaches," (co-authored with R.O. Decker), ISA Instrument-Automation Summer Conference Record, 1961.
11. "Modern Research in Automatic Control," an invited address delivered at the plenary session of the 1961 Joint Automatic Control Conference.
12. "A Method for Solving the Noise Problem in Process Optimization," (co-authored with K.H. Bhavnani), Control Engineering, 1962.
13. "Industrial Internship in System Engineering--A Joint Industry-University Venture," (co-authored with W.K. Linvill). AIEE ITG Automatic Control, Vol. 1, No. 3, 1962.

14. "Dual of the Optimality Principle in Dynamic Programming," (co-authored with K.W. Bhavnani), Westinghouse Research Scientific Paper 62-163-292-pi, 1962.
15. "Some Special Problems of Electric Power Expansion in Developing Countries," (co-authored with W.K. Linvill). Symposium on Possibilities of Operations Research in Developing Countries, organized by the French Society of Operational Research, 1963. Paris Conference co-sponsored by TIMS, ORSA, ORS, and French Society of Operations Research. (Colloque de Paris Juin) 1963.
16. "Quasi-Linearization Design of Nonlinear Feedback Control Systems" IEEE Transactions, Applications and Industry, May, 1964.
17. "The Role of Large Industry in Underdeveloped Areas", Eastern Inter-collegiate Conference on Industrialization of Underdeveloped Areas, 1964.
18. "Computer Simulation of a Steel Mill Ingot Processing Area", (co-authored with E.Y. Kung and P.B. Skov), Record of the 19th Annual ISA Conference, 1964.
19. "Models for Integrated Control," Record of the 2nd Systems Engineering Conference, 1965.
20. "Decision Analysis for Industry," Record of the 21st Annual Meeting of the SRI Associates, 1966.
21. "Objective-Setting in a Large Industrial Firm--Case Study in Steel," (co-authored with T.E. Dancy, O.C. Gochenour, and E.Y. Kung), IEEE Transactions on Systems Science and Cybernetics, Vol. SSC-3, No. 2, 1967.
22. "Optimization of Time-Dependent Systems by Dynamic Programming," (co-authored with K.H. Bhavnani), ISA Transactions, Vol. 6, No. 2, 1967.
23. "A Portable Interpretation of Quality", Record of the 1st International Conference on Systems Sciences (Hawaii), 1968.
24. "The Need for Change Agents in Urban Development", (co-authored with R.C. Amara), Record of the IEEE Systems Science and Cybernetics Conference, 1968.
25. "Private-Public Sector Partnerships in Urban Affairs--The National Perspective," (co-authored with R.C. Amara), Record of the 23rd Annual Meeting of the SRI Associates, 1968.

26. "An Interdisciplinary Team Approach from the Nonengineering Point of View--A Commentary", Industrialization and Development, (a book edited by H.E. Hoelscher and M.C. Hawk), San Francisco Press, 1969.
27. "Branch and Bound Approach for Decision-Tree Analysis", (co-authored with G.T. Patton), Record of the 1970 Operations Research Society of America Meeting, October, 1970.
28. National Priorities (ed.), San Francisco Press, 1970.
29. "Prolegomenon to Value-Oriented Social Systems Analysis", Battelle Seminar Paper, 1970.
30. "Exploring New Directions in Engineering Education", Technological Forecasting and Social Change, Vol. 3, No. 3, 1971; also in Engineering Education, Vol. 63, No. 2, 1972.
31. "A Macrosystem Analysis of the Human Environment", Journal of Environmental Systems, Vol. 1, No. 2, 1971; also in the Record of Joint National Conference on Major Systems, 1971.
32. "Subjectivity in Decision Analysis for Public Policy Planning", Record of the 1971 Joint Automatic Control Conference.
33. "The Role of Science and Technology in Less-Developed Countries--A Systemic Analysis", (co-authored with H.E. Hoelscher), Woods Hole Conference on the Role of Science and Technology in International Development in the 1970's, August, 1971.
34. "Dynamics of Less Developed Countries" (co-authored with H.E. Hoelscher), Proceedings of the 1971 Allerton Conference on Systems and Control.
35. "Environmental Effects of Techno-Economic Systems: A Systems Engineering Interpretation of the Input-Output Approach", Proceedings of the 1971 IEEE Conference on Decision and Control, December 1971
36. "Urban Modeling", (co-authored with W.L. Garrison), IEEE Transactions on Systems, Man and Cybernetics, April, 1972
37. Urban Dynamics: Extensions and Reflections (ed.), San Francisco Press, 1972.
38. "Growth Policy and Alternative Futures", Proceedings of the Third World Future Research Conference (Bucharest, Romania), 1972.

39. "Socially Oriented Engineering Education", Proceedings of the 1972 IEEE Conference on Decision and Control, December 1972.
40. Growth Policy: Population Environment, and Beyond (with K. F. Lagler, et. al.), University of Michigan Press (in press), 1973.
41. "Methodological Approach to Technology Assessment of Remote Sensing", (co-authored with G. J. Zissis), accepted by the First International Congress of Technology Assessment, May, 1973.

ARC ROSS

Professor of Physics, University of Michigan

#### EDUCATIONAL BACKGROUND

B.S. Queens College, New York, 1948  
Ph.D. University of Wisconsin, 1952

Thesis area: Theoretical low energy nuclear physics

#### PAST EXPERIENCE

Research Associate, Brookhaven National Lab., 1953-55

Assistant Professor - Professor, Indiana University, 1955-63

Professor of Physics, University of Michigan, 1963-present

Visiting Professor of Physics, M.I.T., Spring 1966

Visiting Professor, University of London, Spring 1971

Summer positions at Brookhaven, Argonne, and SLAC Laboratories,  
at Florida State University, University of Colorado, University of  
California, University of Washington.

#### PROFESSIONAL SOCIETIES

Member, Argonne ZGS Program Committee, 1963-69

Member, Executive Committee, American Physical Society Division of  
Particles and Fields, 1969-1970. Chairman, Publications Committee

Consultant to University of Missouri on evaluation of Physics Program,  
March, 1972.

#### PUBLICATIONS

Non-Additivity of Nucleon Moments, Phys. Rev. 84, 379 (1951)

Nucleon Moments in Heavy Nuclei, Phys. Rev. 88, 935 (1952).

Pion Photoproduction and Scattering, Phys. Rev. 94, 454 (1954).

Meson-Nucleon Scattering (Dyson et al), Phys. Rev. 95, 1644 (1954).



Meson-Meson Interaction, Phys. Rev. 95, 1687 (1954).

Pion Photoproduction. Phys. Rev. 103, 760 (1956).

$\Lambda$ -Nucleon Forces (with Lichtenberg), Phys. Rev. 103, 1131 (1956).

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Hyperon-Nucleon Forces (with Lichtenberg), Phys. Rev. 107, 1714 (1957).

K-Mesons Contribution to Hyperon Nucleon Forces (with Lichtenberg), Phys. Rev. 109, 2163 (1958).

Compound Model of  $\pi$ -Y Interaction (with Lichtenberg) Nuovo Cimento 10, 104 (1958).

The First Forbidden  $\beta$ -Decay (with Kotani), Prog. Theor. Phys. 20, 643 (1958).

Non-Unique First Forbidden Transition (with Kotani), Phys. Rev. Letters 1, 140 (1958).

$\pi$ -Y Scattering and  $K^-$ -p Reactions, Phys. Rev. 112, 986 (1959).

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Global Symmetry in  $K^-$ -p Reactions (with Shaw), Phys. Rev. 115, 1773 (1959).

$K^-$  Absorption in Deuterium (with Kotani), Nuovo Cimento 14, 1282 (1959).

High-Energy Peaks in  $\pi$ -N Cross Sections (with Wong), Phys. Rev. Letters 3, 398 (1959).

Multichannel Processes (with Shaw), Annals Phys. 9, 391 (1960).

$\Lambda\pi$  Resonance and KYN Parity (with Shaw), Phys. Rev. Letters 5, 578 (1960).

Multichannel Effective Range Theory (with Shaw), Annals Phys. 13, 147 (1961).

Analysis of Multichannel Reactions (with Shaw), Phys. Rev. 126, 806 (1962).

Analysis of S Wave  $K^-$ -p Reactions (with Shaw), Phys. Rev. 126, 814 (1962).

Y- $\eta$  Degeneracy, Phys. Rev. Letters 8, 417 (1962).

Method of Measuring Coupling Constants, Phys. Rev. 131, 2678 (1963).

Position of Resonance Poles Near the Threshold of a Channel, Phys. Rev. Letters 11, 450 (1963).

- Unitarity and Form Factors in the Production Process  $\pi+N \rightarrow \rho+N$ , Phys. Rev. Letters 12, 627 (1964) (with G. Shaw).
- Peripheral Model for  $\rho$  and  $\rho\pi$  Production, XII International Conference on High Energy Physics, Dubna (1964), Vol. 1, p. 300.
- Backward Pion-Nucleon Scattering and Spin Determination of Pion-Nucleon Resonances, Phys. Rev. Letters 14, 1091 (1965) (with R. Heinz).
- Diffraction Dissociation, Proceedings of the 1966 Midwest Conference on Theoretical Physics, Physics Dept., Indiana University (1966).
- Photon Dissociation Model for Vector-Meson Photoproduction, (with L. Stodolsky) Phys. Rev. 149, 1172 (1966).
- Regeneration Effects in  $\omega\text{-}\phi$  Production, Phys. Rev. Letters 17, 563 (1966).
- Wide Angle Pairs Produced in  $\pi N$  Interactions (with G. V. Dass) Physics Letters 24B, 175 (1967).
- Non-resonant Production Amplitudes or the Deck Effect (with Y. Y. Yam), Phys. Rev. Letters 19, 546 (1967).
- Meson Baryon Couplings in a Quark Model, Phys. Rev. 158, 1630 (1967) (with A. N. Mitra).
- Regge Cuts...in Inelastic Scattering (with Henyey, Pumplin and Kane), Phys. Rev. Letters 21, 946 (1968).
- Inelastic Shadow Effects on Nuclear Total Cross Sections (with Pumplin), Phys. Rev. Letters 21, 1778 (1968).
- Regge Cuts, Absorption Model, and Diffractive Effects in Inelastic Scattering (with F. Henyey, G. L. Kane and Jon Pumplin), Phys. Rev. 182, 1579 (1969).
- Modified Extrapolation to Determine the  $\pi\pi$  Cross Section (with G. L. Kane), Phys. Rev. 177, 2353 (1969).
- Structure of the Differential Cross Section at High Energy, published in Pion-Nucleon Scattering, edited by G. L. Shaw and D. Y. Wong, J. Wiley and Sons, 1970.
- Phenomenology of Multiperipheral Processes, contribution to Proceeding of the Boulder Conference on High Energy Physics, K. T. Mahanthappa, Ed., Colorado Associated University Press (1970).
- On the Structure of High-Energy Two-Body Non-Diffractive Reactions (with F. Henyey and G. L. Kane), Nuclear Physics B23, 269 (1970).

Regge Cuts, Absorption Model, and Diffractive Effects in Inelastic Scattering,  
McGill University Summer School 1969, B. Margolis, Ed., Gordon and Breach.

Strong Absorptive Regge-Cut Model for Pion Photoproduction, np-pn, and Related  
Processes, Phys. Rev. Letters 25, 1519 (1970) (with F. Henyey, G. L. Kane,  
D. Richards and G. Williamson).

Maverick Models, Talk at Symposium on High Energy Reactions, Argonne National  
Laboratory, November 1970.

Peripherality and  $\pi N$  Scattering, Phys. Letters, 38B, No. 5 (1972).

Quantitative Decision Making, in "Risk vs. Benefit: Solution or Dream?,"  
H. J. Otway, Ed., Los Alamos Scientific Laboratory LA-4860-MS (Feb., 1972).

KLAUS P. HEISS

Director, Advanced Technology Economics

BORN: August 21, 1941

EDUCATION:

1970-1971 Graduate Course on Space Propulsion Systems (AMS-581),  
Aerospace and Mechanical Science, Princeton University.

1964 Ph. D., Hochschule for Welthandel, Vienna, Austria  
Economics

1962-1963 University of Bocconi, Milan, Italy  
Economics

1962 B. A., Hochschule for Welthandel, Vienna, Austria  
Economics

POSITIONS:

1966 MATHEMATICA Director, Advanced Technology  
Economics 1971  
Senior Economist 1967-1971  
Economist 1966-1967

1965-1966 Research Associate and Lecturer in Economics  
Econometric Research Program, Princeton University

1964-1965 Research Assistant, Econometric Research Program  
Princeton University

EXPERIENCE:

Dr. Heiss has had extensive experience in economics, covering the most recent developments in economic theory and policy. In two years at Princeton University his major fields of research were mathematical economics, econometrics and game theory. In addition to this, his European education gives him a strong background and understanding of international finance, the role of inflation and economic policy planning at a national level.

Since joining MATHEMATICA, Dr. Heiss has worked with success in the economic evaluation of major new technological systems for various U. S. Government Agencies including the U. S. Atomic Energy Commission, the U. S. Department of Transportation, the Office of Naval Research, and the National Aeronautics and Space Administration. Some of this work had a major impact on actual policy decisions.

## EXPERIENCE (continued)

In the past 15 months, Dr. Heiss has been directing a study for the National Aeronautics and Space Administration on a New U. S. Space Transportation System for the 1980's, including the Space Shuttle System and the Space Tug. The study incorporated important innovations in benefit-cost analyses.

Dr. Heiss was called before the U. S. Senate to testify on the Space Shuttle program evaluation. Also, Dr. Heiss gave various presentations to the President's Science Advisory Committee and the National Academy of Engineering on the Space Shuttle Program.

## PUBLICATIONS:

"On the Measurement and Evolution of the Powers of Nations," paper presented to the Economic Seminar at Princeton University, 1966.

"The Economics of the Peaceful Uses of Underground Nuclear Explosions," with Oskar Morgenstern, co-author, prepared for the Atomic Energy Commission, MATHEMATICA, PNE-3005, August 31, 1967.

"Technical and Economic Potential of Gas Stimulation by Nuclear Explosives," prepared for the U. S. Atomic Energy Commission, MATHEMATICA, PNE-3007, August 31, 1967.

"Game Theory and Human Conflicts," Research Memorandum, No. 80, Econometric Research Program, Princeton, March 1966, Published in Festschrift für Prof. Waffenschmidt, 1968.

"Rodolfo Benini," article for the International Encyclopedia of the Social Sciences, 1968.

"Wilhelm Lexis," article for the International Encyclopedia of the Social Sciences, 1968.

"Technical and Economic Potentials of Shale Oil Production by Nuclear Explosives," prepared for the U. S. Atomic Energy Commission, MATHEMATICA, PNE-3006, August 31, 1967.

"The Economic Feasibility of Mining Operations with Nuclear Explosives," prepared for the U.S. Atomic Energy Commission, MATHEMATICA, 1968.

"An Econometric Study of Small and Intermediate Size Diameter Drilling Costs for the United States," with E. B. Dagum, prepared for the U. S. Atomic Energy Commission, MATHEMATICA, 1968 (2 volumes).

"Cost-Benefit Study of the Earth Resources Satellite Program: Grazing Land Applications," with Charles Frank Jr., prepared for RCA-ASTRO Electronics Division, MATHEMATICA, August 1968.

"Cost-Benefit Study of the Earth Resources Satellite Program: Extramarine and Coastal Management," with Edward J. Greenblat, prepared for RCA-ASTRO Electronics Division, MATHEMATICA, June, 1969.

## PUBLICATIONS (continued)

"Theory and Implementation of Cost-Benefit Analysis of Transportation Systems," prepared for the Department of Transportation under sub-contract from the Resource Management Corporation, December, 1969.

"Long Term Projections of Power: Review and Outline", with Klaus Knorr and Oskar Morgenstern, prepared for the Office of Naval Research, March, 1970.

"Estimating the Economic Benefits of Surveying Earth's Resources," in: The Proceedings of the Princeton University Conference on Aerospace Methods for Revealing and Evaluating Earth's Resources, The Princeton University Conference, 1970.

"On the Principals of Public Project Evaluation," volume I of Cost Benefit Analysis of New Launch Systems; with Uwe Reinhardt; prepared for the National Aeronautics and Space Administration, July, 1970.

"The Economics of the Space Program" in: Organizing Space Activities for World Needs, E. A. Steinhoff, editor, Pergamon Press, Oxford & New York, 1971.

"Cost Benefit Analysis of New Launch Systems -- Results of Economic Evaluation", volume II, prepared for the National Aeronautics and Space Administration, July, 1970.

"Benefit-Cost Analysis of New Space Transportation Systems," 2 volumes, main investigator prepared for the National Aeronautics and Space Administration, March, 1971.

Economic Analysis of New Space Transportation Systems, 2 volumes, prepared for the National Aeronautics and Space Administration, June, 1971.

"Our R & D Economics and the Space Shuttle", in Astronautics and Aeronautics, October, 1971, Volume 9, No. 10, pp. 50-62.

Economic Analysis of the Space Shuttle System, with Oskar Morgenstern, et. al., 3 Volumes, prepared for the National Aeronautics and Space Administration, January, 1972.

## CONFERENCES AND SYMPOSIA:

"The Economics of the Space Program," XIX Congress of the International Astronautical Federation, New York, October, 1968.

"Estimation of Drilling Costs in Unconventional Applications," The Offshore Exploration Conference, OECON, San Diego, California, March 7, 1969.

## CONFERENCES AND SYMPOSIA (continued)

"Planning Space Activities in the 1970's," American Astronautical Society -- Operations Research Society, Denver, Colorado, June 19th through June 26th, 1969.

"Estimating the Economic Benefits of Surveying Earth's Resources," The Princeton University Conference on Aerospace Methods for Revealing and Evaluating Earth's Resources, September 25th through 26th, 1969.

"Wealth, the World Oceans and Economics," The Oceanic Maritime Symposium of the Navy League of the United States, February, 1970.

"Die Wirtschaftliche Planung eines Technischen Fortschrittes: Raumfahrt Transportsysteme für die achtziger Jahre (The economic Planning of Technical Change: Space Transportation Systems of the 1980's)", Conference on Economic and Social Effects of Technological Change, University of Mannheim, Mannheim, Germany, November, 1970.

"Economic Principles for the Evaluation and Pricing of Transportation Systems," Session Chairman, Corridor Symposium, College of Europe, Bruges, Belgium, June, 1971.

To be published: Book on Antonio Serra, an Italian Economist, 1971.

Dissertation (in German):

"On Models of Economic Growth," Vienna, 1964.

Scientific Paper for B. A. (in Italian):

"Efficiency, Rate of Interest, and Growth of Capital," 1962, Vienna.

"Orbit to Orbit Shuttle Economics", XXIIIrd International Astronautical Congress, Vienna, October, 1972.

"An Economic Research and Development Policy for Austria", prepared for the Exploratory Conference on the Future of Science and Technology in Austria, Vienna, October, 1972.

## TESTIMONIES AND PRESENTATIONS:

Senate Committee on Appropriations-Subcommittee on HUD-Space-Science, Economic Evaluation of Reusable Space Transportation Systems, June 29, 1971.

President's Science Advisory Committee, Space Shuttle Panel, "The Economics of a Fully Reusable Space Transportation System," Woodshole, Massachusetts, August 15, 1971.

U. S. Senate Committee on Aeronautical and Space Sciences, Economics of the Space Shuttle, Washington, D. C., April 12, 1972.

TEACHING COURSES:

On the Accuracy of Economic Observations (1968-69)  
The Economics of Weapons Acquisitions (1968-69)  
National Economic Policy (1969-70)  
The Technique of "Learning Curves" (1969-70)  
Input-Output Analysis (1970-71)  
Evaluation of Technological Forecasting Techniques (1970-71)

AFFILIATIONS:

American Economic Association  
Atomic Industrial Forum  
American Astronautical Society  
Honorary Faculty Member of the U. S. Army Logistics Management Center



Samuel D. Estep, A.B., J.D.

1. Professor of Law
2. Director, Atomic Energy Research Project, Law School
3. Member, Executive Committee, Michigan Memorial Phoenix Project

### Publications

- "The Legislative Process and the Rule of Law: Attempts to Legislate Taste in Moral and Political Beliefs," 59, Michigan Law Review, pgs. 575-602 (1961).
- "Some Damage and Proof Problems Arising from the Statistical Character of Incidence of Radiation Injuries," chapter in Legal and Administrative Problems of Protection in the Peaceful Uses of Atomic Energy, pgs. 195-243. Brussels (1961).
- "State Control of Radiation Hazards: An Intergovernmental Relations Problem," 60, Michigan Law Review, pgs. 41-80 (1961). (Co-author with Adelman).
- "Radiation and the Law: With Emphasis on Damage and Proof Problems," chapter in Radioactivity in Man, pgs. 355-372. Illinois (1961).
- "Statement and Testimony of Samuel D. Estep, Professor of Law and Director of the Atomic Energy Research Project, University of Michigan Law School, Ann Arbor, Mich.," before Select Subcommittee on Labor of the Committee on Education and Labor House of Representatives Eighty-Seventh Congress Second Session on H.R. 1267 and H.R. 2731 on Radiation Workers Compensation Act, pgs. 229-249. Washington, D.C. (1962).
- "Causal Relationship -- Possibilities for a New Approach," chapter in Workmen's Compensation and Radiation Injury, 1, The Department of Labor and the Atomic Energy Commission, pgs. 34-48. (1965).
- "Legal Liability for Genetic Injuries from Radiation," XXIV, Louisiana Law Review, pgs. 1-53 (1963). (Co-author with Forgotson).

"Radiation Injuries and Time Limitations in Workmen's Compensation Cases," 62, Michigan Law Review, pgs. 259-308 (1963). (Co-author with Allan).

"Radiation Injuries: Statute of Limitations Inadequacies in Tort Cases," 62, Michigan Law Review, pgs. 753-794 (1964). (Co-author with Van Dyke).

"Space Communications and the Law: Adequate International Control After 1963?" 60, Michigan Law Review, pgs. 873-904 (1962). (Co-author with Kearsse).

"Some International Aspects of Communications Satellite Systems," 58, Northwestern University Law Review, pgs. 237-266 (1963).

"International Lawmakers in a Technological World: Space Communications and Nuclear Energy," 33, The George Washington Law Review, pgs. 162-180 (1964).

"Legal and Social Policy Ramifications of Remote Sensing Techniques," printed as part of Fifth Annual Symposium on Remote Sensing of Environment, University of Michigan, 1968.

"Some Legal Aspects of Nuclear Industry," to be printed as part of ALI-ABA Course on Atomic Energy Licensing and Regulation, Fall 1970.

"The ITU and International Regulation of Communications Satellites," (co-author) to be published by American Society of International Law, 1971.

Book Review - Bloomfield, "Outer Space: Prospects for Man and Society," 7, The Journal of Conflict Resolution, pgs. 85-89 (1963).

Book Review - Mullenbach, "Civilian Nuclear Power: Economic Issues and Policy Formation," 5, Natural Resources Journal, pgs. 202-211 (1965).

Book Review - Rosenthal, Korn, Lubman, "Catastrophic Accidents in Government Programs," 17, Stanford Law Review, pgs. 343-353 (1965).

Book Review - Price, "The Scientific Estate," 34, The George Washington Law Review, pgs. 974-980 (1966).

## EDUCATION

BS University of California, Berkeley, 1960  
 MF University of Michigan, 1961  
 PhD University of California, Berkeley, 1965

## EMPLOYMENT

University of California, School of Forestry, Teaching Assistant, 1960  
 University of Michigan, School of Natural Resources, Teaching Assistant, 1961  
 University of California, Giannini Found. Agri. Econ., Research Assistant,  
 1961-1962  
 University of California, School of Forestry, Associate in Forestry,  
 Assistant Specialist, 1962-1963  
 Iowa State University, Instructor, 1963-1965  
 Iowa State University, Assistant Professor of Forestry, 1965-1966  
 University of Wisconsin, Assistant Professor, Associate Professor of  
 Forestry and Agriculture Economics, 1968-1969  
 Consultant to George Banzhaf & Company, Milwaukee, 1968-1969  
 Texas A & M University, Visiting Scientist, 1971-1972  
 Natural Resources Management Corp., Eureka, Calif, Associate  
 University of Massachusetts, Consultant to METLANDS Project, 1972-1975  
 University of Michigan, Associate Professor, 1969-present

## PROFESSIONAL SERVICE TO NATIONAL, STATE OR LOCAL GOVERNMENTS OR OTHER CIVIC ACTIVITIES

Bureau of Standards, Washington, D. C., Consultant on lumber standards, 1964  
 U. S. Forest Service, Berkeley, Calif, Forestry Aide, 1957-1960  
 California Division of Forestry, Monterey, Calif. Forest Firefighter, 1955-1956  
 Michigan Representative to HOMTROP Committee on Continuing Education  
 in Forestry, 1972-1973

## MEMBERSHIPS IN CIVIC, RELIGIOUS, OR FRATERNAL ORGANIZATIONS

Madison Air Association, 1966-1969  
 Wisconsin Historical Society, 1966-1969  
 Friends of the Madison Library, 1966-1969

## MEMBERSHIPS IN PROFESSIONAL, HONORARY, AND LEARNED SOCIETIES

Society of American Foresters, 1958-1970  
 American Agricultural Econ. Assoc., 1961-1969  
 The Institute of Management Science, 1963-1969  
 Xi Sigma Pi, 1959-1969  
 Board of Editors, Land Economics, 1969-1972  
 Natural Resource Economics Committee  
 SNR Curriculum Committee  
 Program Chairman, Resource Systems Management  
 Distinguished Alumni Speakers Program Chairman  
 ESL Interim Program Chairman  
 Michigan Academy of Science, Arts and Letters  
 Sea Grant Advising Committee, 1972-1975  
 SNR Undergraduate Program Committee

BENTLEY, WILLIAM ROSS

LISTED IN

American Men of Science  
Who's Who in Midwest

PUBLICATIONS

- Bentley, W. R. and D. E. Teeguarden. 1965. Financial Maturity: a theoretical review. *Forest Science* 11: 76-87
- Bentley, W.R. and L. L. Streeby. 1966. Protection economics: a new approach. *Jour. Forestry* 64(8): 556-560.
- Bentley, W. R. and R. D. Fight. 1966. A zero-interest comparison of forest rent and soil rent. *Forest Science* 12(4): 460.
- Bentley, W. R. 1967. The political economy of allowable cut. *Proc. 1966. Soc. Amer. Foresters Ann. Meeting.* pp. 116-120
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- Davis, L. S. and W. R. Bentley. 1967. Resource policy analysis: relationships between values and facts. *Jour. Forestry* 65(9): 612-620.
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- Gottsaker, J. H., H. F. Kaiser, and W. R. Bentley. 1966. A guide to Christmas tree management. *Iowa State Univ. Coop. Ext. Bull. Pm-234.* 8 pp.
- Bentley, W. R. 1967. Quotas -- a solution for public timber sale problems? *Western Timber Industry* (August 1967) 18(8): 5, 8.

- Bentley, W. R. 1967. Essential concepts in forestry education. Jour. Forestry 66(5): 402-403
- Bentley, W. R. 1963. Economics of recreation concessionaires on national forests. Report to Pacific Southwest Forest and Range Experiment Station. On file School of Forestry, University of California, Berkeley. 50 pp.
- Beuter, J. H. and W. R. Bentley. 1965. A program for optional stumpage pricing. Report to the Pacific Northwest Forest and Range Experiment Station. On file Department of Forestry, Iowa State University, Ames. 41 pp.
- Bentley, W. R. 1969. Model of public timber sales. Jour. Forestry 67 (6): 405-409.
- Ferrell, R. S. and W. R. Bentley. 1969. Plantation investment opportunities in Black Walnut. Jour. Forestry 67(4): 250-254.
- Holland, I. I. and W. R. Bentley. 1969. Furniture manufacturing and wood use in the North Central Region. North Central Region Research Publication No. 193 and Illinois Agricultural Experiment Station Bull. 734. 70 pp.
- W. R. Bentley. 1969. Preliminary evaluation of present and alternative systems of in lieu tax payments for state-owned forest lands in Wisconsin. Report to the Wisconsin Department of Natural Resources, 55 pp.
- Gordon, J. C. and W. R. Bentley. 1970. Wood, fiber production in an industrial society. Wisc. For. Res. Note No. 150. 10 pp.
- W. R. Bentley. 1970. Technological change in the forest industries--a problem analysis. Wisc. For. Res. Note No. 151. 12 pp.
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J. Hilbert Anderson, Jr.  
York, Pennsylvania

Biography of Dr. Anderson not received in time  
for inclusion in this proposal

Replacement pages with important corrections:  
For ERIM 73-144-L1

Page 2-44

" 4-2

" 4-11

On page 2-10, 12th line from bottom of page  
word "educational" should be changed to  
"industrial"



effects of previous geothermal technology. Their expertise extends to solar power conversion as well. They have given testimony to Senate Committee hearings on the subject of Geothermal Energy Resources and Research (1972).

The time available to prepare this proposal did not allow completion of all feasible arrangements for consultants and advisors. Discussions were held with members of the U. S. Geological Survey and by means of requests to the Director of U.S.G.S. it should prove possible to have the active if limited participation of Dr. R. Williams on IR Remote Sensing and inventorying of geothermally rich regions, as well as experts in Menlo Park and Denver on power extraction techniques.

APPENDIX 4.1 UNIVERSITY OF MICHIGAN  
COLLEGE OF ENGINEERING SUMMER CONFERENCE

**7312—NEW APPROACHES TO LOW-POLLUTION AND  
RESOURCE-CONSERVING POWER GENERATION**

July 16-20 Fee: \$250

George I. Haddad and Dale M. Grimes, Co-Chairmen

Pollution-free, resource-conserving power generation is becoming one of our most important needs. It is also becoming quite obvious that in order to accomplish these objectives man must apply technologies and systems which in the past have appeared too expensive to be practical. This course will be concerned with nonconventional methods of power generation which include, dry-well geothermal sources, ground-based solar-cell arrays and also direct solar house heating and air-conditioning.

In particular a detailed consideration of the concept, proposed by Dr. Peter E. Glaser, of utilizing a space satellite power station will be presented. In this concept a space station is utilized to convert the sun's energy through solar cells to DC power which in turn can be employed to generate microwave power which can be transmitted to the earth and reconverted into usable electric power.

**PREREQUISITE**

Applicants should have a bachelor's degree in either engineering or a physical science or the equivalent experience.

**COURSE CONTENT**

Topics to be covered include:

- The World Energy Problem: Pollution and Resource Depletion
- Dry-Well Geothermal Sources
- Ground-Based Solar Arrays
- Direct Solar House Heating and Air-Conditioning
- A Space Satellite Power Station Concept
- Solar Cell Technology
- Microwave Power Generation, Transmission, Reception and Rectification
- Atmospheric Phenomena (Attenuation, Scattering and Diffraction)
- Other Alternatives for Low-Pollution and Resource-Conserving Power Generation
- Biological Effects and Radio Frequency Interference
- Transportation and Assembly of Space Station, Overall System Consideration, Alignment and Tracking Problems
- Integration into National Power Grids
- Economic Trade-Offs

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**STAFF**

**From The University of Michigan:**

Professor George I. Haddad, Director, Electron Physics Laboratory, Department of Electrical and Computer Engineering, co-chairman of the course

Professor Dale M. Grimes, Department of Electrical and Computer Engineering, co-chairman of the course

**Visiting Lecturers:**

W.C. Brown, Raytheon Company

W.R. Cherry, NASA, Goddard Space Flight Center

V.J. Galcone, Jr., Air Force Cambridge Research Laboratories

P.E. Glaser, Arthur D. Little, Inc.

G. Goubau, Institute for Exploratory Research, U.S. Army Electronics Command

G.O.G. Lof, Colorado State University

J.M. Osepchuk, Raytheon Research Division

E. Ralph, Spectrolab

M.C. Smith, Los Alamos Scientific Laboratory, University of California

TECHNOLOGY ASSESSMENT OF GEOTHERMAL  
ENERGY RESOURCE DEVELOPMENTBIOGRAPHICAL SUMMARIES  
ERIM PERSONNEL

Presented on the following pages are biographical summaries for key personnel who are expected to be available to participate directly on the proposed research program. Their names and titles are listed below.

Dr. George J. Zissis	-	Research Physicist
Dr. Virginia L. Prentice	-	Associate Research Geographer
Mark R. Berg	-	Graduate Research Assistant
Daniel M. Steinway	-	Research Assistant
Robert K. Vincent	-	Associate Research Engineer
Ms. Bette C. Salmon	-	Assistant in Research
Dr. Gwynn H. Suits	-	Research Physicist
Sheldon R. Weiner	-	Associate Research Physicist
Thomas B. Feagans	-	Graduate Research Assistant
Irvin J. Sattinger	-	Research Engineer
Robert H. Abrams	-	Graduate Research Assistant