MASTER

GEO ENERGY RESEARCH AND DEVELOPMENT:
TECHNOLOGY TRANSFER UPDATE

SAND83-0018

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Abstract

Sandia Geo Energy Programs in geothermal, coal, oil and gas, and synfuel technologies have been effective in transferring research concepts to applications in private industry. This report updates the previous summary (SAND82-0211, March 1982) to include recent technology transfers and to reflect recent changes in philosophy on technology transfer. Over 40 items transferred to industry have been identified in the areas of Hardware, Risk Removal and Understanding. Successful transfer is due largely to personal interactions between Sandia engineers and the technical staffs of private industry.

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i-ii

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TABLE OF CONTENTS

	<u>Page</u>
Technology Transfer from Sandia to Industry (Introduction).....	1
Technology Transfer Processes.....	3
Geo Energy Technology Transfer.....	9
Technology Transferred.....	9
<u>New Concepts</u>	
Drilling, Completions and Mining...	9
Diagnostics.....	11
Processes.....	13
<u>Risk Removal</u>	
Drilling, Completions and Mining...	13
Diagnostics.....	16
Processes.....	16
<u>Understanding</u>	
Drilling, Completions and Mining...	17
Diagnostics.....	17
Processes.....	17
Technology with Potential for Transfer.....	21
<u>New Concepts</u>	
Drilling, Completions and Mining...	21
Diagnostics.....	21
Processes.....	22
<u>Risk Removal</u>	
Drilling, Completions and Mining...	24
Summary.....	25
References.....	27
Appendices	
A. Advisory Panels.....	29
B. Major Publications.....	33
C. Exhibits.....	38

SANDIA R & D - PROGRAM MATRIX

PROGRAM AREAS

RESEARCH AREAS

SCIENCES

COMBUSTION
ENGINEERING
GEOSCIENCES
MATERIALS
SOLID STATES
SYSTEMS

TECHNOLOGIES

DIAGNOSTICS
ELECTROCHEMISTRY
ELECTROMECHANICS
ELECTRONICS
EXPLOSIVES
TESTING

WEAPON
SYSTEMS

NUCLEAR
SECURITY
SYSTEMS

NUCLEAR
FUEL
CYCLE

NUCLEAR
WASTE
MANAGEMENT

ENERGY
PROGRAMS

Matrix system provides an effective mechanism for utilizing advanced weapons technologies to meet energy and other non-weapon needs.

TECHNOLOGY TRANSFER FROM SANDIA TO INDUSTRY

Recognition that mechanical switching devices could never meet the increasing demands of communication networks, Bell Telephone Labs initiated a research program resulting in the now ubiquitous transistor. This successful development with the ensuing transfer of multiple technologies to many industries is a recognized achievement of this century and details are well documented [e.g., References 1,2]. This concept of research directed to solve one problem with a requirement of transferring results to a manufacturing facility has been passed down from Bell Laboratories to Sandia for developing the sophisticated, high reliability components needed for nuclear weapon systems. Since all the weapon components are produced by private industry, all advanced technology has to be transferred effectively from the government laboratory to industrial process lines on defined schedules.

When the energy shortage had serious national security implications and the national laboratories were asked to assist development of solutions, Sandia made a conscious decision to apply its technology base to resolve problems then existing in the fossil and geothermal energy producing communities rather than to develop new energy producing concepts. This decision required intimate interactions with industry personnel from the research labs to field operations. The decision also required an understanding of the economics, definition of a development schedule and specification of a product that would be adopted by private industry.

This report is a summary of those results from the Geo Energy (geothermal, oil, gas and synfuels) Programs at Sandia. The following briefly reviews technology transfer concepts, how they were evolved by Sandia, and then summarizes the technology that has been or is being transferred. Composition of the industrial advisory panels and some relevant references are included in the appendix for general information. This report will hopefully demonstrate that government laboratories and private industry can work effectively to solve national problems and the results can catalyze effective industry-government interactions.

TECHNOLOGY TRANSFER PROCESSES

Large government investments in R&D result in many developments that have potential application in U.S. industry. The mechanism of transferring this technology has been the subject of books [3-5], conferences [6,7] and many papers. NASA [8] has implemented a major technology transfer program including state, university and industry applications centers, a computer software and management center, a distribution of NASA Tech Briefs and applications teams. Nevertheless, the amount of spinoff technology from all government R&D has been disappointing considering the total federal investment [9]. The difficulty of technology transfer is not unique to government research results but is a universal problem even in the transfer of ideas from research to production within individual companies. A number of reasons for limited transfer are given in Table 1.

Sandia focused their energy research activities to develop and directly transfer technology to energy producing industries. A number of mechanisms have been suggested for transferring technology; some are listed in Table 2. However, with all the rhetoric, modeling and analyses, one fact keeps being repeated:

"The key to successful technology transfer lies not in procedures, but people." [12]

"...feedback, direct personal links...direct contacts" [13]

The real problem is that we ignore the human involvement." [14]

Technology transfer is "movement of people...agents versus agencies." [15]

"In fact, it appears that the early establishment of a strong innovator-manufacturer linkage--strong enough so that the manufacturer becomes the co-inventor--is one of the keys to successful transfer of federal laboratory technology." [16]

Successful transfer requires "a champion." [14]

Table 1. Impediments to technology transfer from national laboratories

Lag Time:	An approximate six-year lag time [10] exists between the actual transfer operation and visible industry use.
Mission Goals:	Mission-oriented laboratories have defined goals (e.g., reliable weapons, safe waste disposal, etc.). Attempts to transfer technology to other industries detract from those goals and do not improve the viability of the labs.
Program Termination:	Successful transfer of technology terminates an R&D program with no assurance of combining support for a researcher; i.e., the researcher works himself out of a job.
Visibility:	Direct transfer of technology needed to meet mission goals is usually not considered a spinoff to industry; secondary applications of this technology may not be visible.
Not Technical:	The mechanics of transfer are difficult, expensive, and not usually technically challenging.
Solution Oriented:	Most scientists work in a discipline-oriented environment (solid state, shock wave, circuit design...), not a problem-oriented environment. Thus, they have many solutions searching for problems.
Incentives:	No incentives exist to encourage transfer efforts. However, NASA's actions were legislated and the recent Stevenson-Wydler Act [11] requires other federal agencies to make a conscientious effort to transfer technologies.
National Security:	Technologies transferred to international companies will be available to Communist bloc countries.

Table 2. Mechanisms of technology transfer

Initiation of Transfer

Presentations and Discussions

Conferences

Advisory Panels and Joint Programs

Workshops

Publications

Transfer Process

Personal Discussions

Reports, Drawings and Computer Codes

Joint Testing Programs

Prototype Testing in Industrial Environment

Contracts to Industry

Workshops

Journal Articles

To assure strong communication links, extensive industrial interaction is designed into all programs as outlined in Table 3. The "Stages of Development" are standard for any R&D program. System and economic analyses are continued through the development activities to:

- . Identify critical areas requiring R&D plus those that have the most potential for influencing reducing costs
- . Involve industry to understand commercial constraints and incentives
- . Develop realistic schedules and goals
- . Provide a rationale for shutting down a program if results cannot be justified
- . Identify new areas for needed R&D

Advisory panels of industrial personnel, plus academic and government experts provide semi-annual critiques of the programs, identify capabilities for joint endeavors and become personally involved in technologies of interest to their firms. None of the panel members have, nor expect contracts from the programs they advise. Industry has been most supportive in these interactions; advisory panel members who have supported Sandia programs are listed in the appendix.

The funding sequences obviously vary with different projects, but it is important that projects be carried through the verification stage to assure transfer. The industrial funding has typically been to support the advisory panels, provide hardware or computer analyses specific to a given development, offer test or operational facilities to evaluate prototype equipment and supply the design and manufacturing support for building final hardware parts.

The following chapter summarizes the results of this methodology as applied to the geotechnology programs.

Decreasing emphasis of the DOE geotechnology programs will not only limit future research accomplishments but will also limit the current opportunity to apply and transfer weapon developed technologies. The potential of transferring defense related technology, either directly or indirectly, to Communist bloc countries is also of major concern [18]. New mechanisms for providing federally supported technological developments to industry will have to be defined. Whatever those mechanisms are, however, they will have to include the person-to-person interaction essential for technology transfer.

	<u>EVALUATION</u>	<u>FEASIBILITY</u>	<u>DEVELOPMENT</u>	<u>VERIFICATION</u>	<u>TRANSFER</u>
ACTIVITY	SYSTEM & ECONOMIC ANALYSIS	MATH & LAB MODES	PROTOTYPE LAB TESTS	PROTOTYPE FIELD TEST	DESIGN, MANUFACTURE & USE
SANDIA	MODELING	RESEARCH	TEST DESIGN & DATA ANALYSIS	DIAGNOSTICS & DATA ANALYSIS	CONSULTATION
INDUSTRY	CRITIQUE, ECONOMICS	CRITIQUE, SPECIAL TESTS	HARDWARE OR SOFTWARE CONSTRUCTION	OPERATE FIELD TEST	INCORPORATE IN PRODUCT LINE
TYPICAL TIME SCALES (MONTHS)	3-12	6-12	12-24	24-48	12

Table 3. Stages in geoenergy technology transfer

GEO ENERGY TECHNOLOGY TRANSFER

The effective transfer of technology occurs for many reasons and in several ways. A new concept--hardware, computer program, material--that has an economic or market advantage, will be readily transferred. Such a transfer is obvious and easy to document. In some cases, a technology exists but industry is reluctant to pick it up because of the risk involved in modifying an existing plant or procedure. In the case where that technology exists at a federal laboratory, some directed research can catalyze adoption of that technology by industry. Since the technology does exist, the catalytic role of a laboratory may be difficult to quantify. When technology transferred consists of information or understanding, the transfer usually cannot be quantified. Such "inventions" have many fathers. Industrial personnel will also have been thinking along similar lines due to past contacts and the new concept is undoubtedly an evolution of many peoples' thoughts.

The following discussion is divided into these three categories: New Concepts, Risk Removal and Understanding. There will be fuzzy boundaries between the areas. The results described are those by Sandia researchers and contractors. In most outside contracts, a Sandia engineer or scientist was involved in research on one aspect of the project to maintain technical expertise in that area and contribute to the problem's solution.

Technology Transferred

New Concepts

Drilling, Completions and Mining: The following activities are all oriented to accessing resources including geothermal, oil and gas, coal and minerals.

- . Developed computer code to place polycrystalline diamond compact cutters on bit to optimize cutter life. Code now used by several major bit companies (Reed, PCI, Smith, Security).
- . Developed process for diffusion bonding of PDCs to bit studs. Petroleum Concepts Inc. is now applying this technology.

- . Developed (with Hydronautics, Inc.) cavitating jets to enhance cutting and cleaning ability of bi-cone and tri-cone bits. Nozzles now available in Smith A-1 bits.
- . Two-dimensional heat and mass transfer analyses for analyzing fluid and formation temperatures during geothermal well drilling, completing or fluid production. Developed with Enertech, marketed by Enertech, and used by several companies.
- . Developed and field tested new high-temperature drilling fluid using sepiolite clay. Formulation now available from NL Baroid.
- . Developed (with L'Garde) high-temperature elastomers for "O" ring applications. Now available through L'Garde, Precision Rubber, and Parker Seal Company.
- . Developed (by Pacer Industries) high-temperature lubricant for roller-cone bearings. Marketed by Pacer Industries as GeobondTM.
- . Identified stabilizing agents and detergents for making aqueous foams stable at high temperature. Foamair is using results in foam drilling and Chevron in foam drive for enhanced oil recovery.
- . Low invasion organic and water-based coring fluids developed for sampling depleted oil reservoirs are now in use by Pressure Coring Inc. and Christensen.
- . Design (with Foster-Miller) of inert gas generator which cleans diesel exhaust gas for use as a substitute for air (when air drilling) to reduce drill pipe corrosion.
- . Designed and demonstrated a roof bolt bit for coal mining applications which has a lifetime approximately 100 times greater than conventional bits in abrasive overburdens. This bit which uses polycrystalline diamond compact cutters is now being marketed by several companies.

Diagnostics: The major portion of diagnostics R&D has been oriented toward instrumentation and analyses of in situ processes as enhanced oil recovery, oil shale retorting, underground coal gasification and stimulation, and to the evaluation of reservoirs by improved logging tools. Other efforts in high temperature electronics and laboratory techniques were also successful.

- . Quartz crystal transducer research led to new company, Quartex, and establishment of lab at Schlumberger.
- . New thick film resistor inks and discrete resistors for hybrid use at high temperature were developed and marketed by Cermalloy, DuPont, Craddock and Corning.
- . Development of new circuits, materials, rotating transformer, acoustic transducers and other improvements are being incorporated into the borehole televiewer by Simplec, the original manufacturer, and by Hot Hole Instruments, a new company established to provide high temperature field instrumentation.
- . High temperature, sheathed mono- and multi-conductor cables for use at temperatures exceeding 300°C. Marketed by Halpin Engineering and others.
- . High temperature, high pressure viscometer for evaluating drilling fluids is being used at Texas Tech University and Union Geothermal. The viscometer is marketed by Benecheck Manufacturing.
- . Monitoring of in situ temperatures, pressures, flows and gas compositions is combined with retort model calculations, for oil shale retorting by Geokinetics and Occidental Oil Shale.
- . Developed, designed, built and installed a non-intrusive gamma-radiometric catalyst level detector for Hydrocarbon Research, Inc. Requests for similar hardware from Lummus and others.

Figure 1. Advanced Roof Bolt Bit--This bit uses polycrystalline diamond compact cutters optimally positioned to increase bit lifetime and drill rate by up to 100 times in abrasive coal mine overburdens.

Processes: Hardware or concepts to improve processes have been developed with major emphases on enhanced oil recovery and stimulation.

- . Development and test of a downhole steam generator for enhanced oil recovery is a new concept that has provided technology for five firms currently marketing generators; one of the firms, Enhanced Energy Systems, is a new company.
- . Development of advanced packer designs for high temperatures resulted in marketing of new designs by Baker, L'Garde and Foster-Miller.
- . Developed and demonstrated the tailored pulse loading concept for creating multiple fractures for well stimulation. Currently offered as a commercial service through several companies.
- . Identified and quantified the importance of in situ stress in hydraulic fracturing phenomena. Now viewed as the predominate design criteria by industry for conducting fractures.

Risk Removal

Drilling, Completions and Mining:

- . Catalyzed design and use of bits using polycrystalline diamond compact (PDC) cutters. Prior to Sandia involvement, there were no commercial PDC bit manufacturers in the United States; now there are fifteen-plus companies marketing PDC bits (PCI, Stratabit, Davis Hicks, Security, Christensen, American Coldset, etc.).
- . Developed (with Drilling Research Labs) new seals and materials for tri-cone bits which enable survival at geothermal temperatures. Program cost shared with Reed Tool Company.
- . Redesigned (with DOWDCO) a pressure coring system for higher pressure use, to recover a longer core, with improved seals, and to incorporate a core orientation device; is in commercial use and resulted in establishment of a new company, Pressure Coring Inc.

Figure 2. Downhole Steam Generator Concept--Steam is used to recover heavy oils in oil reservoirs and tar sands. The downhole generator has advantages over surface boilers of high thermal efficiencies, reduced air pollutants and more rapid recovery of oil.

Figure 3. Downhole Steam Generator--The generator is being installed in a well in conjunction with the City of Long Beach, California.

Diagnostics:

- . Developed 275°C hybrid circuitry for: voltage regulators, line drivers, pulse stretchers, and voltage-to-frequency converters. Products are now available from Teledyne-Philbrick.
- . Developed a multiplexer (GE marketing) and an op-amp (Harris marketing) for use to 275°C in downhole logging tools.
- . Demonstrated (with Gearhart Industries) the application of hybrid microcircuit technology to logging tool instrumentation; adopted for use by Gearhart and Schlumberger.
- . Design changes on clock bearings and lubricants now used in slick line logging tools transferred to Kuster Tool and Geophysical Research; also a new company, Thermodurics, established.
- . Developed several advanced instrumentation techniques for in situ process monitoring. A tilt meter concept for determining fracture propagation direction was developed by Fracture Technology, Inc. and is now marketed by Fracture Technology and Hunton Geophysics. A borehole seismic system developed for stimulation research is now marketed by Fracture Technology and Birdwell.

Processes:

- . Verification of insulation effectiveness on downhole tubular goods resulted in a new injection string insulation system by GE and catalyzed work on new downhole pipe insulation concepts by several companies.
- . Identified catalytic role of pyrite, pyrrhotite, and other minerals in the direct hydroliquefaction of coal. Work has provided major impetus to the recycle of slurry bottoms in all processes and the initiation of DOE programs in slurry phase catalysts.

Understanding

Drilling, Completions and Mining:

- . Software for analyzing casing stress and failure in geothermal environments adapted by Union and Aminol.

Diagnostics:

- . Developed gamma-ray gas/solids mass flowmeter, based on time cross-correlation of density variations in orthogonal planes. Prototype unit successfully evaluated at PETC (cold) coal flow test loop.

Processes:

- . Studies on low temperature coal dissolution mechanisms, preasphaltene formation/ dissociation rates and retrogressive reaction kinetics are being used to provide major thrust into front-end phenomena relevant to the integrated, two-stage coal liquefaction processes (e.g., ITSL).
- . Developed a novel class of catalysts, based on hydrois oxide ion exchange compounds of Ti, Zr, Nb and Ta, whose initial hydrogenation activities are comparable to a commercial Ni/Mo catalyst currently used in pilot plant coal liquefaction studies. Interest in these catalysts has been shown by Catalytica, Inc., and American Cyanamide.
- . Utilized radioactively-tagged catalyst to determine residence time and deactivation rates in H-Coal PDU. This work led to changes in operating procedures and interpretation of reactor mixing dynamics for H-Coal process.
- . Developed an interactive computer code, to facilitate data input to NASA code, to allow multiple case calculations of adiabatic flame temperatures in highpressure, entrained-bed gasifiers. Applied to deflagration/detonation wave assessment of BiGas and Mountain-Fuels gasifiers.

Figure 4. High Temperature Electronics--The high temperature hybrid microcircuits (upper unit) operate to 275°C, are more compact than conventional circuitry (middle unit) and have high reliability. These circuits are packed in a Gearhart temperature logging tool (lower unit).

Figure 5. Logging a Geothermal Well--Operation of the high temperature electronics was confirmed by logging Union's geothermal wells.

- . Characterized the acceleration tensor in sea-floor sediments caused by a major offshore earthquake. This was accomplished for the first time off Santa Barbara, California, using the Sandia designed Seafloor Earthquake Measuring System (SEMS) which is remotely deployed and interrogated. This provides a basis for improved offshore platform design.
- . Characterized the effective stress (and shear strength) of sediments in the Gulf of Mexico by making long-term pore pressure measurements using the Sandia designed, remotely deployed, Geotechnically Instrumented Seafloor Probe (GISP). This information provides a basis for improved offshore platform and pipeline design.
- . Developed a solution mining code (SANSMIC) to predict cavern shape and volume for caverns in salt formations as a function of prescribed flow parameters including raw water flow rate, salinity, and temperature; brine flow rate, salinity and temperature; and hanging string settings. This code is designed to predict leaching in the standard process, leaching while simultaneously injecting oil, and leaching during oil withdrawal using raw water. This code is in use by SPR contractors PB/KBB and Petroleum Operations and Support Services, Inc. (POSSI).

Technology with Potential for Transfer

Extensive interactions with advisory panels and industry assures that many program aspects are in the process of being transferred. The technologies listed in this section have received industrial interest and many should be transferred within a year.

New Concepts

Drilling, Completions and Mining:

- . Application of an inertial navigation system to the spatial mapping of wellbores. Field test of experimental tool successfully completed in 1982. Exxon and Scientific Drilling Controls currently developing hardware; Sperry Sun and Eastman Whipstock following.
- . Design (with Foster-Miller) of inert gas generator which cleans diesel exhaust gas for use as a substitute for air (when air drilling) to reduce drill pipe corrosion.
- . Waterjet descaling system for cleaning scale for geothermal wells. Uses cavitating jets, minimizing casing damage and permitting well to flow while being cleaned. Also being considered for underreaming geothermal wells to increase productivity.
- . Waterjet drill for providing horizontal wellbores in coal seams for methane drainage, in situ gasification or other processes.
- . Reamer bits modified to use polycrystalline diamond compact cutters and Sandia developed wear sensors (to indicate hole gage) to be evaluated in field tests.

Diagnostics:

- . Development of a long-life, high-power electrical switching device for use at elevated temperature. Sprytron tube is being modified to operate as SCR for primary use in cement-bond logging tool.
- . Downhole, periodic seismic source for in situ, geophysical exploration of geothermal and oil or gas reservoirs, mineral resources and in situ processes.

- . Application of Controlled Source Audio Magnetotelluric techniques to monitoring in situ processes as underground coal gasification.
- . Development of high temperature probes for monitoring convection in magma bodies being considered for use in monitoring steel making processes.
- . Remote, underwater seismic equipment with an automated acoustic communications link has been developed and successfully used; detailed designs being disseminated to industry.
- . Inverted thermocouple concept developed and used to monitor temperatures below an insitu process and transmit data via an RF link to the surface. ARCO planned to use on UCG experiments.

Processes:

- . Developed novel chemically vapor deposited (CVD) titanium diboride hard coatings for coal liquefaction letdown valve trim components. Prototype hardened valve successfully tested at Exxon 250 ton/day coal liquefaction pilot plant (Baytown, Texas) facility on Texas lignite feed stream. Future valves to be evaluated at Wilsonville, Alabama (6 ton/day) pilot plant.
- . Research on low temperature coal liquefaction mechanisms and catalyst deactivation processes originated a concept of low severity coal liquefaction now being considered for advanced multi-stage direct coal liquefaction processes.
- . Designed a novel high-pressure helical screw rheometer to provide viscosity data, at temperature, of coalsolvent slurries in the region of gel formation. This work will provide improved understanding of preheater coking and front-end coal dissolution phenomena.

Figure 6. **Geotechnically Instrumented Seafloor Probe**--This complex instrumentation system combines significant artificial intelligence and data storage with a selection of sensors and an acoustic transponder to sense, record, and communicate seafloor geotechnical data in an unattended condition.

- Currently developing and demonstrating technologies to recover gas from lenticular, tight gas sand reservoirs in an extensive field experiment in Colorado; joint industry-Sandia effort constantly transferring technology.

Risk Removal

Drilling, Completions and Mining:

- Seals capable for sealing high-speed turbine/motor bearing packages at geothermal conditions. The HPCR-SF design has operated for 200 hours under laboratory conditions.
- Guidelines for the design of hydraulic configurations to improve cutter cooling and bottomhole cleaning being assessed by industry.
- Developing understanding of coal and rock cutting energetics through laboratory tests and finite element analyses for advanced rock and coal cutting systems.

SUMMARY

The unclassified, energy related, industry oriented Department of Energy Programs at Sandia have provided an excellent mechanism to effectively transfer many of our technologies from government to industry. The strong research base of in situ diagnostics (from weapons testing), transport processes and materials for hostile environments is being coupled with a directed systems approach to get new concepts into the private sector. A recent conference [17] on high temperature electronics, after all federal funding on the project had ceased, attracted over 350 attendees with industry asking to present papers and display new wares. This termination of a geothermal logging instrumentation program signaled the advent of a new industrial move into high temperature electronics for use in the logging of deep gas wells and geothermal resources, for monitoring controls and environments inside nuclear reactor containment vessels, for warning of jet flameout in aircraft engines and other new applications.

Details of the transferred technology, presented in the previous text, can be summarized in facts:

- . Over 40 technology advances have been transferred to industry.
- . Five new companies have been established based on these technology developments.
- . Over thirty engineers and scientists, involved in these energy programs, have joined industry at industry's initiative.
- . A new perspective of electronics use in hostile environments and for describing in situ processes has been initiated. In addition, expertise has been applied to other national needs in areas as coal mine fires in Pennsylvania and Colorado, volcanic hazards at Mt. St. Helens, and oil storage problems at the Strategic Petroleum Reserve sites.

The technology transfer has been largely from the base developed in the weapons programs to the energy sector, but transfer has also occurred in the other direction. Work on special crystallographic cuts of quartz crystals to minimize temperature effects for the evaluation of geopressured resources has resulted in

quartz tuning forks for weapon's timer applications. Work initiated on gallium phosphide and arsenide semiconductor devices for high temperature diodes is being applied to use in radiation hardened circuits for weapons. Research on borehole navigational systems has resulted in improved hardware and software for missile guidance systems. Advanced magnetic bubble memory electronics, used for seabed characterization, are now being applied to defense systems. Aqueous foam systems are being used to prevent unauthorized access to nuclear materials.

The success of these programs reinforce the lessons of past technology transfer studies that person-to-person interactions are essential to effective transfer. These interactions are generally well supported by industry as evidenced by the advisory panels and many joint programs. As the energy programs phase out of the federal budgets, new methods will have to be developed to maintain the existing communications. Unfortunately, these new methods have not yet been identified.

REFERENCES

- [1] M. J. Kelly, Bell Laboratories Record, "The Transistor - Ten Years of Progress," p. 190 (June 1958).
- [2] Electronic Design 24, p. 66 (November 23, 1972).
- [3] G. W. Hough, Technology Diffusion, Lomond Books, Mt. Airy, Maryland (1975).
- [4] D. E. Cunningham, J. R. Craig and T. W. Schlie, Editors, Technological Innovation, Westview Press, Boulder, Colorado (1977).
- [5] W. H. Gruber and D. G. Marquis, Editors, Factors in the Transfer of Technology, MIT Press, Cambridge, Massachusetts (1969).
- [6] 1980 IEEE Engineering and Management Conference Record, November 12-14, 1980, Wakefield, MA.
- [7] Showcase for Technology, October 27-28, 1981, Albuquerque, New Mexico.
- [8] F. I. Robinson, "NASA Technology Transfer," from the Technology Transfer Division, P. O. Box 8757, Baltimore-Washington International Airport, Maryland (1981).
- [9] National Academy of Engineering, Reference 4, "Technology Transfer and Utilization Recommendations for Redirecting the Emphasis and Correcting the Imbalance," p. 55.
- [10] E. B. Roberts in Reference 5, "Entrepreneurship and Technology," p. 219.
- [11] Public Law 96-480 [S. 1250], Stevenson-Wydler Technology Innovation Act of 1980, U.S. Senate (October 21, 1980).
- [12] R. L. Rudman, EPRI Journal, 6(9), "Research Oriented Toward Applications," p. 2 (November 1981).
- [13] J. Douglas, EPRI Journal, 6(9), "Technology Transfer: The Ultimate Measure of R&D," p. 6 (November 1981).
- [14] A. Dupont in Ref. 6, "Technology Transfer and Industries," p. 129.

- [15] T. Burns in Ref. 5, "Models, Images and Myths," p. 11.
- [16] A. H. Teich and W. H. Lambright in Ref. 4, "Federal Laboratories and Technology Transfer: An Inter-organizational Perspective," p. 431.
- [17] High Temperature Electronics Instrumentation Conference, December 7-8, 1981, held at the Marriott at the Astrodome, Houston, Texas, sponsored by Sandia National Laboratories, in conjunction with the U.S. Department of Energy, IEEE, and the University of Houston.

APPENDIX A

ADVISORY PANELS

Geothermal Technology Program Technical Review Panel

Tom Anderson, Venture Innovations
W. E. Bingman, Drilling Engineering Advisory, Shell Oil Company
Larry Diamond, Vice President, Technical Services, Dyna-Drill
John E. Fontenot, Manager, Mechanical Engineering, NL Petroleum Services
Dr. Melvin Friedman, Professor of Geology, Texas A&M University
Tom Turner, Development and Operations Director, Phillips Petroleum Company
Jim Kingsolver, Manager, Geothermal Operations, Smith Tool
James W. Langford, Manager, Research, Security Division, Dresser Industries, Inc.
Harvey E. Mallory, Assistant to President, Field Operations, Loffland Brothers Company
Gene Polk, NL Baroid
Delbert E. Pyle, Manager of Operations, Union Geothermal Division, Union Oil Company of California
John C. Rowley, Field Operations and Engineering, Los Alamos National Laboratory
William D. Rumbaugh, Project Engineer, Research and Development, Otis Engineering
Dwight Smith, Halliburton
Tom Warren, Amoco Production Company
Ed Martin, Superior Oil Company

Consultant Panel for Offshore and Frontier Technologies

Junius Allen, ARCO
Gary Boubel, ARCO
Paul Aagaard, Chevron
Robert Haring, Exxon
F. P. Dunn, Shell Oil Company
Paul Durning, Union Oil
Paul Teleki, U. S. Geological Survey
Louis E. Garrison, U. S. Geological Survey

High Temperature Logging Instrumentation Panel
(Panel dissolved in 1981)

William R. Berry, Occidental Exploration and Production
Bruce Blackman, Electrical R&D Department, Halliburton
Services
R. A. Broding, Amoco Production Company Research Center
Jan Brown, Schlumberger Doll Research
John T. Byrne, Interstate Electronics
Tom Campbell, Campbell Consulting
Stan Coombs, Pacific Resources Management
Carl Dodge, Halliburton Services
Dick Dunlap, Aminol USA, Inc.
John Herrgott, Hewlett Packard
Bob Hoard, Phillips Petroleum Company
Gus Hoehn, Mobil R&D Corporation
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Jack Kusters, Hewlett Packard
Donald R. Lindsay, Occidental Geothermal, Inc.
Bob Macy, Manager of Geothermal Planning and Technology
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Bob Mayer, Gearhart Owen Wireline Services
Bob McElwrath, United Wireline
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Randy Saucier, Shell Oil
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E. J. Hanzlik, Getty Oil
R. C. Ellis, Completion Technology Company
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Paul D. Chase, Public Service Electric and Gas Co.
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Nicholas J. Skorski, American Natural Resources Co.
Robert M. Forrest, Columbia Gas System Service Corp.
Enrest C. Geer, Transco Energy Co.
David P. Giebelhaus, Lone Star Gas Co.
Robert D. Habbit, El Paso Natural Gas Co.
Forrest W. Lewis, TXCO Resources, Inc.
John L. Moore, Consolidated Natural Gas Services Corp.
Alfred T. Schlemmer, Texas Eastern Gas Pipeline Corp.
Harry L. Steadman, National Fuel Gas Supply Corp.
Harry Stout, Florida Gas Transmission Co.
Stanley D. Whitford, Natural Gas Pipeline Co. of America

APPENDIX B

MAJOR PUBLICATIONS

Coal

L. C. Bartel, T. L. Dobecki, et al., "Results of the Characterization of an In Situ Coal Gasification Site in the State of Washington," Proceedings of the Sixth Underground Coal Conversion Symposium, Afton, Oklahoma, 1980.

B. E. Bader and R. E. Glass, "The Role of Site Characteristics in the Control of Underground Coal Gasification," Proceedings of the Fifth Symposium on Instrumentation and Control for Fossil Energy Processes, 1981.

R. E. Glass, "Applications of Reservoir Simulation to In Situ Coal Gasification," SAND80-2579, 3/81 (to be published in In Situ).

S. L. Love, and K. M. Timmerman, "Testing of a Water Jet System for Drilling Horizontal Holes in Coal," Proceedings of the Seventh Underground Coal Conversion Symposium, Fallen Leaf Lake, California, 1981.

Oil and Gas

P. S. Lysne, J. S. Yu, C. N. Vittitoe, and L. E. Duda, "Dielectric Log Interpretation: Probe Response and Dielectric Properties of Rocks," 22nd Annual Meeting of SPWLA, Mexico City, June 23-26, 1981.

D. A. Northrop and A. R. Sattler, "The Multi-Well Experiment: A Field Laboratory for Tight Gas Sands Research," Proceedings of the Intersociety Energy Conversion Engineering Conference, Los Angeles, California, Volume 2, p. 1027-1034 (August 1982).

N. R. Warpinski, R. A. Schmidt and D. A. Northrop, "In Situ Stress: The Predominant Influence on Hydraulic Fracture Containment," Proceedings of the 1980 Symposium on Unconventional Gas Recovery, Pittsburgh, Pennsylvania, May 1980 and J. of Petroleum Technology 34, 653-664 (March 1982).

R. L. McNeill, S. Green, "In Situ Determination of Strength Parameters of Marine Soils, Sandia Laboratories Report SAND80-0693, June 1980.

J. F. Cuderman, "Multiple Fracturing Experiments-- Propellant and Borehole Considerations," Proceedings of the SPE/DOE Unconventional Gas Recovery Symposium, Pittsburgh, Pennsylvania, p. 535 (May 16-18, 1982).

R. L. McNeill, "Derivation of an Approximate Equation for Estimating Shear Strength of Cohesive Materials from Penetrator Deceleration," Sandia National Laboratories Report SAND81-1364, June 1981.

R. L. McNeill, "An Approach for Estimating Soil Attachment During Penetration Events," Sandia National Laboratories Report SAND80-2667, May 1981.

R. L. Fox, et al., "DEEP STEAM: Development of Downhole Steam Generation Systems and Injection String Modifications for DEEP STEAM Injection," 5th DOE Annual Symposium on Enhanced Oil and Gas Recovery, Tulsa, Oklahoma, 1979.

N. R. Warpinski, et al., "High Energy Gas Frac: Multiple Fracturing in a Wellbore," Proceedings of the 20th U. S. Symposium on Rock Mechanics, Austin, Texas, 1979.

R. L. McNeill, "Enhancement of Geophysical Soil Profiles Using Instrumented Marine Sediment Penetrators," Proceedings of Offshore Technology Conference, OTC 3526, 1979.

R. W. Seavey, "Borehole Seismic Unit," SAND82-0373, Sandia National Laboratories, Albuquerque, New Mexico, May 1982.

Synthetic Fuels

P. J. Hommert and C. E. Tyner, "Model Capabilities for In Situ Oil Shale Recovery," Journal of Energy Resources Technology, June 1981.

J. T. Schamaun, "Lumped Mass Modeling of Overburden Motion During Explosive Blasting," Proceedings of the 14th Oil Shale Symposium, Golden, Colorado, 1981.

C. E. Tyner, "In Situ Borehole Retorting of Oil Shale," Proceedings of 15th IECEC, Seattle, Washington, August 1980.

R. R. Boade, M. E. Kipp and D. E. Grady, "Dynamic Fracture and Fragmentation of Oil Shale: Application of a Numerical Model to a Blast Design," Proceedings of the 14th Oil Shale Symposium, Golden, Colorado, 1981.

G. S. Davidson and P. J. Hommert, "Instrumenting and Evaluating Large Scale In Situ Experiments," SAND81-0968C, Sandia National Laboratories Report, 1981.

A. W. Lynch, "Asphaltene Analysis Using Size Exclusion Liquid Chromatography," Waters Western LC Symposium, Newport Beach, California, October 15-16, 1981.

T. D. Padrick, D. Dees, T. M. Massis, "The Catalytic Effect of Iron in Hydrogasification of Coal," North American Thermal Analysis Society Meeting, New Orleans, Louisiana, October 18-22, 1981.

T. D. Padrick, J. K. Rice, T. M. Massis, "Relative Catalytic Activity of Iron Containing Minerals for the Hydrogasification of Coal," American Chemical Society Meeting, Kansas City, Missouri, September 12-17, 1982.

T. D. Padrick, A. W. Lynch, H. P. Stephens, "Effect of Solvent on the Dissolution of Wyodak Coal," Integrated Two-Stage Liquefaction Contractors' Conference, Albuquerque, New Mexico, October 6-7, 1982.

H. P. Stephens, "Mineral Matter Effects in Coal Liquefaction," DOE Contractors' Conference, Pittsburgh, Pennsylvania, September 1982.

H. P. Stephens, "Direct Coal Liquefaction--Reaction Pathways Catalysis and Processes," (invited talk), California State University, Department of Chemistry, Long Beach, California, April 21, 1982.

H. P. Stephens, "Process Course and Selectivity Relationships for Direct Coal Liquefaction," AIChE, New Orleans, November 8-12, 1981.

M. G. Thomas, "The Effect of Coal Dissolution on SCT Liquefaction," Two-Stage Liquefaction Meeting, (DOE sponsored), Saddlebrook, New Jersey, October 15-16, 1981.

D. S. Thakur, F. E. Massoth, M. G. Thomas, "Co-MO/Al₂O₃ Catalyst Deactivation During Coal Liquefaction," 4th International Conference on Chemistry and Use of Molybdenum, Golden, Colorado, August 9-13, 1982.

F. V. Stonl, "Characterization of Aged Catalyst Samples," Integrated Two-Stage Liquefaction Contractors' Conference, Albuquerque, New Mexico, October 6-7, 1982.

A. W. Lynch, "Asphaltene Analysis Using Size Exclusion Chromatography, submitted to Fuel Processing Technology, March 1982.

T. D. Padrick, J. K. Rice, T. M. Massis, "Relative Catalytic Activity of Iron Containing Minerals for the Hydrogasification of Coal," Proceedings of the ACS Meeting, Kansas City, September 12-17, 1982.

H. P. Stephens, M. G. Thomas, T. D. Padrick, and F. V. Stohl, "The Decomposition of Pyrite Under Coal Liquefaction Conditions, A Kinetic Study," Fuel 61, p. 761-764, August 1982.

Geothermal

C. C. Carson and Y. T. Lin, "The Impact of Common Problems in Geothermal Drilling and Completion," Geothermal Resources Council, 1982 Annual Meeting, October 1982.

B. C. Caskey, "Design of a Diesel Exhaust Gas Purification System for Inert Gas Drilling," Geothermal Resources Council, 1982 Annual Meeting, October 1982.

A. Ortega and D. A. Glowka, "Frictional Heating and Convective Cooling of Polycrystalline Diamond Drag Tools During Rock Cutting," Society of Petroleum Engineers 57th Annual Technical Meeting, September 1982.

J. R. Kelsey, "A Wellbore Inertial Navigation System," International Association of Drilling Contractors and Society of Petroleum Engineers 1983 Drilling Conference, February 1983.

Sandra R. Hudson, and J. R. Kelsey, Editors, "Proceedings-High Temperature Electronics and Instrumentation Conference, December 1981.

J. T. Finger, "Laboratory Testing of Percussion Drills for Geothermal Applications," Geothermal Resources Council, September 1980.

P. B. Rand, "Aqueous Foams for Geothermal Drilling Fluids--Surface Screening," Geothermal Resources Council, September 1979.

J. L. Colp and H. M. Stoller, "The Utilization of Magma Energy--A Project Summary," Proceedings, Second Circum-Pacific Energy and Mineral Resources Conference, July 1978.

D. L. Douglass, P. J. Modreski, and J. T. Healey, "The Corrosion of Some Pure Metals in Basaltic Lava at 1150°C, ABS, Proceedings of Hawaii Symposium on Intraplate Volcanism and Submarine Volcanism, Hilo, Hawaii, July 1979.

H. C. Hardee, "Heat Extraction from Magma Bodies," Ibid.

J. F. Hermance, D. W. Forsythe, and J. L. Colp, "Summary of Geophysical Sensing Experiments on Kilauea Iki Lava Lake, Ibid.

T. M. Gerlach, "The Gas Phase of Tholeiitic and Alkaline Magmas," ABS, Abstracts with Programs, 1979 Annual Meeting, Geolog. Soc. Am., San Diego, California, November 1979.

E. J. Graeber, P. J. Modreski, and T. M. Gerlach, "Compositions of Gases Collected During the 1977 East Rift Eruption, Kilauea, Hawaii," J. of Volcanology and Geothermal Research 5, 1978.

Subsidence

D. E. Munson and H. J. Sutherland, "The Empirical and Analytic Approaches to Subsidence Prediction," Proceedings of the Polish-American Conference on Ground Control in Room-and-Pillar Mining, Southern Illinois University at Carbondale, August 6-8, 1980.

N. G. W. Cook, M. Hood, and J. Daemon, "Surface Subsidence Resulting from Underground Coal Mining," Interim Report No. 1 for Contract No. 62-0200, Department of Material Science and Mineral Engineering, University of California, Berkeley, October 15, 1980.

APPENDIX C

EXHIBITS

OIL AND GAS RESEARCH AND DEVELOPMENT

ENHANCED OIL RECOVERY

EXTENSION OF STEAM DRIVE TECHNOLOGY

UNCONVENTIONAL GAS RESOURCES

UNDERSTANDING AND EVALUATION OF STIMULATION TECHNOLOGY

DRILLING TECHNOLOGY

IMPROVEMENTS IN DRILLING SYSTEM PERFORMANCE

OFFSHORE TECHNOLOGY

CHARACTERIZATION OF GEOTECHNICAL ENVIRONMENT

SANDIA OIL AND GAS RESEARCH AREAS

SYNTHETIC FUELS RESEARCH AND DEVELOPMENT

SANDIA RESEARCH AREAS IN SYNTHETIC FUEL DEVELOPMENT

GEOHERMAL TECHNOLOGY PROGRAM

DEVELOPMENT OF ADVANCED DRILLING, COMPLETION, AND LOGGING SYSTEMS FOR ACCESSING THE GEOTHERMAL RESOURCE

GEOHERMAL TECHNOLOGY RESEARCH AREAS

MAGMA ENERGY RESEARCH

GOAL: TO DETERMINE THE SCIENTIFIC FEASIBILITY
OF MAGMA ENERGY UTILIZATION

ACTIVITIES: LAVA LAKE FIELD EXPERIMENTS
LABORATORY CONVECTION
EXPERIMENTS IN FURNACES
MAGMA CHARACTERIZATION
STUDIES

FY81 ACCOMPLISHMENTS:

DRILLED INTO 1100 °C MELT AND
SUCCESSFULLY OPERATED FIRST
OPEN HEAT EXCHANGER
IN MOLTEN BASALT

MEASURED SEISMIC TRANSMISSION
SIGNATURE THROUGH A MELT LENSE

TECHNICAL TRANSFER — STAFF MOVEMENTS —

PROGRAM	STAFF	TO	FOR
WELL LOGGING INSTRUMENTATION	EERNISSE COQUAT VENERUSO	QUARTEX CRC WIRELINE, INC. GEARHART, IND.	QUARTZ CRYSTAL TECHNOLOGY WELL LOGGING SERVICES LOGGING TOOL DEVELOPMENT
DRILLING TECHNOLOGY	VARNADO, McFALL, WESENBERG ST. CLAIR BAKER POLITO HUFF	N. L. PETROLEUM SERVICES EXXON PRESSURE CORING, INC. PRITSKER & ASSOC. PETROLEUM CONCEPTS, INC.	MEASUREMENTS WHILE DRILLING TECHNOLOGY DRILLING - MECHANICAL DESIGN CORING SERVICES FOR OIL & GAS SYSTEMS ANALYSES DRILL BIT CUTTER ASSEMBLY
OIL SHALE	STEVENS BOADE	OCCIDENTAL PETROLEUM PHILLIPS PETROLEUM	PROCESS RESEARCH & ROCK MECHANICS ROCK MECHANICS SHALE
STIMULATION RESEARCH	STOLLER DEBECKI, DROZDA SCHMIDT	TAILORED PULSE LOADING FRACTURE TECHNOLOGY TERRA TEK	FRACTURING SERVICES STIMULATION DIAGNOSTICS ROCK MECHANICS
ENHANCED OIL RECOVERY	FOX, DONALDSON, JOHNSON EISENHOWER, MULAC	ENHANCED ENERGY SYSTEMS	DOWNHOLE STEAM GENERATOR
MAGMA ENERGY	HILLS	N.M. STATE U	GEOPHYSICS-INVERSE PROBLEMS

TECHNOLOGY TRANSFER OIL & GAS PROGRAMS NEW ENDEAVORS BY PRIVATE INDUSTRY

COMPANY

**ENHANCED ENERGY SYSTEMS,
SULLAIR,
ROCKETDYNE, CORCO, AND OTHERS**

GE

BAKER, L'GARDE, FOSTER-WHEELER

TAILORED PULSE LOADING, INC.

**BIRDWELL, HUNTER GEOPHYSICS,
FRACTURE TECHNOLOGY**

NEW ACTIVITY

DOWNHOLE STEAM GENERATORS

STEAM INJECTION STRING INSULATION

HIGH TEMPERATURE PACKERS

GAS FRACTURING SERVICES

**FRACTURE MAPPING VIA
TILTMETERS & BOREHOLE
SEISMICS**

TECHNOLOGY TRANSFER WELL LOGGING INSTRUMENTATION PROGRAM — NEW ENDEAVORS IN PRIVATE INDUSTRY —

COMPANY	NEW ACTIVITY
GEARHART, INC.	HYBRID MICROCIRCUITS
SCHLUMBERGER	HYBRID MICROCIRCUITS QUARTZ CRYSTAL RESEARCH
VECTOR	HIGH TEMPERATURE LOGGING CABLE
TELEDYNE & GE	HIGH TEMPERATURE CIRCUITS
DUPONT & CERMALLOY	NEW RESISTOR INKS FOR CIRCUITS
CRADOCK & CORNING	NEW DISCRETE RESISTORS FOR HIGH TEMPERATURE
HALPEN	SHEATHED, MONOCONDUCTOR CABLE
MOBIL, SIMPLEX	ELECTRONIC AND MECHANICAL MODIFICATIONS TO THE BOREHOLE TELEVIEWER
HARRIS SEMICONDUCTOR	HIGH TEMPERATURE SILICON OPERATIONAL AMPLIFIER CMOS LOGIC CIRCUIT
SEVERAL	HIGH TEMPERATURE ELECTRONIC COMPONENTS

TECHNOLOGY TRANSFER DRILLING & COMPLETIONS PROGRAM — NEW ENDEAVORS BY PRIVATE INDUSTRY —

COMPANY	NEW ACTIVITY
PRESSURE CORING, INC.	CORING DEPLETED OIL RESERVOIRS USE LOW INVASION CORING FLUID
CHRISTIENSEN	NEW LOW INVASION CORING FLUID
ENERTECH	COMPUTER ANALYSES OF WELL BORE TEMPERATURES
BAROID	NEW DRILLING MUD FOR HIGH TEMPERATURES
SEVERAL	NEW DRAG BITS WITH COMPACT CUTTERS ROOF BOLT DRILL BITS/MINING
L'GARDE	HIGH TEMPERATURE ELASTOMERS FOR SEALS, INC.
POLY PLUG, INC.	URETHANE FOAMS FOR LOST CIRCULATION
HYDRONAUTICS; SMITH; NL HYCALOG	CAVIJET NOZZELS FOR TRICONE BITS
PETROLEUM CONCEPTS, INC.	DIFFUSION BONDED CUTTERS ON DRILL BITS