Geothermal technologies

U.S. Department of Energy

Vol.4 Issue 2
May 1999

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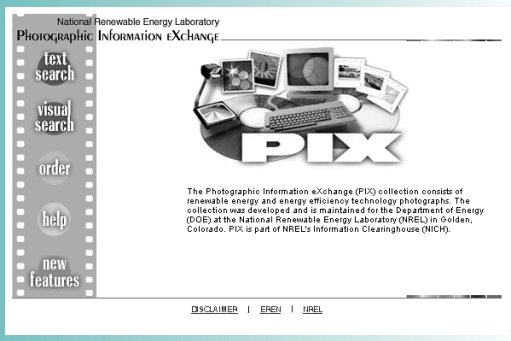
Announcing a New DOE Resource

Did you know that you can use the Internet to easily access a growing electronic collection of geothermal energy-related photographs? Just go to *www.nrel.gov/data/pix/* on the Internet, and you'll see the National Renewable Energy Laboratory Photographic Information Exchange (PIX) Web page shown below:



Once you've arrived at the PIX Web page, you can select suitable features for using this resource. You can use either of two methods to search the PIX database: *Text Search* or *Visual Search*. *Text Search* allows you to use Boolean key words or subjects to search the electronic library. *Visual Search* allows you to select subject headings through thumbnail-sized images. Once you've selected *Visual Search*, you can select *Geothermal* and narrow your search criteria by selecting listed descriptor terms, such as condenser, utilities, or heat pump.

If you single click on the image identification number above the photo, you'll access background information on the image such as manufacturer, capacity, location, and contact names. If you single click directly on the thumbnail image, you'll enlarge it on your computer screen.

The images in this electronic collection can be used in their low-resolution format for overheads and most publications. The resolution of the images available online from PIX is 640 x 480 pixels at 72 dpi. To use images from PIX in this manner, "save" the image as "source" to a folder (e.g., TEMP folder), and then import the image into your word processing, desktop publishing, or presentation software.

The collection, which includes many facets of geothermal power technology, direct use, and geothermal heat pumps, has about 350 images as of Spring 1999. We're adding images daily, so if you would like to contribute, please contact Theresa Waggoner (phone 303-275-3137 or e-mail theresa_waggoner@nrel.gov).

Sandia's Geothermal Advanced Drill Rig Instrumentation Assists Critical Oil and Gas Drilling Operation

A gas well blowout burns near Bakersfield, CA. Photograph taken by Epoch Wellsite Services, Inc.

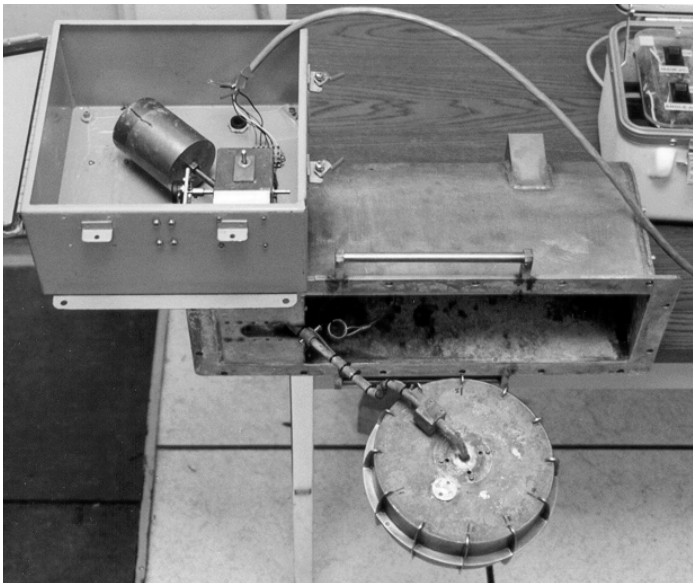
On November 23, 1998, an 18,000-foot wildcat natural gas well being drilled near Bakersfield, CA blew out and caught fire. While the fire has been extinguished, all attempts to kill the well have failed, and it continues to flow under limited control, producing large volumes of natural gas, salt water, and some oil. A relief well is being

drilled approximately one-quarter mile away in an attempt to intercept the blowout and cement it in.

Epoch Wellsite Services, Inc., the mud-logging company for both wells, requested Sandia National Laboratories's rolling float meter (RFM) for the critical drilling operations of the relief well. The RFM is being used to measure the mud outflow rate and to detect kicks while drilling—the drilling will undoubtedly encounter reservoir conditions similar to those responsible for the blow out. Based on its prior experience with the RFM, Epoch believes that it is the only instrument capable of providing the level of accuracy and response to mud flow needed to quickly detect kicks and minimize the risk of a blowout on the relief well.

In response to the urgent request from industry, Sandia and Epoch technicians installed the RFM on the relief well return line, and completed its initial calibration. The data from the RFM is displayed in real-time for the driller, the companyman, and the toolpusher via Epoch's RIGWATCH Drilling Instrumentation System. The RFM has already detected several small kicks while drilling toward the annulus of the blown out well. A conventional paddle meter is located downstream of the RFM to provide redundancy and the opportunity to compare the two meters in an actual drilling operation. The relief well is targeting an intercept at about 17,600 feet, and is expected to be completed in mid-May. Successful performance of these instruments on this important drilling job will reinforce DOE's efforts to commercialize this technology for the geothermal and oil and gas drilling industries.

Sandia's Rolling Float Meter was developed through the Lost Circulation Technology Program sponsored by the U. S. Department of Energy, Office of Geothermal Technologies. It monitors drilling fluid returns to rapidly detect lost circulation, which is a prevalent problem in geothermal wells and which can add as much as 10% to the total cost of drilling. Sandia has been evaluating and demonstrating the capabilities of the RFM to the geothermal industry for several years. In addition to lost circulation, the RFM is also useful for accurately detecting well kicks. Contacts have been made with mud logging companies that are involved with both geothermal and oil and gas drilling operations for the purpose of commercializing this technology.



Sandia's rolling float meter is mounted on top of the rig's outflow line and measures the flowrate of drilling fluids leaving the well. The meter is unique in its ability to accurately quantify flowrate in a partially filled pipe.

For more information, contact George Staller, Sandia National Laboratories, (505) 844-9328 or email gestall@sandia.gov or Gary Whitlow, Sandia National Laboratories, (505) 844-5755 or email glwhitl@sandia.gov. Sandia National Laboratories is a multiprogram lab operated by Sandia Corporation, a Lockheed Martin company, for the U.S. Department of Energy.

racer Tests

The U.S. Department of Energy's (DOE) Office of Geothermal Technologies and the geothermal operating companies jointly funded a multi-year research project at The Geysers Geothermal Field in northern California. This research demonstrated that injection is a crucial factor in extending the power-producing lifetime of the reservoir, concluding that there has been very little heat loss in the geothermal system, but that steam withdrawal has lowered reservoir pressure. Based on this research, the Southeast Geysers Effluent Pipeline (SEGEP) was constructed to bring waste water to The Geysers from Lake County. Construction of the pipeline was jointly funded by The Geysers' geothermal operators, DOE, and several other federal, state, and local agencies. The pipeline provides an innovative way of using waste water to carry the geothermal heat energy from the reservoir rocks to power plants on the surface. Over 5000 gallons per minute of extra water began flowing into the southeast Geysers injection wells during the fall of 1997. Water from this pipeline more than doubles the amount injected into the southeast Geysers, part of the geothermal reservoir where injection-derived steam previously constituted only about 25% to 30% of the steam produced.

The effluent injection program created a need to trace the flow of the new injectate as an important step in verifying that the water is aiding energy production. An exhaustive chemical analysis of the injection water to find any naturally occurring tracers showed that the effluent water has neither distinctive compounds nor an isotopic composition different from the reservoir steam. For several years, the Energy & Geoscience Institute (EGI) of the University of

Injection Well	MLM-1	McKinley-4	P-1	BEF42B-33	McKinley-1	956A-1
Operator	Calpine	Calpine	NCPA	Unocal	Calpine	Calpine
Wells Sampled	10	8	31	26	24	24
Wells with Tracer Detected	10	5	30	17	17	19
Number of Samples Taken	51	23	335	128	69	107

Table 1. Tracer test results.

Utah has received DOE funding for research to develop chemicals that can be used to trace the flow of water through a geothermal reservoir. To be effective, tracers must be compatible with the environment, stable at high temperatures, and detectable in minute quantities. EGI undertook a rapid development program, and two candidate tracers were selected from the testing: R-134a and R-23. Both are HydroFluoroCarbon (HFC) refrigerants containing only hydrogen, fluorine, and carbon. These compounds contain no chlorine that would damage the ozone layer. Thermochem, Inc. developed the analytical methods for the new HFC tracers and injected the tracers.

This program uses many injection wells, so several tracer tests were required to follow the water between an injection well and the surrounding production wells. The tracer injection tests were jointly funded by DOE, the Northern California Power Agency (NCPA), Calpine Corporation, and Unocal Geothermal. Six tracer tests have been conducted to date (see Table 1). The first test was conducted in January 1998, approximately 3 months after SEGEP water was added to the injection. The tracers appeared in production wells within two to four days of injection, and tracer concentration increased to a peak before dropping off. Some peaks took as long as a month to appear. The peak tracer concentrations ranged from 14 parts per million down to 1 part per billion, but these tracers can be detected in concentrations as low as 1 part per trillion.

Tracer injection at The Geysers in 1998.

The tracer tests were designed to evaluate the length of time for flow through the reservoir and the amount of injection-derived steam being produced. Tests also can provide data to determine which production wells receive steam derived from a specific injection well. This knowledge is important when local effects occur, such as when the cool water reaches the bottom of a producing steam well before the water has been heated enough to boil. If a well begins to produce cool water, it must be removed from production, or the water flow to an injection well must be decreased or stopped. There are at least 24 injection wells that can be used for SEGEP water, and it is a complex balancing procedure to optimize water injection to maximize steam production.

The tests also showed that the tracers are stable in the reservoir, where temperatures reach 240°C (464°F). In one case, 93% of a tracer was recovered from the produced steam; it's a clear demonstration of the tracer's stability in the reservoir. There can be rapid transport of tracer through the geothermal reservoir, and in some cases, the tracer was found a kilometer away from the injection well within a few days. The results from this round of injection tracer testing and the analytic methods developed for the tests lead to several possibilities for improvement. Development of more soluble tracers that partition evenly between steam and liquid will be a beneficial refinement of the methodology for use at The Geysers. The two HFC tracers that were used partition strongly to the vapor phase. They can introduce errors into any quantitative estimate of injection-derived steam, if the water boils along the path through the reservoir rather than at a single point on the path.

For more information, contact Mike Adams with EGI at (801) 585-7784 or madams@egi.utah.edu.

Super Energy Savings Performance Contract for

On February 10, 1999, the U.S. Department of Energy (DOE) selected five energy service companies (ESCOs) to finance and manage contracts valued at up to $500 million for the installation of geothermal heat pumps (GHPs) at federal facilities. The initial project in Virginia includes 12 buildings at Naval Air Station Oceana in Virginia Beach and four buildings at nearby Naval Amphibious Base in Little Creek. These and other projects can now be expedited under an umbrella acquisition arrangement called a Super Energy Savings Performance Contract (ESPC).

"To help them meet their energy savings targets and cut greenhouse gas emissions, federal agencies now have this exciting but little known technology, GHPs, available to them at minimum cost and risk ," said Secretary of Energy Bill Richardson. "These contracts alone can save each site up to 40% on energy bills. This innovative business and technology strategy is good for taxpayers and good for the environment."

Super ESPCs allow federal agencies to acquire and pay for GHPs (also known as ground-source heat pumps or GeoExchange) by utilizing the technology's energy and maintenance savings over a 10 to 20 year contractual period to pay for the equipment and installation. Congress has authorized and encourages agencies to use this financing vehicle to retrofit aging facilities in any of the 500,000 federal buildings in the 50 states, District of Columbia, and U.S. territories. The federal government spends nearly $4 billion a year on electricity at these facilities. Through an Executive Order, President Clinton established a goal to reduce federal energy consumption by 30%, as compared to a 1985 baseline, by 2005. The Super ESPC will help achieve that goal.

There are two types of Super ESPCs: regional and technology-specific. Regional Super ESPCs cover certain geographic areas and include all energy saving technologies. Meanwhile, technology-specific Super ESPCs cover the entire nation and emphasize a particular, relatively unknown technology, such as GHPs. The objective in selecting technology-specific Super ESPCs was to provide qualified contractors for these unknown technologies. All projects under the GHP Super ESPCs must center on GHPs; however, other energy conservation measures like improved building envelopes, improved lighting, low-flow shower heads, and improved windows can be included.

Under a Super ESPC, the ESCO incurs all costs to design, install, finance, operate and maintain energy saving systems. In return, the ESCO receives the bulk of the savings that result from substantially reduced energy consumption and maintenance expenses during the contract period. By the end of the period, the ESCO has recovered its costs plus a profit, and the federal site thereafter receives the entire benefit of the energy and maintenance savings.

Before Super ESPCs became available, it would often take 2 to 3 years for an agency to issue an RFP and negotiate energy saving contracts. Now, with the ESCOs pre-approved under the Super ESPC program, it should take only 4 to 8 months.

The five contractors selected under this technology-specific Super ESCO for geothermal heat pumps are:

- Constellation Energy Source, Inc. of Baltimore, Maryland
- Duke Solutions, Inc. of Charlotte, North Carolina
- Exelon Energy Services, Inc. of Philadelphia, Pennsylvania
- The Enron Team—Enron Energy Services & Co-Energy of Las Vegas, Nevada
- The Trane Company, Asset Management Services of St. Paul, Minnesota.

For additional information on the Super ESPC for GHPs, please call Doug Culbreth in the DOE Atlanta Support Office at (919) 782-5238.

railblazing Energy Savings ort Polk Army Base orce Base

Before the Super Energy Savings Performance Contract (ESPC) became available, Fort Polk Army Base in Louisiana issued an RFP and negotiated a standard ESPC with Co-Energy Group to retrofit 4003 units of base housing with geothermal heat pumps (GHPs), as well as attic insulation, energy-efficient lighting, and low-flow shower heads. At a cost of about $19 million, this is the largest energy savings contract completed to date.

An independent and statistically-rigorous evaluation conducted by the U.S. Department of Energy's (DOE) Oak Ridge National Laboratory found the following benefits at Fort Polk:

- Energy savings were 26 million kWh per year (33% of whole-house load).
- Summer peak demand was reduced by 7.5 MW (43%).

- Load Factor was increased from .52 to .62.
- Maintenance costs were reduced by 23%.

In addition to ESPCs and Super ESPCs, contracts between a local electric utility and a federal agency offer another energy saving option. Last year Entergy Corporation, the utility serving Little Rock Air Force Base, completed retro-fitting 1500 base houses with GHPs, making it the second largest completed federal GHP project after Fort Polk.

For more information, please call Lew Pratsch, DOE's GHP program manager, at (202) 586-1512.

Ray LaSala is well known to the geothermal community as a long-time program manager in the U.S. Department of Energy's (DOE) Office of Geothermal Technologies. For many years, he has been in charge of research on energy conversion. He currently also handles most aspects of the brine chemistry program. In fact, his geothermal experience has been very broad, covering logging and instrumentation programs, as well as the materials development program.

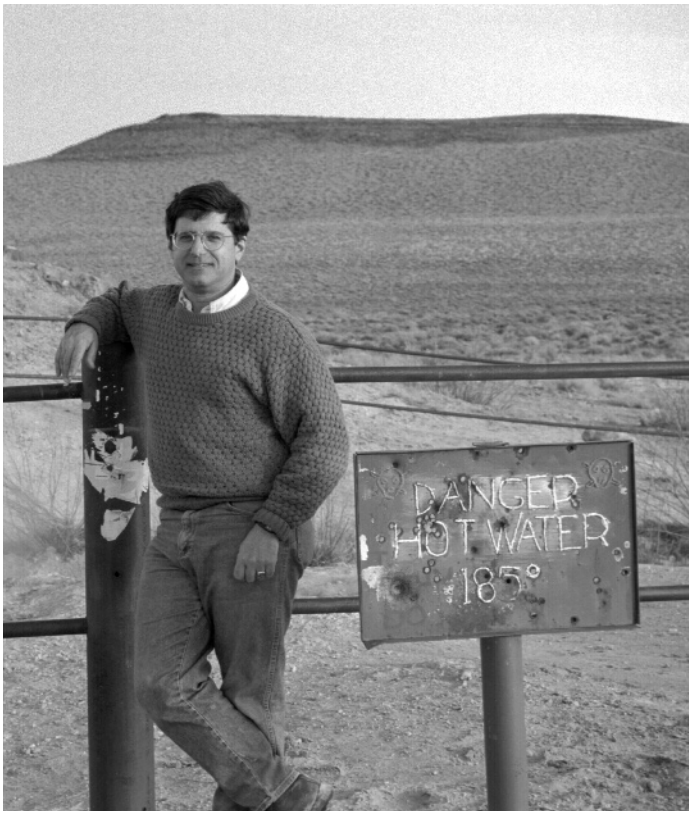
However, even before making his mark in geothermal energy, he had made some important contributions in several other fields that readers of Geothermal Technologies may find interesting.

With a bachelor of science degree in electrical engineering from Princeton, plus a master of business administration from Stanford, Ray was well positioned to make a substantial contribution in many fields of endeavor. Fortunately, he chose a career in federal service where the country as a whole could benefit from his education and talents.

He began in 1972 at the Environmental Protection Agency planning air pollution control strategies. With the onset of the first oil embargo in 1974, he shifted into planning energy conservation policy as a strategy for reducing oil imports. Then, when the Federal Energy Office (FEO) was created in the Nixon White House later that year, he moved over to FEO's energy conservation program. But when federal energy conservation efforts stalled in the late 1970s, he made the transition to the renewable energy program at the Energy Research and Development Administration, one of DOE's predecessor agencies.

And that's where he discovered geothermal energy!

Ray's particular interest is in generating electricity from produced geothermal fluids. "The closer the project is to actually generating useful power," he said, "the more I like it." In this capacity, he has worked on the International Energy Agency's evaluation of the helical screw (Lysholm) expander, which was developed for geothermal wellhead applications by the Hydrothermal Power Company and was field tested in



Ray LaSala in the field.

Utah, Cerro Prieto (Mexico), Cesano (Italy), and Broadlands (New Zealand). Since DOE served as the operating agent on that project, Ray was involved a lot with the engineering evaluation and final report.

As for the future, Ray said, "I'm looking forward to the start-up of Exergy's skid-mounted geothermal electric generation unit at Far West Capital's Steamboat, Nevada power plant late next year. It will employ a cutting-edge design that I hope will encourage others to take a closer look at Kalina-cycle and similar innovative binary cycle technology being supported by DOE."

Many of Ray's colleagues know him as an avid and experienced amateur mycologist. That's right: he studies fungi. He also eats them, which makes him a mycophagist. (It doesn't sound so bad if you call them mushrooms.) Most important of all, he knows which ones not to eat, and that makes him a valuable companion on a camping trip. He became fascinated with mushrooms when he took an evening course on them at the Smithsonian Institution almost 20 years ago. "While there is a systematic body of knowledge regarding identification," he said, "finding mush-rooms is very intuitive (maybe the geophysicists can relate to that!), and at times almost mystical. It's a wonderful change of pace and outlook from dealing with the federal bureaucracy."

echnology

There is a vast amount of data recorded and archived during a drilling operation. Unfortunately, much of the information embedded in this data is not extracted and used effectively for timely decision support, resulting in expensive mistakes, hazardous situations, and increased costs. Under the Small Business Innovation Research (SBIR) program, the Advanced Drilling Program of the U.S. Department of Energy's Office of Geothermal Technologies is working with Knowledge Based Systems, Inc. (KBSI) to develop and commercialize an enabling technology. The goal of KBSI's SBIR Phase I project was to develop and demonstrate a robust expert system for sensory data (SDES) interpretation that will facilitate increased drilling operator understanding and recognition of drilling system data.

Specific objectives included investigating SDES enabling techniques and tools; designing and demonstrating a prototype SDES architecture; and developing an approach for the full-scale implementation of this technology in a real-world environment.

The Phase I effort resulted in specific accomplishments including:

1) SDES Architecture Design—KBSI designed a novel, open-architecture, reconfigurable, and adaptable decision support system for drilling system personnel. Key SDES innovations embodied in this architecture include an innovative approach to drilling system fault detection and prediction using hybrids of artificial neural nets and fuzzy inference systems (see Figure 1).

2) SDES Prototype Development—Using real data provided by Sandia National Laboratories' Geothermal Research Department and Unitrak, Inc., KBSI developed and demonstrated a functional SDES prototype (see Figure 2).

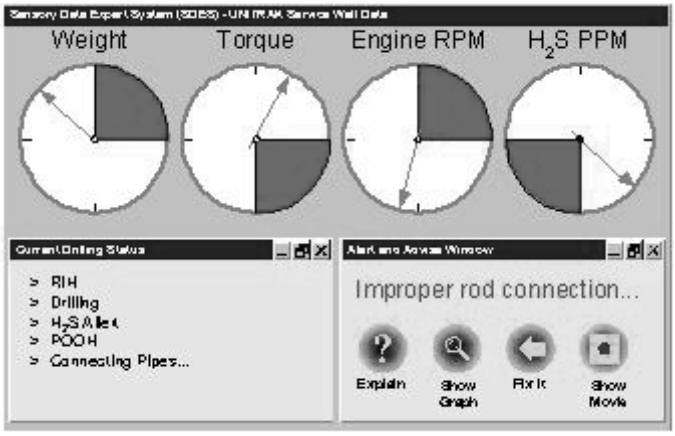


Figure 2. Sample screen from the SDES prototype application.

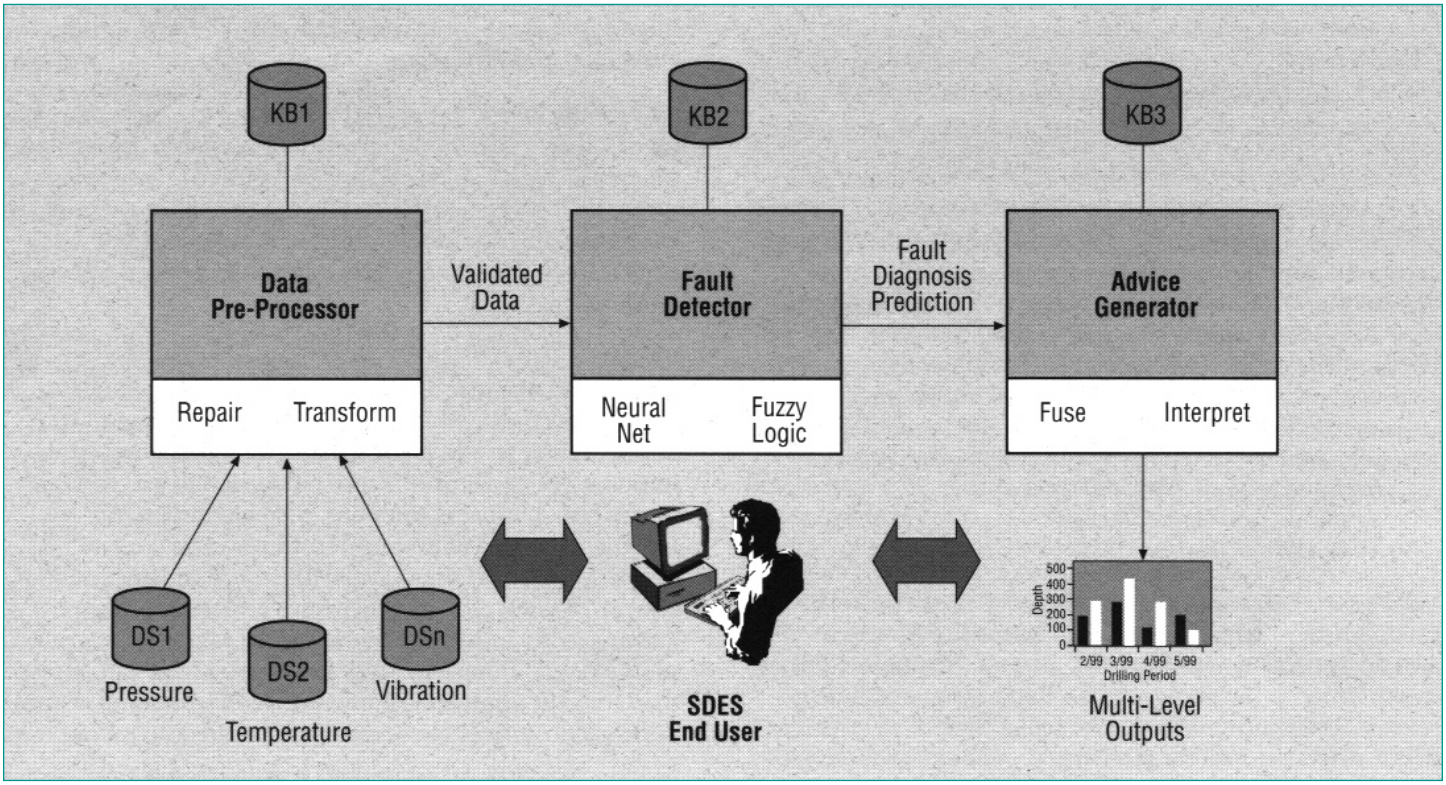


Figure 1. SDES conceptual architecture.

3) Identification of Commercialization Opportunities—Key relationships have already been developed with several leading drilling companies for both geothermal and offshore drilling commercialization. In addition to potential SBIR Phase II development funding, one industry partner is considering matching a portion of the Phase II funding to expedite the development of KBSI's SDES technology.

SDES represents important enabling technology for the advanced drilling systems of the coming millennium. It will enhance operator understanding of drilling equipment conditions, leading to significant cost savings and productivity gains.

For more information, please call Paul Grabowski at (202) 586-0478.

Knowledge Based Systems Inc. (KBSI) of College Station, Texas is developing technology that has the potential to save the geothermal drilling industry upwards of $100 million per year in unnecessary drilling costs[1]. To realize these potential savings, the U.S. Department of Energy's (DOE) Office of Geothermal Technologies (OGT) is using the Small Business Innovation Research (SBIR) program to expedite development and commercialization of the technology. Under an SBIR grant, KBSI has developed and successfully tested a prototype of the advanced knowledge delivery system called MIDAS-DS (Multimedia Interactive Data Acquisition System Drilling Simulator).

The MIDAS-DS project is addressing the current gaps and challenges associated with the adoption of real-time, computer-based training tools within the U.S. drilling industry. KBSI successfully designed a novel, open-architecture, reconfigurable, and simulation-based training system for the drilling domain; developed and tested a prototype system using real field data; and formed several key strategic alliances with drilling industry leaders.

MIDAS-DS incorporates some key innovations including: (a) an innovative approach to real-time knowledge delivery that combines simulation-based training with repository-based training methods; (b) advanced mechanisms for self-adaptation and automatic reconfiguration; and (c) a robust, knowledge-based approach for rapid capture of expert knowledge and cost-effective training system deployment. Figure 1 illustrates the architecture of the proposed system.

The MIDAS-DS prototype demonstration proved the technical viability and practical benefits of delivering training using this approach, and it validated KBSI's expectation that MIDAS-DS can be the cornerstone of an overall drilling information architecture.

This highly-innovative technology can reduce drilling expenditures by significantly reducing training costs,

[1] Based on data fron the Gas Research Institute and the American Petroleum Institute's 1997 *Quarterly Well Completion Report*, 4th Quarter.

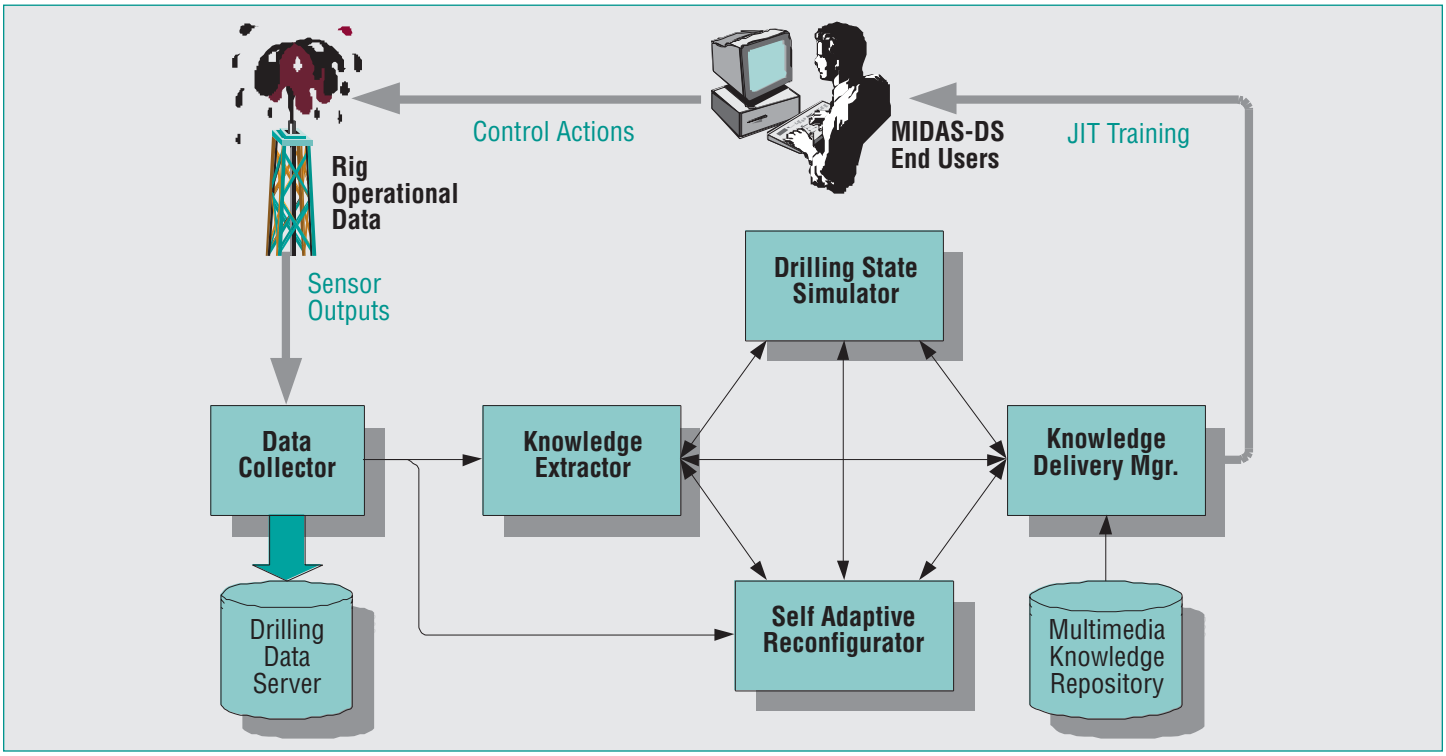


Figure 1. MIDAS-DS architecture.

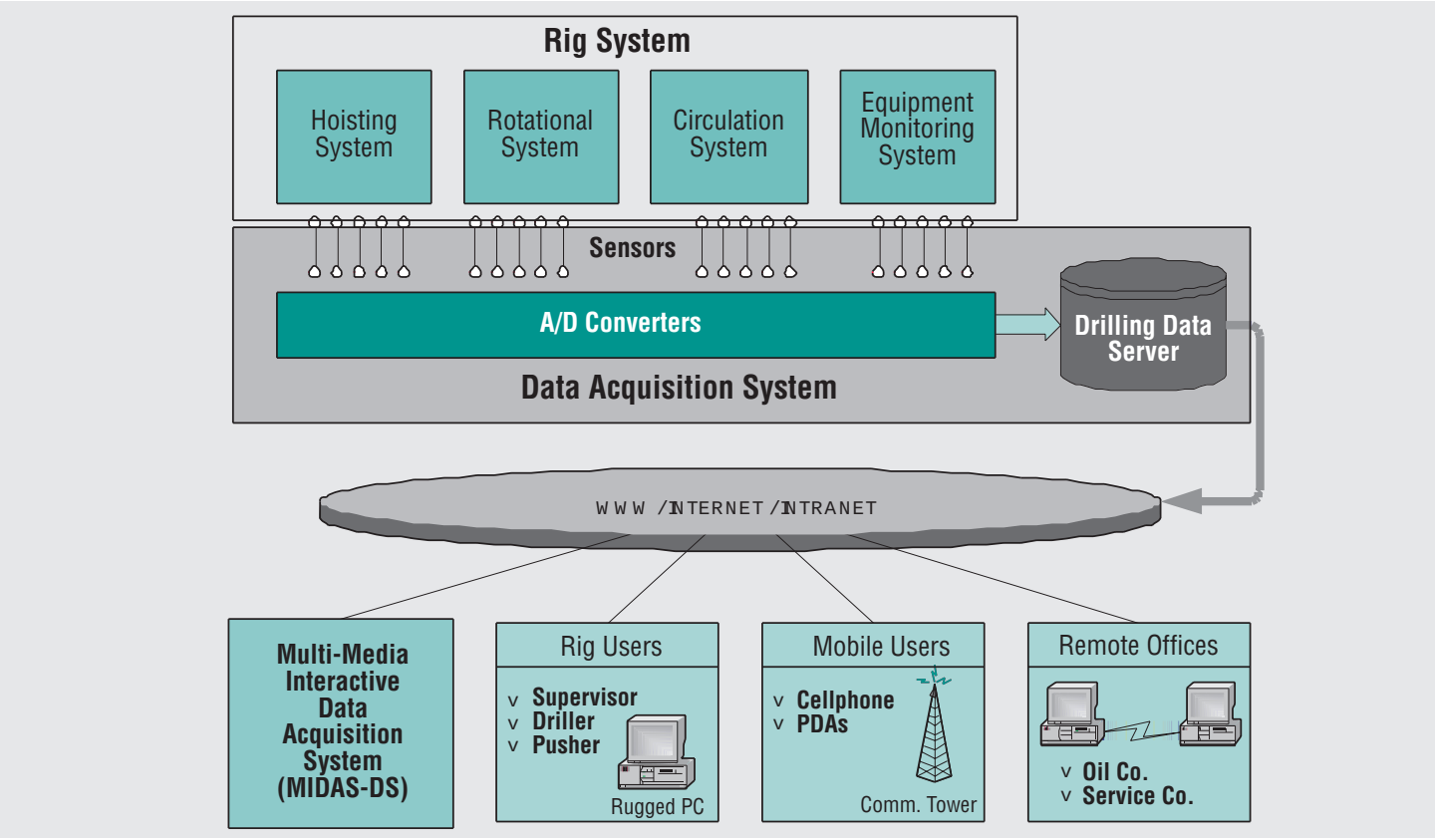


Figure 2. Advanced drilling information architecture.

improving productivity, and increasing the safety of the operators and the wells. In fact, the results of the prototype demonstration were so positive, and the potential cost impact so significant, that drilling industry leaders—such as Unitrak, Inc. (Midland, Texas) and Epoch, a wholly-owned subsidiary of Nabors Drilling, Inc. (Houston, Texas)—are already discussing potential collaborative opportunities with KBSI.

To realize the potential benefits of MIDAS-DS, OGT is considering additional funding for KBSI under the SBIR program. Further development may be needed before wide commercial deployment in geothermal drilling is feasible. If undertaken, KBSI's follow-on efforts would be made in conjunction with its industry partners and with the Geothermal Research Department of DOE's Sandia National Laboratories to ensure that MIDAS-DS meets the needs of the U.S. geothermal drilling industry

For further information, please call Paul Grabowski at (202) 586-0478.

The third edition of the *Geothermal Direct-Use Engineering and Design Guidebook* is available from the Geo-Heat Center at the Oregon Institute of Technology in Klamath Falls, Oregon. Engineers and developers will find valuable technical information on low- and moderate-temperature (100° to 300°F or 38° to 149°C) geothermal applications and equipment in this excellent reference work. Chapters cover exploration, well drilling, well pumps, piping, heat exchangers, space heating/cooling, greenhouse heating, aquaculture, industrial processes, economics, regulations, and environmental aspects of direct use.

The Geo-Heat Center prepared this updated version of the guidebook (470 pages) for the U.S. Department of Energy's Office of Geothermal Technologies. Price: $49 plus $4.50 postage; foreign orders add $8 for surface mail or $15 for airmail.

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