ACTIVITY REPORT

May 2001

Natural Gas & Oil Technology Partnership

bringing department of energy national laboratories capabilities to the petroleum industry

Los Alamos
Los Alamos, NM 87545
(505) 667-7811

Sandia
Albuquerque, NM 87185
(505) 844-7333

Lawrence Livermore
Livermore, CA 94551
(925) 422-5196

Lawrence Berkeley
Berkeley, CA 94720
(510) 486-5961

Argonne
Argonne, IL 60439
(202) 488-2415

Brookhaven
Upton, NY 11973
(516) 344-3819

Idaho
Idaho Falls, ID 83415
(208) 526-7004

Oak Ridge
Oak Ridge, TN 37831
(865) 574-4977

Pacific Northwest
Richland, WA 99352
(509) 372-4565

To: William F. Lawson, Director
National Petroleum Technology Office
U.S. Department of Energy
P.O. Box 3628
Tulsa, OK 74101

From: J. Albright, Los Alamos
D.J. Borns, Sandia
F. Followill, Lawrence Livermore
N. Goldstein, Lawrence Berkeley
D. Schmalzer, Argonne
A. Goland, Brookhaven
C. Thomas, Idaho
T. Schmidt, Oak Ridge
B. Saffell, Pacific Northwest

cy: G. Dehoratiis, DOE Fossil Energy
E. Allison, DOE Fossil Energy
A. Hartstein, DOE Fossil Energy
B. Hochheiser, DOE Fossil Energy
G. Stosur, DOE Fossil Energy
E. Subia-Melchert, DOE Fossil Energy
S.L. Waisley, DOE Fossil Energy
W. Polansky, DOE Office of Science
N.B. Woodward, DOE Office of Science
D. Alleman, DOE-NPTO-Tulsa
J. Casteel, DOE-NPTO-Tulsa
N. Comstock, DOE-NPTO-Tulsa
B. Lemmon, DOE-NPTO-Tulsa
R. Lindsey, DOE-NPTO-Tulsa
D. Sutterfield, DOE-NPTO-Tulsa
J. Ammer, NETL
F. Brown, NETL
H. Guthrie, NETL
B. Gwilliam, NETL
R. Long, NETL
B. Tomer, NETL
A. Yost, NETL

Note: Natural Gas and Oil Technology Partnership projects are reported according to the following schedule:

January, March, May, July, September, November	**February, April, June, August, October, December**
Oil and Gas Recovery Technology Drilling, Completion, and Stimulation Technology Diagnostic and Imaging Technology	Upstream Environmental Technology Downstream Environmental Technology

Natural Gas and Oil Technology Partnership on the World Wide Web: http://www.sandia.gov/ngotp/

Oil and Gas Recovery Technology

Improved Waterflooding Through Control of Brine Composition and Other Factors

(BP Amoco, U of Wyoming, and INEEL)

Highlight:

- Core from five wells selected for laboratory testing.

It has been shown in the laboratory that waterflood oil recovery can be significantly increased under certain circumstances by injecting diluted reservoir brine as compared to waterfloods using reservoir brine.

Experiments involving Minnelusa crude oil and reservoir brine and Berea sandstone of various permeabilities continue. Corefloods done at room temperature with Berea sandstone using Minnelusa reservoir brine and Minnelusa crude oil showed no increase in recovery when diluted brine was used as the displacement water. A second set of experiments is under way where the aging temperature is 75°C and the flooding is being conducted at 75°C. Results at this higher temperature are promising, but still incomplete. One test with diluted brine showed more than a 20% increase in recovery; however, the experimental set is not complete, and no firm conclusions can be drawn at this time.

INEEL researchers are also evaluating the impact of varying initial water saturation on the results. Recent work has shown a trend toward higher "differential recovery" in systems with higher initial water saturation (differential recovery being defined as the difference between waterflood recovery for systems displaced with full-strength reservoir brine versus similar systems displaced with diluted reservoir brine). The combined results of INEEL and University of Wyoming experimental results are anticipated to increase the understanding of the mechanisms controlling the process.

Fluid Identification Acoustic Logging Tool

(BP Amoco, CGG, Chevron, Conoco, Landmark Graphics, Mobil, Schlumberger, Shell, Smedvig, Texaco, Unocal, Ward Petroleum, Western Atlas, and LANL)

No work scheduled during this period.

High-Resolution Reservoir Characterization Using Seismic, Well, and Dynamic Data

(BP Amoco, Chevron, Exxon, Oxy, Phillips, RC2, Texaco, Western Geophysical, Texas A&M, and LBNL)

Report not received.

Measuring Sucker Rod Pump Parameters Downhole

(Harbison-Fischer, Yates Petroleum, UT-Austin, Texas Tech University, and SNL)

Highlight:

- Measurements made of ball position.
- Results presented at Southwestern Petroleum Short Course.

Measurements of the ball position within the traveling valve have been made as a function of plunger position. These measurements will provide the basis for new understandings of how the valve works and chatter within the valve.

Results of work on the project to date were presented at the Southwestern Petroleum Short Course in Lubbock Texas, April 25–26.

Work on the computer model being developed to analyze data collected with the instrumented pump continues. In addition to adding new features, the interface to the model has been undated to allow the user to select individual components of the load. This allows the model to be used as a teaching tool, allowing a student to discern the effect of individual components of sucker rod pump load.

Formation Logging Tools for Microboreholes (DeepLook, Texaco, and LANL)

Highlights:

- Microhole porosity tool study initiated.
- Fabrication of microhole deviation tool initiated.
- Progress reviewed in American Geophysical Union paper.

Under contract to LANL, the Cedar Bluff Group, a company specializing in novel logging tool development, has begun a study of the advantages and technical challenges of making formation porosity measurements in microholes. The focus of the study will be nuclear logging technologies; however, all applicable methods will be reviewed, as they may be relevant to microhole logging measurements.

Design and fabrication of a 1-in.-diameter tool for surveying microhole deviation has begun. The electronics design for the downhole line driver is completed, as well as the mechanical design of the tool housing and pressure boundary. Deviation will be surveyed using 3-axis magnetometers and accelerometers produced by Applied Physics, Inc. The tool will operate through a 3/8-in., 4-conductor wireline.

After a series of measurements, it was learned that the sensitivity of the photomultiplier in the microhole gamma ray logging tool had degraded. Since the tube was under warranty, a replacement was requested.

Progress in microhole technology was reviewed at the American Geophysical Meeting in Boston during a special session devoted to advances in scientific drilling. The session was well attended with international participation.

Coupled Geomechanical Deformation, Fluid Flow, and Seismic Modeling (Mobil, Schlumberger, UT-Austin, and SNL)

Highlight:

- In IPARS/JAS3D, successfully demonstrated the use of the rock compressibility term as a part of the conjugate gradient pre-conditioner.

SNL researchers successfully demonstrated in IPARS/JAS3D the use of the rock compressibility term as a part of the conjugate gradient (CG) pre-conditioner. By including the rock compressibility term in the CG pre-conditioner, we have been able to obtain a coupled flow/geomechanics solution for a problem that was previously intractable. The rock compressibility term provides a convenient method to easily include information about the changing reservoir pore volume, i.e. porosity, in the pre-conditioner, which means that the IPARS solver becomes more robust and more efficient. In addition, we have started the initial development of a multi-processor mapping tool to transfer element information between different meshes.

Semiautomatic System for Waterflood Surveillance (Chevron, Case Services, and LBNL)

Highlight:

- Analysis performed of satellite images obtained from InSAR's for Lost Hills and Belridge oil fields.

A global analysis of the evolution of an entire giant oilfield is now feasible. The oilfield can be viewed as a single complex system consisting of reservoir rock and fluids, and coupled injectors and producers. The vertically averaged aerial signatures of primary and waterflood projects in the field can be tracked in time as the displacement of ground surface above these projects. The Synthetic Aperture Radar interferograms (InSAR) from satellites are the enabling technology.

LBNL researchers have added a new element to our multilevel, integrated surveillance and control system: time- lapse satellite InSAR images of the oilfield surface. In particular, we have analyzed ten differential InSAR images of the South/North Belridge and Lost Hills diatomite fields, CA, between April 1995 and December 1999. The images have been reprocessed and normalized to obtain the ground surface displacement rate. In return, we have been able to calculate section-by-section the net subsidence of ground surface over the entire field areas. The calculated subsidence volumes are thought to be close to the subsidence at the tops of the reservoirs. The images show that the rate of subsidence has decreased in some parts of Lost Hills and Belridge, while it increased in others. Using the production and injection data from the California Conservation Commission and Chevron, we have been able to demonstrate the remarkable behavior of both fields:

1. There is recirculation of injected water through the "tubes" of damaged soft

rock that links injectors with producers, resulting in diminished pressure support from the waterfloods.
2. Consequently, despite more water injection, there is more subsidence in Sections 29, 34, and 33 in Belridge, and in Sections 29, 4, 5, and 32 in Lost Hills.
3. As much of the injected water is recirculated, the rate of subsidence is proportional to water production rate.
4. Compaction remains an important mechanism of hydrocarbon production.
5. In addition to accelerated compaction in the densest and most advanced waterfloods, there is a sizable oil production response to water injection.

Mechanisms of Oil Recovery and Validation of Corefloods (Chevron, Phillips, and LBNL)

Highlight:

- New project started.

A meeting with an industry participant (Phillips Petroleum) was held. The next tasks have been determined. The current MatLab version of the network simulator will be translated into ANSI C/C++ code that can be used on different platforms. The code will be transferred to Phillips.

Drilling, Completion, and Stimulation Technology

Real-Time Coiled Tubing Inspection System (Quality Tubing and INEEL)

Highlight:

- Hall probe system completed and used to test samples.

The final report is in progress.

Perforation Dynamics in Geological Media (Columbia Gas Transmission, Halliburton, National Fuel & Gas Supply, Panenergy, and LLNL)

No activity to report.

Drill Cuttings Injection Field Experiment (BP Amoco, Chevron, Exxon, Gas Research Institute (GRI), Halliburton Energy Services, Hughes Christensen, MSD, Pinnacle Technologies, Schlumberger, Shell, and SNL)

Project is in close-out phase; reporting and technology transfer are under way

Seismic Stimulation for Enhanced Production of Oil Reservoirs (AERA Energy, Applied Seismic Research, Chevron, Conoco, Fluidic Technologies, Halliburton, Marathon, OGCI Management, PerfClean, Phillips, Piezo Sona-Tool, Texaco, UC-Berkeley, LANL, and LBNL)

Highlights:

- Final meeting of project held at LBNL.
- Invited talks will be given at Maximizing Recovery 2001 Conference.

A final general meeting for the project was held at LBNL. Thirty representatives from industry, universities, DOE/NPTO, LBNL and LANL attended the meeting. Project accomplishments were discussed, and plans for continuing the research effort under different funding mechanisms were proposed. The possibility of creating a joint industry/DOE-supported consortium was viewed as feasible. LBNL and LANL principal investigators will pursue this arrangement and present a plan for its implementation.

Project collaborators were invited to present research and case history results at an upcoming conference on June 26 in Houston. The conference, Maximizing Recovery 2001, is being organized by Marcus Evans Ltd. in association with and chaired by the Petroleum Technology Transfer Council.

In-Well Imaging and Heating: Multiple-Use Well Design

(Aera Energy LLC, Chevron, SteamTech Environmental Services, and LLNL)

No activity to report.

3D Analysis for Induction Logging in Horizontal Wells

(BP Amoco, Chevron, Conoco, Electromagnetic Instruments, Exxon, Halliburton, Mobil, Phillips, Schlumberger-Doll, Shell, Texaco, Unocal, Western Atlas, and SNL)

Highlight:

- Manuscript accepted for publication in *Petrophysics*.

Progress continues on the implementation of the Low Induction Number (LIN) preconditioner into the 3D staggered grid anisotropy modeling software. SNL researchers have discovered several competing strategies for the discretization of the differential operator for the scalar potential, a critical part of the LIN methodology. Currently, the modeling software is at the stage where these competing strategies can be assessed in terms of their relative merits (speed, accuracy, and resource usage/management). Results of the testing are expected within 4–6 weeks.

"Visualization of electromagnetic induction in an anisotropic formation" by Weiss et. al. has been accepted for publication in a special issue of *Petrophysics*. Additional manuscripts have been submitted for review by the scientific panel for presentation at the 2001 SEG meeting in San Antonio, TX. News regarding their status is expected shortly.

Downhole Seismic Source for Look-Ahead Pore Pressure Prediction While Drilling

(Chevron, INEEL, and LBNL)

Highlights:

- Savoy Field Research Facility selected for prototype testing.
- Prototype constructed.

The FY01 Field Work Proposal was completed and submitted for funding authorization. The project is on hold until funding is received.

Acoustic Telemetry (MWD)

(ABB, Passband Downhole Communications, Electroacoustics Research Laboratory, and SNL)

Highlights:

- Field test scheduled for August.
- Babel Code written.

Two additional features were added to the telemetry transmitter. An improved annulus pressure sensor and a data port to the microprocessor and memory were installed. This port will allow SNL researchers to assemble the housing and thus pressure seal the tool before we move it to the field site. Currently, new vibration-resistant mounting are also being installed for the logic circuits and power transformer. We plan to deploy the tool in its first field test this August.

The first version of the Babel Code has been written. This is a signal processing code designed to remove echoes and signal distortion from the acoustic-wave transmission. It also synchronizes communications, extracts the binary encoded message from the acoustic transmission signal, and displays graphics of the sensor data broadcast by the tool. This code operates in real time on the rig floor by running on a portable PC.

We have also received all of the hardware components for our full-scale repeater model. This will allow us to assemble a "bread-board" repeater system at our surface facility and begin the process of designing the digital signal processing algorithms that are the heart of the repeater concept.

Development of Chemically Bonded Ceramic Borehole Sealants (GPRI, ANL, and LANL)

Highlights:

- Demonstrated the possibility of using Ceramicrete to produce borehole sealants at high temperatures and pressures for at least 3 hours pumping time.

Previous testing at Chevron established that Ceramicrete formulation is valid for applications in wells with maximum temperature of 150°F and a pressure of 6150 psi. At this temperature and pressure, the pumping time was found to be 3 hours, which is considered to be the minimum time needed to pump cement. All attempts to increase this time by adding commercial retardants failed. It was clear that a detailed theoretical understanding of the setting of Ceramicrete borehole sealants was needed to predict the effect of higher temperatures and pressures on the setting of the Ceramicrete borehole sealants.

Such a theoretical formulation has now been developed for Ceramicrete borehole sealants. Project researchers have developed a basic thermodynamic model that predicts effects of temperature and pressure on the setting reactions. This model showed that the pressure effect in deeper wells could retard the setting time and hence increase the pumping time. To test this, another set of tests were conducted at Chevron. At higher temperatures and pressures, although, a consistent set of data was difficult to obtain, we found the retarding effect at 250°C and obtained a pumping time of more than 3 hours. Clearly, more testing with small modifications in the formulations is needed to obtain a consistent pumping time of more than 3 hours at all temperatures between 150°C and 300°C.

To achieve this, several trials with minor variations in the formulations need to be carried out. Unfortunately, the consistometer purchased at ANL was not suitable for detailed testing at high temperatures and pressures. For this reason, a new consistometer is being traded for the old one with internal funding from ANL.

Coiled-Tubing Deployed Microdrilling with Real-Time, Downhole Monitoring (DeepLook, Phillips, Texaco, and LANL)

Highlights:

- Completed refurbishment of the coiled drilling unit.
- Regulatory approvals pending for a second drilling site near San Ysidro, NM

San Ysidro Demonstration

Preparations for a second microhole demonstration near San Ysidro are nearly completed. A site that is 130 ft higher than the first well has been selected to avoid artesian flow if the same aquifers are penetrated. Regulatory approvals to drill on the second site are expected within the next two weeks. The drilling instrumentation and the data acquisition system have been checked out and minor improvements have been made. Bit and miscellaneous supplies are being procured. 3000 ft of new 1-in. coiled tubing was purchased and 1000 ft of tubing was installed on the coiled tubing unit.

Diagnostic and Imaging Technology

Advanced Sensor Technology for Microborehole and Other Seismic Instrumentation

(Input/Output, Texaco, and LANL)

Highlight:

- Preparations made for testing of the microhole array in the San Ysidro, NM, microhole.

All requisite mechanical and electronic subassemblies for two, 4-level MEMS arrays have been designed and fabricated. Final benchtop assembly and testing is under way. Field testing and evaluation of the array will begin on completion of the San Ysidro microhole.

Development of Single-Well Seismic Imaging Technology

(BP Amoco, Chevron, Conoco, Exxon, OYO Geospace, P/GSI, Phillips, Schlumberger, Shell, Texaco, TomoSeis, Unocal, Western Atlas, Stanford, LBNL, SNL, and INEEL)

LBNL and INEEL tested the INEEL tube wave attenuator at the Chevron Lost Hills site in May, 2001. The experiment was to repeat a single well performed earlier with and without the tube wave attenuator using the LBNL piezoelectric source (500–2000 hertz) and the orbital vibrator (50–400 hertz). Earlier tests in shallow boreholes (250 ft) gave attenuation results of 10–16 db attenuation. The Lost Hills site was intended to test the tube wave attenuator in deeper (up to 2000 ft) environments with greater pressures. The initial results seem to confirm the shallow results with 10–16 db of attenuation.

Large Downhole Seismic Sensor Array

(Chevron, Conoco, Exxon, OYO Geospace, Shell, Texaco, U of Arkansas, and INEEL)

Highlights:

- Construction of demonstration prototype begun.
- Sensor package tested.

The totally passive module (Bowspring) was modified to support another test apparatus. This new concept is part of the new continuation of the Large Downhole Seismic Sensor Array (LDSSA), but it will stress “alternate” concepts. The Bowspring houses the amplifiers, supports the vertical geophone, and will centralize the new sensor package. The new sensor package was tested in April. It demonstrated excellent fidelity. It demonstrated that clamping in a water filled borehole was not required if an appropriate design was used.The vertical component was sensed by the bowspring accurately. Recordings of these tests were sent to associates at LBNL for comment.

The final report draft is back from final review and comments were incorporated. The draft has been submitted for editing.

Improved Prestack Kirchhoff Migration for Complex Structures

(Conoco, Cray/SGI, Golden Geophysical, Kerr-McGee, Mobil, Shell, and LANL)

Highlights:

- Migrations of numerical and field datasets investigated.
- Migrations using single phases conducted and assessed.

At LANL, we continue testing migrations using various portions of the traveltime tables generated by our raytracer. We have completed work on one numerically-generated dataset and one field dataset. We are currently working on a second numerically-generated dataset to see if the conclusions we obtained from the first numerical dataset are robust. We have also been discussing working with one of our industry participants to investigate how the velocity model used for migrating the field dataset may be improved to yield improved migration results. Our assessment is that portions of the velocity model can be better constrained when using amplitudes and phases in the migration operator than can be constrained using the conventional kinematic operator.

Testing Advanced Computational Tools for 3D Seismic Analysis Using the SEG/EAGE Model Dataset

(Advanced Data Solutions, Anadarko, BHP Petroleum, BP Amoco, Burlington Resources, Chevron, Conoco, Edison Chouest Offshore, Exxon, GECO-Prakla, Golden Geophysical, Kerr-McGee, Marathon, Mitchell Energy, Mobil, Paradigm Geophysical, PGS-Tensor, Phillips, Shell, Society of Exploration Geophysicists [SEG], Texaco, Union Pacific Resources, Unocal, Western Geophysical, Houston Advanced Research Center/Rice, Stanford, UC-Davis, U of Houston, LANL, LLNL, and ORNL)

Highlight:

- Processing of physical model data entering final stages.

Migration of both the marine survey and vertical cable data sets obtained for the University of Houston physical model are the final closeout efforts for this project. Final plans are to process the 3D vertical cable data using several migration algorithms, including PSPI, phase screen, and Kirchhoff methods. Selected subsets of the marine survey data will be processed with similar methods. The final images and comparisons of different methods will be made available on an FTP server via the project website.

Integrated Reservoir Monitoring Using Seismic and Crosswell Electromagnetics

(Chevron, Electromagnetic Instruments, TomoSeis, LBNL, and SNL)

Highlight:

- Project work to be presented at June AAPG meeting.

The second crosswell seismic data set was acquired at the beginning of May. A second crosswell electromagnetic (EM) dataset was acquired in late April. Both new data sets have been inverted for the electrical conductivity and velocity structures. These have been differenced with the baseline surveys to produce time-lapse changes in seismic velocity and electrical conductivity associated with the injection of carbon dioxide (CO_2) into a portion of Chevron's Lost Hills oil field.

A 3D flow simulation of the CO_2 pilot area has been completed and converted to velocity, density and electrical properties. 2D and 3D forward modeling based on the flow simulation model have been used to generate synthetic crosswell seismic and EM data. This synthetic data has been processed and inverted with using the same steps taken on field data. The inverse images have been compared to those extracted from the field data. The major conclusions to date are:

1. The fracture permeability is higher than assumed in the flow simulations.
2. Permeability near the fracture is higher than assumed.
3. Permeability away from the fracture is lower than assumed.
4. The crosswell EM difference image indicates that small faults between wells, that have been mapped using multiple well logs, are indicated in the conductivity difference image and act as barriers to flow.

This work will be presented at the June AAPG meeting in Denver.

Frequency-Dependent Seismic Attributes of Fluids in Poorly Consolidated Sands

(Baker-Atlas, Chevron, TomoSeis, Vastar, and LBNL)

Work focused on two efforts: transducer redesign and poroelastic code development. Earlier tests of the 1–10 kHz torsional/extensional wave transducers prior to encapsulation in the massive steel housings yielded favorable results on a 50 cm acrylic bar in the 1–4 kHz range. However, following encapsulation in the source and receiver packages into the steel housings (used for confining pressure shielding), the added mass of the housings were found to produce significant deterioration of the torsional waves. A series of tests were conducted, and based on these results, the decision was made to redesign a

lighter mass version of these transducers. The redesign incorporates a lighter aluminum housing with essentially the same accelerometers and source piezoelectric crystals configuration as before. A suspension system to educable the sample from the confining vessel has also been designed.

The second effort consists of the development of 2D and 3D explicit finite difference codes for modeling wave propagation in poroelastic media. Two codes are currently being developed, one is a pseudo-spectral staggered grid code and the other is an O(8) staggered grid code. Both codes are in the early stages of development. These codes will be used to examine the effect of heterogeneous gas distributions on sonic and seismic frequency waves. Progress for both of these efforts will be reported in the next progress update.

Inversion of Full Waveform Seismic Data for 3D Elastic Parameters

(Amerada Hess, Conoco Fairfield Industries, GX Technology, Marathon, Texaco, Unocal, and SNL)

Highlights:

- Project results and status presented to industry participants.
- Expanded abstracts prepared for SEG meeting.

Project status and results-to-date were presented to industry participants at a meeting in Houston in late May. Much discussion centered on the need for the full waveform inversion algorithm to be tested with synthetic seismic datasets generated from various simple elastic earth models. Two particular models that were suggested include (1) isolated point diffractors located with a uniform background medium, and (2) a 1D medium composed of uniform layers. The point diffractors model will enable examination of the parameter resolution capabilities of the algorithm (i.e., the ability to distinguish between different material parameters like mass density, elastic moduli, seismic wavefields, or seismic impedances). Additionally, the model is ideal for testing the spatial resolving power of the algorithm. The 1D layered model is useful for studying algorithm performance with respect to multiply reflected energy. Currently, there is some debate regarding the ability of the full waveform inversion procedure to correctly handle multiply reflected or scattered waves. All of the industry participants have agreed that testing of the inversion approach with field-recorded seismic datasets remains in the future.

A preliminary version of the full waveform inversion algorithm, based on the time-variant sensitivity equation approach, has been implemented in a parallel computational environment, and testing of the inversion procedure has been initiated. Numerical evaluation of the coefficients in the linear equations entails convolving two 3D elastic wavefields, and thus is computationally demanding. Efficient methods for performing these time convolutions have been developed. The computed coefficients may be stored in a sparse matrix format. Finally, a search for a rapid and robust technique for solving the resulting large and sparse system of linear algebraic equations for the model parameter updates is under way.

An initial test of the inversion algorithm with synthetic data indicates that it recovered the position and magnitude of two point diffractors located within a uniform background medium. Generalization to more complicated 3D models and recording geometries is ongoing.

Two expanded abstracts were prepared for presentations at the Society of Exploration Geophysicists 71st Annual Meeting to be held in San Antonio, TX, in September 2001. These abstracts treat (1) reciprocity conditions for seismic wavefields propagating within linear anelastic media (heterogeneous and/or anisotropic), and (2) 3D elastic parameter inversion utilizing the time-variant sensitivity equation algorithm.

High-Speed 3D Hybrid Elastic Seismic Modeling

(Burlington Resources, GX Technology, and LBNL)

LBNL's Earth Sciences Division has acquired two PC clusters for developing testing and running parallel codes. A first version of parallel MPI 4th order in time and space acoustic code has being installed and is being testing. A 4th order in time and space elastic code is also being installed and its testing is under way. The innovative 4th order in space differencing scheme improves accuracy of time differencing. Therefore it increases a time differencing step for the expense of extra computation within a single node. Since inter SPU communication speed is a major bottleneck for parallel data processing flow, the 4th order scheme increases a computation to communication ratio improving the effectiveness of parallel computations. The 4th order time differencing scheme does not affect memory usage as compare to a 2nd order scheme. It also requires special formulation of absorbing boundary conditions, which are under development.

Next-Generation Seismic Modeling and Imaging

(Advanced Data Solutions, Anadarko, BHP Petroleum, BP Amoco, Burlington Resources, Chevron, Conoco, Exxon, GECO-Prakla, Marathon, Mobil, Paradigm Geophysical, PGS-Tensor, Phillips, Shell, Society of Exploration Geophysicists [SEG], Texaco, Union Pacific Resources, Unocal, Western Geophysical, Stanford, U of Houston, LANL, and LLNL)

Highlights:

- University of Houston joins the project.
- Elastic model designs selected for initial 2D structures.
- Efforts to complete 3D survey of elastic SEG/EAGE model continue.

Personnel from the Allied Geophysical Laboratories at the University of Houston will perform tasks on designing and building selected 2D elastic models to be used for generating synthetic multi-component elastic waveform data with LLNL's modeling code E3D. Initial plans are to create an elastic version of the classic Marmousi model and another model based on an existing multi-component 2D field dataset. These models will include viscoelastic effects in addition to full elasticity. Plans to also include anisotropy are being considered.

A synthetic multi-component seismic survey was begun for the 3D elastic version of the SEG/EAGE numerical salt model. Numerous shot lines were completed previously and data for the remaining shots are now being calculated. These data will be made available to project participants via FTP or the Web.

Rapid Imaging of Interwell Fluid Saturations using Seismic and Multiphase Production Data

(BPAmoco, Chevron, JNOC, Landmark, Phillips, RC2, Statoil, Tomoseis, Total-Fina-Elf, Texas A&M, and LBNL)

Highlight:

- Partial funding received for this new project.

Partial funding for this project was received this month. Work has started, based upon industry funding through Texas A&M. In particular, LBNL researchers have applied the streamline-based inversion method to partitioning interwell tracer data from the Ranger Field in Texas. This method involves conducting two tracer tests. The first uses a conservative tracer, which does not react with subsurface fluids. The second test uses a partitioning tracer, which reacts with the oil in the reservoir. The chromatographic time separation between these tracers measures the oil saturation between the various wells. We have developed a very fast streamline-based inversion scheme in which we can analyze the results of such tests in a matter of minutes or hours. Using this technique we estimated the swept volume in a 320-acre area of the Ranger Field which included 13 production and 4 injection wells.

Work started on extending the asymptotic approach for inverting production data to general finite-difference reservoir simulators. The idea involves using

pressure and saturation histories to generate sensitivities necessary for inversion. Thus, a single reservoir simulation would provide all the information necessary for one step in the inversion. The methodology generalizes our current approach and overcomes some difficulties associated with streamline simulation.

We have developed an efficient seismic waveform inversion method and applied the technique to some crosswell data from Oyster, VA. The approach is much simpler than current methods, and we hope to use it in our integration of seismic and reservoir production data.

LBNL and Texas A&M have signed an agreement with an industry participant to obtain 3D time-lapse and production data from a producing field. We hope to start work on these data in the coming months.

The Partnership Office

Funding

In May, the FY01 funding for new and continuing projects arrived at the Partnership laboratories. Throughout the next quarter, work on new projects will start. Regardless of the upcoming decisions regarding federal funding for the Partnership and the DOE guidance for the Partnership, arrival of the new funds this month assures the continuity of the Partnership into the next fiscal year starting Oct. 1, 2001. Whatever this guidance and funding decision for the Partnership in FY02, the office expects at least a several month shift in the calls for proposal and the associated review cycles as established over the last five years. Of interest to those who follow the Partnership approach, the 2001 White House Energy Policy (National Energy Policy Group [NEPD], May 2001) recognized the importance of new technology for enhanced oil recovery and exploration-and-production with its recommendation in Chapter V.

- The NEPD Group recommends that the President direct the Secretaries of Energy and Interior to promote enhanced oil and gas recovery from existing wells through new technology. (Chapter V)
- The NEPD Group recommends that the President direct the Secretary of Energy to improve oil and gas exploration technology through continued partnership with public and private entities. (Chapter V)