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LLNL-TR-742042

Computer Simulation of Nuclear Well Logging Devices Final Report CRADA No. TC-1114-95

J. M. Ferguson, L. Jacobson, D. Johnson

November 16, 2017

Disclaimer

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Computer Simulation of Nuclear Well Logging Devices

Final Report
CRADA No. TC-1114-95

Date: October 16, 2000 Revision: 5

A. Parties

This CRADA was a relationship between Lawrence Livermore National Laboratory, Halliburton Energy Services and BP Exploration, Inc.

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B. Project Scope

This project's goal was to develop a deterministic simulator of nuclear well logging tools. LLNL's deterministic code would be available throughout the U.S. oil and gas industry. The industry partners in this project would benefit primarily from early access to the code system in addition to their own direct involvement in the development of this computational tool.

Our technical approach consisted of these four components:

1. Development and application of advanced numerical algorithms
2. Implementation of these algorithms on workstation clusters
3. Refinement of the resulting code system on industry-supplied tool designs and data
4. Development for engineering usage and for linking with other logging codes.

The final product was to be a system of codes to calculate response of nuclear logging tools to an environment specified by the user. Because of reduced funding and subsequent reallocation of resources, it was not possible to complete all features of the plan.

Components 1 and 2 above were completed. Component 3 was completed up through running industry supplied test problems and comparison with results of the calculations of others. It would have been desirable to make comparisons with field data, using calculations that included all the engineering features and complex geological details. The first part of component 4 was completed, with the addition of a user-friendly interface for describing problems. However it was not possible to include all the features needed for engineering usage in the field by persons not familiar with the program.

C. Technical Accomplishments

We developed advanced algorithms for a newly developed finite element method. This algorithm provides significant advantages over conventional methods in computing speed and memory requirements, and gives accurate solutions using a reasonable number of zones. We used special methods for treating the relatively small sources and detectors in these problems. These included analytic calculations of first and last flights of the particles, thus mitigating effects of finite spatial and angular zoning.

Our industrial partners directly participated in evaluating the code system on test problems used throughout the industry.
In the course of this project we developed a method for strongly mitigating "ray effects", an unwanted feature of deterministic transport calculations which is generally considered to be the largest source of error for these types of calculation. This methodology has been published and is therefore expected to aid all workers in this field to achieve more accurate computer simulations.

D. Expected Economic Impact

The final product was a system of codes capable of calculating the response of nuclear logging to an environment specified by the user. Because of reduced funding and manpower, it was not possible to carry the development of a code suitable for use in the

field by personnel not familiar with the workings of the code. In the usual lexicon of development of computer applications, the LLNL code would be considered to be in the beta testing phase — suitable for testing and experimentation but not a fully developed application.

The numerical algorithms and methods developed in this program are expected to have wide applicability to future computational modeling in this area. Some of these methods will also find important uses in other problems that require accurate deterministic transport calculations.

This project promoted the continued vitality of the Laboratory's modeling capabilities by preserving and enhancing its intellectual capital. This dual use benefited the Laboratory's programs in defense, energy, environmental, and industrial technologies developed in the national interest. The expertise LLNL brought to this problem was a direct outgrowth of work in the Defense Nuclear Science Program. LLNL used deterministic methods for solving transport problems for a number of years. The codes used in our applied physics studies were among the fastest and most efficient in the world.

E. Partner Contribution

Our industrial partners participated in evaluating the code system with test problems used throughout the industry. They also defined the critical parameters to be calculated, and which features of the nuclear database were most important for the successfully calculating the features of the geological formation most important for their analysis.

F. Documents/Reference List

Indicate protected CRADA Information with an asterisk (*)

The following reports, publications, and conference presentations were produced all or in part as part of this CRADA:

S.F. Ashby, P.N. Brown, M.R. Dorr, and A.C. Hindmarsh, A Linear Algebreic Analysis of Diffusion Synthetic Acceleration for Three-dimensional Transport Equations. SIAM J. Numerical Analysis, pp 128-178. Feb. 1995.

P.N. Brown, A Linear Algebreic Development of Diffusion Synthetic Acceleration for the Boltzmann Transport Equation. SIAM J. Numerical Analysis, pp 179-214. Feb. 1995.

P.N. Brown and M.R. Dorr, Spherical Harmonic Solution of Neutron Transport Systems via Discrete Ordinates, UCRL-JC-II9761, Lawrence Livermore National Laboratory , Dec. 1997

P. N. Brown, B. Chang, and U .R Hanebutte, Spherical Harmonic Solution of the Boltzmann Transport Equation via Discrete Ordinates, to appear in a special issue of Progress in Nuclear Energy.

Also available as LLNL Technical Report UCRL-JC-132006, May 2000.

M.R. Dorr and E.M. Salo, Performance of a Neutron Transport Code with Full Phase Space Decomposition on the Cray Research T3D, Proceedings of the International Conference on Mathematic and Computations, Reactor Physics, and Environmental Analyses, American Nuclear Society, Portland, OR. April 30-May 4, 1995, pp. 1535-1544.

M.R. Dorr and C.H. Still, Concurrent Source Iteration in the Solution of Three-dimensional Multigroup, Discrete Ordinates Neutron Transport Equations, Nucl. Sci. Eng. Vo1122, No. 3, 1996.

Patent/copyright activity or pending applications.

None. The computer modeling was not brought to the point of being a salable, copyrighted product.

Subject inventions disclosed by either the industrial partner or LLNL, and the proposed intellectual property protection measures (see Articles XIII thru XVI of the CRADA).

There were no subject inventions.

Licensing status of Background Intellectual Property (BIP) and subject inventions if not included in the accomplishments summary. If either party will be cross-licensing to the other as a result of CRADA research, this should also be noted in the Final Report.]

No Background Intellectual Property has been licensed. There are no plans to license any of the Background Intellectual Property.

G. Acknowledgement

Participant's signature of the final report indicates the following:

1) The Participant has reviewed the final report and concurs with the statements made therein.
2) The Participant agrees that any modifications or changes from the initial proposal were discussed and agreed to during the term of the project.
3) The Participant certifies that all reports either completed or in process are listed and all subject inventions and the associated intellectual property protection measures generated by his/her respective company and attributable to the project have been disclosed and included in Section E or are included on a list attached to this report.
4) The Participant certifies that if tangible personal property was exchanged during the agreement, all has either been returned to the initial custodian or transferred permanently.
5) The Participant certifies that proprietary information has been returned or destroyed by LLNL.

Larry Jacobson 5 Dec. 2000

Larry Jacobson Date
Chief Scientist
Halliburton Energy

Daniel Johnson Date
Exploitation Geophysicist
BP Exploration

James M. Ferguson 1/2/00

James M Ferguson Date
Principal Investigator
Lawrence Livermore National Laboratory

Attachment I – Final Abstract
Attachment II – Project Accomplishments Summary
Attachment III – Final Quarterly Report

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Larry Jacobson Date
Chief Scientist
Halliburton Energy

Daniel Johnson 2000 Nov 29
Daniel Johnson Date
Exploitation Geophysicist
BP Exploration

James M. Ferguson Date
Principal Investigator
Lawrence Livermore National Laboratory

Attachment I – Final Abstract
Attachment II – Project Accomplishments Summary
Attachment III – Final Quarterly Report

Computer Simulation of Nuclear Well Logging Devices

Abstract
CRADA No. TC-1114-95

Date: October 16, 2000 Revision: 5

This project's goal was to develop a deterministic simulator of nuclear well logging tools. LLNL's deterministic code would be available throughout the U.S. oil and gas industry.

The industry partners in this project would benefit primarily from early access to the code system in addition to their own direct involvement in the development of this computational tool.

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Components 1 and 2 above were completed. Component 3 was completed up through running industry supplied test problems and comparison with results of the calculations of others. It would have been desirable to make comparisons with field data, using calculations that included all the engineering features and complex geological details. The first part of component 4 was completed, with the addition of a user-friendly interface for describing problems. However it was not possible to include all the features needed for an engineering usage in the field by persons not familiar with the program.

Computer Simulation of Nuclear Well Logging Devices

Project Accomplishments Summary (Attachment II)
CRADA No. TC-1114-95

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A. Parties

This was a multi-partner agreement with LLNL, Halliburton Energy Services and BP Exploration.

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B. Background

Nuclear well logging is a method of studying the materials surrounding boreholes. A tool consisting of a neutron or gamma-ray source and one or more detectors is lowered into the borehole. The response of the detectors to radiation returning from outside the borehole depends on the lithology, porosity, and fluid characteristics of the material. In principle, the characteristics of the materials outside the borehole can be inferred from the response of the

detectors. The interpretation of the data is based on benchmark measurements and computer simulation of the measurements with neutron and gamma-ray transport codes. At the time of the CRADA, the existing approach used in industry was the Monte Carlo.

The alternatives to Monte Carlo are deterministic methods. The two methods complement each other, with different sets of advantages and disadvantages. Rapid advances in computer power made it feasible to use deterministic methods for modeling nuclear well logging tools. Advanced algorithms have been developed which further reduce the computational expense. Consequently, there was significant new interest in deterministic transport codes for modeling nuclear well logging tools, particularly by the oil and gas service companies. Whereas Monte Carlo provided the industry with a capability that few, if any, could have produced on their own, complementary deterministic analogs were not yet available.

This project's goal was to develop a deterministic simulator of nuclear well logging tools. LLNL's deterministic code would be available throughout the U.S. Oil and Gas Industry. The industry partners in this CRADA would benefit primarily from early access to the code system in addition to their own direct involvement in the development of this computational tool.

The expertise LLNL brought to this problem was a direct outgrowth of LLNL's work in the Defense Nuclear Science Program. At LLNL we used deterministic methods for solving transport problems for a number of years. The codes used in our applied physics studies were among the fastest and most efficient in the world. In addition to enabling the U.S. Oil and Gas Industry to benefit from the knowledge and experience gained from this long-term investment in defense nuclear technology, this project promoted the continued vitality of the Laboratories' modeling capabilities by preserving and enhancing its intellectual capital in this important area. This dual use benefited the Laboratories' programs in defense, energy, environmental, and industrial technologies developed in the national interest.

C. Description

This project's goal was to develop a deterministic simulator of nuclear well logging tools. LLNL's deterministic code would be available throughout the U.S. oil and gas industry. The industry partners in this project would benefit primarily from early access to the code system in addition to their own direct involvement in the development of this computational tool.

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The numerical algorithms and methods developed in this program are expected to have wide applicability to future computational modeling in this area. Some of these methods will also find important uses in other problems that require accurate deterministic transport calculations.

E. Benefits to DOE

This project promoted the continued vitality of the Laboratories' modeling capabilities by preserving and enhancing its intellectual capital. This dual use benefited the Laboratories' programs in defense, energy, environmental, and industrial technologies developed in the national interest. The expertise LNLL brought to this problem was a direct outgrowth of work in the Defense Nuclear Science Program.

F. Industry Area

Energy, Software Development, Oil and Gas Exploration

G. Project Status

The funding on this project was cancelled in 1996.

H. LLNL Point of Contact for Project Information

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Principal Investigator
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I. Company Size and Point(s) of Contact

Halliburton Energy is a publicly held corporation with $2.623M in sales. The company employs approximately 20,000 people.

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BP Exploration is a publicly held company with $5,600.0M in sales. The company employs 1000 people.

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J. Project Examples

There are no project examples.

K. Release of Information

I certify that all information contained in this report is accurate and releasable to the best of my knowledge.

Karena McKinley, Director
Industrial Partnerships
and Commercialization

1/19/01
Date

Release of Information

I have reviewed the attached Project Accomplishment Summary prepared by Lawrence Livermore National Laboratory and agree that the information about our CRADA may be released for external distribution.

Larry Jacobson, Chief Scientist
Halliburton Energy

5 Dec. 2000
Date

Daniel Johnson, Exploitation Geophysicist
BP Exploration

Date

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Date

Daniel Johnson

Daniel Johnson, Exploitation Geophysicist
BP Exploration

2000 Nov 29

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