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LLNL-TR-739174

Hyperspectral Geobotanical Remote Sensing for Monitoring and Verifying CO2 Containment Final Report CRADA No. TC-2036-02

W. L. Pickles, D. A. Ebrom

September 29, 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.

Hyperspectral Geobotanical Remote Sensing for Monitoring and Verifying CO_2 Containment

Final Report
CRADA No. TC-2036-02
Date Technical Work Ended: December 30, 2003

Date: August 12, 2005 Revision: 4

A. Parties

This is a collaborative effort between The Regents of the University of California, Lawrence Livermore National Laboratory (LLNL) and BP Corporate North America, Inc. (BP America).

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Lawrence Livermore National Laboratory
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B. Project Scope

This collaborative effort was in support of the CO_2 Capture Project (CCP), to develop techniques that integrate overhead images of plant species, plant health, geological formations, soil types, aquatic, and human use spatial patterns for detection and discrimination of any CO_2 releases from underground storage formations.

The goal of this work was to demonstrate advanced hyperspectral geobotanical remote sensing methods to assess potential leakage of CO_2 from underground storage. The timeframes and scales relevant to the long-term storage of CO_2 in the subsurface make remote sensing methods attractive. Moreover, it has been shown that individual field measurements of gas composition are subject to variability on extremely small temporal and spatial scales. The ability to verify ultimate reservoir integrity and to place individual surface measurements into context will be crucial to successful long-term monitoring and verification activities.

The desired results were to produce a defined and tested procedure that could be easily used for long-term monitoring of possible CO_2 leakage from underground CO_2 sequestration sites. This testing standard will be utilized on behalf of the oil industry.

Major Deliverables**:** met**:**

Project Year One

1. Prepared and planned for acquisition of hyperspectral imagery (LLNL and BP America)
2. Participated in a consortium-sponsored workshop and presented technical results (LLNL and BP America)
3. Prepared interim reports on results of Mammoth and Long Valley calibrations (LLNL)

Project Year Two

1. Prepared and planned for acquisition of hyperspectral imagery (LLNL and BP America)
2. Participated in a consortium-sponsored workshop and presented technical results (LLNL and BP America)
3. Prepared reports on results from overhead survey of storage site (LLNL)

Project Year Three

1. Prepared and planned for acquisition of hyperspectral imagery (LLNL and BP America)
2. Participated in a consortium-sponsored workshop and presented technical results (LLNL and BP America)
3. Prepared report on results of satellite survey (LLNL)

C. Technical Accomplishments

LLNL applied advanced hyperspectral geobotanical remote sensing techniques to assess potential CO_2 leakage from underground storage. Hyperspectral remote sensing techniques can be used to rapidly discriminate a wide range of changes over a survey area. While valuable as a primary assessment tool, the method would be particularly useful to monitor any changes that occur over time. The surveys are easy to collect, and the analysis provides an assessment at scales pertinent to the long-term monitoring of CO_2 storage. These methods are currently being used in a wide variety of applications, from mineral resource identification to ecosystem health monitoring.

LLNL demonstrated the geobotanical hyperspectral remote sensing methods to be effective in detecting and discriminating small, slow, spatially complicated and highly time-dependent seepage of CO_2 from underground storage formation. LLNL also developed a methodology and plans for implementing results for long-term monitoring of CO_2 injection, ideally using commercially available resources.

LLNL also expects to see more and improved airborne hyperspectral imaging services available for hire worldwide. This should allow for routine hyperspectral imaging and on-line analysis for CO_2 effluent monitoring purposes.

D. Expected Economic Impact

The US taxpayer benefits by having the fossil energy resource being more sustainable and hence usable for longer periods at higher levels. Developing techniques that integrate overhead images of plant species, plant health, geological formations, soil types, aquatic, and human use spatial patterns for detection and discrimination of any CO_2 releases from underground storage formations will apply to other applications in the DOE mission as well as address many safety concerns regarding CO_2 leakage levels from geological formation storage.

D.1 Specific Benefits

Benefits to DOE
This CRADA benefited the DOE by contributing significantly to the DOE mission of reduction of global warming green house gases.

Benefits to Industry
This CRADA benefited Industry by contributing significantly to their understanding of advanced hyperspectral geobotanical remote sensing methods and assessing potential leakage from underground storage. Remote sensing is a crucial factor in long-term storage of CO2.

E. Partner Contribution

The Industrial partner's major contributions to this project were limited to financial support provided through the CRADA. They also brought their industrial expertise and knowledge to the project as a partner in the CCP, a consortium of 9 energy companies working with DOE and it's laboratories.

F. Documents/Reference List

Reports
Prepared interim reports on results of Mammoth and Long Valley calibrations (LLNL).
Prepared reports on results from overhead survey of storage site in Phase two and Phase three (LLNL)

Copyright Activity
NONE

Subject Inventions
NONE

Background Intellectual Property
NONE

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.

Dan A. Ebrom, 4C Sub Network Co-Leader — Date
BP America, Inc.

William L. Pickles — 5-30-06

William L. Pickles, Principal Investigator — Date
Lawrence Livermore National Laboratory

Karena D. McKinley, IPAC Director — Date
Lawrence Livermore National Laboratory

Attachment I – Final Abstract

G. Acknowledgement

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9-30-2005

Dan A. Ebrom, 4C Sub Network Co-Leader — Date
BP America, Inc.

William L. Pickles, Principal Investigator — Date
Lawrence Livermore National Laboratory

Norma E Dumpert — June 2, 2006

for Karena D. McKinley, IPAC Director — Date
Lawrence Livermore National Laboratory

Attachment I – Final Abstract

Industrial Partnerships and Commercialization

Mail Station L-795

Ext. 3-9353

Fax 3-8988

May 30, 2006

MEMORANDUM

To: Distribution

From: Karena McKinley

Subject: Signature Authority

In my absence May 30 through June 2, I hereby delegate signature authority to Norma Dunipace for all IPAC-related documents.

Karena McKinley

Director, Industrial Partnerships
and Commercialization

Distribution:
Norma Dunipace
Kathy Kaufman
IPAC Staff

University of California

**LAWRENCE LIVERMORE
NATIONAL LABORATORY**

Hyperspectral Geobotanical Remote Sensing for Monitoring and Verifying CO_2 Containment

Final Abstract (Attachment I)
CRADA No. TC-2036-02
Date Technical Work Ended: December 30, 2003

Date: August 12, 2005 Revision: 2

A. Parties

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B. Purpose and Description

This collaborative effort was in support of the CO_2 Capture Project (CCP), to develop techniques that integrate overhead images of plant species, plant health, geological formations, soil types, aquatic, and human use spatial patterns for detection and discrimination of any CO_2 releases from underground storage formations.

The goal of this work was to demonstrate advanced hyperspectral geobotanical remote sensing methods to assess potential leakage of CO_2 from underground storage. The timeframes and scales relevant to the long-term storage of CO_2 in the subsurface make remote sensing methods attractive. Moreover, it has been shown that individual field measurements of gas composition are subject to variability on extremely small temporal and spatial scales. The ability to verify ultimate reservoir integrity and to place individual surface measurements into context will be crucial to successful long-term monitoring and verification activities.

All deliverables were met.

C. Benefit to Industry

This CRADA benefited Industry by contributing significantly to their understanding of advanced hyperspectral geobotanical remote sensing methods and assessing potential leakage from underground storage. Remote sensing is a crucial factor in long-term storage of CO2.

D. Benefit to DOE/LLNL

This CRADA benefited the DOE by contributing significantly to the DOE mission of reduction of global warming green house gases.

E. Project Dates

September 30, 2002 to December 31, 2003