the ENERGY lab

PROJECT FACTS

Carbon Storage – MVA

# Greenhouse Gas Laser Imaging Tomography Experiment (Green LITE)

## Background

The goal of the Department of Energy's (DOE) Carbon Storage Program is to develop and advance technologies to significantly improve the effectiveness of geologic carbon storage, reduce implementation costs, and prepare for widespread commercial deployment between 2025 and 2035. Research to develop these technologies will ensure safe and permanent storage of carbon dioxide ($CO_2$) to reduce greenhouse gas (GHG) emissions without adversely affecting energy use or hindering economic growth.

Geologic carbon storage involves securely and permanently injecting $CO_2$ into onshore and offshore underground formations. Current research and field studies are focused on developing a better understanding of the science and technologies needed for safe and permanent $CO_2$ storage in onshore and offshore storage reservoirs, which include: clastic formations, carbonate formations, unmineable coal seams, organic-rich shales, and basalt interflow zones. DOE's Storage Program is accomplishing this through: (1) developing technologies that address technical challenges and ensure the cost effectiveness of carbon storage, (2) validating technologies that ensure safe and permanent carbon storage, and (3) facilitating public, industry, and international community awareness of research and development (R&D) efforts underway related to carbon storage. These technologies will facilitate future $CO_2$ management for coal-based electric power generating facilities and other industrial $CO_2$ emitters by enabling the safe, cost-effective, permanent geologic storage and utilization of $CO_2$ in all storage types.

The Carbon Storage program is comprised of three primary technology areas (1) Core Storage R&D, (2) Storage Infrastructure, and (3) Strategic Program Support. These three areas work together to address significant technical challenges in order to meet program goals that support the scale-up and widespread deployment of carbon capture and storage (CCS). Within these technology areas, emerging technologies are supported through applied laboratory- and pilot-scale research. In addition, promising technology options are being validated through small- and large-scale field projects. This approach allows technologies to develop from concept through validation in the field and increases the Nation's confidence in future safe, effective, and permanent geologic $CO_2$ storage. The Core Storage R&D technology area is sub-divided into three research areas: (1) Geologic Storage Technologies and Simulation and Risk Assessment (GSRA); (2) Monitoring, Verification, Accounting (MVA), and Assessment; and (3) Carbon Use and Reuse. This project is part of the MVA research area, which is designed to confirm permanent onshore and offshore $CO_2$ storage in geologic formations through monitoring capabilities that are reliable and cost effective. Monitoring is an important aspect of $CO_2$ injection, because it focuses on a number of permanence issues. Monitoring technologies are being developed for

## CONTACTS

**Traci Rodosta**
Carbon Storage Technology Manager
National Energy Technology Laboratory
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507
304-285-1345
traci.rodosta@netl.doe.gov

**William Aljoe**
Project Manager
National Energy Technology Laboratory
626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236
412-386-6569
william.aljoe @netl.doe.gov

**Jeremy Dobler**
Principal Investigator
Exelis, Inc.
1919 Cook Road
P.O. Box 3700
Fort Wayne, IN 46801
260-451-6652
jeremy.dobler@exelisinc.com

## PARTNERS

**Atmospheric & Environmental Research, Inc.**

## PROJECT DURATION

| Start Date | End Date |
|---|---|
| 10/01/2013 | 09/30/2015 |

## COST

**Total Project Value**
$2,093,139

**DOE/Non-DOE Share**
$1,674,503 / $418,636

## AWARD NUMBER

DE-FE0012574

atmospheric, near-surface, and onshore and offshore subsurface applications to ensure that injection, abandoned, and monitoring wells are structurally sound and that $CO_2$ will remain within the storage complex. The focus of this Exelis, Inc. project is to develop two prototype scanning sensors and couple them with a series of retro-reflecting mirrors to create a networked system for producing high-quality $CO_2$ path measurements over an open area.

## Project Description

This project is developing and testing a greenhouse gas laser imaging tomography (Green LITE) system utilizing two scanning laser-based differential absorption sensors, combined with a series of retro-reflectors and intelligent algorithms, to measure $CO_2$ concentrations and generate 2-dimensional $CO_2$ flux maps over a geologic carbon storage site. The project team is developing an autonomous, precise, and accurate system for measuring $CO_2$ remotely across the entire storage field, while making the data available in near real time via a web-based interface. The proposed system uses two laser sensors—located nominally three meters off the ground—pre-programmed to point to a series of 20 retro-reflector targets each (Figure 1). This sensor target system provides an interwoven series of highly accurate, integrated path differential absorption measurements that are subsequently sent to a tomographic retrieval algorithm used to generate near-real-time 2-dimensional $CO_2$ maps. The square configuration presented in Figure 1 is an idealized case, but the system is adaptable to other geometries based on site-specific requirements. The prototype system is being deployed at the Zero Emissions Research and Technology (ZERT) field project site, where controlled, shallow subsurface releases of $CO_2$ can create realistic scenarios that may occur at carbon storage sites. The ZERT test will deliver an extended data set to validate the precision and accuracy of the 2-dimensional concentration and flux maps. In addition, the system will be deployed at the Illinois Basin Decatur Program (IBDP) $CO_2$ storage site (managed by the University of Illinois-Champagne through the Midwest Geological Sequestration Consortium) for remote, autonomous monitoring.

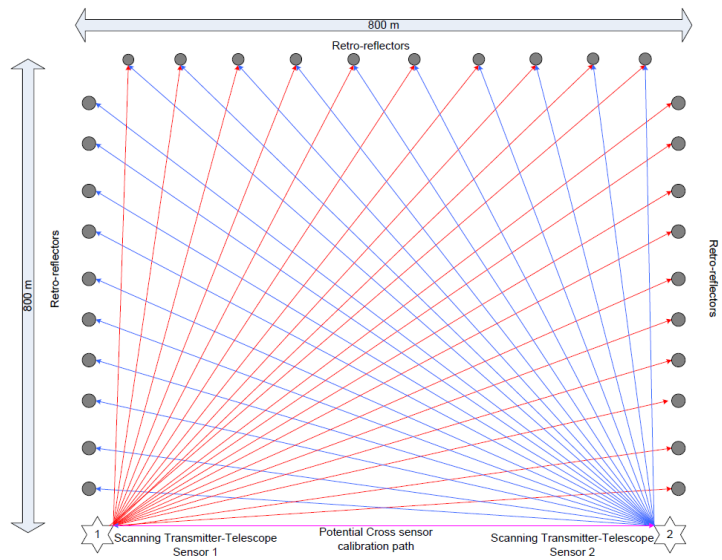


*Figure 1. The baseline topology for the Green LITE MVA system*

## Objectives

The Green LITE system provides continuous, quantified, highly accurate, 2-dimensional $CO_2$ concentrations and flux over a large area (up to several square kilometers) based on existing technology being utilized in a new and innovative way. This project will be conducted in three phases over two years. Specific objectives include the following:

- In Phase 1 of the research effort, the project team will seek to engineer previously validated technology developed by Exelis for remote measurement of atmospheric $CO_2$ into a field system capable of generating 2-dimensional $CO_2$ maps.
- Phase 2 of the research effort will promote the demonstration system to a networked sensor system and deploy it to the ZERT field project site near Bozeman, Montana.
- Phase 3 of the research effort will be to further upgrade the system for autonomous operation requiring limited user interaction and deploy it to the IBDP program site in Decatur, Illinois where it will be installed and operated remotely for a period of six months.

## Accomplishments

- The sensor components have been constructed and validated on a laboratory scale. The design of the system has been completed and integrated with the software.
- Increased dynamic range of $CO_2$ measurement by allowing different electrical signal gains for different chords (retro-reflectors paths coupled with $CO_2$ scanning sensors). Calibration is now performed at each gain setting, and appropriate calibration is applied for each chord based on gain setting for the chord. This enables the system to work over a range of chord lengths that will be encountered for the IBDP site.

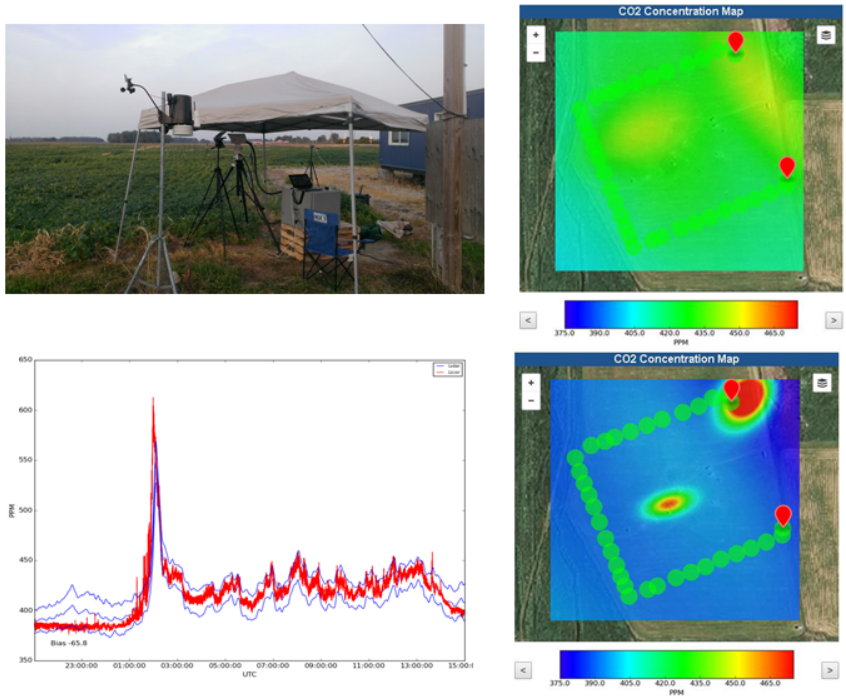


*Figure 2: GreenLITE system setup and 2D outputs from information gathered at the ZERT Site in Bozeman, Montana.*

- Data collection at the ZERT site was conducted from August 18 through September 9, 2014, with subsurface release rates ranging from 0.3T/day to 0.12 T/day. Clear diurnal variations in $CO_2$ concentrations across the site were noted; however, $CO_2$ releases from the test facility were sometimes masked (depending on wind direction) by $CO_2$ releases from a large manure pile on the farm immediately to the east of the ZERT test site. Simple X/Y reconstructions of $CO_2$ concentrations across the site were consistent with the location of the $CO_2$ release pipe and the prevailing wind direction. $CO_2$ measurements tracked very well in time and magnitude with a soil flux device used to monitor atmospheric concentrations.

- Preliminary 2D mapping algorithms have been developed and tested with simulated and measured data (Figure 2). The team completed multiple test runs of variations on the 2D reconstructions to enhance features, such as time-weighted averaging. Testing at the ZERT site indicated that surface environmental factors (such as wind speed, direction, precipitation) played a significant role in the ability to identify small surface releases in the 2D reconstructions.

## Benefits

The project is making a vital contribution to the scientific, technical, and institutional knowledge base needed to establish a framework for monitoring and assessing commercial-scale carbon capture and storage. The sensing system being developed by Exelis will leverage active atmospheric sensing technologies to improve both the accuracy and practicality of ground-based $CO_2$ monitoring. The research will focus on building a lower-cost, user friendly system to autonomously provide timely and accurate tomographic $CO_2$ concentration and flux maps over large areas, even under harsh environmental operating conditions. In addition, the Green LITE instrument is expected to improve worker safety, reduce environmental and economic impacts, and properly account for $CO_2$ flux over long-term, large-scale operations.

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