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LLNL-TR-748997

Improving Technology for Mapping and Imaging Final Report CRADA No. TC02192.0

C. L. Bennett, F. Strange

April 4, 2018

Disclaimer

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

Improving Technology for Mapping and Imaging

Final Report
CRADA No. TC02192.0
Date Technical Work Ended: October 14, 2014

Date: November 13, 2014 Revision: 1

A. Parties

This project was a relationship between Lawrence Livermore National Laboratory (LLNL) and Underground Imaging Technologies, LLC (UIT).

Lawrence Livermore National Security, LLC
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B. Project Scope

This CRADA was a collaborative effort between Lawrence Livermore National Security, LLC as manager and operator of Lawrence Livermore National Laboratory (LLNL) and Underground Imaging Technologies, LLC to further develop an improved technology for mapping and imaging of the underground infrastructure for the land construction industry.

The project consisted of Phase 1, which included three tasks and three deliverables and was originally designated as a three (3) month CRADA. LLNL evaluated UIT-provided data sets using our multistatic processing technology to image and detect buried pipes and conduits in UIT scan data. This effort was then briefed to UIT to help plan efforts for Phase 2. At the end of the incremental early funding, however, UIT was not able to fund Phase 2 work, so none of those activities have taken place.

Deliverables:

Task	Deliverable	Schedule	Responsible Party
Phase 1			
Task 1.1	UIT data set for initial evaluation	Two weeks from CRADA Effective Date	UIT
Task 1.1	Briefing on findings of initial evaluation	End of month 1	LLNL
Task 1.1	UIT system training materials, if any	End of month 3	UIT
Phase 2 (Optional)	**PHASE 2 NOT PERFORMED**		
Task 1.1	Evaluation version of the MAPS 1st Generation Software	Estimated end of month 11	LLNL
Task 1.2	Feedback and Suggested GUI Modifications	End of month 13	UIT
Task 1.3	MAPS 2nd Generation Release	End of month 15	LLNL, with UIT input
	Final Report and Abstract within thirty (30) days of completion or termination of the project, as required under Article XI of the CRADA.	Within 30 days of the end of the CRADA	LLNL, with UIT input

The Phase 1 deliverables were all met.

A No-Cost Time Extension (NCTE) was executed on 2/5/14, extending the CRADA for two (2) months to allow enough time to complete tasks and deliverables.

A second NCTE was executed on 4/16/14, extending the CRADA for an additional three (3) months to allow UIT to secure additional funding for the CRADA.

A third NCTE was executed on 7/7/14, extending the CRADA for an additional three (3) months to give UIT allow enough time to prepare and execute Amendment One to the CRADA. (This Amendment One was never executed).

C. Technical Accomplishments

The specific technical accomplishments were demonstrating imaging and detection of underground pipes and conduits using monostatic GPR data supplied by UIT to LLNL. Even though this data was not taken by our (LLNL) iRadar system which fully exploits multistatic acquisition, the LLNL MAPS algorithms were capable of performing imaging and detection on the vendor supplied data. The potential of the LLNL MAPS technology was evident to UIT, and their management tried to solicit funding to move the CRADA to Phase 2.

D. Expected Economic Impact

Not applicable since the CRADA did not advance.

D.1 Specific Benefits

Benefits to DOE

Had the CRADA advanced, DOE would have benefited from significant support for core capabilities in GPR imaging and signal processing/data analysis.

Benefits to Industry

This CRADA would have provided the technology to detect buried pipelines and conduits prior to digging operations. In addition to reducing pipeline disasters, utilities blackouts, and petrochemical spills, the technology will allow a US company to gain a competitive advantage over foreign competitors.

E. Participant Contribution

UIT provided monostatic GPR datasets acquired in the field for LLNL to analyze. These datasets covered utility and construction applications, an area in which LLNL does not have access to such data.

F. Documents/Reference List

Reports

No reports were completed due to the lack of funding/commitment to move beyond the demonstration phase.

Copyright Activity

N/A

Subject Inventions

No Subject Inventions were conceived or first actually reduced to practice in the performance of work under this CRADA

Background Intellectual Property

Due to UIT's funding constraints, no licenses have been granted for the Background Intellectual Property. The Background Intellectual Property list is:

- U.S. Patent No. 8,482,452, entitled *"Synthetic Aperture Integration (SAI) Algorithm for SAR Imaging"*, Inventors: David W. Paglieroni, David H. Chambers, Jeffrey E. Mast, N. Reginald Beer, Steven W. Bond, issued 7/9/2013, (LLNL Tracking Number IL-12311D)
- U.S. Patent No. 8,508,403 B2, entitled *"Spatially Adaptive Migration Algorithm for Multistatic Imaging"*, Inventors: N. Reginald Beer, David W. Paglieroni, issued 8/13/2013,(LLNL Tracking Number IL-12444A)
- U.S. Patent Application No. 13/219425, entitled *"Attribute and Topology Based Change Detection in a Constellation of Previously Detected Objects"*, Inventors: David W. Paglieroni, David H. Chambers, Haiyin Chen-Harris, N. Reginald Beer, Thomas A. Baginski, Yiming Yao, filed 8/26/2011, (LLNL Tracking Number IL-12310A)
- U.S. Patent Application No. 13/219512, entitled *"Determining Root Correspondence Between Previously and Newly Detected Objects"*, Inventors: David W. Paglieroni, David H. Chambers, Haiyin Chen-Harris, N. Reginald Beer, Thomas A. Baginski, Yiming Yao,filed 8/26/2011, (LLNL Tracking Number IL-12310B)
- U.S. Patent Application No. 13/219410, entitled *"Real-Time System for Imaging and Object Detection with a Multistatic CPR Array"*, Inventors: David W. Paglieroni, David H. Chambers, Jeffrey E. Mast, N. Reginald Beer, Steven W. Bond, filed 8/26/2011, (LLNL Tracking Number IL-12311A)
- U.S. Patent Application No. 13/219456, entitled *"Buried Object Detection in GPR Images"*, Inventors: David W. Paglieroni, David H. Chambers, Jeffrey E. Mast, N. Reginald Beer, Steven W. Bond, filed 8/26/2011, (LLNL Tracking Number IL-12311B)
- U.S. Patent Application No. 13/219466, entitled *"Spot Restoration for GPR Image Post-Processing"*, Inventors: David W. Paglieroni, David H. Chambers, Jeffrey E. Mast, N. Reginald Beer, Steven W. Bond filed 8/26/2011, (LLNL Tracking Number IL-12311C)
- U.S. Patent Application No. 13/219482, entitled *"Radar Signal Pre-processing to Suppress Surface Bounce and Multipath"*, Inventors: David W. Paglieroni, David H. Chambers, Jeffrey E. Mast, N. Reginald Beer, Steven W. Bond, filed 8/26/2011, (LLNL Tracking Number
  IL-12311E)

- U.S. Patent Application No. 13/219493, entitled *"Spatially Assisted Down-Track Median Filter for GPR Image Post-Processing"*, Inventors: David W. Paglieroni, David H. Chambers, Jeffrey E. Mast, N. Reginald Beer, Steven W. Bond, filed 8/26/2011, (LLNL Tracking Number IL-12311F)
- U.S. Patent Application No. 13/219504, entitled *"Zero Source Insertion Technique to Account for Undersampling in GPR Imaging"*, Inventors: David W. Paglieroni, David H. Chambers, Jeffrey E. Mast, N. Reginald Beer, Steven W. Bond, filed 8/26/2011, (LLNL Tracking Number IL-12311G)
- U.S. Patent Application No. 13/313939, entitled *"Object Detection With a Multistatic Array Using Singular Value Decomposition"*, Inventors" Aaron T. Hallquist, David H. Chambers, filed 12/7/2011,(LLNL Tracking Number IL-12322A)
- U.S. Patent Application No. 13/219430, entitled *"Distributed Road Assessment System"*, Inventors: N. Reginald Beer, David W. Paglieroni, Jeffrey E. Mast, filed 8/26/2011, (LLNL Tracking Number IL-12344A)
- U.S. Patent Application No. 13/219435, entitled *"Classification of Subsurface Objects Using Singular Values Derived From Signal Frames"*, Inventors: David W. Paglieroni, David H. Chambers, filed 8/26/2011, (LLNL Tracking Number IL-12389A)
- U.S. Patent Application No. 13/748417, entitled *"Imaging, Object Detection, and Change Detection with a Polarized Multistatic GPR Array"*, Inventors: N. Reginald Beer, David W. Paglieroni, filed 1/23/2013, (LLNL Tracking Number IL-12543A)
- U.S. Patent Application No. 13/748447, entitled *"Point Pattern Match-Based Change Detection in a Constellation of Previously Detected Objects"*, Inventor: David W. Paglieroni, filed 1/23/2013, (LLNL Tracking Number IL-12719)
- iRadar MAPS: Performance, v12.07, (LLNL Tracking Number CP01570)
- iRadar MAPS: Acquisition, v12.07, (LLNL Tracking Number CP01571)
- iRadar MAPS: Detection, v12.07, (LLNL Tracking Number CP01572)
- iRadar MAPS: Real-Time, v12.07, (LLNL Tracking Number CP01573)
- iRadar MAPS: GUI, v12.07, (LLNL Tracking Number CP01574)
- iRadar MAPS - I, v12.07 (Real Time Imaging and Change Detection), (LLNL Tracking Number CP01575)

Underground Imaging Technologies disclosed the following Background Intellectual Property:

None

G. Acknowledgement

Industrial 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.

Gary W. Young — November 17, 2014

Gary Young, Senior Vice President, Operations & Development — Date
Underground Imaging Technologies, LLC

12/8/2014

N. Reginald Beer, LLNL Principal Investigator — Date
Lawrence Livermore National Laboratory

12/16/2014

Michael S. Sharer, Manager, Technology Commercialization — Date
Lawrence Livermore National Laboratory

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Final Abstract (Attachment I)
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B. Purpose and Description

LLNL developed a new imaging technology involving ultrawideband ground penetrating radar which may be useful for penetrating radar imaging equipment. For purposes of this CRADA, the LLNL imaging technology is also referred to as the Multistatic Acquisition and Processing (MAPS) technology.

This was a collaborative effort between Lawrence Livermore National Security, LLC as manager and operator of Lawrence Livermore National Laboratory (LLNL) and Underground Imaging Technologies, LLC to further develop an improved technology for mapping and imaging of the underground infrastructure for the land construction industry.

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C. Benefit to Industry

This CRADA will provide the technology to detect buried pipelines and conduits prior to digging operations. In addition to reducing pipeline disasters, utilities blackouts, and petrochemical spills, the technology will allow a US company to gain a competitive advantage over foreign competitors.

D. Benefit to DOE/LLNL

The DOE will also benefit from having LLNL core capabilities and staff in signal processing and imaging funded for growth and stability.

E. Project Dates

October 16, 2013 – October 14, 2014