COLLABORATIVE RESEARCH IN MILITARY CONSEQUENCE MANAGEMENT: CONSOLIDATED FINAL TECHNICAL REPORT FOR 2009 APPLIED RESEARCH PROJECTS

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INTRODUCTION

April 30, 2015

To the reader:

This report details the results of the Leonard Wood Institute's (LWI) 2009 program year research efforts, which were aimed at finding solutions to a set of priority applied research topics provided to LWI by the U.S. Army Research Laboratory (ARL), the U.S. Army Research, Development and Engineering Centers (RDEC's), and the Army Maneuver Support Center of Excellence (MSCoE). Our approach involved investigating advanced concepts and technologies, providing "state of the art" knowledge to Capability Developers, and assisting the Army to define how research results can be implemented to rapidly and effectively benefit Soldiers.

The Army is working to accelerate the delivery of technical capabilities to prepare for an era of persistent conflict, and to cope with declining budgets. In this challenging environment, it is our intent to provide the Army with an innovative method of accessing dozens of high-quality research outcomes that will lead to new capabilities more quickly—and at a lower cost—than most traditional, applied research programs.

LWI is committed to supporting applied research and development projects that help the U.S. Army to continue to be the most capable fighting force in the world. Through our efforts to benefit the Army, we also hope to support economic growth in our region and state. LWI has a specific focus on the technology needs of the MSCoE at Fort Leonard Wood, Missouri, and works with private sector technology companies, universities, and other researchers to meet the Army's stated research needs.

Consistent with its mission, LWI was awarded federal funding for applied research in 2009 through its Cooperative Agreement with ARL. We initiated, funded, managed, and collaborated on applied research projects in ARL-approved subject areas, including:

- Detection of improvised explosive devices (IEDs) and landmines
- Detection of biological and chemical agents
- New approaches to base camp power management and wastewater treatment
- Improved sensor capabilities for robots
- Enhancement of human systems integration (HSI) methods to improve readiness for responding to man-made or natural disasters
- Virtual environments for more realistic and effective training

The project results detailed in this report include findings aimed at developing and supporting training programs, training delivery system capabilities, and operational capabilities that are consistent with LWI's Program Plan and Cooperative Agreement with ARL.

We are grateful to ARL—particularly to its Human Research and Engineering Directorate—for the cooperation and partnership it has provided in administering the federal funding that was allocated by Congress. We anticipate that many of the research findings in this consolidated report will be of immediate and substantive benefit to the Army and Soldiers.

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1 EXECUTIVE SUMMARY

1.1.1 PURPOSE OF ORGANIZATION

The Leonard Wood Institute (LWI) is a tax-exempt, non-profit public purpose research organization focused primarily on fulfilling the technology needs of the U.S. Army Maneuver Support Center of Excellence (MSCoE) and Fort Leonard Wood (FLW), Missouri. Founded in 2004, LWI was created to enable and manage collaborative efforts to assist in developing solutions that meet Army Maneuver Support, Force Protection, and Consequence Management requirements, as well as other military missions.

1.1.2 FOUNDING OF THE INSTITUTE

The state of Missouri provided initial funding to organize LWI, and a consortium of government, industry, and academic organizations were founding partners. Those founders included:

- Missouri Enterprise, which manages the National Institute of Standards and Technology-sponsored Manufacturing Extension Partnership in Missouri
- The University of Missouri System
- The Missouri Department of Economic Development
- Battelle Memorial Institute
- The Missouri Technology Corporation, Missouri's technology development proponent
- Boeing Integrated Defense Systems, a division of the Boeing Company

1.1.3 INSTITUTE MISSION

LWI connects regional, private sector technology companies and researchers with articulated Army research needs, especially in technology areas with some application to training. LWI has been involved in supporting initiatives at FLW that include:

- Explosive/toxic hazards
- Chemical, biological, radiological, and nuclear (CBRN) defeat
- Force protection
- Consequence management
- Geospatial information systems
- Modeling and simulation
- Non-lethal force capabilities

The desired outcomes from LWI's work are to provide better technology solutions for the Army and to increase the capabilities of Missouri businesses, universities, and research organizations to provide future technology support to the Army. By increasing the capabilities of the Army's state and regional research partners, LWI is helping to create a more robust technology base in Missouri that can meet future military technology requirements and strengthen regional economic conditions.

2 RESEARCH SUMMARIES

The research presented in this technical report was performed by many different principal investigators, representing a variety of universities, businesses, and non-profit organizations from Missouri and other states. The researchers were chosen and funded by the Leonard Wood Institute through the process described in Section 1 of this report.

In their proposals to LWI, offerors of proposals were required to provide:

- Detailed statements of work (SOWs)
- Project schedules
- Milestones and deliverables
- Management approaches
- Qualifications of investigators
- References
- Current and pending support
- Cost information

LWI required that each SOW clearly detail the scope, objectives, and technical approach of the proposed effort, including detailed listings of the technical tasks and subtasks organized by month. The offerors selected for funding were required to negotiate and execute a cost-reimbursable subaward agreement, with the SOW incorporated as an attachment. The subaward agreements were executed and administered pursuant to LWI's solicitation for proposals, and are subject to the Department of Defense Grant and Agreement Regulations (DoDGARs), 32 CFR Parts 21-37.

Research projects presented in this report are summarized in the following section. Each summary was constructed to give a broad overview of what each research project encompasses. The summaries explain:

- Who did the work
- What approaches were used
- What was discovered
- Why the work is significant
- How discoveries can be implemented

Each summary also contains a reference and a link to its detailed technical report, which appears in its entirety in the appendices of this document.

2.1 A NET-CENTRIC CHANGE DETECTION TOOL FOR IMPROVED CONSEQUENCE MANAGEMENT AND BATTLESPACE AWARENESS

Project Reference #	LWI 191-011	Click here for full report
Mission Area	Protection	
Technology Focus Area	Network	
Principal Researcher	Dr. Curt H. Davis	
Research Organization	University of Missouri—Columbia	
Research Period	September 1, 2009 – December 15, 2010	
Total Funding	$494,190	

PROJECT OVERVIEW

This project developed a prototype "GeoCDX" tool that helps imagery analysts quickly and efficiently search for important changes in airborne and satellite imagery—including visual data from the U.S. Army's Buckeye sensor. The GeoCDX has a simple web interface that allows the user to:

- Perform user searches (similar to a search engine)
- Generate reports
- Manage alert notifications
- Provide feedback and refinement

RELEVANCE

Military intelligence relies on using the most current topographical information available for making strategic decisions in such locations as Afghanistan, Iraq, and North Korea. Imagery analysts spend a lot of time studying satellite maps and images, looking for new construction and new features—such as bridges, nuclear facilities, weapons of mass destruction (WMD), and communication towers.

Today, this comparison process is very difficult, because of the large number of images to study, and the high volume of changes taking place very quickly. The sheer volume of data makes it difficult to perform this job quickly and accurately.

APPLICATION

The GeoCDX tool helps troops in the field learn about potential hazards faster by giving imagery analysts the tools to quickly and easily find new structures in foreign locations. These analysts can then provide much more accurate intelligence to leaders by querying the latest satellite and airplane mapping images, and finding new structures—such as new forward operating bases, communications towers, or weapons plants. Changes to the land topography can also be quickly identified to allow for safer missions.

CONCLUSIONS

The GeoCDX is a functional, easy-to-use, web-based portal that can access satellite and airborne imagery data quickly to find important changes and new structures. System capabilities include:

- An enterprise-wide computing solution that can automatically and efficiently process large volumes of airborne and satellite imagery.
- The ability to process digital imagery from the U.S. Army's Buckeye sensor.
- The ability to automatically detect changes between airborne and satellite imaging sensors.
- An internet-based database with a user-friendly web interface.
- A system that allows users to query results, create reports, perform analysis, receive alert notifications, and provide feedback for refinement.
- The ability to organize change results, based on change signature.
- The ability to display results in 2D and 3D earth-browser applications, such as GoogleEarth.

In addition, the results were published in two journals, *Proceedings of International Geoscience and Remote Sensing Symposium*, and *IEEE Transactions on Geoscience & Remote Sensing.*

CHALLENGES

The U.S. Army Buckeye images were particularly difficult to work with. Despite these challenges, the GeoCDX change detection system was successfully enhanced to automatically process Buckeye imagery.

Otherwise, all tasks were completed successfully with the exception of Task 6, Ingestion of User-Supplied Geospatial Data/Information, which was replaced by additional refinements suggested by Maj. Joe Mullins (AGC) and MANSCEN subject matter expert Mr. Ken Bergman. By their suggestion, a Web Mapping Service (WMS) feature was added to the system to allow the Buckeye images to be disseminated using a virtual globe, such as Google Earth™.

RESEARCHER RECOMMENDATIONS

The prototype is online and available for Army evaluation and feedback for 6 months. The National Geospatial Intelligence Agency is funding additional research to expand the set of satellite and airborne data available on the GeoCDX tool.

In addition, the GeoCDX tool is being used in a pilot project for the Defense Intelligence Agency to discover new facilities and activities that have value for military intelligence. The change detection technology developed through this project has also been licensed to Terra 4D Systems, LLC for possible commercialization.

For complete details of this research, please see the Appendix.

2.2 SUSPICIOUS ACTIVITY DETECTION FOR PERIMETER SAFETY AND FORCE PROTECTION

Project Reference #	LWI 191-181	Click here for full report
Mission Area	Protection	
Technology Focus Area	Network	
Principal Researcher	Dr. Zhihai (Henry) He	
Research Organization	University of Missouri—Columbia	
Research Period	September 1, 2009 – December 30, 2010	
Total Funding	$498,759	

PROJECT OVERVIEW

The goal of this project was to develop a prototype camera network system for persistent surveillance, suspicious activity detection, and force protection. It demonstrated that it is possible to automate the task of suspicious activity detection through video content analysis—by using changes in biometric features, deceptive behavior indicators, and other visual cues.

RELEVANCE

Detecting unseen objects in 3D environments from multi-source videos is very important for battlefield intelligence, homeland security, and robot navigation. However, this task is nearly impossible for human beings to perform, due to limited memory and data processing capability.

It would be very helpful to be able to attach a video camera to a Soldier, convoy, or unmanned ground vehicle (UGV) that could automatically detect suspicious changes to the surrounding environment. These changes might indicate adversary actions or other potential hazards.

A successful change detection framework could also be very useful in many homeland security scenarios to detect new modifications or damages to infrastructures—such as buildings, bridges, and driveways.

APPLICATION

The proposed technologies, once successfully developed, will significantly enhance the military's capability to perform persistent surveillance, battlefield awareness, perimeter safety, and force protection. The proposed sensor networking framework is fully expandable to incorporate additional sensors and cameras in future phases of the project.

The technology developed in this project can also be adapted to civilian and commercial applications for corporate loss prevention, law enforcement, infrastructure protection, and transportation safety.

CONCLUSIONS

Overall, the project was successful. The team developed a high-performance, intelligent video

surveillance software system. This level of performance—an 80% detection rate, with only a 3% false alarm rate—is very promising. Other methods using conventional photometric image descriptors fail to detect any changes in the 3D environment whatsoever.

This research also made significant progress in computer vision algorithm research and practical system development. It improved the performance of:

- Adaptive background modeling
- Object extraction from surveillance videos under various weather and lighting conditions
- Text recognition using support vector machine methods
- Accuracy and robustness of face feature tracking and face recognition

CHALLENGES

3D change detection remains an open and challenging problem. This work is among the first to attempt to detect unseen objects in a 3D environment from multi-source videos captured by different moving cameras. This work is the first step toward a solution to this challenging problem.

RESEARCHER RECOMMENDATIONS

In future work, the algorithms and detection performance will be further refined. Beyond this project, the next steps would be:

- **Field evaluation**—Evaluating the algorithm and system in field military and civil applications.
- **Embedded system design**—Implementing the algorithms on embedded devices so they can easily be deployed on commercial applications.

For complete details of this research, please see the Appendix.

2.3 POLYMER MATRIX RESINS WITH THERMALLY STABLE REFRACTIVE INDICES FOR USE IN TRANSPARENT COMPOSITES

Project Reference #	LWI 191-042	Click here for full report
Mission Area	Protection	
Technology Focus Area	Protection	
Principal Researcher	Dr. Heping Wang	
Research Organization	Brewer Science, Inc.	
Research Period	September 1, 2009 – December 30, 2010	
Total Funding	$662,539	

PROJECT OVERVIEW

The goal of this project was to identify better polymer matrix resins that could be used in transparent composite applications in the battlefield, such as windshields or glass. The goal was to find composites that are more lightweight, easy to see through, and offer better blast protection than older composites.

RELEVANCE

Currently, the glass composite material used in the windshields of military vehicles to protect Soldiers from blasts or ballistic attack is very thick and heavy. It also shatters when receiving a significant blast, after which it can no longer be used for protection.

APPLICATION

This new composite is lighter weight, and offers better blast protection as a windshield or window. Even if a bullet penetrates it, it does not completely shatter the glasslike material, so it can still offer passengers protection after a hit.

CONCLUSIONS

This project successfully identified two polymeric matrices that can be used in these composites: polysulfone and cyclic olefin copolymer (COC). These two chemistries provide 3 to 4 times the temperature stability compared with current epoxy-based composites.

The team also developed testing panels and processes to manufacture the composite. The ribbon-reinforced composites met the requirement of ballistic performance.

As a result of this project, two SBIR proposals were submitted, one patent application is ready to file (while another is being drafted), and a paper has been scheduled for submission in 2011.

CHALLENGES

The schedule was adjusted slightly because of changes in direction and approach. In addition, one of the challenging issues was adhering the glass ribbon to the polymer. By changing the coupling chemistry and increasing the hot-press temperature, the problem was eliminated.

RESEARCHER RECOMMENDATIONS

The next step is to further validate the fundamental design, and expand the value of the new findings by:

1. Completing the process for making high index glass ribbon.
2. Utilizing high-clarity polysulfone to improve the optical clarity of the composite.
3. Continuing to develop the very promising COC polymer approach.
4. Changing the dimension of glass ribbon to accommodate composites with high glass content.
5. Upgrading the hot-press to produce 12" x 12"ballistic testing panels.
6. Proving the concept of a gradient composition composite.
7. Exploring other uses for the material.
8. Making armor windows with the transparent composite and polymer backings without using the hard, brittle glass plates.

For complete details of this research, please see the Appendix.