VACCINE

Visual Analytics for Command, Control and Interoperability Environments
A U.S. Department of Homeland Security
Science and Technology Center of Excellence

VACCINE ANNUAL REPORT – YEAR 7
JULY 1, 2015 – JUNE 30, 2016

Cooperative Agreement No. 2009-ST-061-CI0001

PURDUE UNIVERSITY

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I. Summary

A. Overview

Established in July of 2009, the Visual Analytics for Command, Control, and Interoperability Environments Center (VACCINE), along with its co-lead, Rutgers University, has served as the Department of Homeland Security's (DHS) Center of Excellence in Visual and Data Analytics. VACCINE's mission continues to focus on creating methods, tools, and applications to analyze and manage vast amounts of information for all mission areas of homeland security in the most efficient manner. VACCINE accomplishes its mission through an integrated program of research, education, and outreach, spanning the disciplines of visualization and computer graphics, engineering, computer science, geographic information systems, cognitive psychology, information technology, and emergency management and public safety. VACCINE is an international center with the overall management handled by Purdue University. The education/MSI mission is directed by Purdue University with partners Morgan State University, Florida International University, Jackson State University, Prairie View A&M University and Bethune-Cookman University.

The VACCINE team is currently comprised of the following 26 entities with the associated Principal Investigator listed for each school:

University	***PI***
Arizona State University	Dr. Ross Maciejewski
Carleton University, CA	Dr. Jim Davies
Dalhousie University, CA	Dr. Kirstie Hawkey
Florida International University (MSI)	Dr. Shu-Ching Chen
Georgia Institute of Technology	Dr. John Stasko
University of Maryland	Dr. Niklas Elmqvist
Justice Institute of British Columbia, CA	Dr. John Dill
Morgan State University (MSI)	Dr. Timothy Akers
Ontario Institute of Technology, CA	Dr. Christopher Collins
Pennsylvania State University	Dr. Alan MacEachren
Purdue University	Dr. David Ebert
Simon Fraser University, CA	Dr. Brian Fisher
Stanford University	Dr. Pat Hanrahan
University of Oxford, England	Dr. Min Chen
University of British Columbia, CA	Dr. John Dill
University of Calgary, CA	Dr. Sheelagh Carpendale
Jackson State University (MSI)	Dr. Richard Alo

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University	PI
University of North Carolina, Charlotte	Dr. William Ribarsky
University of Oxford, UK	Dr. Min Chen
University of Stuttgart, Germany	Dr. Tom Ertl
University of Texas at Austin	Dr. Kelly Gaither
University of Victoria, CA	Dr. Evert Lindquist
Oak Ridge National Labs	Dr. Robert Bridges
University of Notre Dame	Dr. Pat Flynn
Virginia Tech	Dr. Chris North
Bethune-Cookman University	Dr. Raphael Isokpehi
Prairie View A&M University	Dr. Louis Ngamassi

Figure 1: University Partners and Principal Investigators

VACCINE is strategically positioned to support the Department of Homeland Security in confronting the challenges of safeguarding our nation in preventing, responding to, and recovering from events including: criminal investigation, health surveillance, fraud detection, emergency response, natural disasters, and border and infrastructure security. VACCINE focuses on the research, development, and deployment of interactive visual analytic environments for decision making and communicating information among the massive homeland security data deluge. VACCINE integrates data and analysis into interactive visual displays to enable users to make discoveries, decisions, and plan action using a variety of information sources and visual/analytical techniques. Turning massive data into actionable knowledge through the field of visual analytic is vital to the mission of the Department of Homeland Security and its mission areas.

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B. Accomplishments

Throughout Year 7, the VACCINE team worked diligently to create a robust portfolio of research and academic projects, as well as to make significant progress in our outreach and overall transition activities. Highlights of our team's efforts include the data in Figure 2 as well as the following:

- VACCINE continued to build our **multi-agency public safety consortium** as well as our team of experts with additional organizations; we developed new relationships with organizations such as the Cleveland Indians Baseball Park, USCG MIFLANT, LEIC/HUMINT CRM, Oklahoma Bureau of Investigation, Homeland Security Tennessee Intel Fusion Center, and Cleveland Area Police Departments that supported the Republican National Convention; Independence PD, Independence Fire and Rescue, North Olmsted PD, Twinsburg PD, Westlake PD, Rocky River PD, Solon PD, Brecksville PD, and the Greater Cleveland Regional Transit Authority.
- **Facilitated Southern Border Goals and Metrics Working Group:** A workshop was conducted in San Juan, PR, under the guidance of DHS Joint Task Force East Director, Coast Guard Vice Admiral Dean Lee, with participation from DHS component agencies, NORTHCOM and SOUTHCOM. The workshop fostered discussions with U.S. government senior officers to identify common, key strategic-level objectives between the respective southern border initiatives of the participating entities. The outcome of this working group was a summary of recommendations to senior leaders present in Puerto Rico regarding the future coordination of tasks in support of these common strategic objectives. To ensure the alignment of these newly identified shared goals with performance metrics, the group also began to explore how success would be measured.
  The catalyst for the workshop was the announcement by DHS Secretary Jeh Johnson regarding the creation of three DHS Joint Task Forces in January 2014 with the goal of integrating DHS component agency activities along the southern U.S. border and approaches in order ensure a unified and coordinated DHS approach to combat threats and reduce risks related to terrorism, illicit market-driven flows and illegal migration.
- Our **Visual Analytic Law Enforcement Toolkit (VALET)** is actively being used at the Lafayette, West Lafayette, Purdue University, and Evansville Police Departments. Further, the Indianapolis Police Department, the Tippecanoe County Sheriff's Office, the Ohio State Highway Patrol, the Illinois State Police, and the New York Police Department have all begun testing or deploying the tool. As the predictive analytics component of the software continues to improve, we continue to receive input and feedback to make adjustments to the technology in order to optimize it for use in the field. One of those adjustments is the development of the Officer Performance solution to gamify the performance of police officers in Lafayette Police Department for better performance comparison and for motivating maximized performance. Additionally, we have contracted with a consulting firm to ensure the software is commercial grade. The mobile version of VALET (iVALET) continues to be a popular option for law enforcement officers depending upon their roles and responsibilities. VALET has been utilized to devise novel data guided patrolling strategies and has led to a paradigm operational shift at several police

departments. VALET has also supported investigative analysis tasks at the departments who utilize the system. For example, the system played a critical part in the investigation of a string of business burglaries by the Evansville police department. In keeping with the goal of transitioning this software, we have licensed the technology to a startup company called Davista Technologies, LLC that was born out of the VACCINE center. The company is developing a sustainable transition model in order to continue the development and commercialization efforts of the technology. The company is also currently engaged in developing a data driven solution for a large private corporate firm for optimally allocating their safety and security related resources. Davista is leveraging the core VALET technology in the development of this solution.

- **Jigsaw** is being used by the Indianapolis Police Department, the West Lafayette Police Department, the Rock Hill Police Department (SC), and the Lafayette Police Department. We have continued our development and distribution of the Jigsaw visual analytics system. (See http://www.cc.gatech.edu/gvu/ii/jigsaw.) During the past year, we did not add new functionality to the system per se, but we made a number of bug fixes and we released a new version. We have had approximately 7000 downloads of the Jigsaw system in its history. It is being used in various university classes on visual analytics and intelligence analysis and has been downloaded by a wide variety of organizations in government and industry. (We do not formally track who is using it and how they are using, but some are listed at the end of this paragraph.) We have just recently begun discussions with some Defense Dept. individuals who would like to have the system be approved for deployment on defense computers. Examples of organizations that have downloaded JIGSAW are; Air Force Intelligence, AFRL Wright Patterson, Army Counterintelligence, Boeing Deloitte, Naval Research Lab, NCIC, PayPal, Thomson Reuters, United Nations Investigators Office, US Attorney's Office Organized Crime Taskforce, as well as numerous newspapers and police departments.

- **GARI (Gang Graffiti Recognition and Analysis)** is a cell-phone-based and desktop-based tool for gang graffiti and tattoo analysis and recognition. This tattoo identification system finished second in the NIST/FBI TATT-C challenge in 2015. It is being used by the Indianapolis Metropolitan Police, the Indiana Intelligence Fusion Center Gang Task Force, the INGang program, the Cook County Sherriff's Department, the Navajo Nation, and the Illinois State Police. Additionally, a number of other law enforcement entities (approximately 400) have expressed interest in using and deploying the tool. We have developed a community version for release that runs in a similar manner, but only allows for the reporting of graffiti with no information visible to the individual uploading/reporting the graffiti image. The tool is in operation and has servers installed at the Indiana Intelligence Fusion Center in Indianapolis and the Cook Country Sherriff's Department in Chicago; a long term plan for maintenance and support is being explored. There are currently 227 users of the system in Indianapolis with 3682 images, and 114 within Cook County with 6332 images and 17 users in Stockton, CA with 568 images.
Currently, discussions are underway with the Purdue Foundry on commercialization efforts of GARI.

- **Catching Criminals on Video: Video Be on the Lookout (vBOLO)** Video surveillance systems are used by law enforcement and transportation authorities as an important safety measure. It can be challenging to link a subject who was recorded committing a crime in one surveillance camera to their re-entry the surveillance system hours or days later. The Center for Visualization at Data Analytics (CVADA) at Purdue University and ALERT is developing the **Video Be on the Lookout (vBOLO)** system that can help re-identify subjects of interest as they re-appear in a surveillance system. The first phase of the project demonstrated the potential effectiveness of computer-vision-based re-identification, but also indicated areas where more research or better physical infrastructure was required. The current vBOLO system can currently find the correct person in a lineup of 10 automatically-detected candidates 90% of the time for one camera. CVADA-Purdue and ALERT expect to improve performance of vBOLO to find the correct person in a lineup of five candidates 95% of the time. This would involve the addition of high resolution video, facial analysis, motion features, improved body features, and subject attributes.
- **The Social Media Analytics and Reporting Toolkit (SMART)** system provides users with scalable and interactive social media data (e.g., Twitter, Instagram) analysis and visualization, which includes real-time monitoring of social media channels, extraction of trending and abnormal topics, interactive geospatial and temporal visualizations, and task-tailored message categorization and dynamic filtering tools. In addition, web and news media sources are incorporated in the system so that users can search and correlate news articles of interest with social media posts. The system enables users to perform their exploration and analysis across a range of data scales from local (e.g., precinct, neighborhood) to global (e.g., city, state). In addition, SMART incorporates novel visual analytic techniques to extract and visualize crowd movement patterns and trajectories using social media data in order to allow users to detect anomalies and outlier patterns. SMART also provides an email alert/summary service to automatically send emails related to user-defined topics. The system provides such functionalities through not only a desktop application, but also a highly interactive and accessible web interface. SMART has been actively used by several local, state, and federal HSE organizations, including the US Coast Guard, US Customs and Border Protection (CBP), and US Citizenship and Immigration Services (USCIS). The US Coast Guard has utilized SMART to obtain a situational awareness during several of their events (e.g., Fleet Week, Riverfest). The Purdue University police and Ohio State Depart of Homeland Security have utilized SMART during their home football games and have been able to obtain actionable information and thwart potential safety and security related incidents using the system. Additionally, the SMART tool was deployed at the joint Canadian-US Enhanced Resiliency Experiment (CAUSE) organized by the US DHS S&T Directorate and the Defense Research and Development Canada's Center for Security Science. The system was utilized to provide a shared situational awareness during the binational exercise. Moreover, SMART has been used to support the investigative analysis of hoax distress calls by Coast Guard analysts in order to utilize social media data as another source of information. This analysis was driven by approximate locational information obtained from Rescue 21 system. Finally, the SMART system was utilized by over 12 law enforcement agencies and first responder groups at the Republican National Convention held in Cleveland in July 2016 in order to provide actionable intelligence and early warning indicators of potential demonstrations and acts of violence or disruptions during the event. SMART has also been licensed to

Davista Technologies who continue to support the existing end-user groups and are actively seeking partnerships with commercial corporations to further refine their market penetration strategy with the technology.

- **Multimedia-Aided Disaster Information Integration System (MADIS)** The goal of this project is to design and develop data-driven solutions to achieve context-aware and user-specific information integration, delivery, analysis, sharing, and collaboration in disaster information management. This year, a new component for the searching and retrieval of disaster videos was added to the MADIS system, which enables the system to retrieve both videos and images relevant to a specific disaster. Moreover, situation reports which are uploaded by users will be automatically converted to the PDF format and highlighted with the defined keywords.
- **Context-Driven Visual Analytics for Cyber Defensive Operations** We've developed a novel graph-analytic approach for detecting anomalies in network flow data called GraphPrints. Building on foundational network-mining techniques, our method represents time slices of traffic as a graph, then counts graphlets--small induced subgraphs that describe local topology. By performing outlier detection on the sequence of graphlet counts, anomalous intervals of traffic are identified, and furthermore, individual IPs experiencing abnormal behavior are singled-out. Initial testing of GraphPrints is performed on real network data with an implanted anomaly. Evaluation shows false positive rates bounded by 2.84% at the time-interval level, and 0.05% at the IP-level with 100% true positive rates at both.
- **Chicago LTE Pilot Project** The goals of this project were to test the viability and performance of the LTE National Public Safety Broadband Network (NPSBN) with respect to transport of video imagery. One cell using the NPSBN was installed in Chicago at the Chicago Police Department District 7. We conducted a test plan to characterize the performance of the network and analyzed the data collected. The test plan consisted of three parts: First, objective perceptual video quality tests designed to measure the video quality when video is streamed in real-time over the LTE network were conducted. Second, subjective measurements were conducted to characterize the performance of applications of interest under various test conditions. Third, network performance metrics were obtained to test the key performance indicators associated with the network. Based on the analysis of the data collected during our testing it was concluded that a PSBN LTE network provides an unprecedented opportunity to increase the capacity and to meet the needs and requirements of public safety with respect to video delivery. Careful analysis should be used for Quality of Service (QoS), prioritization and Radio Frequency (RF) planning when designing a NPSBN LTE system. It was also noted that adaptive video coding methods, used in many video systems, might not suit public service operational scenarios. System designer should also take into consideration video usage in a task-based approach.

- **VASA** - A system of systems model has been set up for investigating a regional electric smart grid infrastructure under duress from natural or man-made disasters. This system can investigate weak points and cascading effects due to failures in an overall infrastructure including electrical, water, transportation, food distribution, and other components. A Web service was set up so that onsite managers could access the results of these large scale simulations on mobile devices such as a laptop or tablet computer, providing the capability to determine what will happen, when and where it will occur, and who and what infrastructures will be affected so that immediate, appropriate action can be taken. Work is being done with NC government partners, utility companies, and VACCINE colleagues.

- **The Coast Guard Data Profiling and Quality Assurance** project undertaken by VACCINE focused on developing a visual analysis system that facilitates the data Quality Assurance (QA) tasks currently manually performed by CG analysts. The purpose of this effort was to design and prototype a data profiling visual analysis system that enables CG analysts to identify and communicate the data quality problems in the CG MISLE database that pertain to law enforcement sightings and boardings. The system designed by VACCINE allows CG analysts to upload data from the MISLE database and provides a graphical user interface to perform the different data profiling tasks. This system automates the data cleaning tasks that are currently being manually performed by the CG analysts. Analysts have been provided with the ability to analyze and evaluate the intermediate results in order to make any appropriate adjustments and refinements. The prototype system incorporates data visualization techniques that allows CG analysts to publish the QA results at various levels of aggregation (e.g., unit, station, sector, district). It is anticipated that this tool will reduce the overall time spent on the Quality Assurance tasks and improve the accuracy of the data.
- **Finding anomalies in complex financial data** is a challenging task. Many metrics and statistical algorithms exist for the purpose of finding statistical/data anomalies. These anomalies represent unusual occurrences, and without context, explanation, and evidence it is difficult for people to determine if these are relevant anomalies and if corresponding actions should be taken. Conventional charts (e.g., line graphs) traditionally used in financial data analysis provide limited support to detect and explore such financial anomalies, especially in the absence of any related contextual information. Contextual evidence is often available through additional data sources such as news articles, blogs, social media posts, etc. However, finding relevant contextual evidence in these additional data sources is a challenging problem. In this work, we have collaborated with groups of financial analysts and identified tasks, goals and requirements of a visual analytics system that could be used to not only detect and explore anomalies in financial data but also explore contextual evidences available through news media sources to understand the relevance of these anomalies. Our system integrates state-of-the-art visualization techniques combined with automated anomaly detection, enabling an anomaly-driven exploration of financial and news data. We demonstrate the effectiveness of our system with case studies and feedback from groups of domain experts.
- **SuccessVis:** We have started the development of a visualization of the Center's historical success and impact over the eight year period. The Center will create an interactive "event river" visualization tool of our COE success and impact that will be placed on our website in the form of a "timeline." Key pieces of information about each project that will be able to be accessed from this visualization through time include the project reports and videos, links to news stories, one-page fact sheets about each technology, etc. Such a visualization tool will aid in easy and lasting sharing of information in presentations, iPad demos, etc. by VACCINE as well as any DHS staff when communicating about the work of the Center. We plan to complete this visualization tool in 2017.

- **Safety in View:** Campus security and police departments have implemented a multitude of safety precautions, including CCTV cameras. The efficiency and effectiveness of using CCTV camera resources for preventing crimes result in higher demand. We implemented a visual analytics tool to analyze the existing CCTV camera resources and suggest improved allocation schemas based on blind spots and crime data. Our tool provides the user with an interactive safe path calculation method for walking purpose on the basis of the maximum monitoring area. Additionally, avoiding buildings in the calculated path is an optional control factor. Our tool also provides functions for crime data analysis. The camera-ranking function highlights the camera that records the largest number of crime incidents. Based on the historical crime data, we suggest locations for future camera installation. In addition, we have included features of discovering public network cameras from heterogeneous sources and find the accurate locations and orientations of the cameras.
- We continue to develop our network of **Minority Serving Institutions** for engaging in visual analytics research and education. Over the past year, there were numerous engagement opportunities and a number of collaborative projects with the MSI partners in both education and research. We welcome our newest MSI partner, Louis Ngamassi from Prairie View A&M. Additionally, this year we rotated the MSI Faculty Training to host at our partner school, Florida International University (FIU). FIU continues to research and develop various visual analytics tools and systems for first responders in the Miami-Dade community.

Totals	
Categories of Accomplishments	7/1/2015 through 06/30/2016 : (Number/Amount; numbers only)
Student Enrollment in COE Programs:	
Traditional undergraduate and graduate students attending classes	631
Students registered in on-line or other distance learning courses	0
Homeland security professionals attending courses	0
COE Funded Students	28
Papers	43
Software Products Developed	8
New Courses Developed	1
New Certificates or Degree Programs Developed:	
New Degree Programs	0
New Certificates	0
New private or public licencees/partners using coursework licensed by the COE	0
Patent Applications	1
Patents Awarded	0
Requests for assistance or advice from DHS (# of different DHS contacts/projects/requests)	6
Requests for assistance or advice from Federal, State, Local Government	26
Follow-on funding from other sources	$70,000
Presentations	37
Congressional Testimonies	0
Projects Completed	3
Collaborative Projects	

Figure 2: Summary of VACCINE Accomplishments

C. Business Model and Management Scope

The role of developing detailed operational requirements is critical for the successful transition of technologies into the various homeland security fields. The VACCINE Center of Excellence recognizes the need for significant end-user involvement through the entire life cycle development process. The VACCINE team has refined our business model (Figure 3) with the goal of connecting homeland security researchers with the intended end-users. Understanding the requirements of our end-users is critical to the research and development of technologies, which will be transitioned to the broader homeland security community, and secondarily to other markets. Part of that understanding takes the form of our Public Safety Consortium exchanges as well as our regular project meetings with stakeholders and end-users.

The Public Safety Consortium consists of a number of law enforcement, first responder, emergency management, and federal agencies that allow for data to be shared and research conducted, furthering the development of next generation homeland security technologies. The Consortium provides a framework where VACCINE can deploy its tools to the various agency members, and our end-users provide in-field or real world evaluation and feedback. The group meets regularly to discuss ongoing changes to technology and tools being developed, improvements to technologies that have been deployed and are being evaluated, as well as to brainstorm future tools that would facilitate increased accuracy and ease of understanding data. Year after year, the Public Safety Consortium continues to grow, and VACCINE continues to expand its end-user community beyond our local community. Technologies designed in this fashion have the ability to be translational across a larger community of end-users geographically.

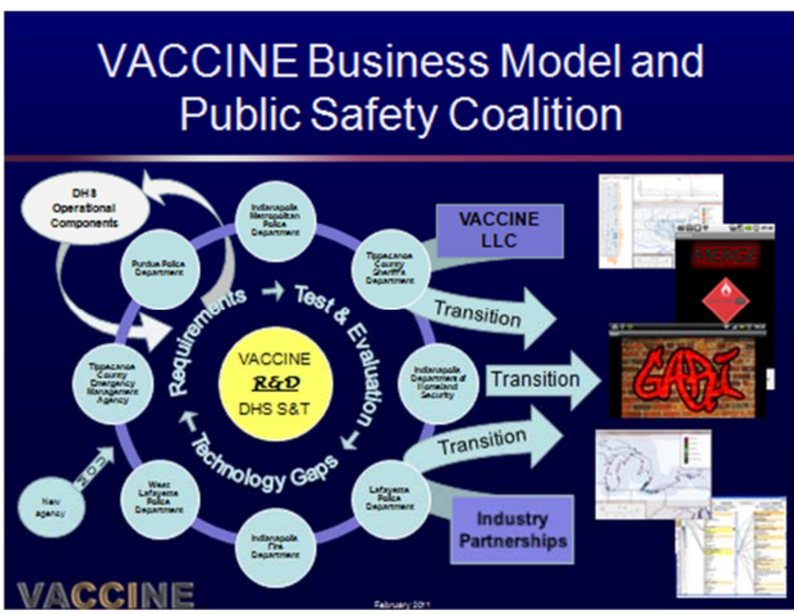

Figure 3: VACCINE Business Model

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The VACCINE team has a strong, collaborative history and experience, which is essential to fostering internal collaboration, as well as collaboration with other DHS COEs, government agencies, field personnel, and researchers. Our Center's management structure has three components: management staff, a leadership board, and an external advisory board. The management staff is kept intentionally lean in order to maximize research and education funding while minimizing overhead. This team is responsible for overseeing the strategy, as well as the day to day operations of VACCINE. VACCINE staffing includes a director, managing director, research scientist, center coordinator/administrative assistant, and education manager (part time) and finally an engagement and transition manager.

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II. Research and Development Scope

The overarching mission of VACCINE is to address the challenges associated with analyzing and managing the vast amounts of information for all mission areas of homeland security. VACCINE has focused on creating, deploying, and evaluating innovative and effective visual analytic environments in order to analyze massive, heterogeneous, incomplete, and dynamically evolving data for anticipating, detecting, and responding to the different homeland security mission needs. VACCINE has developed novel dynamic visual analytic techniques based on cognitive and perceptual principles that increase the user's effectiveness and create precision information environments. VACCINE's primary goal is to enable homeland security personnel to make sense of the sea of text, sensor, audio, and video data by developing powerful analytical tools and interactive visual decision making environments that enable quick, effective decisions as well as effective action and response based on available resources. To do this, VACCINE integrates data and analysis into interactive visual displays that allow users to make discoveries, decisions, and plan actions.

The ever-growing volume of homeland security, science, engineering, and user-generated data has created a need for valuable, timely analytical tools that enable interactive visual analysis for comprehension and provide critical insights from this sea of data. This problem, often referred to as the "Big Data" problem, continues to be a growing topic within the IT and business community. VACCINE researchers have focused on Big Data challenges since 2004 when Dr. Joe Kielman and DHS-funded Dr. Jim Thomas led a team to define the research challenges of visual analytics for the problems facing our nation. Our team has developed innovations in this area for over a decade and has extensive experience in solving Big Data challenges in the homeland security enterprise. Human-guided visual analytics can solve many of the problems that are still unsolved by most automated Big Data Analytics techniques.

VACCINE has focused on improving both data management and statistical data modeling in innovative visual analytic environments. To continue the successful deployment, scalability, and usability of developed technologies, we focused on integrating end-users from the beginning of a specific research and development project. Having our customers directly integrated with our projects allows them to instigate new projects, provide input and feedback, and transition paths for DHS technology transfer. Our projects are planned to be 6 to 36 months in duration with clearly defined deliverables and transition paths. Our main research thrusts are the following:

- **Core Visual Analytics Techniques –** Focusing on integrated, interactive visual exploration, analysis, and decision making environments to enable effective decisions from massive, time-evolving multivariate, and multisource data.
- **Interactive Scalable Analytics Techniques –** A key challenge is developing statistical, spatiotemporal, image, video, signal, machine learning techniques designed and adapted for human-in-the-loop visual analytic environments that scale to real world "Big Data" solutions.

- **Science of Interaction for Visual Analytics** – Key findings in visual analytics have demonstrated that collaboration over, and interaction with, data are key components of an integrated computational-human decision-making loop. This human-information interaction occurs at many levels from individual manipulation of data representation, to interactive cognitive discovery combined with automated analysis, to coordinative and distributed interactive analysis among groups of individuals. VACCINE has focused on clearly defining and developing a **Science of Interaction** to support ubiquitous and collaborative analysis and discovery utilizing new, transparent interaction tools.
- **Evaluation of Visual Analytics in Real World Environments** – Determining the effectiveness of visual analytic techniques and systems in actual operations use is a tremendous challenge since we are trying to determine if these new techniques and tools provide new insights, increase the rate of insights, or increase the effectiveness and efficiency of people doing complicated and sometimes very lengthy tasks. This is a completely different challenge than determining if someone can more readily find an outlier or pattern in a visualization or if someone can complete a very simple task more quickly. Traditional perceptual testing, computer interface, and human-computer interaction techniques are insufficient. Therefore, VACCINE researchers bridging cognitive science, visual cognition, human computer interaction, and visual analytics are exploring and advancing research in this area expanding and adapting techniques such as cognition in the wild and paired analytics.

Themes

Our research and development efforts can also be categorized into two thematic overarching projects, our End-to-End (E2E) projects, related to topic area and the end user community as follows:

- **Theme 1: Public Safety Coalition Projects** (e.g., state or local law enforcement, fire, emergency management)
- **Theme 2: Federal Operating Component Projects** (e.g., TSA, FEMA, Secret Service, ICE, CBP, USCIS, Coast Guard)

All of the projects associated with these themes have the following key pervasive homeland security problem characteristics: massive, time evolving, heterogeneous data of varying quality; multiple-scales of problem solving, planning, management, and action; coordinated information analysis; information security and privacy challenges; and a wide variety of needs, skills, and computing resources of involved personnel. The following is a list of research highlights that occurred during Year 7. Detailed descriptions of individual research projects can be found in Part V, Research Projects and Descriptions (listed by institution).

Theme 1: Public Safety Coalition Projects Representative Project Highlights

- VACCINE continued to provide support to its **multi-agency public safety consortium** with organizations within the state of Indiana and across the Midwest and Country.
- **Jigsaw** is available for free download and is being used by the Indianapolis Police Department, the West Lafayette Police Department, the Rock Hill Police Department (SC), and the Lafayette Police Department. The program has been downloaded over 1100 downloads by various organizations, including Air Force Intelligence, AFRL Wright Patterson, Army Counterintelligence, Boeing, Deloitte, Naval Research Lab, NCIC, PayPal, Thomson Reuters, United Nations Investigators Office, US Attorney's Office Organized Crime Taskforce, as well as numerous newspapers and police departments.
- **GARI (Gang Graffiti Recognition and Analysis)** has been transitioned and deployed for use across Indiana through deployment the Indiana Fusion Center Gang Task Force Network (INGANG). It has also been deployed to the Cook County Illinois Sherriff's department and they are in the process of uploading over 20,000 gang graffiti images into the database. Furthermore, the system was also delivered to the Stockton, CA police for use in their investigative analyses. The system now also supports a tattoo database as well and the Indiana Department of Corrections is populating that database from their records. The center also received additional monies from Mitre to work on Gang Tattoos.
- The **Chicago LTE project** was developed to test the viability and performance of the LTE National Public Safety Broadband Network (NPSBN) with respect to transport of video imagery. One cell using the NPSBN was installed in Chicago at the Chicago Police Department District 7. VACCINE conducted a test plan to characterize the performance of the network and analyzed the data collected.
- An improved prototype system and iPad application based on Florida International's "**Integration Framework for Enhancing Emergency Response**" system continues to be evaluated by personnel at Miami-Dade Emergency Management (MDEM), and further pilot activities are planned as part of the evaluation process.
- VACCINE has developed an **officer performance application for law enforcement agencies** to assist them with designing effective metrics to evaluate the performance of their officers. This project entails creating a visual analytics system that enables supervisors to interactively develop metrics in order to evaluate the performance of officers, understand officer patterns and trends, and assist them in their operational decision making. A prototype version of the system has been delivered to the Lafayette, IN police department, and the system is being refined based on their feedback.
- Our **vBOLO (Video Be On the Lookout) project** is a collaborative effort between the ALERT and VACCINE centers. This tool has been developed to help identify subjects of interest as they re-appear in a surveillance CCTV network system. The system is being evaluated and refined by the Greater Cleveland Regional Transit Authority (GCRTA).

- The **GeoTxt application** has been designed to extract geolocation information from large, unstructured textual data generated via social media, news blogs, official reports and other sources. This application has wide applications in crises situations and threats of all kinds to the larger homeland security enterprise where locational information is critical in assessing the evolving situations. GeoTxt is available as an API upon request to the DHS partners and other collaborators.
- Our **VALET (Visual Analytics Law Enforcement Toolkit)** continues to be used at several partner law enforcement agencies for their daily operational use. The system is also being refined to incorporate novel predictive tools to devise effective data driven patrolling strategies for police departments.

Theme 2: Federal Operating Component Projects

- **SMART (Social Media Analysis and Reporting Tool)** continues to gain popularity with several new agencies that have requested the tool. It is currently being used by the USCG, CBP, as well as the American Red Cross. The USCG, for example, used SMART at the Thunder over Louisville event in 2015. This is a day-long air show and fireworks display held on and along the Ohio River in Louisville, Kentucky. Additionally, SMART was utilized by several of Greater Cleveland police departments to prepare for the Republican National Convention held in July 2016. The SMART tool was deployed at the joint Canadian-US Enhanced Resiliency Experiment (CAUSE) organized by the US DHS S&T Directorate and the Defense Research and Development Canada’s Center for Security Science. The system was utilized to provide a shared situational awareness during the binational exercise. Furthermore, SMART has been used to support the investigative analysis of hoax distress calls by Coast Guard analysts in order to utilize social media data as another source of information. This analysis was driven by approximate locational information obtained from the Rescue 21 system.
- We engaged with the **United States Citizenship and Immigration Services (USCIS)** on a project that involves integrating news sources into the SMART toolkit to provide contextual information on their refugee and asylum cases. This enhanced SMART solution prototype was delivered to the USCIS for further testing and refinement.
- The **Coast Guard Data Profiling and Quality Assurance project** undertaken by VACCINE comprised of developing a suite of analytical tools for the U.S. Coast Guard in order to enable analysts to verify the quality of data entered into the MISLE sightings and boarding database. An initial prototype of the solution has been delivered to the Coast Guard.

III. Education Programs and Outcomes

VACCINE's mission is to educate current homeland security stakeholders and the next generation of talent in effective development and use of visual analytics systems. Our educational initiatives span the career development pipeline ranging from undergraduate and graduate level work to professional education and training programs. Our goal is to build a diverse, highly capable, technical workforce for the Department of Homeland Security enterprise by administering various programs and initiatives at our center, partner research institutions, and minority-serving institutions.

During Year 7, VACCINE's educational initiatives maintained focus on undergraduate and graduate level work (including work with MSI institutions), professional education and training programs. This process of educating various groups provides an outreach component for VACCINE we could not otherwise accomplish. The VACCINE team is able to reach a variety of audiences and give them a brief, but helpful view of visual analytics and what can be accomplished.

Minority Serving Institution Partners

VACCINE has a number MSI partners which are Florida International University, Morgan State University and Jackson State University. We have worked closely with these schools in the research area as well as the educational mission of the center. Throughout year 7 of the VACCINE center, there were numerous engagement and learning activities conducted with our MSI partners. A few are mentioned below:

- Our fourth annual MSI Faculty workshop on Visual Analytics was held at Florida International University in May of 2016. We had 20 active faculty members participate in the workshop from all over the country. Faculty instructors Dr. David Ebert (Center Director, VACCINE), Dr. Ross Maciejewski (Ph.D., Arizona State) and Louis Ngamassi (Ph.D., Prairie View A& M) gave a two-day summary of visual analytics applications and content, how that can apply to various disciplines, and how to successfully integrate VA into their course curriculum. The attendees were other faculty members from MSIs who do not have familiarity with visual analytics. The second day of the workshop was a group strategy session on developing learning modules to insert into current curriculum. The workshop was also attended by a DHS representative who spoke to our group about the various MSI initiatives DHS has to offer.
- VACCINE hosted two Morgan State University undergrads who visited Purdue's campus for a one-week boot camp in Visual Analytics. The students were exposed to a number of VACCINE Center and commercial tools, and research to help understand the power of using visual analytics.
- Prairie View A&M University has become VACCINE's newest MSI partner thanks to the dedicated relationship with Dr. Louis Ngamassi. Dr. Ngmassi worked with VACCINE in July of 2016 as part of the DHS SRT program, and was awarded follow-on funding from this program and from VACCINE. Louis was successful in creating a new course on Crisis Informatics with Visual Analytics integration.

Undergraduate/Graduate Course Program

HS-STEM Career Development Program

The HS-STEM Career Development program is a competitive program funded through DHS that was established at Purdue in 2007 under Dr. David Ebert. Monthly HS STEM lunches are provided in order to offer learning and networking opportunities for students with various disciplines, but who all share an interest in Homeland Security. This is a time for students to discuss their career aspirations and status, and determine if their plans are consistent with a career in homeland security. Additionally, students are required to submit semester reports and updates on their research and any service in which they are participating. The VACCINE team, encourages the HS STEM Fellows to serve as research assistants in the VACCINE lab if they are qualified. This initiative began in the fall of 2014, and it is expected they will have a more direct understanding of Homeland Security as a result of their participation on VACCINE projects. The following is a brief description of each HS STEM Fellow:

Phillip Forsberg successfully completed the program and graduated in August of 2016. His year of service was fulfilled by working full-time at Pacific Northwest National Laboratory (PNNL) at the Department of Energy in Washington DC. He worked within NA-14, the Office of Decision Support, within Defense Programs (NA-10). They are responsible for directing the safe, secure, and effective operation of nation's nuclear stockpile. At the end of his year of service, he was offered a permanent position as a federal employee at the Department of Energy.

Scott Carr passed his preliminary exams. He is currently working on his thesis, and Scott is on track to graduate in December 2016. His accomplishments include a paper accepted to Network and Distributed Systems Security Symposium, a top tier cybersecurity conference, and he submitted a paper to Computer and Communications Security Symposium 2016. Scott was awarded the Network and Distributed Systems Security Symposium Travel Grant. During the spring semester, Scott interned at Mozilla in San Francisco, CA where he worked on the Rust programming language compiler. Rust is a system programming language designed to increase the security and reliability of performance critical applications.

Jeff Avery passed his preliminary exams, and he will begin focus on his thesis. Jeff is on track to graduate in May 2017 or August 2017. This past year he continued to work 10-20 hours a week as a Research Assistant under Professor Gene Spafford. His research develops methods to apply deception to security, with an interest in applying deception to the vulnerability patching cycle. Jeff also presented his ideas on "The Cost of Deception" and "Ending Password Cracking" at the 2016 CERIAS Symposium. He is co-author to two of three papers submitted to conferences and journals, and was also awarded AGEP Scholar.

Whitney Huang continues his role as a research assistant and he is currently working on his Ph.D. with a major focus on statistics of extremes with applications to atmospheric sciences. He is studying an alternative approach, namely Logspline density estimation, to the most commonly used extreme value theory (EVT) based approaches. Whitney attended a Workshop on Spatial Statistics in Texas and a workshop on Uncertainty and Causality Assessment in Modeling Extreme and Rare Events for the National Center for Atmospheric Research in Colorado. Whitney gave several presentations throughout the year, including one on "estimating changes in temperature extremes for millennial scale climate simulations using generalized extreme vale (GEV) distributions" to the Data Science Seminar at the College of William and Mary in Virginia. He is also co-author on the following publications that have been submitted and waiting on acceptance: 1. "Estimating changes in temperature extremes from millennial scale climate simulations using generalized extreme value (GEV) distributions" 2. "Evaluation of dynamically downscaled extreme temperature using a spatially-aggregated generalized extreme (GEV) model. He is also an award recipient for the Purdue Research Foundation (PRF) Fellowship 2016/2017.

Rachel Sitarz is currently working on her dissertation and she is starting on her preliminary exam preparation. She is working full-time as a Senior Computer Scientist for Computer Science Corporation (CSC) where she specializes in Threat Intelligence. Rachel monitors networks for malicious activities. She was selected as a Duo Security Women in Cyber Security award recipient, and she was invited to sit on the board for Harrison College Criminal Justice Program. She has provided many presentations on internet safety at schools in Indiana, Illinois and Iowa. Rachel's anticipated date of graduation is in 2017.

Kelly Cole is currently working on her dissertation proposal and is on track to graduate in 2017 in the field of Cyber Forensics. She has published two papers in the past year and she worked as an intern at Sandia National Labs. She participated in several research studies including "Email Scam Awareness, A Review of Current Case Law Related to Digital Forensics."

Thomas Gorko successfully graduated, earning a MS in Computer Science in August 2016. Tom is currently employed at Epic Systems, a privately held healthcare software company. He is working toward completing his Year of Service requirement.

Brian Olsen graduated with a masters of Computer Science in May of 2016, and he has successfully completed the HS-STEM program by meeting all of the requirements and completing his year of service. Brian is currently working at Trustwave, a security firm that aims primarily to help businesses and government agencies secure their information.

David Wizsowaty graduated with a Masters of Computer Science in May of 2016, and he has successfully completed the HS-STEM program by meeting all of the requirements and completing his year of service. David is currently working full-time for Allstate Insurance as a software developer.

Kevin Xu was unable to complete the program.

Frederick V. Greene graduated with his Ph. D. in August 0f 2016, and he has successfully completed the HS-STEM program by meeting his requirements, and completing his year of service. Fred presently serves as an Associate Professor of Business Law and Management at Eastern New Mexico University.

Tyshia Gwinn Wellman has successfully completed the HS-STEM program and she met all of her requirements. Tyshia is currently working on her Ph.D. at Harvard University. Her research has been on the HPV virus on a cellular level.

Summer Undergraduate Research Fellowship (SURF) Program

Every year VACCINE participates in the SURF Program. This year, the VACCINE lab was home to 4 students for the summer of 2016 as a part of Purdue University's SURF (Summer

Undergraduate Research Fellowships) Program. The 10-week program allows students to conduct research and work closely with our graduate students and research assistants in the VACCINE research laboratory, and it gives them the ability to explore, discover, and transform ideas into reality. The SURF program gives undergraduate students with interest in engineering, science, and technology the opportunity to conduct research and work closely with faculty members, graduate students, and other researchers throughout the summer. Students worked on VACCINE projects and technology throughout their summer fellowship, which concluded with a poster presentation of their research at the annual SURF Symposium on August 4th. The four participants and their research are as follows:

- **Pradeep Lam**: Viticulture NSF Grant
    - He worked on a visual analytics interface for GDD (Growth Degree Day) prediction model. The interface will allow the users to interactively load historical/current temperature datasets and specify different seasons for the historical growth cycle of the grapevines. The system will then automatically calculate the seasons of the current year based on the GDD value. The interface will also show the detailed time-series of different temporal ranges so that users are able to investigate the reasons behind the different prediction results.
- **Igal Flegman**: iVALET and Viticulture NSF Grant
    - With a focus on iOS platforms, he worked on stabilizing the iValet program. He also worked on prototyping the viticulture visual interface on the IOS platform.
- **Qian Zhang**: VALET
    - Qian worked on police officer resource allocation for patrol routes. In order to improve the efficiency of police officer patrol routes, Qian developed a useful extension tool of the current VALET system. The new widget takes advantage of the crime prediction in the near future, which is generated based on the historical crime data. This project incorporates three steps to generate recommended police patrol routes. First, using the historical crime data to generate predicted crime hotpots and show the results using a Heatmap. Second, it provides a detailed contour lines visualization to distinguish the crime count and crime categories. Third, police officers can be assigned to a customized patrol route according to their specialties. With the proposed enhancement, law enforcement agencies are able to explore the relevant crime information intelligently and they can allocate patrols wisely.
- **Kush Rustogi**: SMART
    - Kush spent his summer developing widgets that enable the passive monitoring of SMART. He developed specific user interface plugins that allow an analyst to easily realize and distinguish the events that occurred while the system was unmonitored.

Professional Development

Webinar Series with American Military University

During the past year, VACCINE and American Military University collaborated to present a quarterly webinar series. The webinars are in coordination with the framework of The National

Conversation on Homeland Security Technology that was created by the Department of Homeland Security Science and Technology Directorate (DHS S&T). Each webinar focused on a specific structured topic related to homeland security technology in an effort to get people talking about problems, challenges, and solutions to keep our country safe. Over the year, we conducted four successful webinars:

1. **Decision-Making and Counter Terrorism: How the Visual Analytics of Data Can Help Save Lives**, presented by Dr. Dennis Thom, VACCINE PI, Institute for Visualization & Interactive Systems, University of Stuttgart, and Dr. James Hess, Faculty Director & Associate Professor, School of Security and Global Studies, APUS, American Military University.
2. **Visual Analytics: A Case for Ethical Decision Making**, presented by Dr. Abish Malik, Research Scientist, VACCINE Center, and Charles M. Russo, Intelligence Analyst & Certified Adjunct Faculty Member, Federal Bureau of Investigation, Adjunct Instructor, School of Security & Global Studies, American Military University.
3. **Maritime Smuggling: How Technology Can Disrupt the Network**, presented by Dr. Edward Delp, Professor of Electrical and Computer Engineering, Purdue University, and Dr. Joe DiRenzo, III, Professor of Intelligence Studies, American Military University.
4. **Unlocking the Power of Resilient Communities: How Veterans Help HRD Practitioners Optimize their Workforce**, presented by Brian Fisher, VACCINE PI, Associate Professor, School of Interactive Arts and Technology, Simon Frasier University, and Dr. Valerie E. Davis, Associate Professor, School of Security and Global Studies, American Military University.

Education and Training for First Responders

VACCINE routinely presents the tools and technology developed to a number of different law enforcement entities. Occasionally those presentations take the form of professional training in addition to demonstrations on the types of tools and applications developed by VACCINE. Additionally, some of the tools have completed training videos that are shared with first responders. During the VACCINE Annual Meeting in October 2015, law enforcement officers and first responders were trained on a number of VACCINE tools (VALET/iVALET, SMART, and GARI) by our Research Assistants.

Over the course of the year, there were several training sessions and webinars for our social media tool, SMART. SMART was presented to Natalie Grant from US DHHS/ASPR/OEM/Recovery, Darrell Eaton and Mathew Leclaire from the United States Coast Guard, and Omar Jufko, manager of security for the Cleveland Indians Baseball team.

VALET, our law enforcement toolkit, has an ongoing webinar/call ever 2 weeks with the Ohio State Highway Patrol to visualize their accident database. We also continue to share VALET's latest features with the Lafayette Police Department (LPD). We recently delivered to LPD a resource allocation tool that enables the distribution of police patrols based upon predicted crime and officer performance.

IV. Technology Transition

Throughout this document, it should have become evident that VACCINE is committed to getting our technologies and programs into the hands of the individuals that need them. Since VACCINE's inception in 2009, DHS has gradually moved towards an aggressive technology transition strategy. It is imperative to show value to the end-users via getting VACCINE tools deployed. As mentioned earlier, the role of developing detailed operational requirements is critical for the successful transition of technologies into the various homeland security fields. The VACCINE Center of Excellence recognizes the need for significant end-user-in-the-loop involvement in the entire life cycle development process.

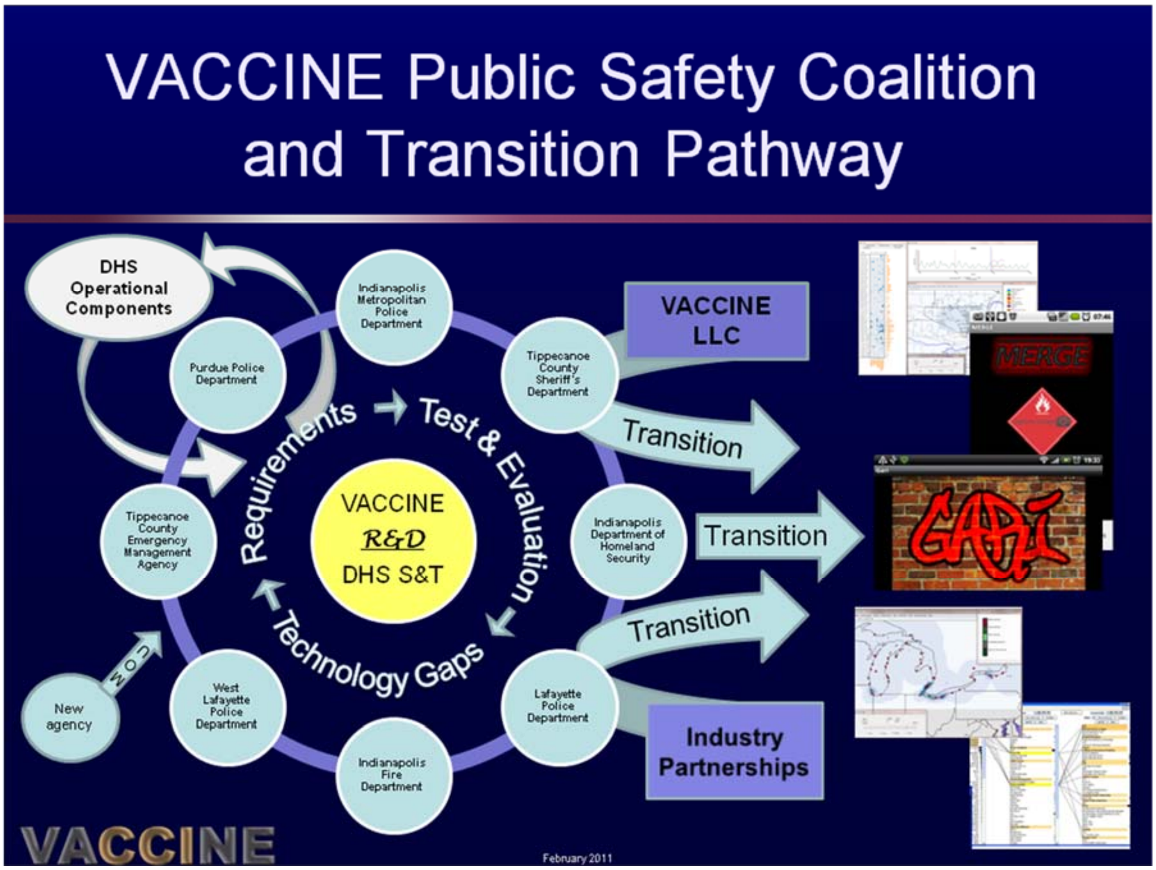

Figure 4: VACCINE Transition Pathway

The following list summarizes the VACCINE technologies and their stage of transition and deployment. While deployed for evaluation, the feedback we receive has resulted in continuous refinements to meet the needs of the users. In some cases, we are releasing new versions of technologies once a month.

JigSaw – Visual Analytics for Exploring and Understanding Document Collections (Georgia Tech)

- Deployed and currently used
- Available for download (free) on the website

VALET **-** Visual Analytics Law Enforcement Toolkit

- Deployed for test & evaluation feedback
- Lafayette PD, W. Lafayette PD, Purdue PD, Tippecanoe County Sheriff, Illinois State Police, Ohio State Highway Patrol, NYPD, Indianapolis Public Safety Department, University of Texas at Austin Police Department, New Albany Police Department, Evansville Police Department
- Licensing negotiations underway

GARI - Gang Graffiti Automatic Recognition and Interpretation

- Initial Prototype Deployed May 2011
- GARI server transitioned to the Indiana Intelligence Fusion Center March 2013
- GARI server transitioned to the Cook County Sherriff's Department May 2013
- Requested by hundreds of agencies
- Exploring providing the tool as a national app via iTunes and the Android App store and having a third party screen users.

cgSARVA - Coast Guard Search and Rescue Visual Analytics

- Deployed for Operational Use – USCG LANT – 2010
- Phase II almost complete for transition to 771

MERGE - Mobile Emergency Response Guide

- Initial Prototype deployed May 2011
- Indianapolis Fire, Lafayette Fire
- Being deployed to iTunes and Android App store

SMART – Social Media Analysis Reporting Toolkit

- Initial Prototype deployed in July 2013 to the Boy Scouts of America for testing at their Annual Jamboree
- The USCG tested SMART at the Thunder Over Louisville event. This is a day-long air show and fireworks display held on and along the Ohio River in Louisville, Kentucky. Thunder Over Louisville serves as the kickoff event for the annual Kentucky Derby Festival, culminating with the Kentucky Derby on the first Saturday in May. The 2014 event drew an estimated 650,000 spectators to the Kentucky and Indiana sides of the Ohio River, as well as approximately 120 recreational boats that anchored in the river.
- Still in testing and evaluating with a number of police and federal agencies. The Red Cross is interested in testing SMART for its application and use in disaster preparedness and response initiatives.

Table of Contents

Arizona

State University

ARIZONA STATE UNIVERSITY

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by July 30, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Institution: Arizona State University

PI and/or Co-PI: Ross Maciejewski

Project Name: Geographic Network Analytics Correlations for VALET

Academic Disciplines: Computer Science

Keywords associated with project: Crime Map, Visual Analytics, Networks, Geography

Theme for Research Projects (Check all that apply)
If this is not a research project, indicate "NA" below.

x	Public Safety Coalition Projects (state or local law enforcement, fire, emergency management, etc.)
	Federal Operating Component Projects (TSA,FEMA, Secret Service, ICE, CBP, USCIS, Coast Guard)
	Enterprise Resiliency Environments
	Event Evacuations
	Visual Analytics for Security Applications
	International Collaborations
	N/A

Theme for Education Projects (Check all that apply)

If this is not an education project, indicate "NA" below.

	Minority or Underserved Programs
	Undergraduate and Graduate Education Program
	Professional Education and In-Service Programs
x	N/A

VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

Students Supported on Project

Graduate Research Assistants (include name(s), university and department)

Feng Wang, Arizona State University, Computer Science Yifan Zhang, Arizona State University, Computer Science

Undergraduate supported students (need number only) 2

Other Graduate Students (non-supported) involved in project (need number only) 2

Other Undergraduate Students (non-supported) involved in project (need number only) 1

Student Thesis in 2015 (include name, thesis title, university, department, degree, date)
Yifan Zhang, *Visual Analytics for Spatiotemporal Cluster Analysis*. Arizona State University, Tempe AZ

Research Problem /Abstract (in 200 words or less, provide a summary of the project goals and objectives, **in simple language understandable to someone outside the project's field).**

In the field of security, the exploration of criminal incident reports for detecting trends, discovering anomalies and evaluating resource usage is an ever expanding issue for law enforcement agencies. An especially useful tool would be an analyzer program to reveal the relationship between infrastructure and crimes so as to make inferences about how to best deploy officials to enable smarter cities. Previous work on VALET in collaboration with ASU and PU has seen the deployment of geographical network analytics to create novel hotspot maps. In this work, we propose the use of the network data to form the basis of a predictive analytics method to capture correlations between infrastructure (locations in the town such as grocery stores, bus stops, etc.) and crimes. The first part of this task involves developing the methodology of automatically extracting city infrastructure using publically available data sources. Once this information is extracted, we will fuse this as a layer in VALET and enable the exploration of correlations of spatiotemporal hotspots to regional locations (businesses, parks, etc.). In this way, analysts can explore relationships on the geographic network. Using the spatial and temporal autocorrelations, we will then develop a novel method of criminal incident prediction along the geographic network. The second component of this project is to integrate these features into a visual analytics environment for law enforcement agencies and learn various design principles for Human-Computer Interaction and data visualization. This would involve working directly with VACCINE and PU and for this task we propose a graduate student exchange with PU (as done in the summer of 2015) to engage in the addition of these techniques to the current VALET system. This will enable the final technology transfer piece of this work.

VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

Technical Approach (Check all that apply)

Data Collection Methods

	Compiling & Sorting DB
x	Data Mining
	Expert Consultation
	Field Monitors
	Survey
	Other:

Analytic Methods

x	Case Studies
	Modeling
	Sampling
x	Statistical Analysis
	Other:

Nature of Research

x	Applied
	Basic
	Consultation
	Coordination/Integration
	Education
	Hybrid Basic—Applied
	Hybrid Applied—Consultation

Deliverables (other than publications and reports listed below)

Visualization modules for the VALET software and geographic network analytics services.

VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

Technology Transitions (describe any products/technologies in process or that have completed transition to commercialization; include actions and progress to date)

NA

Additional Funding Sources Leveraged: include amount, source of funding, PI and period of performance

NA

VACCINE Annual Report – Year 7

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Collaborating Partners (academic Co-PI's, businesses, or other government funding agencies)

NA

Collaborating End-Users (specific DHS operating components such as FEMA, TSA, Coast Guard or federal, state, local law enforcement, fire, emergency management, etc.)

Please provide name of agency, contact name and email address.

NA

Collaboration with other VACCINE project teams, national labs, and other Homeland Security Centers of Excellence (CREATE, NCFPD, START, PACER, ALERT, NCBSI, MIREES, ZADD, CHC and NTSCOE).

Describe purpose and nature of the collaboration and any follow-up to the discussion, if applicable. NA

VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

Project Period (only complete if different than 4/1/12-6/30-13) MARY, THESE DATES SEEM WRONG HERE?

VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

Project Outcomes (Publications, Presentations, etc., based on this VACCINE-funded project)

Peer-Reviewed/Refereed Publications, Journals, Conferences: list only citation below, must also provide/attach electronic copy of all individual publications to VACCINE

If additional space is needed, please attach a separate Word document listing relevant materials.

Submitted:

Accepted:

Visualizing the Impact of Geographical Variations on Multivariate Clustering, Y Zhang, W Luo, EA Mack, R Maciejewski, Computer Graphics Forum 35 (3), 101-110

Michael Steptoe, Robert Krueger, Yifan Zhang, Xing Liang, Wei Luo, Rolando Garcia, Sagarika Kadambi, Thomas Ertl, Ross Maciejewski. VADER/VIS VAST 2015 Grand Challenge Entry. *Proceedings of the IEEE Visual Analytics Science and Technology Challenge Workshop*, 2015.

Other Reports (including white papers, book chapters, manuscripts submitted, in revision or accepted/in press [not including those in preparation], other publications)

NA

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

Presentations (include title, presenter, date, meeting, location. Attach PowerPoint if available). If additional space is needed, please attach a separate Word document listing relevant materials.

Michael Steptoe, VADER/VIS VAST 2015 Grand Challenge Entry, IEEE VIS, October 25, 2015.

Ross Maciejewski, "Visualizing the Impact of Geographical Variations on Multivariate Clustering,"EuroVis, June 8, 2016 (Netherlands)

Patents/Copyrights (List names)

Applications: NA

Awarded: NA

VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

Summary of Outcomes and Impact of Project

Currently, ASU has developed a network based density estimate model to explore geographical boundaries of gang territories as well as improve hostpot analysis and detection. This work has resulted in an online service for creating network density estimate models and we are in the process of porting these features to other systems for further deployment. The expected impact is improved data analytics for law enforcement as well as serving as a basis for improved network based modeling of crime and crime hotspots.

Impact or success story associated with project

NA

Issues Encountered, if applicable: intellectual property, data sensitivity, publication of high risk/sensitive/proprietary findings, institutional collaboration and relationships, etc.

NA

Changes in research plans, if applicable: describe any major changes in the project's plans or objectives, such as initiatives added or omitted, compared to those outlined in the original, funded proposal.

NA

Supporting Documentation: list items and attach electronically, including survey instruments, photos, models, letters to participants, or other unique documentation.

NA

Florida

International University

VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

Institution:

PI and/or Co-PI: Dr. Shu-Ching Chen (PI)

Project Name: A Data Integration Framework for Enhancing Emergency Response Situation Reports with Multi-Agency, Multi-Partner Multimedia Data

Academic Disciplines: Computer Science

Theme for Research Projects (Check all that apply)

If this is not a research project, indicate "NA" below.

X	Public Safety Coalition Projects (state or local law enforcement, fire, emergency management, etc.)
	Federal Operating Component Projects (TSA,FEMA, Secret Service, ICE, CBP, USCIS, Coast Guard)
	Enterprise Resiliency Environments
	Event Evacuations
	Visual Analytics for Security Applications
	International Collaborations
	N/A

Theme for Education Projects (Check all that apply)

If this is not an education project, indicate "NA" below.

	Minority or Underserved Programs
X	Undergraduate and Graduate Education Program
	Professional Education and In-Service Programs
	N/A

VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

Students Supported on Project

Graduate Research Assistants (include name(s), university and department)

1. Wubai Zhou, Florida International University, School of Computing and Information Sciences

0

3

0

Undergraduate supported students (need number only)

Research Problem /Abstract (in 200 words or less, provide a summary of the project goals and objectives, **in simple language understandable to someone outside the project's field).**

The goal of this project is to design and develop data-driven solutions to achieve context-aware and user-specific information integration, delivery, analysis, sharing, and collaboration in disaster information management. The project conducts research on: (1) design and develop effective information integration and summarization methods to help users improve situational awareness; (2) design and develop intelligent information delivery techniques to help users quickly identify the information they need; (3) design and develop automatic techniques for dynamic community generation; and (4) improve the work of all the agencies and emergency managers involved in the recovery process of a disaster scenario.

These research components constitute a holistic effort to effectively organize, discover, search and disseminate real-time disaster information and create a collaborative platform for preparedness and recovery that helps disaster impacted communities to better understand what the current disaster situation is and how the community is recovering.

Technical Approach (Check all that apply)

Data Collection Methods

X Compiling & Sorting DB

X Data Mining

X Expert Consultation

X Field Monitors

X Survey

Other:

Analytic Methods

X Case Studies

X Modeling

X Sampling

X Statistical Analysis

Other:

Nature of Research

X Applied

Basic

Consultation

X Coordination/Integration

X Education

Hybrid Basic—Applied

Hybrid Applied—Consultation

Deliverables (other than publications and reports listed below)

1. Intelligent techniques for effective information integration and summarization, information delivery, and dynamic community generation
2. An integrated solution to address the information explosion problem during the disaster period
3. Prototypes and tools for system demonstration and distribution
4. Improving iOS user interface of the Multimedia-Aided Disaster Information System (MADIS) by

using a web-based PDF viewer. Thus, the system can support various text file formats and convert them into PDF reports with highlighted keywords.

5. A new component for disaster videos is implemented, including functionalities such as video search and video playing for efficient disaster information retrieval.

Technology Transitions (describe any products/technologies in process or that have completed transition to commercialization; include actions and progress to date)

NA

Additional Funding Sources Leveraged: include amount, source of funding, PI and period of performance

"BDD: Data-Driven Critical Information Exchange in Disaster Affected Public-Private Networks," NSF CNS-1461926, $299,998, 7/1/2015 - 6/30/2018, with Tao Li (PI), Shu-Ching Chen (Co-PI), and Steven Luis (Co-PI).

VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

Collaborating Partners (academic Co-PI's, businesses, or other government funding agencies)

Dr. Tao Li (Co-PI) and Steven Luis (Senior Investigator)

Collaborating End-Users (specific DHS operating components such as FEMA, TSA, Coast Guard or federal, state, local law enforcement, fire, emergency management, etc.)

Please provide name of agency, contact name and email address.

Soheila Ajabshir - GISP, FPEM

Systems Manager

Miami-Dade County Department of Emergency Management (DEM)
9300 NW 41 St., Doral, FL 33178

Phone: 305-468-5417

Steve Detwiler

Emergency Management Planner

Miami-Dade County Department of Emergency Management (DEM)
9300 NW 41 St., Doral, FL 33178

Phone: 305-468-5423

Collaboration with other VACCINE project teams, national labs, and other Homeland Security Centers of Excellence (CREATE, NCFPD, START, PACER, ALERT, NCBSI, MIREES, ZADD, CHC and NTSCOE).

Describe purpose and nature of the collaboration and any follow-up to the discussion, if applicable. N/A

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VACCINE Annual Report – Year 7

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Peer-Reviewed/Refereed Publications, Journals, Conferences: list only citation below, must also provide/attach electronic copy of all individual publications to VACCINE

If additional space is needed, please attach a separate Word document listing relevant materials.

Submitted: N/A
Accepted:

1. Wei Xue, Tao Li, Naphtali Rishe. Aspect Identification and ratings inference for hotel reviews. World Wide Web Journal, 2016, in press.
2. Liang Tang, Yexi Jiang, Lei Li, Chunqiu Zeng, and Tao Li. 2015. Personalized Recommendation via Parameter-Free Contextual Bandits. In *Proceedings of the 38th International ACM SIGIR Conference on Research and Development in Information Retrieval* (SIGIR '15).
3. Wei Xue, Tao Li, Naphtali Rishe: Aspect and Ratings Inference with Aspect Ratings: Supervised Generative Models for Mining Hotel Reviews. WISE (2) 2015: 17-31
4. Mingjin Zhang, Huibo Wang, Yun Lu, Tao Li, Yudong Guang, Chang Liu, Erik Edrosa, Hongtai Li, Naphtali Rishe: TerraFly GeoCloud: An Online Spatial Data Analysis and Visualization System. ACM TIST 6(3): 34 (2015)
5. Yilin Yan, Min Chen, Mei-Ling Shyu, and Shu-Ching Chen, "Deep Learning for Imbalanced Multimedia Data Classification," IEEE International Conference on Multimedia (ISM 2015), Miami, FL, pp. 483-488, December 14-16, 2015.
6. Hsin-Yu Ha, Yimin Yang, Samira Pouyanfar, Haiman Tian, and Shu-Ching Chen, "Correlation-based Deep Learning for Multimedia Semantic Concept Detection," The 16th International Conference on Web Information System Engineering (WISE 2015), Miami, FL, pp. 473-487, November 1-3, 2015.
7. Hsin-Yu Ha, Shu-Ching Chen, and Mei-Ling Shyu, "Negative-based Sampling for Multimedia Retrieval," The 16th IEEE International Conference on Information Reuse and Integration (IRI 2015), San Francisco, USA, pp. 64-71, August 13-15, 2015. 3.
8. Yimin Yang and Shu-Ching Chen, "Ensemble Learning from Imbalanced Data Set for Video Event Detection," The 16th IEEE International Conference on Information Reuse and Integration (IRI 2015), San Francisco, USA, pp. 82-89, August 13-15, 2015

Other Reports (including white papers, book chapters, manuscripts submitted, in revision or accepted/in press [not including those in preparation], other publications)

N/A

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by July 30, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Presentations (include title, presenter, date, meeting, location. Attach PowerPoint if available). If additional space is needed, please attach a separate Word document listing relevant materials.

- NSF-Japan Big Data Summit, May 2016

Patents/Copyrights (List names)

Applications:N/A
Awarded:N/A

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by July 30, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Summary of Outcomes and Impact of Project

- We have several research papers published in archival journals including ACM Transactions on Information System and Technology (2015) and World Wide Web Journal (2016, to appear), and in various conference venues including ACM SIGIR International Conference, IEEE International Conference on Information Reuse and Integration (IRI), and International Conference on Web Information and System Engineering (WISE).
- A new component for the searching and retrieval of disaster videos was added to the MADIS system, which enables the system to retrieve both videos and images relevant to a specific disaster. Moreover, situation reports which are uploaded by users will be automatically converted to the PDF format and highlighted with the defined keywords.

Impact or success story associated with project

Issues Encountered, if applicable: intellectual property, data sensitivity, publication of high risk/sensitive/proprietary findings, institutional collaboration and relationships, etc.

N/A

Changes in research plans, if applicable: describe any major changes in the project's plans or objectives, such as initiatives added or omitted, compared to those outlined in the original, funded proposal.

N/A

Supporting Documentation: list items and attach electronically, including survey instruments, photos, models, letters to participants, or other unique documentation.

N/A

Georgia

Institute

of Technology

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by July 30, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Institution: Georgia Institute of Technology

PI and/or Co-PI: John Stasko & Alex Endert

Project Name: Visual Analytics for Investigative Analysis on Text Documents

Academic Disciplines: Computer science, visual analytics

Theme for Research Projects (Check all that apply)

If this is not a research project, indicate "NA" below.

XXX	Public Safety Coalition Projects (state or local law enforcement, fire, emergency management, etc.)
	Federal Operating Component Projects (TSA,FEMA, Secret Service, ICE, CBP, USCIS, Coast Guard)
	Enterprise Resiliency Environments
	Event Evacuations
	Visual Analytics for Security Applications
	International Collaborations
	N/A

Theme for Education Projects (Check all that apply)

XXX

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

Students Supported on Project

Graduate Research Assistants (include name(s), university and department)

Alex Godwin, Georgia Tech, School of Interactive Computing

Sakshi Pratap, Georgia Tech, School of Interactive Computing

0

0

Undergraduate supported students (need number only) 0

Research Problem /Abstract (in 200 words or less, provide a summary of the project goals and objectives, **in simple language understandable to someone outside the project's field).**

Many people and organizations routinely perform analysis that involves large collections of documents, and in particular, textual documents such as case reports, news articles, or suspicious activity reports.

Investigators may seek to investigate an individual or incident, or they may simply be exploring with hopes to discover stories, narratives, or threats that may be embedded across the document collection. We have developed a visual analytics system named Jigsaw that helps investigators in such scenarios. Jigsaw pairs computational analysis of the documents with a collection of visualizations that each portrays different aspects of the documents, including connections between different entities. Thus, the system acts like a visual index onto a document collection, highlighting connections between entities and allowing the investigator to understand the context of events in a more timely and accurate manner. Jigsaw helps analysts "put the pieces together" and link initially unconnected activities into a more coherent story. We are working with law enforcement and public safety organizations to explore how Jigsaw can be used in their work.

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by July 30, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Technical Approach (Check all that apply)

Data Collection Methods

	Compiling & Sorting DB
	Data Mining
	Expert Consultation
	Field Monitors
XXX	Survey
	Other:

Analytic Methods

XXX	Case Studies
	Modeling
	Sampling
	Statistical Analysis
XXX	Other:

Nature of Research

XXX	Applied
XXX	Basic
	Consultation
	Coordination/Integration
	Education
	Hybrid Basic—Applied
	Hybrid Applied—Consultation

Deliverables (other than publications and reports listed below)

We have made the Jigsaw system available on the internet for anyone to download. It is a java-based application. We also are working on a version that runs on a web browser. It is not quite ready yet to be made available to all.

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

Technology Transitions (describe any products/technologies in process or that have completed transition to commercialization; include actions and progress to date)

NA

Additional Funding Sources Leveraged: include amount, source of funding, PI and period of performance

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by July 30, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Collaborating Partners (academic Co-PI's, businesses, or other government funding agencies)

Collaborating End-Users (specific DHS operating components such as FEMA, TSA, Coast Guard or federal, state, local law enforcement, fire, emergency management, etc.)

Please provide name of agency, contact name and email address.

NA

Collaboration with other VACCINE project teams, national labs, and other Homeland Security Centers of Excellence (CREATE, NCFPD, START, PACER, ALERT, NCBSI, MIREES, ZADD, CHC and NTSCOE).

Describe purpose and nature of the collaboration and any follow-up to the discussion, if applicable.

NA

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by July 30, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Project Period (only complete if different than 4/1/12-6/30-13)

7/1/15 – 6/30/16

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

Project Outcomes (Publications, Presentations, etc., based on this VACCINE-funded project)

Peer-Reviewed/Refereed Publications, Journals, Conferences: list only citation below, must also provide/attach electronic copy of all individual publications to VACCINE

If additional space is needed, please attach a separate Word document listing relevant materials.

Submitted:

Alex Godwin and John Stasko, "HotSketch: Drawing Police Patrol Routes among Spatiotemporal Crime Hotspots", submitted to the Hawaii International Conference on System Sciences, January 2017.

Accepted:

Alex Godwin and John Stasko, "Drawing Data on Maps: Sketch-Based Spatiotemporal Visualization", (Poster), IEEE Information Visualization Conference, Chicago, IL, Oct. 2015.

Kwon, Bum Chul, Kim, Hannah, Choo, Jaegul, Park, Haesun, and Endert, Alex, "AxiSketcher: Interactive Nonlinear Axis Mapping through User's Drawing on Visualization" IEEE TVCG 2017 (to appear at IEEE VAST 2016).

Other Reports (including white papers, book chapters, manuscripts submitted, in revision or accepted/in press [not including those in preparation], other publications)

Presentations (include title, presenter, date, meeting, location. Attach PowerPoint if available). If additional space is needed, please attach a separate Word document listing relevant materials.

"The Value of Visualization for Exploring and Understanding Data", John Stasko, October 2015, Invited lecture at Emory University, Atlanta, GA.

"The Value of Visualization for Exploring and Understanding Data", John Stasko, November 2015, Invited lecture at Lehigh University, Bethlehem, PA.

"New Approaches for Information Visualization: Rethinking Existing Notions", John Stasko, Jaunary 2016, Invited lecture at Oak Ridge National Lab, Oak Ridge, TN.

"Introduction to Visual Analytics", Alex Endert, March 2016, Presented at Visual Analytics Spring School at Middlesex University, London, UK.

"Putting User Interaction First: The Importance of User Interaction for Visual Analytics", Alex Endert, April 2016, Invited lecture at Oak Ridge National Laboratory, Oak Ridge, TN.

"The Value of Visualization for Exploring and Understanding Data", John Stasko, April 2016, Invited lecture at Bentley University, Waltham, MA.

"The Value of Visualization for Exploring, Presenting, and Understanding Data", John Stasko, May 2016, Invited

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by July 30, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Summary of Outcomes and Impact of Project

We have continued our development and distribution of the Jigsaw visual analytics system. (See http://www.cc.gatech.edu/gvu/ii/jigsaw.) During the past year, we did not add new functionality to the system per se, but we made a number of bug fixes and we released a new version. Also, our Masters student Sakshi Pratap has been working on a new version of the system that runs native in a web browser. It is not quite ready to release yet, but we hope to be able to do that soon.

Dr. Stasko presented 7 invited lectures at universities, companies, and government research labs this past year.

This grant also has supported research of a PhD student exploring geospatial visual analytics including pen- and touch-based interaction. In one aspect of the project, we're building a system that allows police officials to sketch on a visualization showing crime hotspots, as a way to assist with planning and patrols. We presented a poster at InfoVis '15 about this work and we have submitted a paper to HICSS '17..

Impact or success story associated with project

We have had approximately 7000 downloads of the Jigsaw system in its history. It is being used in various university classes on visual analytics and intelligence analysis and has been downloaded by a wide variety of organizations in government and industry. (We do not formally track who is using it and how they are using.) We have just recently begun discussions with some Defense Dept. individuals who would like to have the system be approved for deployment on defense computers.

Issues Encountered, if applicable: intellectual property, data sensitivity, publication of high risk/sensitive/proprietary findings, institutional collaboration and relationships, etc.

NA

Changes in research plans, if applicable: describe any major changes in the project's plans or objectives, such as initiatives added or omitted, compared to those outlined in the original, funded proposal.

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

NA

Supporting Documentation: list items and attach electronically, including survey instruments, photos, models, letters to participants, or other unique documentation.

Morgan State

University

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Institution: Morgan State University

PI and/or Co-PI: Dr. Timothy Akers, PI, Dr. Kevin Peters, CoPI

Project Name: Visual Analytics for Science and Technology at a Minority Serving Institution (VAST MSI)

Theme for Research Projects (Check all that apply)

If this is not a research project, indicate "NA" below.

x	Public Safety Coalition Projects (state or local law enforcement, fire, emergency management, etc.)
	Federal Operating Component Projects (TSA,FEMA, Secret Service, ICE, CBP, USCIS, Coast Guard)
	Enterprise Resiliency Environments
	Event Evacuations
x	Visual Analytics for Security Applications
	International Collaborations
	N/A

Theme for Education Projects (Check all that apply)

If this is not an education project, indicate "NA" below.

x	Minority or Underserved Programs
x	Undergraduate and Graduate Education Program
	Professional Education and In-Service Programs
	N/A

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Students Supported on Project

Graduate Research Assistants (include name(s), university and department)

6

Undergraduate supported students (need number only)

Other Graduate Students (non-supported) involved in project (need number only)

Research Problem /Abstract (in 200 words or less, provide a summary of the project goals and objectives, **in simple language understandable to someone outside the project's field).**

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

Technical Approach (Check all that apply)

Data Collection Methods

NA	Compiling & Sorting DB
NA	Data Mining
NA	Expert Consultation
NA	Field Monitors
NA	Survey
	Other:

NA

x

x

Analytic Methods

x

NA x	Case Studies
	Modeling
	Sampling
	Statistical Analysis
x	Other:

Nature of Research

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Deliverables (other than publications and reports listed below)

- Morgan VAST students received high marks in their participation in the VACCINE Summer Institute July 19-25, 2015 at Purdue University. Dr. Peters was approached by VACCINE staff who commented on how students were eager to learn and very much engaged in the one-week summer institute. The compliment was given at the VACCINE Annual Conference at Purdue University. This was the first opportunity for the new cohort of VAST students to participate in a Visual Analytics Summer Institute at another university outside of Morgan State University.
- The VAST Team consisting of Drs. Tim Akers, James Hunter, Gregory Ramsey, Douglas Gwynn, and Kevin Peters attended the VACCINE sponsored visual analytics workshop at Bethune-Cookman University on June 18-19, 2015. The focus of the workshop richer under- standing of visual analytics and how to connect visual analytics to the curriculum. The workshop included hands-on tools involving Tableau, Jigsaw, and NodeXL.

- Dr. Peters attended VACCINE's Annual Conference held October, 2015. The focus was to provide a forum to discuss VACCINE activities and challenges of visual analytics, data, and homeland security. The event included invited presentations, panel discussions, and a technology showcase of decision-making tools with hands-on demonstrations of state-of-the-art technologies. Attendees comprised the U.S. Coast Guard, Department of Homeland Security, law enforcement, and emergency response personnel, as well as faculty and students from Purdue.

Collaborating Partners (academic Co-PI's, businesses, or other government funding agencies)

Collaborating End-Users (specific DHS operating components such as FEMA, TSA, Coast Guard or federal, state, local law enforcement, fire, emergency management, etc.)

Please provide name of agency, contact name and email address.

Collaboration with other VACCINE project teams, national labs, and other Homeland Security Centers of Excellence (CREATE, NCFPD, START, PACER, ALERT, NCBSI, MIREES, ZADD, CHC and NTSCOE).

Describe purpose and nature of the collaboration and any follow-up to the discussion, if applicable.

The VAST PIs (Dr. Akers and Peters) and faculty met with administrators and scientists from the Springfield Virginia Forensic Laboratory to discuss collaborative research opportunities with students and faculty focused on APP development. Director Stevens brought a distinguished entourage of scientists, engineers, and agents to Morgan State to visit the visual analytics lab and to learn more about the

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

projects being undertaken by MSU.

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

Project Outcomes (Publications, Presentations, etc., based on this VACCINE-funded project)

Peer-Reviewed/Refereed Publications, Journals, Conferences: list only citation below, must also provide/attach electronic copy of all individual publications to VACCINE

If additional space is needed, please attach a separate Word document listing relevant materials.

Submitted: N/A

Accepted: N/A

Other Reports (including white papers, book chapters, manuscripts submitted, in revision or accepted/in press [not including those in preparation], other publications)

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Presentations (include title, presenter, date, meeting, location. Attach PowerPoint if available). If additional space is needed, please attach a separate Word document listing relevant materials.

Patents/Copyrights (List names)

Applications:

Awarded:

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

Summary of Outcomes and Impact of Project

In summary, the collaborative efforts between VACCINE and the Morgan State University VAST project included the following during this reporting period: 1) attendance and participation in the VACCINE Annual Visualization Conference (at Purdue); 2) participation in the Visual Analytics Summer Institute sponsored by VACCINE; and 3) Visual Analytics Summer Workshop for Morgan undergraduate students during the summer of 2015 (at Purdue). These collaborative and partnership activities have had a tremendous impact on the VAST project with regard to knowledge gained from students and faculty with regard to visual analytics and the tools that can be used as a resource for visualizing big data. Using visualization strategies is an important strategy in describing and interpreting research data, as well as, linking these strategies to the STEM and education courses at the University.

Impact or success story associated with project

Faculty at Morgan State are now using visual analytics in various aspects in the STEM and education curriculums. In addition, our students are required to use visual analytics tools in their research with faculty mentors. This has had a tremendous affect on the teaching and learning of STEM as well as in our course

Issues Encountered, if applicable: intellectual property, data sensitivity, publication of high risk/sensitive/proprietary findings, institutional collaboration and relationships, etc.

VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

Changes in research plans, if applicable: describe any major changes in the project's plans or objectives, such as initiatives added or omitted, compared to those outlined in the original, funded proposal.

Supporting Documentation: list items and attach electronically, including survey instruments, photos, models, letters to participants, or other unique documentation.

Oak Ridge

National Laboratory

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

Institution: Oak Ridge National Laboratory, Cyber & Information Security Research Group

PI and/or Co-PI: Robert A. Bridges

Project Name: Context-Driven Visual Analytics for Cyber Defensive Operations

Academic Disciplines: Graph Theory, Anomaly Detection, and Visualization

Keywords associated with project: Graph Theory, Graphlet, Clustering, Outlier Detection, Anomaly Detection

Theme for Research Projects (Check all that apply)

If this is not a research project, indicate "NA" below

	Public Safety Coalition Projects (state or local law enforcement, fire, emergency management, etc.)
	Federal Operating Component Projects (TSA,FEMA, Secret Service, ICE, CBP, USCIS, Coast Guard)
	Enterprise Resiliency Environments
x	Event Evacuations
	Visual Analytics for Security Applications
	International Collaborations

Theme for Education Projects (Check all that apply)

If this is not an education project, indicate "NA" below

	Minority or Underserved Programs
	Undergraduate and Graduate Education Program
	Professional Education and In-Service Programs
x	N/A

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

Students Supported on Project

Graduate Research Assistants (include name(s), university and department)

½ summer

Undergraduate supported students (need number only)

½ summer

Other Graduate Students (non-supported) involved in project (need number only)

Research Problem /Abstract (in 200 words or less, provide a summary of the project goals and objectives, **in simple language understandable to someone outside the project's field).**

We've developed a novel graph-analytic approach for detecting anomalies in network flow data called GraphPrints. Building on foundational network-mining techniques, our method represents time slices of traffic as a graph, then counts graphlets--small induced subgraphs that describe local topology. By performing outlier detection on the sequence of graphlet counts, anomalous intervals of traffic are identified, and furthermore, individual IPs experiencing abnormal behavior are singled-out. Initial testing of GraphPrints is performed on real network data with an implanted anomaly. Evaluation shows false positive rates bounded by 2.84\% at the time-interval level, and 0.05\% at the IP-level with 100\% true positive rates at both.

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VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

Technical Approach (Check all that apply)

Data Collection Methods

- [ ] Compiling & Sorting DB
- [x] Data Mining
- [ ] Expert Consultation
- [ ] Field Monitors
- [ ] Survey
- [ ] Other:

Analytic Methods

- [ ] Case Studies
- [ ] Modeling
- [ ] Sampling
- [x] Statistical Analysis
- [x] Other:

Nature of Research

- [x] Applied
- [x] Basic
- [ ] Consultation
- [ ] Coordination/Integration
- [ ] Education
- [ ] Hybrid Basic—Applied
- [ ] Hybrid Applied—Consultation

Deliverables (other than publications and reports listed below)

Poster: Flocon 2016

~~Submitted a small ORNL-internal proposal for future funding (not awarded)~~

VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

GraphPrints presentation given to DHS S&T Cyber Security program manager Ann Cox Conference Presentation CISRC 2016.

Best Short Paper Award, CISRC 2016

Invite Talk, SIAM Annual Meetings, 2016, Mining in Graph Data session

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

Technology Transitions (describe any products/technologies in process or that have completed transition to commercialization; include actions and progress to date)

Additional Funding Sources Leveraged: include amount, source of funding, PI and period of performance

VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

Collaborating Partners (academic Co-PI's, businesses, or other government funding agencies)

Collaborating End-Users (specific DHS operating components such as FEMA, TSA, Coast Guard or federal, state, local law enforcement, fire, emergency management, etc.)

Please provide name of agency, contact name and email address.

Collaboration with other VACCINE project teams, national labs, and other Homeland Security Centers of Excellence (CREATE, NCFPD, START, PACER, ALERT, NCBSI, MIREES, ZADD, CHC and NTSCOE).

Describe purpose and nature of the collaboration and any follow-up to the discussion, if applicable.

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

Project Period (only complete if different than 4/1/12-6/30-13)

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

Project Outcomes (Publications, Presentations, etc., based on this VACCINE-funded project)

Peer-Reviewed/Refereed Publications, Journals, Conferences: list only citation below, must also provide/attach electronic copy of all individual publications to VACCINE

If additional space is needed, please attach a separate Word document listing relevant materials.

Submitted:

Accepted:

Other Reports (including white papers, book chapters, manuscripts submitted, in revision or accepted/in press [not including those in preparation], other publications)

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

Presentations (include title, presenter, date, meeting, location. Attach PowerPoint if available). If additional space is needed, please attach a separate Word document listing relevant materials.

Patents/Copyrights (List names)

Applications:

Awarded:

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

Summary of Outcomes and Impact of Project

Impact or success story associated with project

Issues Encountered, if applicable: intellectual property, data sensitivity, publication of high risk/sensitive/proprietary findings, institutional collaboration and relationships, etc.

VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

Changes in research plans, if applicable: describe any major changes in the project's plans or objectives, such as initiatives added or omitted, compared to those outlined in the original, funded proposal.

Supporting Documentation: list items and attach electronically, including survey instruments, photos, models, letters to participants, or other unique documentation.

Pennsylvania

State University

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

Institution:

PI and/or Co-PI: Alan M. MacEachren

Project Name: GeoTxt Geoparsing API: Evaluation and Deployment

Academic Disciplines: Geography & Information Sciences and Technology

Theme for Research Projects (Check all that apply)
If this is not a research project, indicate "NA" below.

x	Public Safety Coalition Projects (state or local law enforcement, fire, emergency management, etc.)
x	Federal Operating Component Projects (TSA,FEMA, Secret Service, ICE, CBP, USCIS, Coast Guard)
x	Enterprise Resiliency Environments
	Event Evacuations
x	Visual Analytics for Security Applications
	International Collaborations
	N/A

Theme for Education Projects (Check all that apply)

If this is not an education project, indicate "NA" below.

	Minority or Underserved Programs
	Undergraduate and Graduate Education Program
	Professional Education and In-Service Programs
	N/A

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Students Supported on Project

Graduate Research Assistants (include name(s), university and department)

Morteza Karimzadeh, Penn State University, Geography

Undergraduate supported students (need number only) 2

O**ther Graduate Students** (non-supported) involved in project (need number only)

Other Undergraduate Students (non-supported) involved in project (need number only)

Student Thesis in 2016 (include name, thesis title, university, department, degree, date)

Funded partially through DHS-VACCINE COE on earlier research, not related to GeoTxt: Alexander Savelyev, Ph.D. (2015) Empirical Investigation of Typographic Overprinting Displays and Their Legibility in the Context of Information and Geographic Visualization of Text

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Research Problem /Abstract (in 200 words or less, provide a summary of the project goals and objectives, **in simple language understandable to someone outside the project's field).**

Place matters for crises and threats of all kinds, whether due to natural disasters, terrorism, drug trafficking, illegal border crossing, or other activities. A large volume of place information is typically found in unstructured text generated via social media, news blogs, official reports, and other sources. This place information has high potential value to homeland security, but only if it can be recognized, disambiguated, and geolocated. While commercially available natural language processing tools are relatively effective at entity recognition, including named place entities with relatively well-structured text (e.g., news stories), they are much less successful at recognizing place references in less structured text such as social media, and at disambiguating among the many places with the same name to geolocate the place references accurately.

Disambiguation is particularly challenging when it must deal with the many variations in spelling of and abbreviations for the same place name; non-standard abbreviation is very common in social media text. This research is focused on developing, assessing, and deploying GeoTxt, a geoparsing application programing interface (API) plus GeoCorpra, a visual analytics process and set of tools for building annotated corpora for use in training and testing GeoTxt or any other geoparsing tools.

Technical Approach (Check all that apply)

Data Collection Methods

x	Compiling & Sorting DB
x	Data Mining
x	Expert Consultation
	Field Monitors
	Survey
x	Other: Amazon Mechanical Turk-based named-entity recognition for corpus construction

Analytic Methods

x	Case Studies
	Modeling
	Sampling
x	Statistical Analysis
	Other:

Nature of Research

	Applied
	Basic
	Consultation
x	Coordination/Integration
	Education

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Deliverables (other than publications and reports listed below)

- The improved *GeoTxt* API, available on request to DHS partners and other collaborators.
- The improved *GeoCorpora – GeoAnnotator* web interface that supports the geo-location component of text corpus building

---

Technology Transitions (describe any products/technologies in process or that have completed transition to commercialization; include actions and progress to date)

GeoTxt has been integrated as the backend geographic entity recognition, disambiguation, and co-coding systems to support SensePlace 2, our spatial-temporal twitter analytics environment. The early stages of SensePlace 2 (and its precursor SensePlace) were funded through VACCINE.

GeoTxt has been made available to other VACCINE partners. We have worked actively with partners at both Purdue and UNCC to test use of the GeoTxt API from software applications under development by those teams.

Additional Funding Sources Leveraged: include amount, source of funding, PI and period of performance

None at this time

VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

Collaborating Partners (academic Co-PI's, businesses, or other government funding agencies)

Collaborating End-Users (specific DHS operating components such as FEMA, TSA, Coast Guard or federal, state, local law enforcement, fire, emergency management, etc.)

Please provide name of agency, contact name and email

address. None yet

Collaboration with other VACCINE project teams, national labs, and other Homeland Security Centers of Excellence (CREATE, NCFPD, START, PACER, ALERT, NCBSI, MIREES, ZADD, CHC and NTSCOE).

Describe purpose and nature of the collaboration and any follow-up to the discussion, if applicable.

As part of our collaboration with the team at Purdue, we have continued to extend GeoTxt capabilities to deal with large, streaming data from microblog sources.

We also collaborated with a National Geospatial-Intelligence Agency funded effort by colleagues at Penn State focused on event prediction based on space-time news analytics (STempo) that integrated GeoTxt as their geoparsing tool. Results are detailed here:

Robinson, A. C., D. J. Peuquet, S. Pezanowski, F. A. Hardisty, and B. Swedberg. 2016. Design and evaluation of a geovisual analytics system for uncovering patterns in spatio-temporal event data. *Cartography and Geographic Information Science*:1-13.

Additionally, GeoTxt has been incorporated in research to study class discussions of 100,000+ students who have enrolled in Anthony Robinson's MOOC on Maps and the Geospatial Revolution. Results of that activity are detailed here:

Robinson, A. 2015. Exploring Class Discussions from a Massive Open Online Course (MOOC) on Cartography. In *Modern Trends in Cartography*, eds. J. Brus, A. Vondrakova and V. Vozenilek, 173-182: Springer International Publishing.

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading.

Project Period (only complete if different than 9/1/15-6/30-16)

Project Outcomes (Publications, Presentations, etc., based on this VACCINE-funded project)

Peer-Reviewed/Refereed Publications, Journals, Conferences: list only citation below, must also provide/attach electronic copy of all individual publications to VACCINE

If additional space is needed, please attach a separate Word document listing relevant materials.

Submitted:

GeoCorpora: Building a Corpus to Test and Train Microblog Geoparsers (submitted) International Journal of Geographical Information Science

Accepted:

None at present

Other Reports (including white papers, book chapters, manuscripts submitted, in revision or accepted/in press [not including those in preparation], other publications)

Presentations (include title, presenter, date, meeting, location. Attach PowerPoint if available). If additional space is needed, please attach a separate Word document listing relevant materials.

None directly supported by DHS funding. However, multiple presentations both within Penn State and at conferences and workshops have highlighted aspects of this work (and acknowledged the DHS funding for those aspects).

- Kim, E.-K. and MacEachren, A.M. (2015) Spatial Bursts of Geo-Tweeting Behaviors in Geo-Located Twitter data. International Conference on Location-Based Social Media Data, Athens, GA: March 13-14, 2015.
- MacEachren, Alan M. (2016) Geovisual Analytics: Reimagining the "analytical" in GIScience,

Invited: Waldo Tobler Distinguished Lecture in GIScience, Annual Meeting of the Association of American Geographers, March 31, 2016.

- Wallgr, J. O., #252, A. Klippel, and M. Karimzadeh. 2015. Towards contextualized models of spatial relations. In Proceedings of the 9th Workshop on Geographic Information Retrieval, 1-2. Paris, France: ACM.

Patents/Copyrights (List names)

Applications:

Awarded:

Summary of Outcomes and Impact of Project

We have improved the throughput of GeoTxt substantially by reengineering the system to take full advantage of both advanced text indexing methods and high-performance computing.

We have produced the first Gold Standard corpus of geolocated places in tweets that can be used to test and train any geoparsing tools. This corpus will be made available to other researchers (on publication of the submitted paper documenting creation of the corpus).

We have developed a flexible geovisual analytics application to support building geolocation corpra. This application could be easily extended to support other corpus building activities for testing and training text processing tools. In the process of building the Gold Standard corpus cited above, we have generated a range of insights (detailed in our submitted paper) concerning how "places" are referred to in informal text such as microblogs. These insights have the potential to substantially increase the accuracy with which references to places can be captured from unstructured text, something with direct implications for threat assessment, criminal investigations, and crisis response.

Impact or success story associated with project

No new success story yet.

Issues Encountered, if applicable: intellectual property, data sensitivity, publication of high risk/sensitive/proprietary findings, institutional collaboration and relationships, etc.: NA

Changes in research plans, if applicable: describe any major changes in the project's plans or objectives, such as initiatives added or omitted, compared to those outlined in the original, funded proposal.

Building an unbiased and accurate corpus of tweets with place references annotated, disambiguated, and located has proved to be challenging. The process has generated many insights and has prompted development of a separate geovisual analytics application (GeoAnnotator) to enable building copora of tagged and geolocated place features in text. This application is relevant well beyond the GeoTxt project and is currently supporting the dissertation work of the graduate student on the project and will be incorporated in other follow on work.

Supporting Documentation: list items and attach electronically, including survey instruments, photos, models, letters to participants, or other unique documentation.

- GeoTxt can be tried manually at: www.GeoTxt.org
- A video tutorial to GeoCorpora:GeoAnnotator (the geolocation interface) is posted at: https://youtu.be/5K2C0BsGqpg

Prairie View

A & M University

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by July 30, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Institution: Prairie View A&M University

PI and/or Co-PI: Dr. Louis Ngamassi

Project Name: COURSE DEVELOPMENT / ENHANCEMENT PROPOSAL

Academic Disciplines: Management Information Systems

Theme for Research Projects (Check all that apply)

If this is not a research project, indicate "NA" below.

	Public Safety Coalition Projects (state or local law enforcement, fire, emergency management, etc.)
	Federal Operating Component Projects (TSA,FEMA, Secret Service, ICE, CBP, USCIS, Coast Guard)
	Enterprise Resiliency Environments
	Event Evacuations
	Visual Analytics for Security Applications
X	International Collaborations

Theme for Education Projects (Check all that apply)

If this is not an education project, indicate "NA" below.

X	Minority or Underserved Programs
	Undergraduate and Graduate Education Program
	Professional Education and In-Service Programs
	N/A

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If any item does not apply to your project, please indicate "NA" under the heading

Students Supported on Project

Graduate Research Assistants (include name(s), university and department)

NA

Undergraduate supported students (need number only)

NA

O**ther Graduate Students** (non-supported) involved in project (need number only)

NA

Research Problem /Abstract (in 200 words or less, provide a summary of the project goals and objectives, **in simple language understandable to someone outside the project's field).**

The goal of this project is to enhance and grow a newly developed course entitled "*Crisis Informatics*". This course explores the use of information and communication technologies in crisis management. In particular, it examines how information generated through social media is managed, organized, coordinated, and used for crisis management.

VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

Technical Approach (Check all that apply)

Data Collection Methods

Compiling & Sorting DB

Data Mining

Expert Consultation

Field Monitors

Survey

X Other: Course evaluation and feedback provided by the students who took this course (Fall 15)

Analytic Methods

Case Studies

Modeling

Sampling

Statistical Analysis

X Other: Content analysis

Nature of Research

Applied

Basic

Consultation

Coordination/Integration

X Education

Hybrid Basic—Applied

Hybrid Applied—Consultation

Deliverables (other than publications and reports listed below)

NA

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If any item does not apply to your project, please indicate "NA" under the heading

Technology Transitions (describe any products/technologies in process or that have completed transition to commercialization; include actions and progress to date)

NA

Additional Funding Sources Leveraged: include amount, source of funding, PI and period of performance

NA

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If any item does not apply to your project, please indicate "NA" under the heading

Collaborating Partners (academic Co-PI's, businesses, or other government funding agencies)

NA

Collaborating End-Users (specific DHS operating components such as FEMA, TSA, Coast Guard or federal, state, local law enforcement, fire, emergency management, etc.)

Please provide name of agency, contact name and email address.

NA

Collaboration with other VACCINE project teams, national labs, and other Homeland Security Centers of Excellence (CREATE, NCFPD, START, PACER, ALERT, NCBSI, MIREES, ZADD, CHC and NTSCOE).

Describe purpose and nature of the collaboration and any follow-up to the discussion, if applicable.

NA

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Project Period (only complete if different than 4/1/12-6/30-13)

12/1/15 - 6/30/16

VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

Project Outcomes (Publications, Presentations, etc., based on this VACCINE-funded project)

Peer-Reviewed/Refereed Publications, Journals, Conferences: list only citation below, must also provide/attach electronic copy of all individual publications to VACCINE

If additional space is needed, please attach a separate Word document listing relevant materials.

Submitted:

NA

Accepted:

NA

Other Reports (including white papers, book chapters, manuscripts submitted, in revision or accepted/in press [not including those in preparation], other publications)

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by July 30, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Presentations (include title, presenter, date, meeting, location. Attach PowerPoint if available). If additional space is needed, please attach a separate Word document listing relevant materials.

Title: Applied Curriculum Integration Overview : Crisis Informatics with NodeXL

Presenter: Dr. Louis Ngamassi

Date: May 12, 2016

Meeting: 2016 Visual Analytics MSI Faculty Training Workshop

Location: Miami, Florida

Patents/Copyrights (List names)

Applications: **NA**

Awarded: **NA**

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by July 30, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Summary of Outcomes and Impact of Project

NA

Impact or success story associated with project

NA

Issues Encountered, if applicable: intellectual property, data sensitivity, publication of high risk/sensitive/proprietary findings, institutional collaboration and relationships, etc.

NA

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading.

Changes in research plans, if applicable: describe any major changes in the project's plans or objectives, such as initiatives added or omitted, compared to those outlined in the original, funded proposal.

NA

Supporting Documentation: list items and attach electronically, including survey instruments, photos, models, letters to participants, or other unique documentation.

NA

Purdue

University

Chicago LTE Pilot Project

Final Report

DHS Center For Visual Analytics for Command, Control, and Interoperability Environments (VACCINE)

Video and Image Processing Laboratory (VIPER)

Purdue University

West Lafayette, Indiana

Khalid Tahboub and Edward J. Delp

Version 1.4

August 25, 2015

Executive Summary

The goals of this project were to test the viability and performance of the LTE National Public Safety Broadband Network (NPSBN) with respect to transport of video imagery. One cell using the NPSBN was installed in Chicago at the Chicago Police Department District 7. We shall refer to this system in this report as the Chicago Long Term Evolution (LTE) network. This report contains the results of the test plan conducted to characterize the performance of the network, analysis of the data collected, recommendations and conclusions. The test plan consisted of three parts: First, objective perceptual video quality tests designed to measure the video quality when video is streamed in real-time over the LTE network were conducted. The measurements are based on generally accepted objective metrics from the video compression community. Second, subjective measurements were conducted to characterize the performance of applications of interest under various test conditions. Third, network performance metrics were obtained to test the key performance indicators associated with the network. An application server was installed and integrated into the network to host some of the services required for testing, such as an FTP and video streaming servers. Objective key performance indicators (KPI) were measured while users access these services using the LTE network. Data throughput using various protocols, delay, jitter and power measurements are examples of KPIs. Our initial test plan intended to conduct subjective assessments of non-video applications used by the CPD such as RTVI, CAD, VidSys and Shotspotter. However, due to operational issues and requirements by the CPD, only subjective assessment of RTVI was conducted. Based on the analysis of the data collected during our testing it was concluded that a PSBN LTE network provides an unprecedented opportunity to increase the capacity and to meet the needs and requirements of public safety with respect to video delivery. Careful analysis should be used for Quality of Service (QoS), prioritization and Radio Frequency (RF) planning when designing a NPSBN LTE system. It was also noted that adaptive video coding methods, used in many video systems, might not suit public service operational scenarios. System designer should also take into consideration video usage in a task-based approach.

Table of Contents

1 Lessons Learned and Recommendations

The Chicago LTE pilot project demonstrates that the 700MHz National Public Safety Broadband Network (NPSBN) will provide unprecedented resources in terms of network capacity and communication speeds.

Peak throughputs in District 7 were close to 29 Mb/s in the downlink direction and 20 Mb/s in the uplink direction. We estimate such resources can be shared by approximately 40 users to view a real-time video stream simultaneously assuming a video data rate of 650 kb/s as observed for the RTVI system. If the users wanted to view more than one video stream then there is a trade off in the number of users that could be supported.

Other applications of interest to the CPD such as CLEAR, CAD and Shotspotter were not tested but known to require lower bandwidth. As shown by our results and widely known in communication theory the capacity of the network depends on the signal quality. Therefore, peak throughputs were observed closer to the police station where the eNodeB is located. Throughputs and network capacity along the coverage area edges (cell edges) were significantly reduced. Network attachment success rate was 100% during the full extent of testing. No cases of dropped connections were observed.

In multi-user testing cases, network resources were shared accordingly. Throughputs, video quality, delay and jitter were impacted as detailed in the results section. This becomes more apparent when the network is accessed from locations close to the cell edges. Therefore, based on our observations, testing results and to meet the special needs required by public safety we recommend the following:

1. Quality of Service (QoS) and prioritization should be taken into consideration while scheduling network resources. Mission critical users or emergency responders should be allocated resources according to a well-defined QoS and prioritization model. This becomes more significant in the case where an emergency takes place along cell edges.

2. Careful RF planning and analysis should be performed to make sure the anticipated performance degradation along the cell edges is within acceptable measures. Our tests were only conducted with one LTE cell and hence we will not able to test issues such as cell hand-off which are also critical in the design and deployment of these systems.

3. LTE USB dongles were only used for our tests. However, variations in signal quality observed by various LTE USB dongles makes the case for establishing an acceptance test to be conducted each time a vehicular modem is installed. The goal of this test would be to make sure the alignment of antennas and the calibration of various RF components produce signal qualities within acceptable measures.

4. The complexity of the IP configuration in LTE network exceeds that for legacy networks. Therefore, we recommend establishing a configuration verification procedure to ensure no interruption of service. One incident of a configuration error resulted in loss of access to the application server during our tests.

5. Since the network resources are limited, the number of IP cameras connected to the network using an LTE connection should be properly determined.

6. Adaptive video coding techniques adjust to the available wireless resources. In the case of an emergency, hundreds of users might be in the field trying to access the network. In such scenarios, and as shown by our tests, video quality will degrade significantly and the video stream might be eventually interrupted. Therefore, adaptive video coding techniques might not suit emergency scenarios or cases where many users are trying to access the network. Fixed data rate video coding techniques and guaranteed data resources could be allocated to the video streams. This may limit the number of users that could access a particular video resource.

7. Video quality requirements should be based on the task. Spatial resolution, frame rate and data rate should be governed by video usage in a task-based approach and the number of users needs to access a particular video resource.

2 Introduction

The Federal Communications Commission (FCC) identified 3GPP Long-Term Evolution (LTE) as the network technology for the National Public Safety Broadband Network (NPSBN). Advancements in broadband technology are leveraged to deploy an interoperable NPSBN. LTE is the latest commercial wireless communications technology which addresses the increasing demand for high speed data communication. This is the same WAN wireless networking technology the public uses in the “4G cell phone” network. The NPSBN, when fully deployed, will be a dedicated wireless communications network that allows public safety to transmit and receive data at high speeds and provides higher capacity compared to any Land Mobile Radio (LMR) network, which support mission critical voice communications and is separate and separately managed from the public 4G cell phone network.

The goals of this project were to test the viability and performance of a LTE NPSBN with respect to transport of video imagery. A pilot LTE network consisting of one cell was deployed by Motorola to provide LTE coverage in the Chicago Police Department (CPD)’s seventh district. The cell was located at the police station. Figure 1 shows the borders of District 7 within the city of Chicago. District 7 is approximately 20 blocks (north/south direction) by 35 blocks (east/west direction) as shown in Figure 2.

This report contains the results of the test plan conducted to characterize the performance of the network, analysis of the data collected, recommendations and conclusions. The tests were conducted by Purdue University as part of Purdue's DHS Center of Excellence, VACCINE[1].

The high-level network architecture of LTE is comprised of two main parts:

- The Evolved Packet Core (EPC)
- The Evolved UMTS Terrestrial Radio Access Network (E-UTRAN).

The E-UTRAN handles communications between mobile devices and the evolved packet core. It is comprised of a single component called the evolved base station (eNodeB). Each eNodeB is a base station that controls mobile devices in one or more cell. This sends and receives radio transmissions in the LTE air interface using antennas. The eNodeB was installed in District 7 Police Station located to the north and west of the district center as shown in Figure 2.

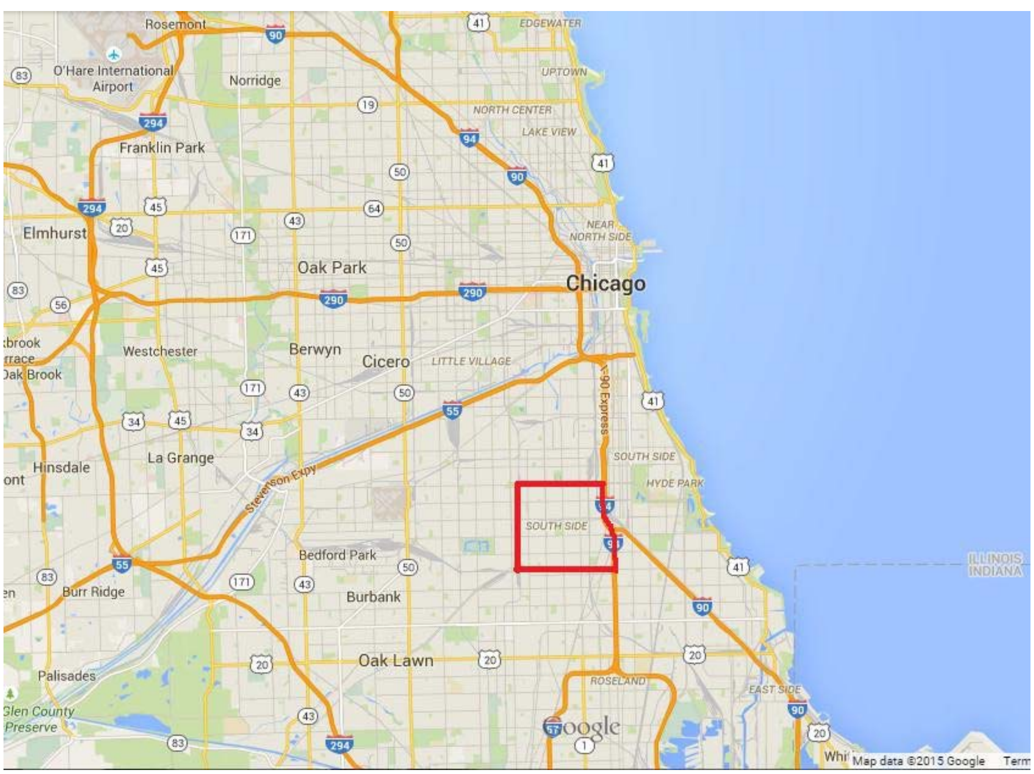

Figure 1: CPD District 7 Borders

[1] https://www.purdue.edu/discoverypark/vaccine/

The evolved packet core handles communications with the outside world, such as the Internet, and has a central database, which contains information about all the network's subscribers. It also provides integration capabilities with applications of interest to public safety, such as the video management system (VMS), Computer Aided Dispatch (CAD), the Shotspotter system and Citizen and Law Enforcement Analysis and Reporting (CLEAR). Figure 3 shows the connectivity of LTE system deployed for our tests. The evolved packet core is leased from Motorola in the form of cloud core services. The radio access network (E-UTRAN) resides in the District 7 police station. Please note that due to operational issues and requirements by the CPD, testing of CAD, CLEAR and Shotspotter were not executed to avoid any interruption in the access to those services in District 7. Please also note that an application server is connected to the network and co-located with the servers in District 7. The application server, not shown in this Figure, hosts some of the services needed to conduct the test plan. In our tests we connected to the network using laptop computers via a USB dongle as shown as in Figure 4.

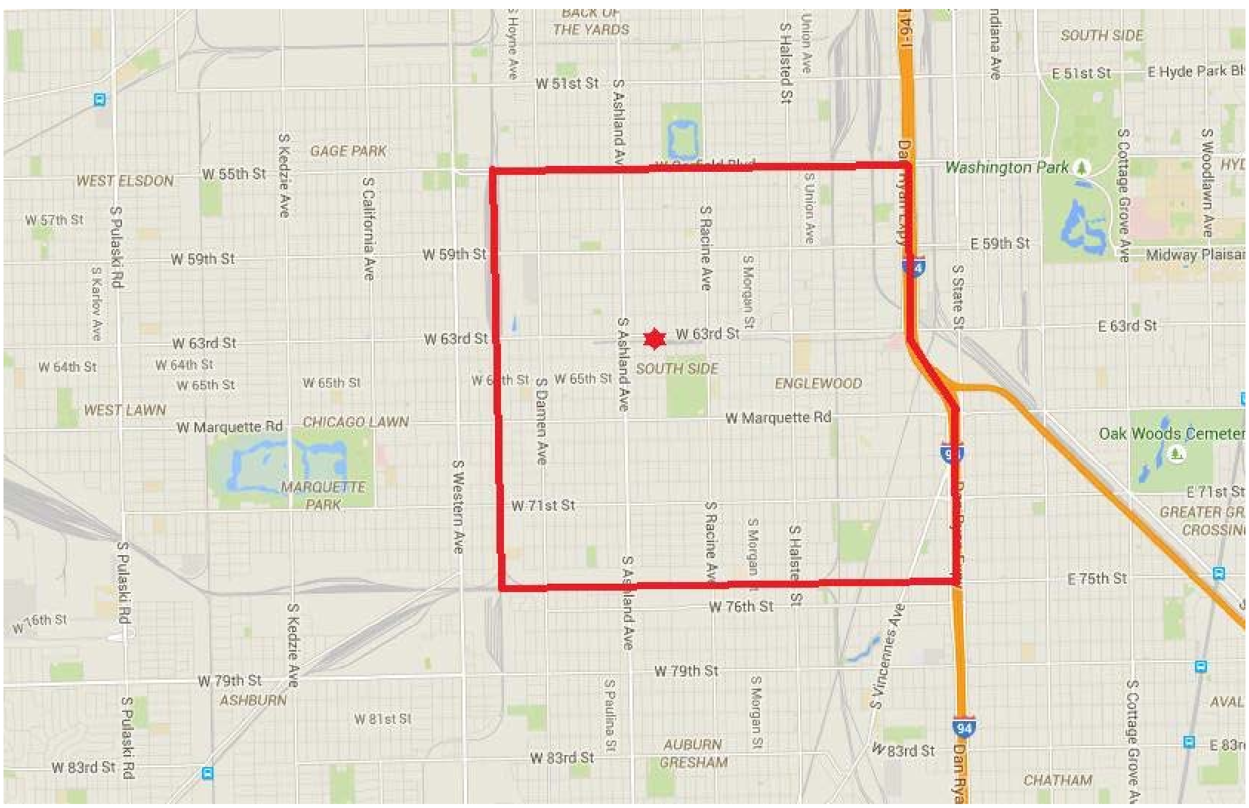

Figure 2: CPD District 7 Borders and Police Station (red star)

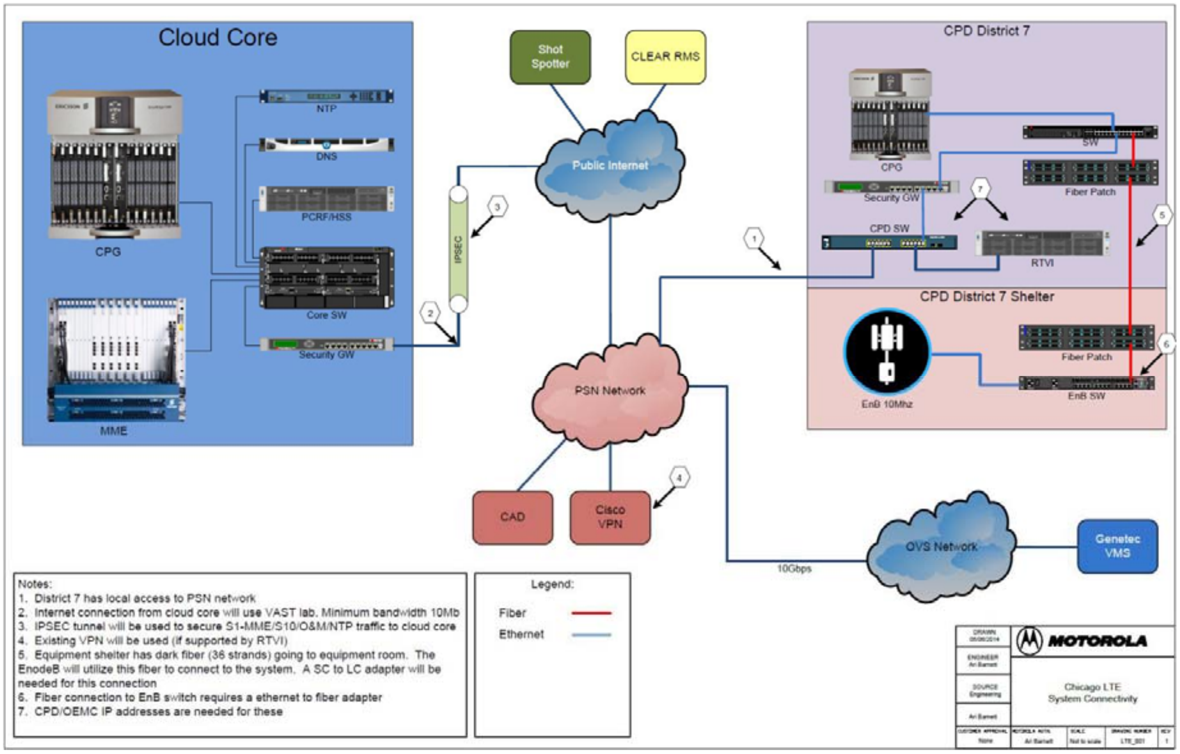

Figure 3: Chicago LTE Pilot System Connectivity

The test plan consisted of three parts: First, objective perceptual video quality tests designed to measure the video quality when video is streamed in real-time over the LTE network were conducted. The measurements are based on generally accepted objective metrics from the video compression community. Second, subjective measurements were conducted to characterize the performance of applications of interest under various test conditions. Third, network performance metrics were obtained to test the key performance indicators associated with the network. Section 3 presents results and observations based on the data collected. Section 4 contains ideas for future work.

Figure 4: Police Laptop Connected to LTE Using a USB Dongle

3 Test Results and Discussion

3.1 Objective Video Quality Measurement

Our goal is to study video quality delivered over the LTE network. Many variables influence video quality when streamed over LTE networks. To investigate the impact of the LTE wireless interface a non-adaptive configuration was used. Video spatial and temporal resolution (frame size and frame rate) and video date rate (bits/second) were not altered. Pre-encoded test video sequences were streamed with fixed spatial resolutions, frame rates and data rates to emulate a live stream scenario. The test video sequence database used for this testing was selected from the Public Safety Communication Research (PSCR) video samples with applications in public safety shared in the Consumer Digital Video Library (CDVL)[2].

Five video sequences were selected: An angled walkway video sequence at the top of an indoor stadium, above the seating, with many people walking around during a break. A car entering/leaving a parking lot capturing the license plate. Bank teller robbery, the sequence captures one teller's window and a frontal shot of the robber. The fourth sequence shows a person walking down a hallway holding a small object in his hand. The fifth sequence shows some people browsing a store aisle of mostly office supplies. The objects differ, as does distance between the camera and person. Some of the objects are put in basket, put in a pocket, or returned to shelf. Each of the five video sequences was transcoded according to the data rates and spatial resolutions described in Appendix A.1.1. Each video sequence was 30 frames/s and compressed using the H.264 video compression standard using default parameters.

Figure 5 shows the locations for static testing while Figure 6 displays the driving routes used to investigate mobility impact on performance. At each testing location, the test video sequences

[2] http://www.cdvl.org/

were streamed and captured according to the testing procedure described in Appendix A.1.1. At the end of each test, the reference video and the captured (degraded) video were compared and a quality measurement was obtained using the criteria described in Appendix A.1.1.

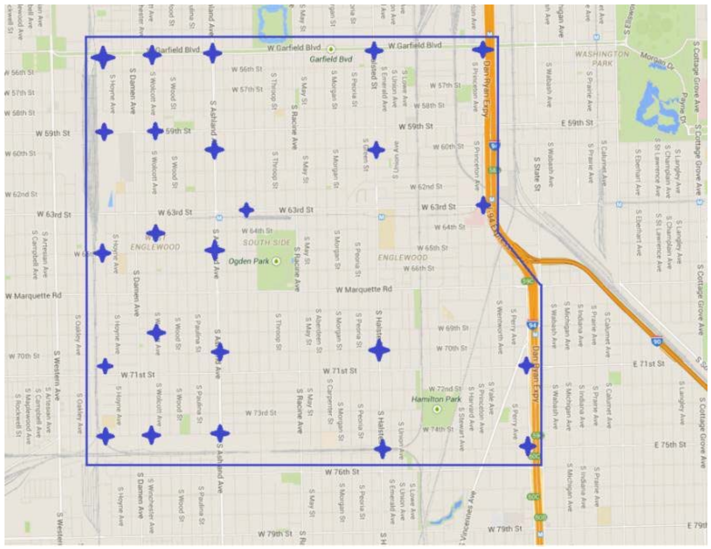

Figure 5: Locations Used for Static Video Testing

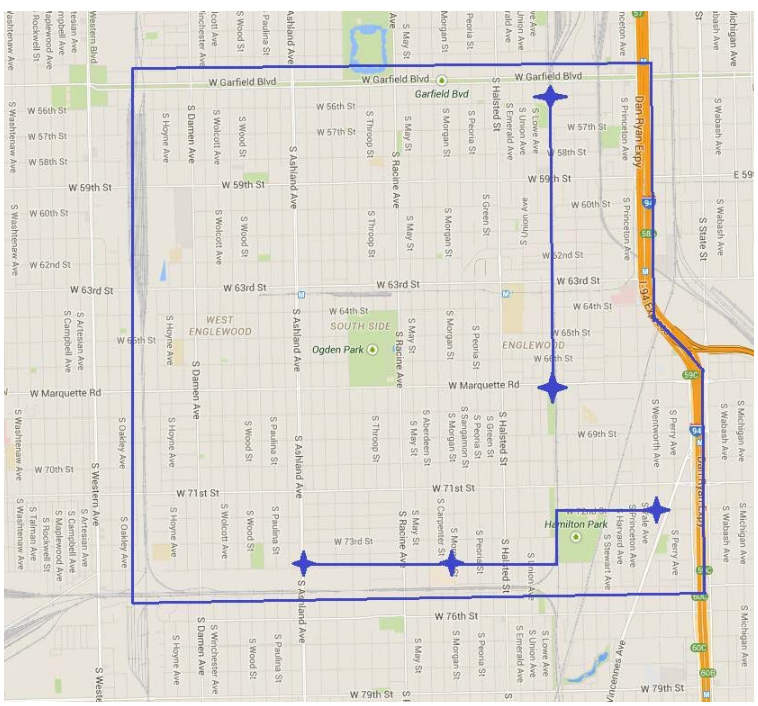

Figure 6: Driving Routes Used For Testing

To summarize the results we divided them into two main parts: test locations with excellent channel conditions and test locations at the cell edge. At test locations with excellent channel conditions (close to the eNodeB), network resources can accommodate several users at large data rates. Figure 7 and Figure 8 shows the captured video quality measurements using PSNR (Peak Signal-to-Noise Ratio) and SSIM (Structural Similarity) [1-2] for a video sequence displaying a shoplifting event. The video was transmitted at 720p (30 frames/s) at the following data rates: 200, 400, 700, 1000, 2000 and 4000 kb/s. 720p is a progressive High Definition video format which has a resolution of 1280×720. The video was transmitted/streamed from the application server to laptop connected to the LTE network. The detailed descriptions of PSNR and SSIM are presented in Appendix A.1.1. PSNR measures the mean error between input (reference video at the application server) and output (captured video on the laptop connected to the LTE network) and expresses the result as a ratio of the peak signal expressed in dB. It measures the absolute difference between two signals, which is completely quantifiable. Typical values for the PSNR in lossy video compression are between 15 and 50 dB. A PSNR value of 30db to 35dB is generally considered good. Higher values correspond to better video quality. The Structural Similarity Index (SSIM) is also a full reference metric for measuring the similarity between two images or video sequences. SSIM considers image degradation as perceived change in structural information. SSIM possible range of values is between -1 and 1 where values closer to 1 have a better video quality. SSIM value of 0.8 to 0.85 is generally considered very good.

Congestion was introduced in the network by following the specifications of network traffic level 3 described in Appendix A.1.1. At these test locations, network traffic did not have an impact on video quality as the network can accommodate several users at large data rates. All measured PSNR are larger than 42 dB and all measured SSIM are larger than 0.94. No significant change in measurements was observed after the introduction of network traffic. Figure 7 and Figure 8 show one sample result. All streamed videos at locations with excellent channel conditions followed the same pattern with no quality degradation. A consistent pattern is observed for the other test video sequences and the result is indicative of the large data rate possible at test locations with excellent channel conditions.

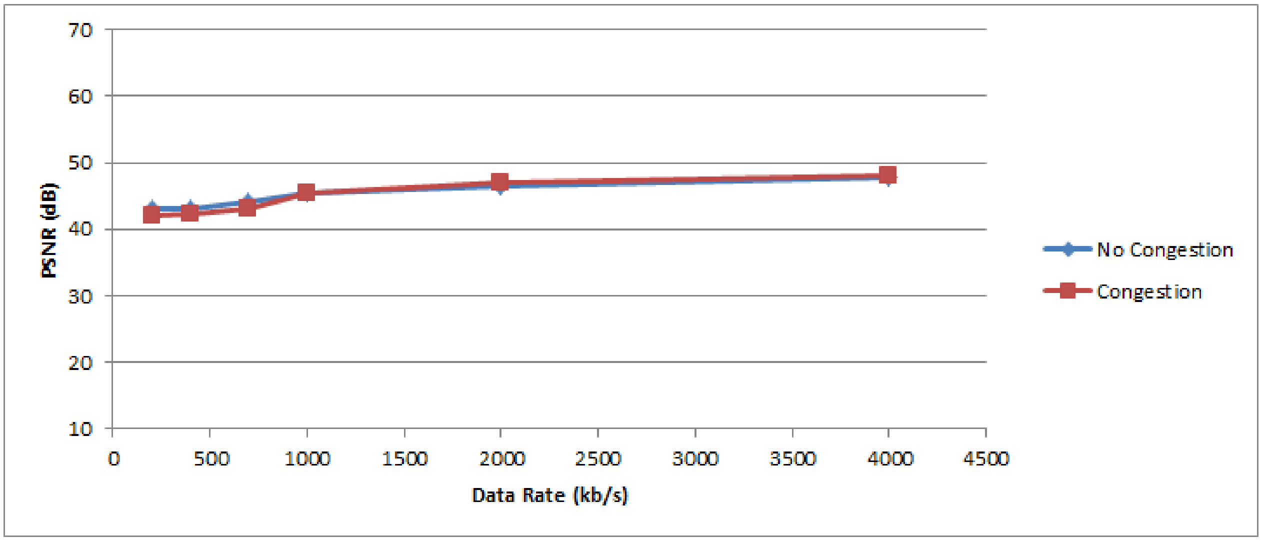

Figure 7: PSNR Video Quality Measurement

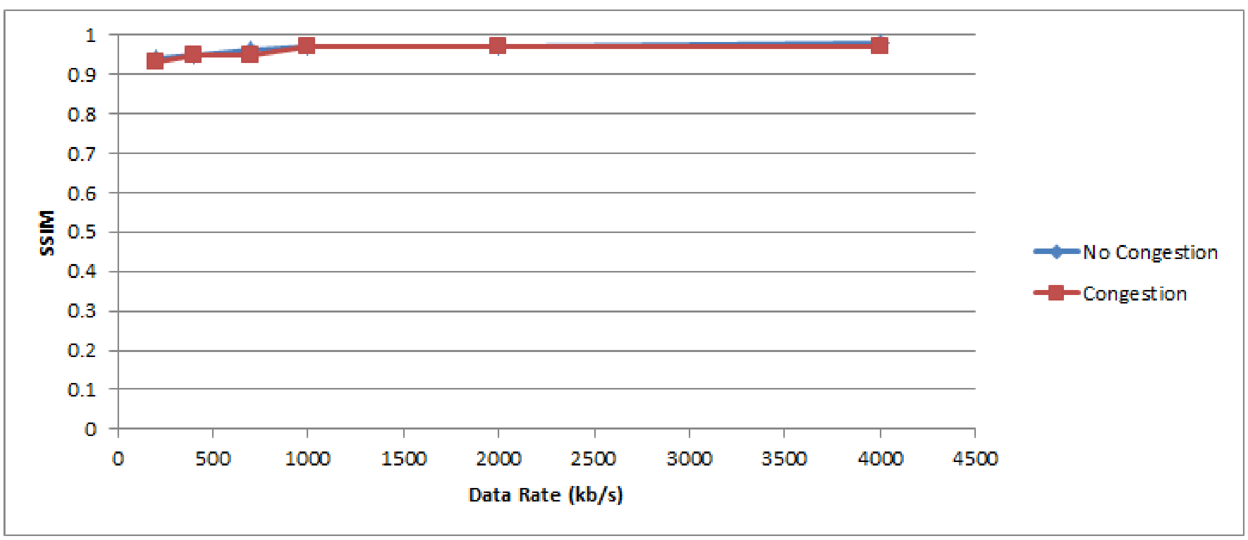

Figure 8: SSIM Video Quality Measurements

For test locations close to the cell edge, the video quality suffered from packet losses. Introducing network traffic and congestion in the network resulted in more quality degradation. Figure 9 and 10 display the captured video quality measurements using PSNR and SSIM for a video sequence transmitted at 720p at the following data rates: 200, 400, 700, 1000, 2000 and 4000 kb/s.

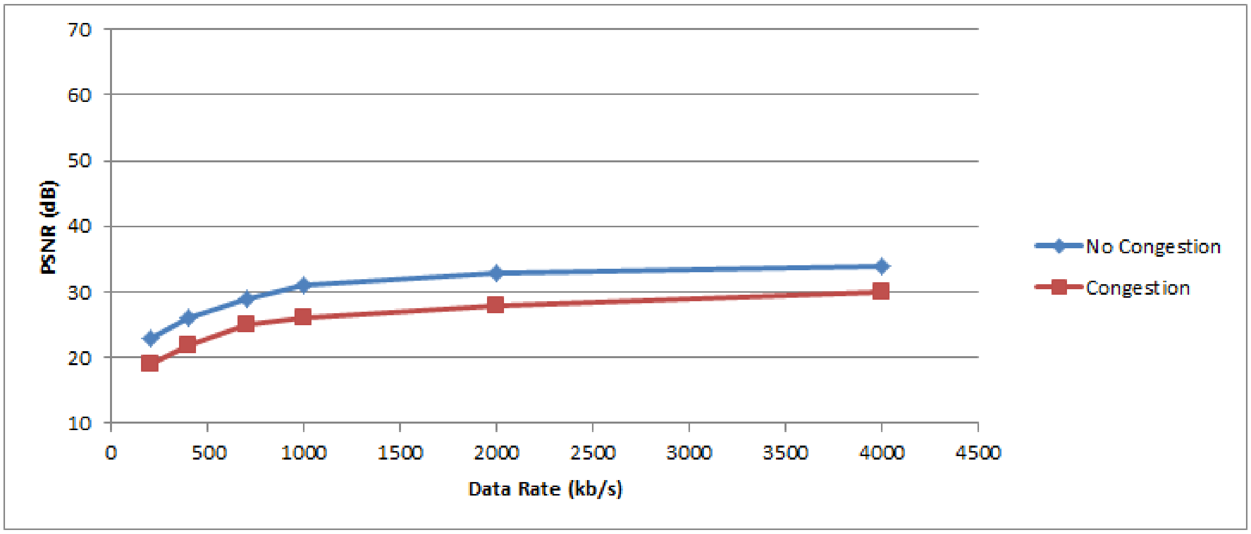

Figure 9: PSNR Video Quality Measurements (Cell Edge)

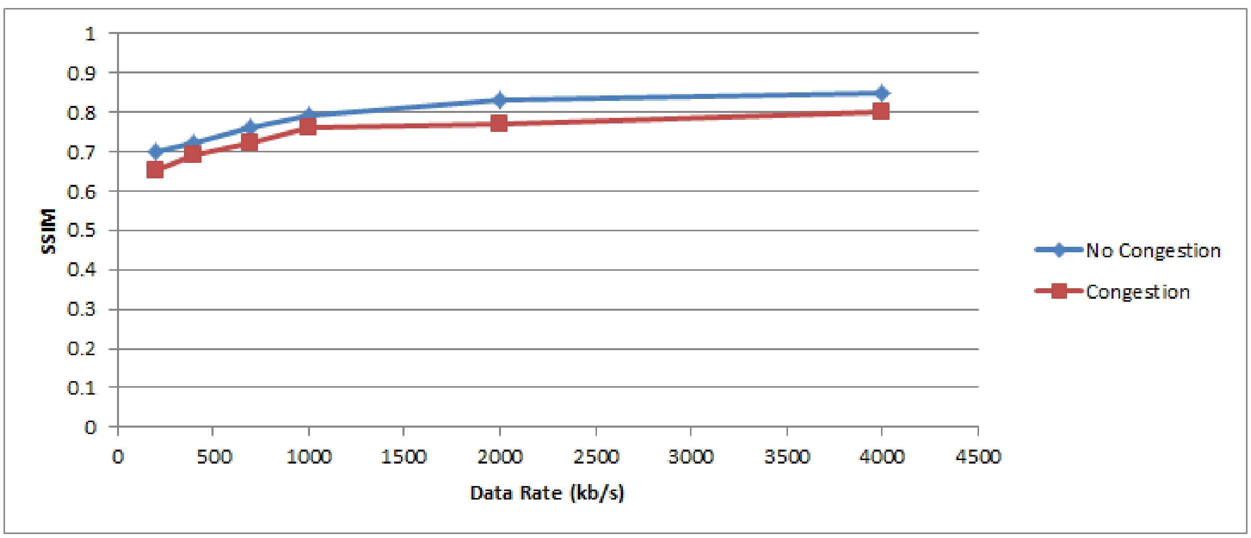

Figure 10: SSIM Video Quality Measurements (Cell Edge)

As shown, video quality is significantly impacted by available network resources. PSNR values are around 27 dB when no congestion is introduced in the network compared to 42dB for the case mentioned above. On average a loss of 5dB in PSNR value was observed due to the introduction of network traffic. SSIM measurements indicated the same result where the measured values were approximately 0.77 and the introduction of network traffic resulted in 0.05

drop in the measured metric. The captured video sequences are poor quality and not "clear" enough for public safety tasks such as the identification of the person involved in shoplifting, recognition of license plate or crowd analysis. A consistent pattern appears with all the test sequences following the test procedure described in Appendix A.1. Congestion and traffic in the network or weak channel conditions lead to poor video quality.

For many public safety applications, the task plays a significant role in the video quality requirements. License plate recognition, motion detection, person identification or anomaly detection are examples of such tasks. Each of these tasks requires varying levels of video quality. For example, it was observed that for 720p video sequence, a license plate could be recognized at 700 kb/s for a car moving close to the far end of the camera field of view but not at 400 kb/s. However, at 400 kb/s a person involved in bank robbery could be recognized as long as the person was close to the camera. Various objects in crowded scenes in a stadium walkway could not be recognized at 400 kb/s nor at 700 kb/s. Therefore, video quality requirements should be based on the desired task. Spatial resolution, frame rate and data rate should be governed by video usage in a task-based approach.

3.2 Subjective Quality Assessment of CPD Applications

As mentioned above only subjective assessment of the Real Time Video Intelligence (RTVI) system was conducted. The RTVI system allows real time video transmission from cameras to the command center and to mobile devices. The RTVI system was designed to dynamically adapt to the variances in bandwidth that are regularly experienced by mobile broadband networks. If the available bandwidth decreases, the video transmission data rate is automatically adjusted. The assessment of the RTVI was performed in the locations shown in Figure 5.

For each location, the RTVI application was started and video streams were viewed and assessed according to the procedures described in Appendix A.2. The RTVI system uses adaptive video coding techniques, the data rate was observed to be approximately 650 kb/s for all testing locations with the exceptions of the points close to the cell edges.

At test locations with excellent channel conditions, the clarity of the image and the apparent fluidity of the motion were evaluated to be 4 out of 5. Clarity of the image refers to the amount of detail an image can convey. Fluidity of the motion refers to motion continuity and smoothness [3]. Introduction of network traffic, mobility, increased use of other applications and affiliations of new users did not have an impact on the quality level. This is due to the fact that network resources at these locations are adequate to accommodate many users. Network traffic levels definitions are described in Appendix A.1.1 while evaluation methodology is described in Appendix A.2.1.

Closer to the cell edges, the introduction of network traffic had a significant impact on the quality level. Figure 11, 12 and 13 show the relationships. Level 0 refers to no other traffic in the network while level 3 had the most amount of traffic. The introduction of the network traffic caused adjustment of data rate in the variable rate video encoder used by RTVI and degradation of video quality consequently.

Adaptive video coding techniques adjust to the available network resources. In the case of an emergency, hundreds of users might be in the field trying to access the network. In this scenario, as shown by the testing results, the video quality will degrade significantly and the video data stream might be eventually interrupted. Therefore, adaptive video coding techniques might not suit emergency scenarios where many users are trying to access the network. Fixed data rate video coding techniques and guaranteed data resources should be allocated to the video streams[3].

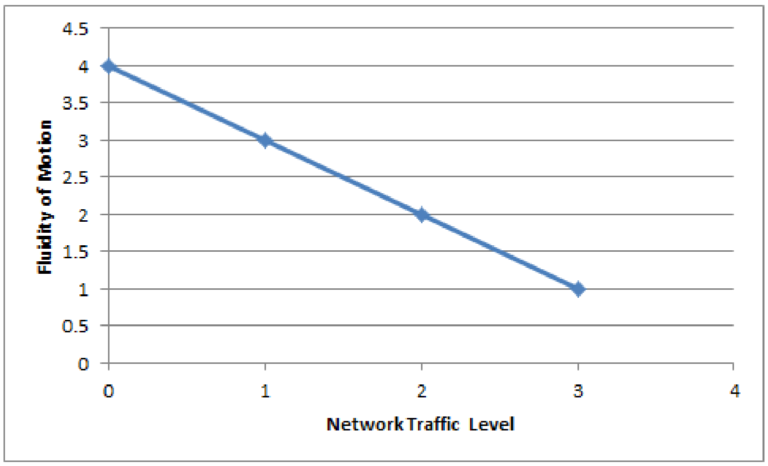

Figure 11: Fluidity of Motion Along The Cell Edges - RTVI

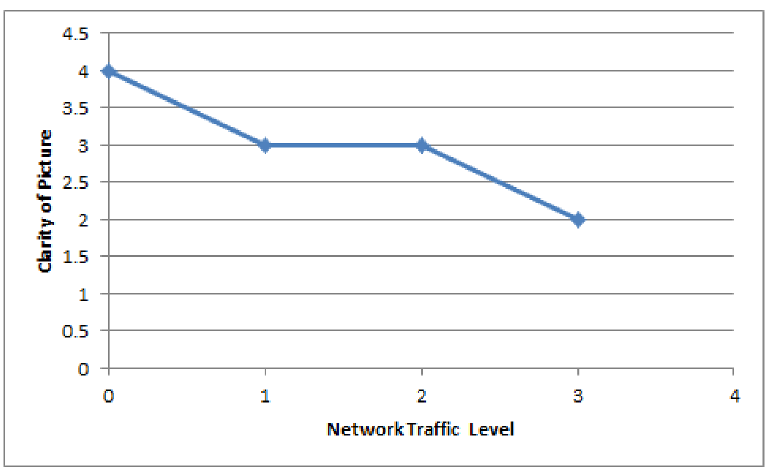

Figure 12: Clarity of Picture Along The Cell Edges - RTVI

[3] We understand this may be application dependent and further study needs to be conducted.

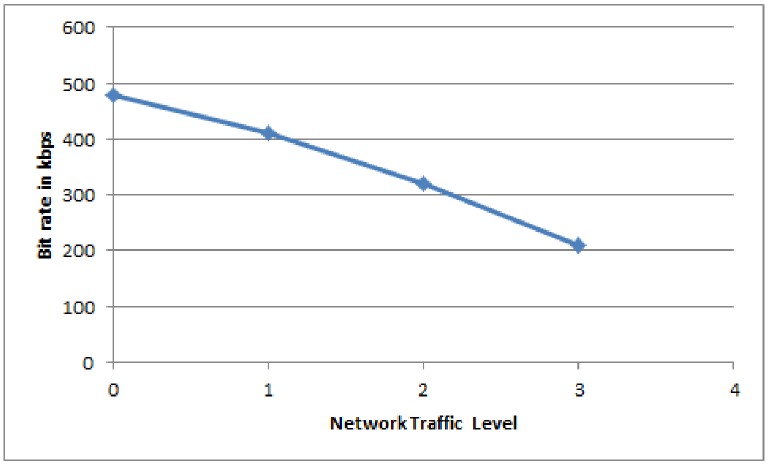

Figure 13: Video Data Rate Along The Cell Edges – RTVI

Previous measurements above investigated video quality when video streams were viewed by a user connected to the LTE network. The user had to be located within the cell coverage area and used the LTE network to access video streams using the RTVI system. Such video streams originate outside the LTE network and are captured by Police Observation Devices (PODs). They transmit video data continuously to the command center using an established infrastructure. We shall refer to the established infrastructure over which PODs transmit video data to the command center as the legacy network. The LTE network can be also used to connect a POD or a camera to the command center such that a user located in the command center can view the POD video stream directly. By connecting a POD to the LTE network, video data are transmitted in the uplink direction (form the LTE device to the network).

To conduct the test procedure described in Appendix A.2.1, a video camera was installed in close proximity to a legacy network POD to facilitate the comparison between LTE based and legacy based systems. For a user located at a command center, RTVI was used to view a video sequence of both cameras: LTE camera and legacy network POD. The clarity of the picture and the fluidity of the motion were observed to be equal for both cameras at 5 and 4 respectively. Congestion was introduced in the network by following the specifications of network traffic level 1 described in Appendix A.1.1. The introduction of traffic did not have an impact on the quality observed by the user located in the command center.

3.3 Network Performance Measurements

Network performance measurements were conducted at static locations displayed in Figure 5 and driving routes displayed in Figure 6. Network performance metrics were obtained to test the key performance indicators associated with the network. To summarize results, we divide them into three main parts: peak throughputs (measurements close to the eNodeB), cell edges and remaining points.

For points yielding peak throughputs, Received Signal Strength Indicator (RSSI) was measured at -71dBm. RSSI is a parameter which provides information about total received power over the whole bandwidth including all interference and noise. Reference Signal Received Power (RSRP) was measured at -92dBm. RSRP is the average power of Resource Elements (RE) that carry cell specific Reference Signals (RS) over the entire bandwidth. RSRP is reported in the range -44 to 140 dBm. RSRP does a better job of measuring signal power from a specific sector while potentially excluding noise and interference from other sectors. RSRP levels for usable signal typically range from about -75 dBm close to eNodeB to -120 dBm at the edge of LTE coverage. Reference Signal Received Quality (RSRQ) was measured at -18dBm. RSRQ gives better indication of signal quality. RSRQ is defined as the ratio of RSRP to the carrier received signal strength indicator (RSSI). Measuring RSRQ becomes particularly important near the cell edge when decisions need to be made to perform a handover to the next cell [4]. Signal to Noise Ratio (SNR) was measured at 6. Those measurements are indicative of very good channel quality.

Transmission Control Protocol (TCP) enables two hosts to establish a connection and exchange streams of data. It guarantees that packets will be delivered in the same order in which they were transmitted. TCP throughput is the rate of successful message delivery over the network is usually measured in bits per second (bit/s). TCP throughput varies according to the direction of transmission. In the case of LTE network, downlink (DL) refers to data being sent from the network towards the mobile device while uplink (UL) refers to data sent from the mobile device towards the network. [5]

The peak TCP throughput was measured at 29.8 Mb/s in the DL and 20 Mb/s in the UL. Figure 14 displays the TCP throughput in the DL (direction as a function of network traffic). Network traffic levels definitions are described in Appendix A.1.1. Level 0 refers to no other traffic in the network while level 3 had the most amount of traffic. When network traffic is introduced throughput values are reduced. However, such locations benefit from excellent channel signal quality and maintain high communication speeds.

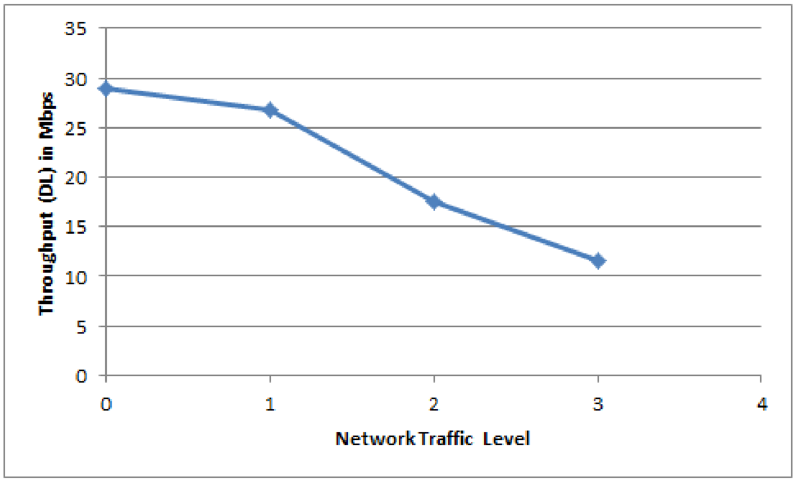

Figure 14: Throughput (DL) Versus Network Traffic

Figure 15 displays the packet loss rate as a function of network traffic for a 15 Mb/s steady UDP connection. User Datagram Protocol (UDP) uses a simple connectionless transmission model with no guaranteed services. For network traffic level 3, the packet loss rate was measured at 15% for a 15 Mb/s UDP connection. Packet delays and jitter were negligible and measured at approximately 2 ms. Jitter is the latency variation and is particularly important on networks supporting multimedia communication. It is calculated as the maximum variation difference between packet delays.

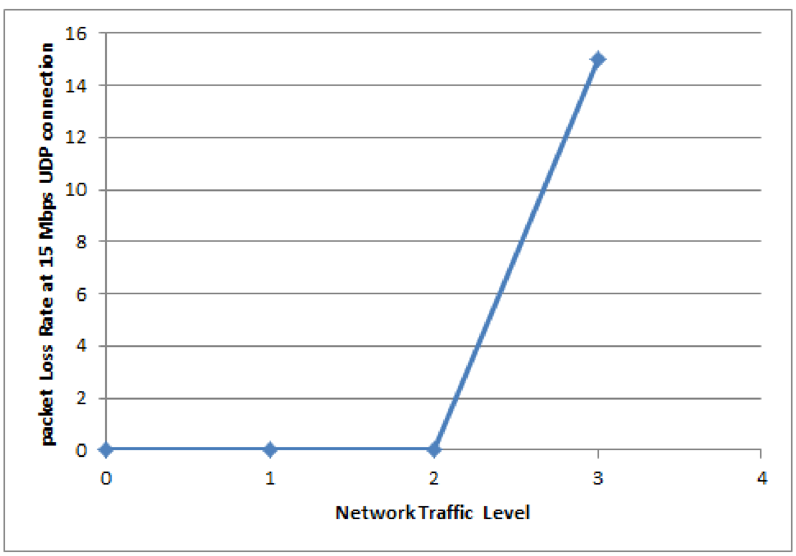

Figure 15: Packet Loss Rate at 15 Mb/s for UDP Connections

For testing locations close to cell edges, the TCP throughput was measured at 1.7 Mb/s. Received Signal Strength Indicator (RSSI) was measured at -92dBm, RSRP (Reference Signal Receive

Power) was measured at -110dBm, Reference Signal Receive Quality (RSRQ) was measured at -24dBm and Signal to Noise Ratio (SNR) was measured at 1. Those measurements are indicative of fair to poor quality. Figure 16 displays the TCP throughput in the DL direction as a function of network traffic. Due to the limited amount of network resources, it becomes very significant to follow a QoS (Quality of Service) and prioritization model at such locations [6].

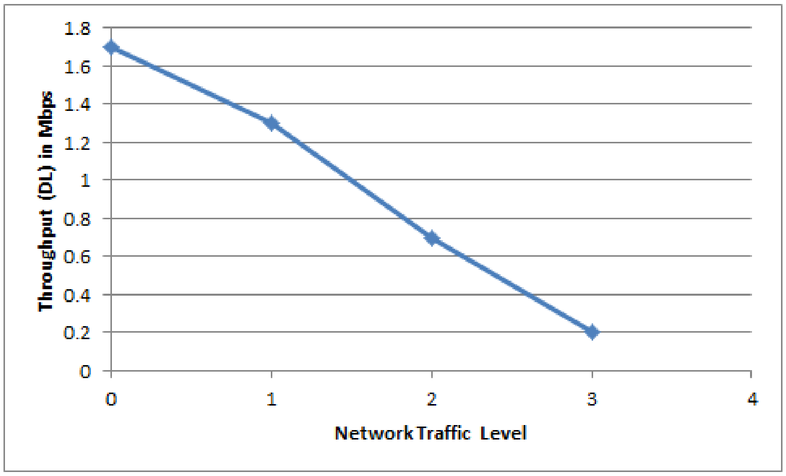

Figure 16: TCP Throughput (DL) Versus Network Traffic – Cell Edges

Figure 17 displays this relationship for the UL direction where the resources are very limited as well.

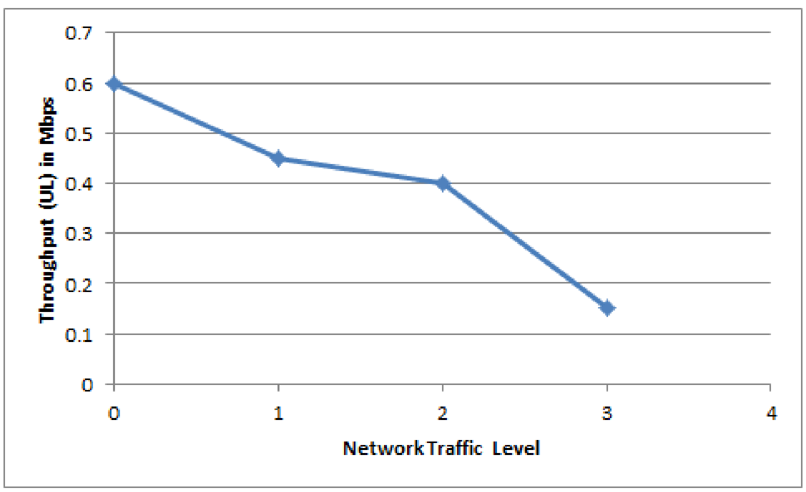

Figure 17: TCP Throughput (UL) versus network traffic – cell edges

The introduction of network traffic and congestion also leads to higher jitter as shown in Figure 18. This has a direct impact on video quality when streamed over LTE network at those locations.

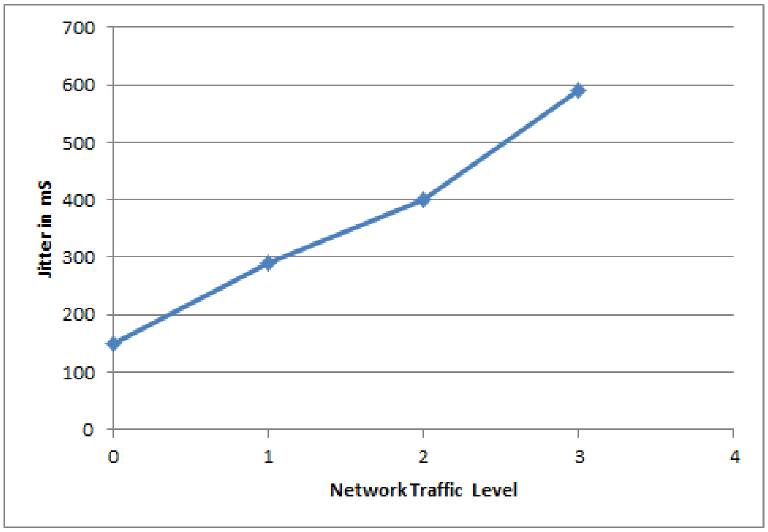

Figure 18: Jitter (mS) Versus Network Traffic – Cell Edges

For the remaining locations, on average the Received Signal Strength Indicator (RSSI) was measured at -82dBm, the RSRP (Reference Signal Receive Power) was measured at -100dBm, the Reference Signal Receive Quality (RSRQ) was measured at -20dBm and the Signal to Noise Ratio (SNR) was measured at 3. Those measurements are indicative of good channel quality. Figure 19 displays the averaged TCP throughput in the DL direction as a function of network traffic.

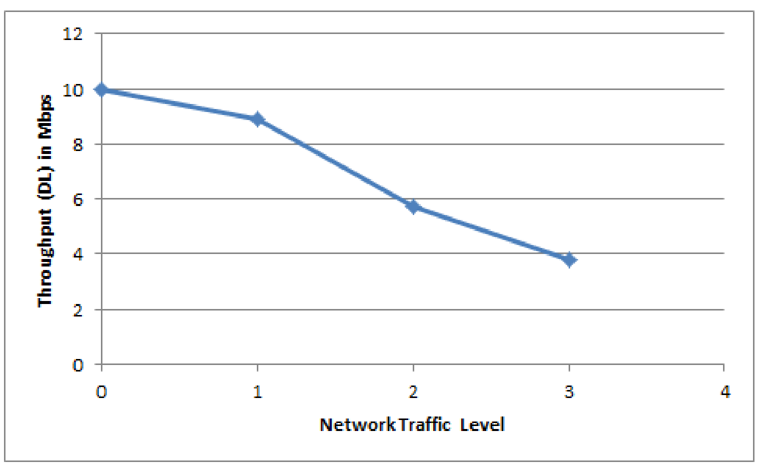

Figure 19: Throughput (DL) versus network traffic

Performance results for driving routes yield very similar results to the ones mentioned above. The current approach to scheduling of network resources seem to aim at fair distribution of resources. Therefore, to meet the requirements of public safety, the incorporation of QoS and prioritization becomes crucial.

Network attachment success rate was 100% during the full extent of testing. Mobility is a crucial aspect to public safety and did not have an impact on the performance as long as the distance to the eNodeB remained relatively the same. No cases of dropped connections were observed.

4 Future Work

4.1 Objective Video Quality Metric with Applications in Video Analytics in Public Safety

For many public safety applications, the law enforcement task at hand plays a significant role in determining video quality requirements. Our preliminary study have shown that the NPSBN has great promise for delivering high video to law enforcement in the field (particularly to vehicles) Other than just watching the video feed, license plate recognition, motion detection, person identification and anomaly detection are examples of video analytic tasks that a law enforcement officer might want to perform using the LTE system in the field. Each of these tasks requires varying levels of video quality. Spatial resolution, frame rate and data rate should be governed by video usage in a task-based approach.

Current approaches for video quality requirements rely on subjective assessment focused on determining the minimum acceptable video quality. These approaches give valuable insights but still face significant challenges. For example, recognition of objects in a video sequence is constrained by the size of the objects as they appear in the video. Equivalently, person re-identification is constrained by the size of the person appearing in the video sequence, pose and distance from the camera. Therefore, minimum acceptable video quality for a specific task changes dynamically with changing scenes.

Our goal is to design an objective video quality metric based on advanced image and video processing techniques combined with machine learning strategies to estimate video quality in dynamic scenes. This metric would indicate to the law enforcement officer which video analytic might be useful to him/here given the video quality. We want to conduct a comprehensive study of public safety tasks and investigate video quality requirements for each one of them under dynamic scenes. We will study different approaches to extracting features and using them to estimate video quality. We will also investigate methods that allow one to fix or conceal errors that could occur in the video stream and study how the errors would impact the “usability” of the video.

Such an objective video quality metric becomes very valuable in high speed broadband environment such as the LTE National Public Safety Broadband Network (NPSBN). Public safety applications such as video streaming and management systems can use an objective video quality metric to estimate video quality and adjust the scheduling of network resources to meet the requirements of public safety tasks. The interaction between public safety applications and network resources management plays a vital role in the successful adoption of NPSBN.

4.2 *Quality of Service (QoS) and Prioritization in the Nationwide Public Safety Broadband Network (NPSBN)*

The Chicago LTE pilot project demonstrates that the 700MHz National Public Safety Broadband Network (NPSBN) will provide unprecedented resources in terms of network capacity and communication speeds. However, Quality of Service (QoS) and prioritization should still be taken into consideration while scheduling network resources. Mission critical users or emergency responders should be allocated resources according to a well-defined QoS and prioritization model. This becomes more significant in the case where an emergency takes place along cell edges. Due to the limited amount of network resources, it becomes very significant to follow a QoS and prioritization model at such locations.

National Public Safety Telecommunications Council (NPSTC) priority and QoS task group has outlined the requirements for the Nationwide Priority and QoS Framework in the "Priority and QoS in the Nationwide Public Safety Broadband Network" document.

Our goal is to characterize the performance of the NPSBN when a Priority and QoS framework is implemented within the network. We want to devise a test plan following the uses cases defined in the document and characterize the performance with respect to transport of video imagery. Our goal is to stage emergency cases and study the performance of the network accordingly.

4.3 Proximity Services and Device to Device Communication

Release 12 is the latest version of the 3rd Generation Partnership Project (3GPP) standard for LTE. It was finalized in the first quarter of 2015. One of the new features in Rel-12 is Proximity Services (ProSe). Proximity services allow for direct device to device (D2D) communication between nearby mobile devices. It is of a particular interest to public safety as this mode of communication allows for a fallback solution when broadband networks are not available.

For this purpose, two proximity services were defined:

1. ProSe Discovery: a process that identifies that a device is in proximity of another
2. ProSe Communication: a communication between two devices in proximity by means of a communication path established between the devices

The path for discovery and communication could be established directly between devices or network based (routed via local eNB).

Our goal is to characterize the performance of the NPSBN when the network is no longer available. We want to devise a test plan to investigate the performance of Proximity Services with respect to transport of video imagery. This study is constrained by the availability of devices supporting proximity services.

5 References

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2. A. C. Bovik, "Automatic Prediction of Perceptual Image and Video Quality," Proceedings of the IEEE, Vol. 101, No. 9, September 2013, pp. 2008-2024.

3. Recommendation ITU-T P.910: Subjective video quality assessment methods for multimedia applications

4. 3GPP TS 36.314 V11.1.0 (2012-12): 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Layer 2 – Measurements (Release 11)

5. Leon-Garcia, Alberto, and Indra Widjaja. *Communication networks*. McGraw-Hill, Inc., 2003

6. 3GPP TS 23.203 V12.4.0 (2014-03): 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Policy and charging control architecture (Release 12)

7. The Motorola document dated April 14, 2014: “CHICAGO LTE PILOT TEST PLAN”

A Appendix A: Testing Procedure and Tools

The Chicago LTE Pilot is a Public Safety Broadband Network (PSBBN) providing LTE coverage in Chicago's seventh district. This section describes the test procedure conducted by Purdue University to characterize the performance of the network. The test procedure consisted of three parts: First, objective perceptual video quality tests designed to measure the video quality when video is streamed in real-time over the LTE network. Measurements were based on generally accepted objective metrics from the video compression community. Second, subjective measurements designed to characterize the performance of applications of interest under various test conditions. Third, network performance measurements to test the key performance indicators associated with the network. An application server was used to host some of the services required for testing purposes, such as a video streaming server. Objective key performance indicators (KPI) were measured while users access services using the LTE network. The following subsections describe the test cases in details:

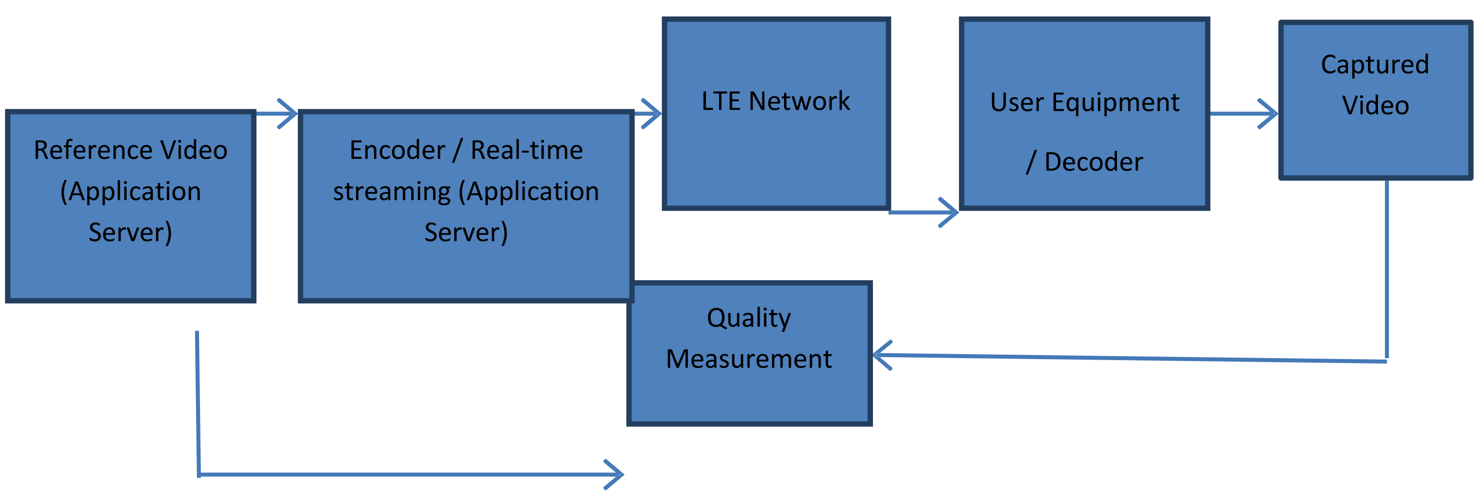
A.1 Objective Video Quality Measurement

The goal of this testing procedure is to study video streaming quality over LTE network with applications in public safety. Many variables influence video quality when streamed over LTE network. To investigate the impact of the LTE wireless interface a non-adaptive configuration was used. Spatial resolution and data rate were not altered. Pre-encoded videos were streamed with fixed spatial resolutions, frame rates and data rates to emulate a live stream scenario. The following subsections explain the details of the testing procedure:

A.1.1 Operation Test Plan

Testing Model

This section provides guidelines for the objective perceptual video quality measurement when a full reference video signal is available. Measurements were based on the following model:



An application server was connected to the LTE backhaul network and was accessible from the User Equipment (UE). The application server hosts the necessary tools to stream a pre-encoded video emulating a live stream scenario.

Objective Quality

At the end of each test, the reference video and the captured (degraded) video were compared and a quality measurement was obtained using the following criteria:

1. Peak Signal-to-Noise Ratio (PSNR)
2. Structural Similarity (SSIM) [1]

Structural similarity index is also a full reference metric for measuring the similarity between two images or video sequences. SSIM considers image degradation as perceived change in structural information. SSIM possible range of values is between -1 and 1 where values closer to 1 have a better video quality. SSIM value of 0.8 to 0.85 is generally considered good. [1-2]

PSNR measures the mean error between input (reference video) and output (captured video). It measures the absolute difference between two signals, which is completely quantifiable. Typical values for the PSNR in lossy video compression are between 15 and 50 dB. A PSNR value of 30db to 35dB is generally considered good. Higher values correspond to better video quality. Since PSNR is a full reference method, access to the original (reference) video is required. The signal in this case is the original video data, and the noise is the error introduced by compression or transmission over networks. It is the most traditional way of evaluating quality of digital video processing systems. PSNR refers to the ratio between the maximum possible value of a signal and the power of corrupting noise that affects the fidelity of its representation. The power of corrupting noise is represented by the mean squared error (MSE). Since video sequences have a wide dynamic range, PSNR is usually expressed in terms of the logarithmic decibel scale.

Given an original (reference) M×N image (I) and its noisy approximation (K, image captured after transmission over network). MSE is defined as:

$$\frac{\quad}{\quad} \sum \sum \qquad) \qquad))$$

Accordingly, PSNR is defined as:

$$\frac{\quad}{\quad}$$

Since a video is comprised of a sequence of images, PSNR value is calculated by averaging the PSNR of each pair of images.

Streaming Protocols

Each test was done using Real-Time Transport Protocol (RTP) over UDP as a streaming protocol. The Real-Time Transport Protocol (RTP) is an Internet protocol standard that specifies a way to manage the real-time transmission of multimedia data over network services. Transmission Control Protocol (TCP) enables two hosts to establish a connection and exchange streams of data. It guarantees that packets will be delivered in the same order in which they were transmitted. TCP throughput is the rate of successful message delivery over the network is usually measured in bits per second (bit/s or bps). TCP throughput varies according to the direction of transmission. In the case of LTE network, downlink (DL) refers to data being sent from the network towards the mobile device while uplink (UL) refers to data sent from the mobile device towards the network. User Datagram Protocol (UDP) uses a simple connectionless transmission model with no guaranteed services.

Video Resolution and Frame Rate

Each test case was performed using the following video resolutions at 30 FPS:

1. CIF 50, 100, 300, 1000 kb/s
2. VGA 100, 300, 500, 1000, 2000 kb/s
3. 720p 200, 400, 700, 1000, 2000, 4000 kb/s
4. 1080p 200, 400, 700, 1000, 2000, 4000 kb/s

Common Intermediate Format (CIF) defines a video sequence with a resolution of 352 × 288. Video Graphics Array (VGA) means the 640x480 resolution. 720p is a progressive High Definition signal format which has a resolution of 1280×720. 1080p is a progressive High Definition signal format which has a resolution of 1920x1080.

Testing Conditions

Band = 14
Bandwidth = 10 MHz

Handset device: USB Dongle

Data-only device: Broadband

Network Traffic

Congestion was introduced in the network by a mixture of data streams. Three distinct levels of network congestion were considered to test the objective video quality under various traffic conditions. Network traffic was composed of RTP (over UDP) data and FTP (over TCP).

Three levels of network traffic were considered:

1. Low traffic

   Low traffic consisted of one user initiating an RTP/UDP stream at 2 Mbps along an FTP session, both in the downlink or uplink direction

2. Medium traffic

   Medium traffic consisted of one user initiating an RTP/UDP stream at highest possible speed in the downlink or uplink direction

3. High traffic

   High traffic consisted of two users initiating an RTP/UDP stream at highest possible speed along with one user initiating a File Transfer Protocol (FTP) session, all in the downlink or uplink direction

A.1.2 Test Scenarios

Single User, Static Conditions

Test description

Determine the objective video quality measurement a streaming protocol under static conditions with no network congestion.

Test Procedure

1. Select a test location and establish a LTE data connection
2. Configure the application server to start streaming
3. Receive the real-time stream and capture the video locally
4. Compare the reference video and the captured video using the criteria specified in Objective Quality in Appendix A.1.1
5. Repeat step 2-4 for the specifications mentioned in Video Resolution and Frame Rate section in Appendix A.1.1
6. Store the quality score for each test
7. Testing complete

Single User, Dynamic Conditions

Test description

Determine the objective video quality using a streaming protocol under dynamic conditions with no congestion in the network.

Test Procedure

1. Select a test location and establish a LTE data connection
2. User begins moving throughout the coverage area
3. Configure the application server to start streaming
4. Receive the real-time stream and capture the video locally

5. Compare the reference video and the captured video using the criteria specified in Objective Quality in Appendix A.1.1
6. Repeat step 2-4 for the specifications mentioned in Video Resolution and Frame Rate section in Appendix A.1.1
7. Store the quality score for each test
8. Testing complete

Multi User, Static Conditions

Test description

Determine the objective video quality using various streaming protocols under static testing conditions with congestion in the network.

Test Procedure

1. Select a test location and establish a LTE data connection
2. Configure the application server to start streaming
3. FTP and RTP traffic is introduced in the network as specified in Network Traffic in Appendix A.1.1
4. Receive the real-time stream and capture the video locally
5. Compare the reference video and the captured video using the criteria specified in Objective Quality in Appendix A.1.1
6. Repeat step 2-4 for the specifications mentioned in Video Resolution and Frame Rate section in Appendix A.1.1
7. Store the quality score for each test
8. Testing complete

Multi User, Dynamic Conditions

Test description

Determine the objective video quality using various streaming protocols under dynamic testing conditions with congestion in the network.

Test Procedure

1. Select a test location and establish a LTE data connection
2. User begins moving throughout the coverage area
3. Configure the application server to start streaming
4. FTP and RTP traffic is introduced in the network as specified in Network Traffic in Appendix A.1.1

5. Receive the real-time stream and capture the video locally
6. Compare the reference video and the captured video using the criteria specified in Objective Quality in Appendix A.1.1

7. Repeat step 2-4 for the specifications mentioned in Video Resolution and Frame Rate section in Appendix A.1.1
8. Store the quality score for each test
9. Testing complete

A.2 *Subjective Quality Assessment of CPD Applications*[4]

Subjective measurements were conducted to characterize the performance of applications of interest under various test conditions. Due to operational requirements by the Chicago Police Department, applications under test were limited to video streaming though Real Time Video Intelligence (RTVI) system. RTVI system allows real time video transmission from camera to command center and out to mobile devices. RTVI system was designed to dynamically adapt to the variances in bandwidth that are regularly experienced by mobile broadband networks. If the available bandwidth falls, the video transmission is automatically adjusted based on how law enforcement is using that video.

A.2.1 Operation Test Plan

Performance Rating Methodology and Criteria

1. Application operability will be evaluated during the test using the following scale
    a. Rate the clarity of the picture or video on a scale of 1-5 (resolution). Clarity of the image refers to the amount of detail an image can convey.
        i. 1 is unable to see anything, 5 is clear as looking at a live scene
    b. Rate the frame rate of the images/data and “fluidity” of the motion on a scale of 1-5. Fluidity of the motion refers to motion continuity and smoothness.
        i. 1 is a still image, 5 is like looking at a live scene
2. Applications available for below tests should include
    a. Streaming Video –through RTVI
        i. This is intended to be a single stream or multiple streams
        ii. This is intended to be a downlink stream to the car or an uplink stream from an LTE connected camera

Static Environment Test Procedures

Test procedures for a user connected through LTE

1. Single user confirms LTE network connectivity
2. The user opens an RTVI video
    a. This happens while the user remains fixed in one location without moving through the coverage area
3. Without changing the environment external to the user in the vehicle (ie: There are no other user affiliations, or requests for applications over the LTE network), any or all of the following occur:
    a. The user increases the request of the same application on the same laptop in the same location
    b. Other users (which were affiliated to the network at the time of the initial application request) make requests of the same application as the subject user
    c. FTP and RTP traffic is introduced in the network as specified in Network Traffic in Appendix A.1.1

[4] We have adopted, with modifications, the subject testing plan described by Motorola in their April 14, 2014 test document provided to Purdue University. We describe the modified plan in this section. [7]

4. Results are documented based on the criteria listed above.

Previous measurements investigated video quality when video streams were viewed by a user connected to the LTE network. The user had to be located within the cell coverage area and used the LTE network to access video streams using the RTVI system. Such video streams originate outside the LTE network and are captured by Police Observation Devices (PODs). They transmit video data continuously to the command center using an established infrastructure. We shall refer to the established infrastructure over which PODs transmit video data to the command center as the legacy network. The LTE network can be also used to connect a POD or a camera to the command center such that a user located in the command center can view the POD video stream directly. By connecting a POD to the LTE network, video data are transmitted in the uplink direction (form the LTE device to the network).

Test procedures for a user located at the command center

1. User confirms LTE network connectivity to LTE connected camera
2. The user opens a single application at the command center
3. Without changing the environment external to the user (i.e., there are no other user affiliations, or requests for applications over the LTE network), any or all of the following occur:
    a. Other users (which were affiliated to the network at the time of the initial application request) make requests of the same application as the subject user.
        i. This can include requesting the exact same video stream from the same camera that is connected via the Public Safety LTE network
    b. FTP and RTP traffic is introduced in the network as specified in Network Traffic in Appendix A.1.1
4. Results are documented based on the criteria listed above.

Dynamic Environment Test Procedures

Test procedures for a user connected through LTE

1. User(s) confirm LTE network connectivity
2. The user(s) opens application(s) on the in-car police laptop (Streaming video…)
3. Baseline state is observed and documented
4. Without changing the users' request to the application in the vehicle, any or all of the following occur:
    a. User begins moving throughout the coverage area, with no other changes to the number of affiliated users in the coverage area
    b. Multiple users enter the coverage area or turn on their LTE device and affiliate to the network, without making any application requests
    c. Multiple users that were already affiliated to the network leave the coverage area or turn off their affiliated device
    d. Multiple users already affiliated to the network make a surge of requests for

service on the same application that the user is operating

    e. Multiple users already affiliated to the network make a surge of requests for service on other applications than the one being operated by the user in the vehicle
    f. Multiple users, not affiliated to the network both affiliate and make application requests in rapid succession
5. Results are documented based on the criteria listed above.

Test procedures for a user located at the command center

1. Above procedures are repeated with the application user being located in a fixed site and connected to a video feed that uses the public safety network as a backhaul mode.

A.2.2 Test Scenarios

Single User

1. A single user in the coverage area affiliates and confirms connectivity on the LTE network.
2. The user opens an application for a “normal operation” within the application.
3. User evaluates the use of the application on the network, with no other changes taking place (i.e., no other applications are opened by that user, no other users affiliate to the network during that time, no other services are requested within that application by that user).
4. Results are documented
    a. This is rated against the above criteria described in Performance Rating Methodology and Criteria in Appendix A.2.1 and establishes a baseline for further measurement and comparison.
5. Evaluations are made from a single user, and evaluated on a single application, throughout the test procedures identified in Static Environment Test Procedures in Appendix A.2.1.

Multiple Users

1. Multiple users in the coverage area affiliate and confirm connectivity on the LTE network
2. User1 and User2 open up a single application (RTVI) for “normal operation” within the application (note: User1 and User2 perform the same operation within RTVI)
3. Both User1 and User2 evaluate the use of RTVI on the network, with no other changes taking place (i.e., no other applications are opened by that user, no other users affiliate to the network during that time, no other services are requested within that application by that user).
4. Results are documented
    a. This is rated against the above criteria described in Performance Rating Methodology and Criteria in Appendix A.2.1 and establishes a baseline for further measurement and comparison.
6. Evaluations are made throughout the test procedures identified in Dynamic Environment Test Procedures in Appendix A.2.1.

A.3 Network Performance Measurements

Network performance measurements were conducted to test the key performance indicators associated with the network. An application server hosted services required for testing purposes, such as FTP and video streaming servers. Objective key performance indicators (KPI) were measured while users access these services using the LTE network. Data throughput using various protocols (e.g. TCP/UDP), delay, jitter and power measurements are examples of the objective KPIs. These indicators give insight into the capacity of the network and serve to predict application level performance. The Real-Time Transport Protocol (RTP) is an Internet protocol standard that specifies a way to manage the real-time transmission of multimedia data over network services. Transmission Control Protocol (TCP) enables two hosts to establish a connection and exchange streams of data. It guarantees that packets will be delivered in the same order in which they were transmitted. TCP throughput is the rate of successful message delivery over the network is usually measured in bits per second (bit/s or bps). TCP throughput varies according to the direction of transmission. In the case of LTE network, downlink (DL) refers to data being sent from the network towards the mobile device while uplink (UL) refers to data sent from the mobile device towards the network. User Datagram Protocol (UDP) uses a simple connectionless transmission model with no guaranteed services. Jitter is the latency variation and is particularly important on networks supporting multimedia communication. It is calculated as the maximum variation difference between packet delays.

A.3.1 Summary

The following table is a summary of the test cases carried in this section. Each test is executed under various traffic conditions:

Test Number	Test Name
1	UDP Throughput / Packet Loss Rate – Downlink & Uplink
2	TCP Throughput / Downlink & Uplink
3	Ping Latency
4	Jitter Probes
5	Downlink Signal Strength – Power Measurements
6	Network Attachment Success Rate

A.3.2 Test Condition Requirements

Band = 14

Bandwidth = 10 MHz

Handset device: USB Dongle

A.3.2 Network Traffic

Congestion was introduced in the network by a mixture of data streams. Three distinct levels of network congestion were considered to test the objective video quality under various traffic conditions. Network traffic was composed of RTP (over UDP) data and FTP (over TCP).

Three levels of network traffic were considered:

1. Low traffic

   Low traffic consisted of one user initiating an RTP/UDP stream at 2 Mb/s along an FTP session, both in the downlink or uplink direction

2. Medium traffic

   Medium traffic consisted of one user initiating an RTP/UDP stream at highest possible speed in the downlink or uplink direction

3. High traffic

   High traffic consisted of two users initiating an RTP/UDP stream at highest possible speed along with one user initiating an FTP session, all in the downlink or uplink direction

A.3.4 Test Scenarios

Test: 1. UDP Throughput / Packet Loss Rate – Downlink & Uplink

Test description

Determine the Test Unit's (TU) LTE packet loss rate at various data rates in the downlink and uplink directions using UDP in a field environment in Band 14 with the network supporting a bandwidth of 10 MHz.

This test should verify:

• The UDP downlink throughput over the LTE network meets requirement in live network in specified conditions
• The device is stable during the test with no reset, stall, freeze, etc.

Test Procedure

1. Select a test location and establish a LTE data connection.
2. Configure test tool to start UDP DL & UL transfer and begin testing
3. Results and logs are stored
4. Repeat step 2-3 with FTP and RTP traffic being introduced in the network as specified in Network Traffic in Appendix A.1.1

5. Review test results on device
6. Verify throughput meets or exceeds threshold based on established pass/fail criteria
7. Testing complete

Test: 2. TCP Throughput / Downlink & Uplink

Test description

Determine the TU's LTE downlink and uplink data speed using TCP in a field environment in Band 14 with the network supporting a bandwidth of 10 MHz.

This test should verify:

• The TCP downlink and uplink throughput over the LTE network meets the requirements in live network in specified conditions
• The device is stable during the test with no reset, stall, freeze, etc.

Test Procedure

1. Select a test location and establish LTE data connection.
2. Configure test tool to start TCP DL and UL transfer and begin testing
3. Results and logs are stored
4. Repeat step 2-3 with FTP and RTP traffic being introduced in the network as specified in Network Traffic in Appendix A.1.1
5. Verify throughput meets or exceeds threshold based on established pass/fail criteria
6. Testing complete

Test: 3. Ping Latency

Test description

Determine the TU's Ping Latency in a field environment in Band 14 with the network supporting a bandwidth of 10 MHz.

This test should verify:

• The Ping Latency over the LTE network meets the requirements in live network in specified conditions
• The device is stable during the test with no reset, stall, freeze, etc.

Test Procedure

1. Select a test location and establish LTE data connection
2. Configure test tool to execute ping test and begin testing
3. Results and logs are stored

4. Repeat step 2-3 with FTP and RTP traffic being introduced in the network as specified in Network Traffic in Appendix A.1.1
5. Review test results on device
6. Verify delays meet or exceeds threshold based on established pass/fail criteria
7. Testing complete

Test: 4. Jitter Probes

Test description

Determine the TU's variation in delay over time from point-to-point in a field environment in Band 14 with the network supporting a bandwidth of 10 MHz.

This test should verify:

• The variation in delay over the LTE network meets the requirements in live network in specified conditions
• The device is stable during the test with no reset, stall, freeze, etc.

Test Procedure

1. Select a test location and establish a LTE data connection.
2. Configure test tool to probe jitter effect and begin testing
3. Results and logs are stored
4. Repeat step 2-3 with FTP and RTP traffic being introduced in the network as specified in Network Traffic in Appendix A.1.1
5. Review test results on device
6. Verify variations meet or exceeds threshold based on established pass/fail criteria
7. Testing complete

Test: 5. Downlink Signal Strength – Power Measurements

Test description

Determine the TU's LTE downlink signal strength in the field environment in Band 14 with the network supporting a bandwidth of 10 MHz.

This test should give insights into:

• The coverage area in District 7

Test Procedure

1. Power up the device
2. With assistance from the local RF engineering team, develop a drive route which traverses many city blocks in the same cell coverage
3. Identify 25 points with variable distance from the eNodeB
4. Drive to each point and measure the Downlink Signal Strength
5. Testing complete

Test: 6. Network Attachment Success Rate

Test description

Determine the TU's LTE network attachment success rate in the field environment in Band 14 with the network supporting a bandwidth of 10 MHz.

This test should verify that:

- Network attachment success rate meets the requirements in live network in specified conditions
- The device is stable during the test with no reset, stall, freeze, etc.

Test Procedure

1. Identify 30 points with variable distance from the eNodeB
2. Drive to each point and power up the device
3. Wait until network attachment is complete
4. Store network attachment result
5. Testing complete

A.4 Testing Tools

This subsection outlines the tools used to conduct the test procedure mentioned earlier:

1. LTE USB dongles:

   LTE USE dongles supporting band 14 were solely used to connect to the LTE network. No vehicular modems were used at any point during the testing procedure.

2. Police laptops equipped with the RTVI application

   Police laptops connected to the LTE network using the LTE USB dongles mentioned above were used to view the video stream through the RTVI application. No other CPD application was used or tested besides RTVI.

3. Standard laptops

   Several standard laptops with the following specifications were used to conduct tests as described in Appendix A.1 and Appendix A.3.

   64-bit Windows 7 Professional operating on Dell Laptop with 4 GB RAM and dual core i5 CPU @ 2.67 GHz

4. Application Server

   An application server with the specifications mentioned below was used to host some of the services required for testing purposes such an FTP server and video streaming server.

   Dell PowerEdge R420 with 1x Intel Xeon E5-2430 2.2GHz, 6-core, 16GB RAM, 2x 1TB drives and redundant power supplies

5. Motorola LTE connection manager

Motorola LTE connection manager was used to record power measurements as part of the test procedure detailed in Appendix A.3.

6. FFmpeg[5] software tool

   FFmpeg was installed on the application server and standard laptops. Video streaming and capturing were conducted using FFmpeg as explained in Appendix A.1

7. iPerf[6] software tool

   iPerf was installed on the application server and standard laptops. Throughputs, delays and jitter measurements were conducted using iPerf as detailed in Appendix A.3

8. Video database

   The Public Safety Communication Research (PSCR) video samples with applications in public safety shared in the Consumer Digital Video Library (CDVL) were stored and streamed as detailed in Appendix A.1. Each of the five video sequences was transcoded according to the data rates and spatial resolutions described in Appendix A.1.1.

[5] http://ffmpeg.org/

[6] https://iperf.fr/

B Appendix B: Video Database

B.1 Original Video Sequences

Five video sequences were selected from the Public Safety Communication Research (PSCR) shared in the Consumer Digital Video Library (CDVL) [7]:

1. An angled walkway video sequence at the top of an indoor stadium, above the seating, with many people walking around during a break
2. A car entering/leaving a parking lot capturing the license plate
3. Bank teller robbery scene where a man is robbing a teller, the sequence captures one teller's window and a frontal shot of the robber
4. A person walking down a hallway holding a small object in his hand
5. Some people browsing a store aisle of mostly office supplies

B.2 Transcoded Video Sequences

Each of the five video sequences was transcoded according to the following data rates and spatial resolutions. Each video sequence was 30 frames/s and compressed using the H.264 video compression standard using default parameters.

1. Common Intermediate Format (CIF) resolution (352x288) at 50, 100, 300, 1000 kb/s
2. Video Graphics Array (VGA) resolution (640x480) at 100, 300, 500, 1000, 2000 kb/s
3. Progressive High Definition (720p) resolution (1280×720) 200, 400, 700, 1000, 2000, 4000 kb/s
4. Full High Definition (1080p) resolution (1920x1080) at 200, 400, 700, 1000, 2000, 4000 kb/s

The video sequences were streamed according to the testing procedure detailed in A.1.

B.3 Captured Video Sequences

The streamed video sequences were captured and stored locally according to the testing procedure detailed in A.1.

Original, transcoded and captured video sequences are available upon request.

[7] http://www.cdvl.org/

VACCINE Annual Report – Year 6

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu and Heather Trueblood at

Institution: Purdue University

PI and/or Co-PI: Edward J. Delp

Project Name: Chicago LTE Pilot Project

Academic Disciplines:

Keywords associated with project:

Theme for Research Projects (Check all that apply)

XX	Public Safety Coalition Projects (state or local law enforcement, fire, emergency management, etc.)
	Federal Operating Component Projects (TSA,FEMA, Secret Service, ICE, CBP, USCIS, Coast Guard)
	Enterprise Resiliency Environments
	Event Evacuations
	Visual Analytics for Security Applications
	International Collaborations

Theme for Education Projects (Check all that apply)

XX

VACCINE Annual Report – Year 6

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu and Heather Trueblood at

Students Supported on Project

Graduate Research Assistants (include name(s), university and department)

Khalid Tahboub, Electrical and Computer Engineering, Purdue University

0

0

Undergraduate supported students (need number only)

1

Other Graduate Students (non-supported) involved in project (need number only)

Research Problem /Abstract (in 200 words or less, provide a summary of the project goals and objectives, **in simple language understandable to someone outside the project's field).**

The goals of this project were to test the viability and performance of the LTE National Public Safety Broadband Network (NPSBN) with respect to transport of video imagery. One cell using the NPSBN was installed in Chicago at the Chicago Police Department District 7. We conducted a test plan to characterize the performance of the network and analyzed the data collected. The test plan consisted of three parts: First, objective perceptual video quality tests designed to measure the video quality when video is streamed in real-time over the LTE network were conducted. Second, subjective measurements were conducted to characterize the performance of applications of interest under various test conditions. Third, network performance metrics were obtained to test the key performance indicators associated with the network. Based on the analysis of the data collected during our testing it was concluded that a PSBN LTE network provides an unprecedented opportunity to increase the capacity and to meet the needs and requirements of public safety with respect to video delivery. Careful analysis should be used for Quality of Service (QoS), prioritization and Radio Frequency (RF) planning when designing a NPSBN LTE system. It was also noted that adaptive video coding methods, used in many video systems, might not suit public service operational scenarios. System designer should also take into consideration video usage in a task-based approach.

Technical Approach (Check all that apply)

Data Collection Methods

Compiling & Sorting DB

Data Mining

Expert Consultation

Field Monitors

xx Survey

XX Other: Objective perceptual video quality assessment, network performance test

Analytic Methods

Case Studies

XX Modeling

Sampling

Statistical Analysis

Other: Image and video analysis

Nature of Research

Applied

xx Basic

VACCINE Annual Report – Year 6

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu and Heather Trueblood at htrueble@purdue.edu by **July 30, 2015**

Deliverables (other than publications and reports listed below)

An application server was installed and integrated into the network to host some of the services required for testing, such as an FTP and video streaming servers.

Technology Transitions (describe any products/technologies in process or that have completed transition to commercialization; include actions and progress to date)

none

Additional Funding Sources Leveraged: include amount, source of funding, PI and period of performance

none

VACCINE Annual Report – Year 6

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu and Heather Trueblood at

VACCINE Annual Report – Year 6

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu and Heather Trueblood at

Collaborating Partners (academic Co-PI's, businesses, or other government funding agencies)

Motorola Solutions

Office of Emergency Management and Communications (OEMC), Chicago Police Department

Collaborating End-Users (specific DHS operating components such as FEMA, TSA, Coast Guard or federal, state, local law enforcement, fire, emergency management, etc.)

Please provide name of agency, contact name and email address.

None

Collaboration with other VACCINE project teams, national labs, and other Homeland Security Centers of Excellence (CREATE, NCFPD, START, PACER, ALERT, NCBSI, MIREES, ZADD, CHC and NTSCOE).

Describe purpose and nature of the collaboration and any follow-up to the discussion, if applicable. None

VACCINE Annual Report – Year 6

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu and Heather Trueblood at htrueble@purdue.edu by **July 30, 2015**

Project Period (only complete if different than 4/1/12-6/30-13)

VACCINE Annual Report – Year 6

Please complete **ALL** fields.

This form must be emailed to Mary Padget at
padget@purdue.edu and Heather Trueblood at
htrueblo@purdue.edu by July 30, 2015

Project Outcomes (Publications, Presentations, etc., based on this VACCINE-funded project)

Peer-Reviewed/Refereed Publications, Journals, Conferences: list only citation below, must also provide/attach electronic copy of all individual publications to VACCINE

If additional space is needed, please attach a separate Word document listing relevant materials.

Submitted: none

Accepted: none

Other Reports (including white papers, book chapters, manuscripts submitted, in revision or accepted/in press [not including those in preparation], other publications)

Chicago LTE Pilot Project Final Report

DHS Center For Visual Analytics for Command, Control, and Interoperability Environments (VACCINE) Video and Image Processing Laboratory (VIPER)

Purdue University

West Lafayette, Indiana

Khalid Tahboub and Edward J. Delp
Version 1.4

August 25, 2015

Presentations (include title, presenter, date, meeting, location. Attach PowerPoint if available). If additional space is needed, please attach a separate Word document listing relevant materials.

none

Patents/Copyrights (List names)

Applications: none

Awarded: none

VACCINE Annual Report – Year 6

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu and Heather Trueblood at htruebl[...]@purdue.edu **by July 20, 2015**

Summary of Outcomes and Impact of Project

The outcome of the project is a lessons-learned document supported by testing results. The recommendations are based on our observations and testing results to meet the special needs required by public safety.

Impact or success story associated with project

Issues Encountered, if applicable: intellectual property, data sensitivity, publication of high risk/sensitive/proprietary findings, institutional collaboration and relationships, etc.

VACCINE Annual Report – Year 6

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu and Heather Trueblood at htruebla@purdue.edu **by July 30, 2015**

Changes in research plans, if applicable: describe any major changes in the project's plans or objectives, such as initiatives added or omitted, compared to those outlined in the original, funded proposal.

Our initial test plan intended to conduct subjective assessments of non-video applications used by the CPD such as RTVI, CAD, VidSys and Shotspotter. However, due to operational issues and requirements by the CPD, only subjective assessment of RTVI was conducted.

Supporting Documentation: list items and attach electronically, including survey instruments, photos, models, letters to participants, or other unique documentation.

Edward J. Delp
August 9, 2016

VACCINE Year 7 Report

Conference Papers

J. Kim, L. Huffman, H. Li, J. Yue, J. Ribera, E. Delp, " Automatic and Manual Tattoo Localization," Proceedings of the IEEE International Symposium on Technologies for Homeland Security, Waltham, MA, May 2016.

J. Kim, H. Li, J, Yue, E, Delp, "Tattoo Image Retrieval for Region of Interest,"Proceedings of the IEEE International Symposium on Technologies for Homeland Security, Waltham, MA, May 2016.

B. Delgado, K. Tahboub and E. J. Delp, "Superpixels shape analysis for carried object detection," Proceedings of the IEEE Winter Applications of Computer Vision Workshops, Lake Placid, NY, 2016, pp. 1-6.

Students Supported

Blanca Delgado (vBOLO)
Khalid Tahboub (vBOLO)

He Li (GARI)

Joonsoo Kim (GARI)
Jiaju Yue (GARI)

Other (GARI)

The Stockton, CA police is now using GARI

Project Description

Name: GARI: Gang Graffiti Recognition and Analysis

Gangs are a serious threat to public safety throughout the United States. Gang members are continuously migrating from urban cities to suburban areas. They are responsible for an increasing percentage of crime and violence in many communities.According to the National Gang Threat Assessment, approximately 1 million gang members belonging to more than 20,000 gangs were criminally active within all 50 states and the District of Columbia as of September 2008. Criminal gangs commit as much as 80 percent of the crime in many communities according to law enforcement officials throughout the nation. Street gang graffiti is their most common way to communicate messages, including challenges, warnings or intimidation to rival gangs. It is, however, an excellent way to track gang affiliation and growth, or even sometimes to obtain membership information.

The goal of this project is the development of a mobile-based system capable of gang graffiti and gang tattoo image analysis. This system will provide an accurate and useful output to a user based on a database of gang graffiti tattoo images.

We have added many new tools in the past year to GARI including various tattoo image analysis methods

Joint Center Project

The vBOLO (formally known as eBOLO) project is a joint project between ALERT and VACCINE.

The goal of this project is to investigate methods for re-identifying subjects as they appear in surveillance video at the Greater Cleveland Regional Transit Authority (GCRTA). The GCRTA has expressed interest in tools that will allow them to identify subjects as they re-appear in their surveillance system. In many cases a subject who has previously committed a crime will re-enter the system hours or days later and appear in GCRTA surveillance video. The GCRTA would like to re-identify (re-id) that subject so they can be apprehended after their re-entry to the system. In some sense, what the GCRTA would like to create is an automatic or electronic "be on the lookout" (BOLO) system. We call this system EBOLO.

We envision the EBOLO system would be one where the subject to be added to a BOLO would be manually highlighted by the GCRTA from surveillance video of an incident. The system would then use computer vision and image processing techniques to create features of the subject from the surveillance video. One could think of these features as the subject's "EBOLO fingerprint." We then use these features to continuously monitor the video surveillance system to determine when that subject reappeared in the video. The systems would then flag or alarm that the subject has reappeared and where they are located.

Collaborating Partners (academic Co-PI’s, businesses, or other government funding agencies)

Collaborating End-Users

GARI:

InGang

Indiana Intelligence Fusion Center
302 W. Washington Street

Room W198

Indianapolis, Indiana 46204

Cook County Sheriff

John Blair

Deputy Chief, Intelligence and Investigations
Cook County Sheriff's Police Department
Office: 773 674-4775

Cellular: 312 515-0004

E-M ail: john.blair@cookcountyil.gov

vBOLO: The Greater Cleveland Regional Transit Authority (GCTRA)

John P. Joyce

Chief of Police / Director of Security
216 575-3910 office

216 575-3892 fax

jpjoyce@gcrta.org

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Institution: Purdue University

PI and/or Co-PI: Edward J. Delp

Project Name: GARI: Gang Graffiti Recognition and Analysis

Academic Disciplines: Electrical and Computer Engineering

Keywords associated with project:

XX

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading.

Theme for Education Projects (Check all that apply)

1see

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Students Supported on Project

Graduate Research Assistants (include name(s), university and department)

See attached

Undergraduate supported students (need number only)

O**ther Graduate Students** (non-supported) involved in project (need number only)

Other Undergraduate Students (non-supported) involved in project (need number only)

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading.

Research Problem /Abstract (in 200 words or less, provide a summary of the project goals and objectives, **in simple language understandable to someone outside the project's field).**

See attached

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Technical Approach (Check all that apply)

Data Collection Methods

Compiling & Sorting DB

Data Mining

Expert Consultation

Field Monitors

Survey

XX Other: image and video data collection and analysis

Analytic Methods

Case Studies

Modeling

Sampling

Statistical Analysis

XX Other: image analysis and machine learning

Nature of Research

Applied

Basic

Consultation

Coordination/Integration

Education

XX Hybrid Basic—Applied

Hybrid Applied—Consultation

Deliverables (other than publications and reports listed below)

We have demonstrated some very basic prototyping concepts to the Greater Cleveland Regional Transit Authority (GCTRA) police and given them presetnatation on this.

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Technology Transitions (describe any products/technologies in process or that have completed transition to commercialization; include actions and progress to date)

Additional Funding Sources Leveraged: include amount, source of funding, PI and period of performance

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Collaborating Partners (academic Co-PI's, businesses, or other government funding agencies)

Collaborating End-Users (specific DHS operating components such as FEMA, TSA, Coast Guard or federal, state, local law enforcement, fire, emergency management, etc.)

Please provide name of agency, contact name and email address.

See attached list

Collaboration with other VACCINE project teams, national labs, and other Homeland Security Centers of Excellence (CREATE, NCFPD, START, PACER, ALERT, NCBSI, MIREES, ZADD, CHC and NTSCOE).

Describe purpose and nature of the collaboration and any follow-up to the discussion, if applicable. See attached list

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Project Period (only complete if different than 4/1/12-6/30-13)

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

Project Outcomes (Publications, Presentations, etc., based on this VACCINE-funded project)

Peer-Reviewed/Refereed Publications, Journals, Conferences: list only citation below, must also provide/attach electronic copy of all individual publications to VACCINE

If additional space is needed, please attach a separate Word document listing relevant materials. See attached list

Accepted:

Other Reports (including white papers, book chapters, manuscripts submitted, in revision or accepted/in press [not including those in preparation], other publications)

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading.

Presentations (include title, presenter, date, meeting, location. Attach PowerPoint if available). If additional space is needed, please attach a separate Word document listing relevant materials.

Patents/Copyrights (List names)

Applications:

Awarded:

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Summary of Outcomes and Impact of Project

See attached list

Impact or success story associated with project

See attached list

Issues Encountered, if applicable: intellectual property, data sensitivity, publication of high risk/sensitive/proprietary findings, institutional collaboration and relationships, etc.

nine

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Changes in research plans, if applicable: describe any major changes in the project's plans or objectives, such as initiatives added or omitted, compared to those outlined in the original, funded proposal.

None

Supporting Documentation: list items and attach electronically, including survey instruments, photos, models, letters to participants, or other unique documentation.

See attached list

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Institution: Purdue University

PI and/or Co-PI: Edward J. Delp

Project Name: GARI: Gang Graffiti Recognition and Analysis

Academic Disciplines: Electrical and Computer Engineering

Keywords associated with project:

XX

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

Theme for Education Projects (Check all that apply) ... please indicate "NA" under the heading

1see

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Students Supported on Project

Graduate Research Assistants (include name(s), university and department)

See attached

Undergraduate supported students (need number only)

O**ther Graduate Students** (non-supported) involved in project (need number only)

1

Other Undergraduate Students (non-supported) involved in project (need number only)

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

Research Problem /Abstract (in 200 words or less, provide a summary of the project goals and objectives, **in simple language understandable to someone outside the project's field).**

See attached

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Technical Approach (Check all that apply)

Data Collection Methods

Compiling & Sorting DB

Data Mining

Expert Consultation

Field Monitors

Survey

XX Other: image and video data collection and analysis

Analytic Methods

Case Studies

Modeling

Sampling

Statistical Analysis

XX Other: image analysis and machine learning

Nature of Research

Applied

Basic

Consultation

Coordination/Integration

Education

XX Hybrid Basic—Applied

Hybrid Applied—Consultation

Deliverables (other than publications and reports listed below)

We have delivered to both InGang, the Cook Sheriff Department the GARI system and Stockto, CA police. We are in the process of discussing the delivering GARI to several other law enforcement agencies.

Technology Transitions (describe any products/technologies in process or that have completed transition to commercialization; include actions and progress to date)

We have had several discussions with the Purdue Foundary on commercialization efforts of GARI. We are discussing forming a company.

Additional Funding Sources Leveraged: include amount, source of funding, PI and period of performance

We received $30,000 from Mitre to work on Gang Tattoos

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Collaborating Partners (academic Co-PI's, businesses, or other government funding agencies)

Collaborating End-Users (specific DHS operating components such as FEMA, TSA, Coast Guard or federal, state, local law enforcement, fire, emergency management, etc.)

Please provide name of agency, contact name and email address.

See attached list

Collaboration with other VACCINE project teams, national labs, and other Homeland Security Centers of Excellence (CREATE, NCFPD, START, PACER, ALERT, NCBSI, MIREES, ZADD, CHC and NTSCOE).

Describe purpose and nature of the collaboration and any follow-up to the discussion, if applicable. See attached list

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

Project Period (only complete if different than 4/1/12-6/30-13)

VACCINE Annual Report – Year 7

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Other Reports (including white papers, book chapters, manuscripts submitted, in revision or accepted/in press [not including those in preparation], other publications)

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Presentations (include title, presenter, date, meeting, location. Attach PowerPoint if available). If additional space is needed, please attach a separate Word document listing relevant materials.

Patents/Copyrights (List names)

Applications:

Awarded:

VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

Summary of Outcomes and Impact of Project

See attached list

Impact or success story associated with project

See attached list

Issues Encountered, if applicable: intellectual property, data sensitivity, publication of high risk/sensitive/proprietary findings, institutional collaboration and relationships, etc.

nine

VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

Changes in research plans, if applicable: describe any major changes in the project's plans or objectives, such as initiatives added or omitted, compared to those outlined in the original, funded proposal.

None

Supporting Documentation: list items and attach electronically, including survey instruments, photos, models, letters to participants, or other unique documentation.

See attached list

VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

Institution: Purdue University

PI and/or Co-PI:

Project Name: Coast Guard Data Profiling and Quality Assurance

Academic Disciplines: Engineering, Computer Science

Theme for Research Projects (Check all that apply)

If this is not a research project, indicate "NA" below

	Public Safety Coalition Projects (state or local law enforcement, fire, emergency management, etc.)
X	Federal Operating Component Projects (TSA,FEMA, Secret Service, ICE, CBP, USCIS, Coast Guard)
	Enterprise Resiliency Environments
	Event Evacuations
	Visual Analytics for Security Applications
	International Collaborations

Theme for Education Projects (Check all that apply)

If this is not an education project, indicate "NA" below

	Minority or Underserved Programs
	Undergraduate and Graduate Education Program
	Professional Education and In-Service Programs
X	N/A

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

Students Supported on Project

Graduate Research Assistants (include name(s), university and department)

David Wiszowaty - Purdue University, Computer Science

Hanye Xu Purdue University, Electrical and Computer Engineering

Siqiao Chen Purdue University, Electrical and Computer Engineering

Undergraduate supported students (need number only) 0

O**ther Graduate Students** (non-supported) involved in project (need number only) 0

Other Undergraduate Students (non-supported) involved in project (need number only) 0

Student Thesis in 2013 (include name, thesis title, university, department, degree, date)

Research Problem /Abstract (in 200 words or less, provide a summary of the project goals and objectives, **in simple language understandable to someone outside the project's field).**

The Coast Guard Data Profiling and Quality Assurance project undertaken by VACCINE will focus on developing a visual analysis system that facilitates the data Quality Assurance (QA) tasks currently manually performed by CG analysts. The purpose of this effort is to design and prototype a data profiling visual analysis system that enables CG analysts to identify and communicate the data quality problems in the CG MISLE database that pertain to law enforcement sightings and boardings. The system designed by VACCINE will allow CG analysts to upload data from the MISLE database and will provide a graphical user interface to perform the different data profiling tasks. This system would automate the data cleaning tasks that are currently being manually performed by the CG analysts. Analysts will be provided with the ability to analyze and evaluate the intermediate results in order to make any appropriate adjustments and refinements. The prototype system will also entail incorporating data visualization techniques that will allow CG analysts to publish the QA results at various levels of aggregation (e.g., unit, station, sector, district). The tool would reduce the overall time spent on the Quality Assurance tasks and improve the accuracy of the data.

VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

Technical Approach (Check all that apply)

Data Collection Methods

- Compiling & Sorting DB
- Data Mining
- Expert Consultation
- Field Monitors
- Survey
- X Other:

Analytic Methods

- Case Studies
- Modeling
- Sampling
- Statistical Analysis
- X Other: Profiling

Nature of Research

- Applied
- Basic
- Consultation
- X Coordination/Integration
- Education
- Hybrid Basic—Applied
- Hybrid Applied—Consultation

Deliverables (other than publications and reports listed below)

A data profiling visual analysis system that is interactive. The system would identify data quality issues. Allow users to import/export data from the system. Allow the user to modify and filter through the inputted data.

VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

Technology Transitions (describe any products/technologies in process or that have completed transition to commercialization; include actions and progress to date)

NA

Additional Funding Sources Leveraged: include amount, source of funding, PI and period of performance

NA

VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

Collaborating Partners (academic Co-PI's, businesses, or other government funding agencies) Coast Guard

Collaborating End-Users (specific DHS operating components such as FEMA, TSA, Coast Guard or federal, state, local law enforcement, fire, emergency management, etc.)

Please provide name of agency, contact name and email address.

Coast Guard, Luke Walsh, Luke.A.Walsh1@uscg.mil

Coast Guard, Ian Callander, Ian.L.Callander@uscg.mil

Collaboration with other VACCINE project teams, national labs, and other Homeland Security Centers of Excellence (CREATE, NCFPD, START, PACER, ALERT, NCBSI, MIREES, ZADD, CHC and NTSCOE).

Describe purpose and nature of the collaboration and any follow-up to the discussion, if applicable.

NA

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

Project Period (only complete if different than 4/1/12-6/30-13)

1/1/2016 – 6/31/2016

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

Project Outcomes (Publications, Presentations, etc., based on this VACCINE-funded project)

Peer-Reviewed/Refereed Publications, Journals, Conferences: list only citation below, must also provide/attach electronic copy of all individual publications to VACCINE

If additional space is needed, please attach a separate Word document listing relevant materials.

Submitted: **NA**

Accepted: **NA**

Other Reports (including white papers, book chapters, manuscripts submitted, in revision or accepted/in press [not including those in preparation], other publications)

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

NA

Presentations (include title, presenter, date, meeting, location. Attach PowerPoint if available). If additional space is needed, please attach a separate Word document listing relevant materials.

NA

Patents/Copyrights (List names)

Applications: **NA**

Awarded: **NA**

Summary of Outcomes and Impact of Project

Impact or success story associated with project

Issues Encountered, if applicable: intellectual property, data sensitivity, publication of high risk/sensitive/proprietary findings, institutional collaboration and relationships, etc.

NA

VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

Changes in research plans, if applicable: describe any major changes in the project's plans or objectives, such as initiatives added or omitted, compared to those outlined in the original, funded proposal.

NA

Supporting Documentation: list items and attach electronically, including survey instruments, photos, models, letters to participants, or other unique documentation.

NA

VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

Institution: Purdue University

PI and/or Co-PI: David S. Ebert

Project Name: Officer Performance

Academic Disciplines: Computer Engineering

Keywords associated with project: Performance Evaluation

Theme for Research Projects (Check all that apply)

If this is not a research project, indicate "NA" below.

	Public Safety Coalition Projects (state or local law enforcement, fire, emergency management, etc.)
	Federal Operating Component Projects (TSA,FEMA, Secret Service, ICE, CBP, USCIS, Coast Guard)
	Enterprise Resiliency Environments
	Event Evacuations
	Visual Analytics for Security Applications
X	International Collaborations

Theme for Education Projects (Check all that apply)

If this is not an education project, indicate "NA" below.

	Minority or Underserved Programs
	Undergraduate and Graduate Education Program
	Professional Education and In-Service Programs
	N/A

VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

Students Supported on Project

Graduate Research Assistants (include name(s), university and department)
Jieqiong Zhao, Purdue University, Electrical and Computer Engineering
Hanye Xu, Purdue University, Electrical and Computer Engineering

0

0

Undergraduate supported students (need number only) 0

Other Graduate Students (non-supported) involved in project (need number only)

Research Problem /Abstract (in 200 words or less, provide a summary of the project goals and objectives, **in simple language understandable to someone outside the project's field).**

Collaborating with Chief Patrick Flannelly, we proposed the Officer Performance project to gamify the performance of police officers in Lafayette Police Department for better performance comparison and for motivating maximized performance.

VACCINE Annual Report – Year 7

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VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

Technical Approach (Check all that apply)

Data Collection Methods

X	Compiling & Sorting DB
	Data Mining
	Expert Consultation
	Field Monitors
X	Survey
	Other:

Analytic Methods

	Case Studies
X	Modeling
	Sampling
X	Statistical Analysis
	Other:

Nature of Research

	Applied
X	Basic
	Consultation
X	Coordination/Integration
	Education
	Hybrid Basic—Applied
	Hybrid Applied—Consultation

Deliverables (other than publications and reports listed below)

Web Application

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

Technology Transitions (describe any products/technologies in process or that have completed transition to commercialization; include actions and progress to date)

N/A

Additional Funding Sources Leveraged: include amount, source of funding, PI and period of performance

N/A

Collaborating Partners (academic Co-PI's, businesses, or other government funding agencies)

Collaborating End-Users (specific DHS operating components such as FEMA, TSA, Coast Guard or federal, state, local law enforcement, fire, emergency management, etc.)

Please provide name of agency, contact name and email address.

Lafayette Police Department, Patrick J. Flannelly, pjflannelly@lafayette.in.gov

Collaboration with other VACCINE project teams, national labs, and other Homeland Security Centers of Excellence (CREATE, NCFPD, START, PACER, ALERT, NCBSI, MIREES, ZADD, CHC and NTSCOE).

Describe purpose and nature of the collaboration and any follow-up to the discussion, if applicable. N/A

VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

Project Period (only complete if different than 4/1/12-6/30-13)

VACCINE Annual Report – Year 7

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Peer-Reviewed/Refereed Publications, Journals, Conferences: list only citation below, must also provide/attach electronic copy of all individual publications to VACCINE

If additional space is needed, please attach a separate Word document listing relevant materials.

Submitted:

N/A

Accepted:

N/A

Other Reports (including white papers, book chapters, manuscripts submitted, in revision or accepted/in press [not including those in preparation], other publications)

N/A

Presentations (include title, presenter, date, meeting, location. Attach PowerPoint if available). If additional space is needed, please attach a separate Word document listing relevant materials.

N/A

Patents/Copyrights (List names)

Applications: N/A

Awarded: N/A

VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

Summary of Outcomes and Impact of Project

We provided Lafayette officers the first web version of the project. The project is currently still in progress.

Impact or success story associated with project

Compared to the last year, we added animation of sorting performance of officers and comparison between selected officers.

Issues Encountered, if applicable: intellectual property, data sensitivity, publication of high risk/sensitive/proprietary findings, institutional collaboration and relationships, etc.

N/A

VACCINE Annual Report – Year 7

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N/A

Supporting Documentation: list items and attach electronically, including survey instruments, photos, models, letters to participants, or other unique documentation.

N/A

VACCINE Annual Report – Year 7

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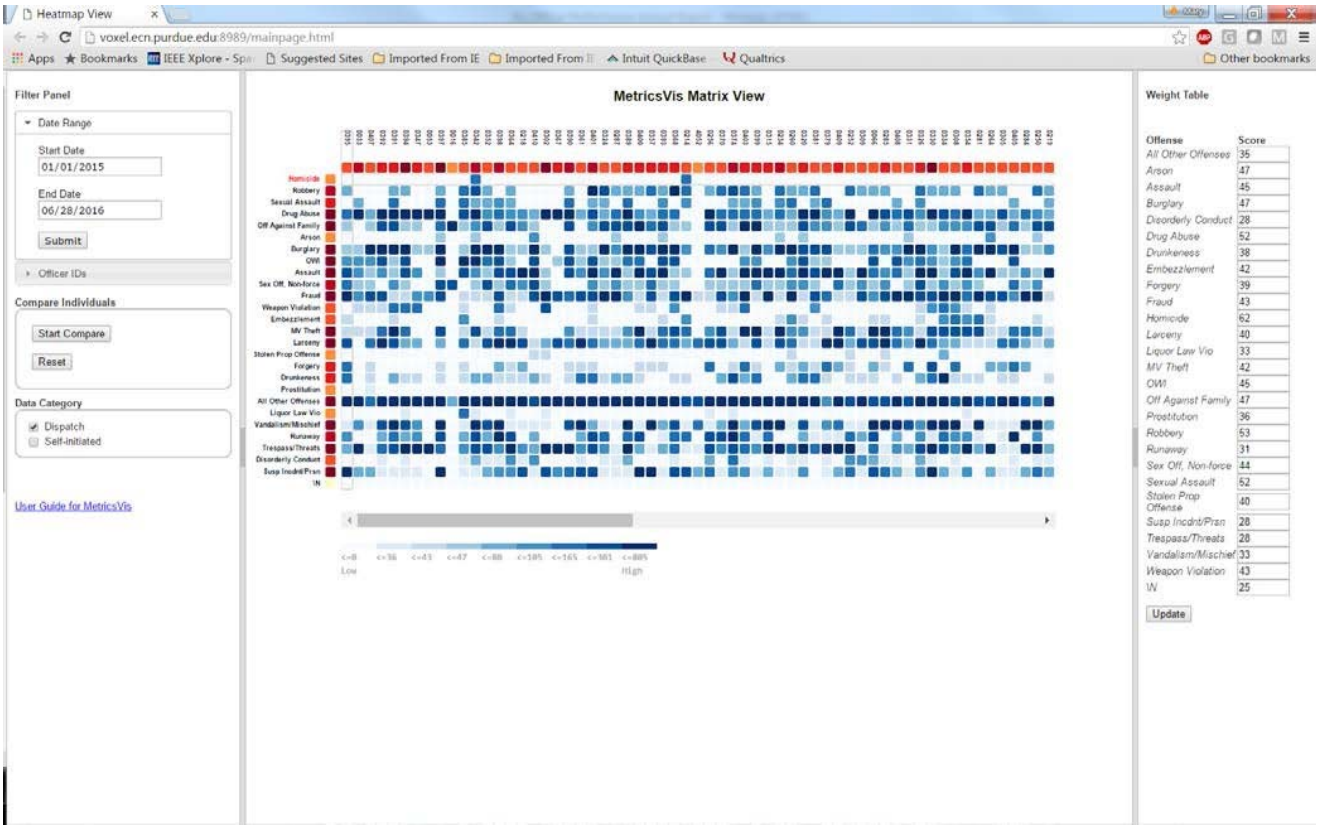

VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

Institution: Purdue University

PI and/or Co-PI: Dr. David S. Ebert

Project Name: Safety in View: A Public Safety Visual Analytics Tool Based on CCTV Camera Angles of View

Academic Disciplines: Computer Engineering

Theme for Research Projects (Check all that apply)

If this is not a research project, indicate "NA" below.

X	Public Safety Coalition Projects (state or local law enforcement, fire, emergency management, etc.)
	Federal Operating Component Projects (TSA,FEMA, Secret Service, ICE, CBP, USCIS, Coast Guard)
	Enterprise Resiliency Environments
	Event Evacuations
	Visual Analytics for Security Applications
	International Collaborations

Theme for Education Projects (Check all that apply)

N/A

If this is not an education project, indicate "NA" below.

	Minority or Underserved Programs
	Undergraduate and Graduate Education Program
	Professional Education and In-Service Programs
X	

VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

Students Supported on Project

Graduate Research Assistants (include name(s), university and department)

Hanye Xu, Purdue University, ECE

Abish Malik, Purdue University, ECE
Shehzad Afzal, Purdue University , ECE

0

Undergraduate supported students (need number only) 0

Other Graduate Students (non-supported) involved in project (need number only) 0

Research Problem /Abstract (in 200 words or less, provide a summary of the project goals and objectives, **in simple language understandable to someone outside the project's field).**

Campus security and police departments have implemented a multitude of safety precautions, including CCTV cameras. The efficiency and effectiveness of using CCTV camera resources for preventing crimes result in higher demand. We implemented a visual analytics tool to analyze the existing CCTV camera resources and suggest improved allocation schemas based on blind spots and crime data. Our tool provides the user with an interactive safe path calculation method for walking purpose on the basis of the maximum monitoring area. Additionally, avoiding buildings in the calculated path is an optional control factor. Our tool also provides functions for crime data analysis. The camera-alarming function highlights the cameras that a specific crime occurred in their visible range. The camera-ranking function highlights the camera that records the largest number of crime incidents. Based on the historical crime data, we suggest locations for future camera installation.

VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

Technical Approach (Check all that apply)

Data Collection Methods

	Compiling & Sorting DB
	Data Mining
X	Expert Consultation
	Field Monitors
	Survey
	Other:

Analytic Methods

X	Case Studies
	Modeling
	Sampling
	Statistical Analysis
	Other:

Nature of Research

X	Applied
X	Basic
	Consultation
	Coordination/Integration
	Education
	Hybrid Basic—Applied
	Hybrid Applied—Consultation

Deliverables (other than publications and reports listed below)

An interactive map that allows users to choose start point and destination for generating a path.

Technology Transitions (describe any products/technologies in process or that have completed transition to commercialization; include actions and progress to date)

N/A

Additional Funding Sources Leveraged: include amount, source of funding, PI and period of performance

N/A

Collaborating Partners (academic Co-PI's, businesses, or other government funding agencies)

N/A

Collaborating End-Users (specific DHS operating components such as FEMA, TSA, Coast Guard or federal, state, local law enforcement, fire, emergency management, etc.)

Please provide name of agency, contact name and email address.

Captain Eric H. Chin Purdue Police Department ehchin@purdue.edu

Collaboration with other VACCINE project teams, national labs, and other Homeland Security Centers of Excellence (CREATE, NCFPD, START, PACER, ALERT, NCBSI, MIREES, ZADD, CHC and NTSCOE).

Describe purpose and nature of the collaboration and any follow-up to the discussion, if applicable.

VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

N/A

Project Period (only complete if different than 4/1/12-6/30-13)

VACCINE Annual Report – Year 7

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Peer-Reviewed/Refereed Publications, Journals, Conferences: list only citation below, must also provide/attach electronic copy of all individual publications to VACCINE

If additional space is needed, please attach a separate Word document listing relevant materials.

Submitted:

Y. Koh, A. Mohan, G. Wang, H. Xu, A. Malik, Y. Lu, and D. S. Ebert. Improve Safety using Public Network Cameras. IEEE Symposium on Technologies for Homeland Security 2016.

Accepted:

Y. Koh, A. Mohan, G. Wang, H. Xu, A. Malik, Y. Lu, and D. S. Ebert. Improve Safety using Public Network Cameras. IEEE Symposium on Technologies for Homeland Security 2016.

Other Reports (including white papers, book chapters, manuscripts submitted, in revision or accepted/in press [not including those in preparation], other publications)

VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

N/A

Presentations (include title, presenter, date, meeting, location. Attach PowerPoint if available). If additional space is needed, please attach a separate Word document listing relevant materials.

N/A

Patents/Copyrights (List names)

Applications: N/A

Awarded: N/A

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Summary of Outcomes and Impact of Project

N/A

Impact or success story associated with project

N/A

Issues Encountered, if applicable: intellectual property, data sensitivity, publication of high risk/sensitive/proprietary findings, institutional collaboration and relationships, etc.

N/A

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading.

Changes in research plans, if applicable: describe any major changes in the project's plans or objectives, such as initiatives added or omitted, compared to those outlined in the original, funded proposal.

N/A

Supporting Documentation: list items and attach electronically, including survey instruments, photos, models, letters to participants, or other unique documentation.

N/A

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Institution: Purdue University

PI and/or Co-PI: Dr. David S. Ebert

Project Name: SMART (Social Media Analytics and Reporting Toolkit)

Academic Disciplines:

Theme for Research Projects (Check all that apply)
If this is not a research project, indicate "NA" below.

V	Public Safety Coalition Projects (state or local law enforcement, fire, emergency management, etc.)
V	Federal Operating Component Projects (TSA,FEMA, Secret Service, ICE, CBP, USCIS, Coast Guard)
	Enterprise Resiliency Environments
	Event Evacuations
V	Visual Analytics for Security Applications
	International Collaborations
	N/A

Theme for Education Projects (Check all that apply)

If this is not an education project, indicate "NA" below.

	Minority or Underserved Programs
	Undergraduate and Graduate Education Program
	Professional Education and In-Service Programs
V	N/A

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Students Supported on Project

Graduate Research Assistants (include name(s), university and department)
Junghoon Chae, Ph.D. Purdue University, Electrical and Computer Engineering
Jiawei Zhang, Ph.D. Purdue University, Electrical and Computer Engineering
David Wiszowaty, MS, Purdue University, Computer Science

1

0

Undergraduate supported students (need number only) 0

Research Problem /Abstract (in 200 words or less, provide a summary of the project goals and objectives, **in simple language understandable to someone outside the project's field).**

Recent advances in technology have enabled social media services to support space-time indexed data. Such spatiotemporal data has immense value for increasing situational awareness of local events, providing insights for investigations and understanding the extent of incidents. However, the large volume of unstructured social media data hinders effective exploration and examination. Thus, analysts require new methods for monitoring their topics of interest, identifying trends and anomalies, and dealing with the large volume of data and its dynamic nature. Our system provides users with scalable and interactive social media data (e.g., Twitter, Instagram) analysis and visualization including the exploration and the examination of abnormal topics and events. We have developed a new approach to let analysts build task-tailored message filters (classifiers) in an interactive and visual manner. The created filter methods can be orchestrated and adapted afterwards for interactive, visual real-time monitoring and analysis. In addition, web and news media sources (i.e., Google and CNN trends) are incorporated in the system. Our system also provide an email alert service to automatically send emails if the number of incoming tweets containing specific keywords exceeds a threshold. We provide such functionalities through not only desktop application, but also highly interactive and accessible Web interfaces.

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Technical Approach (Check all that apply)

Data Collection Methods

	Compiling & Sorting DB
V	Data Mining
	Expert Consultation
	Field Monitors
	Survey
	Other:

Analytic Methods

V	Case Studies
V	Modeling
	Sampling
V	Statistical Analysis
	Other:

Nature of Research

	Applied
	Basic
	Consultation
	Coordination/Integration
	Education
V	Hybrid Basic—Applied
	Hybrid Applied—Consultation

Deliverables (other than publications and reports listed below)

USCG in Louisville used our system to monitor Thunder over Louisville festival and Riverboat festival in 2015 and 2016.

USCG sector Guam Coat Guard used our system to monitor the Guam festival in May,

2015. USCG in Seattle coast guard used our system to monitor the kayaktivist in July,

2015.

Purdue Police Department used our system to monitor Purdue Football in fall,

2015. USCIS used our system to monitor Twitter around Syria in western Asia

in 2015.

Office of University Programs used our system to monitor RNC in July,

2015. St. Clair County in Michigan used our email alerts function in

2015.

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Technology Transitions (describe any products/technologies in process or that have completed transition to commercialization; include actions and progress to date)

N/A

Additional Funding Sources Leveraged: include amount, source of funding, PI and period of performance

N/A

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Collaborating Partners (academic Co-PI's, businesses, or other government funding agencies)

Dr. Alan MacEachren at Penn State University. We used the Geotxt (geotxt.org) system to extract place reference in text of Tweets that has no geolocation.

Collaborating End-Users (specific DHS operating components such as FEMA, TSA, Coast Guard or federal, state, local law enforcement, fire, emergency management, etc.)

Please provide name of agency, contact name and email address.

US Coast Guard, Darrell Eaton, darrell.l.eaton@uscg.mil

Purdue Police Department, John Cox, jkcox@purdue.edu

USCIS, Markus Montezemolo, markus.k.montezemolo@uscis.dhs.gov, Derrick Swift, errick.swift@uscis.dhs.gov

Office of University Programs, David Canty, David.Canty@hq.dhs.gov

Saint Clair County (MI) DHS, Jeff Friedland, jfriedland@stclaircounty.org

Collaboration with other VACCINE project teams, national labs, and other Homeland Security Centers of Excellence (CREATE, NCFPD, START, PACER, ALERT, NCBSI, MIREES, ZADD, CHC and NTSCOE).

Describe purpose and nature of the collaboration and any follow-up to the discussion, if applicable.

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate “NA” under the heading

N/A

Project Period (only complete if different than 4/1/12-6/30-13)

N/A

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Project Outcomes (Publications, Presentations, etc., based on this VACCINE-funded project)

Peer-Reviewed/Refereed Publications, Journals, Conferences: list only citation below, must also provide/attach electronic copy of all individual publications to VACCINE

If additional space is needed, please attach a separate Word document listing relevant materials.

Submitted:

Chae, J., Zhang, J., Jeong, S., Jang, Y., Malik, A., Ebert, D., "Forecasting the Flow of Human Crowds", IEEE Visual Analytics Science and Technology (VAST) Conference, 2016

Accepted:

Zhang, J., Ahlbrand, B., Malik, A., Chae, J., Min, Z., Ko, S. and Ebert, D., "A Visual Analytics Framework for Microblog Data Analysis at Multiple Scales of Aggregation", Computer Graphics Forum, 35: 441–450, 2016.

Chae, J., Zhang, J., Ko, S., Malik, A., Connell, H., Ebert, D., "Visual Analytics for Investigative Analysis of Hoax Distress Calls using Social Media", IEEE International Conference on Technologies for Homeland Security, 2016

Other Reports (including white papers, book chapters, manuscripts submitted, in revision or accepted/in press [not including those in preparation], other publications)

Presentations ~~(include title, presenter, date, meeting, location. Attach PowerPoint if available). If~~ additional space is needed, please attach a separate Word document listing relevant materials.

Patents/Copyrights (List names)

Applications: N/A

Awarded: N/A

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

Summary of Outcomes and Impact of Project

This technology provides analysts with scalable and interactive social media analysis and visualization through topic extraction, combination of filters, cluster examination, and stream categorization for increasing situational awareness in disaster events and accidents using social media data. These components are tightly integrated into a highly interactive visual analysis workbench that allows an analyst to observe, supervise, and configure the methods in each individual analysis process.

The system also incorporates automatic notifications through email alert and summary. Based on user-defined keywords, the system collects relevant social media information and send to users through emails for better and quicker situational awareness in various abnormal events.

Impact or success story associated with project

N/A

Issues Encountered, if applicable: intellectual property, data sensitivity, publication of high risk/sensitive/proprietary findings, institutional collaboration and relationships, etc.

N/A

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading.

Changes in research plans, if applicable: describe any major changes in the project's plans or objectives, such as initiatives added or omitted, compared to those outlined in the original, funded proposal.

N/A

Supporting Documentation: list items and attach electronically, including survey instruments, photos, models, letters to participants, or other unique documentation.

N/A

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Institution: Purdue University

PI and/or Co-PI: Dr. David S. Ebert

Project Name: Social Media and Healthcare Analytics for Identification of Emerging Health Threats

Academic Disciplines: Computer Engineering, Statistics

Theme for Research Projects (Check all that apply)

If this is not a research project, indicate "NA" below

✓	Public Safety Coalition Projects (state or local law enforcement, fire, emergency management, etc.)
	Federal Operating Component Projects (TSA,FEMA, Secret Service, ICE, CBP, USCIS, Coast Guard)
	Enterprise Resiliency Environments
	Event Evacuations
	Visual Analytics for Security Applications
	International Collaborations

Theme for Education Projects (Check all that apply)

If this is not an education project, indicate "NA" below

	Minority or Underserved Programs
	Undergraduate and Graduate Education Program
	Professional Education and In-Service Programs
✓	N/A

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Students Supported on Project

Graduate Research Assistants (include name(s), university and department)

Shehzad Afzal, Purdue University, Department of Electrical and Computer Engineering

0

0

Undergraduate supported students (need number only)

0

Research Problem /Abstract (in 200 words or less, provide a summary of the project goals and objectives, **in simple language understandable to someone outside the project's field).**

Assessing current and emerging public health threats is important for public health officials in order to make decisions regarding mitigative actions and allocation of resources. Syndromic surveillance systems often rely on analyzing data received from a specific domain such as chief complaints data collected through hospitals, social media streams, aggregated web searches, news stories, etc. Information collected through multiple data sources could provide better understanding of extent and severity of emerging health threats, and also reduces dependence on a single data source. It also helps scientists understand the characteristics of syndromic diseases, discover correlations among different factors and understand contributing factors in disease outbreak scenarios. This project focusses on providing a visual analytics environment that enables analysts combine chief complaints data collected through hospitals, social media data from Twitter's API, and weather data to make comprehensive assessments about disease outbreaks.

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Technical Approach (Check all that apply)

Data Collection Methods

- ✓ Compiling & Sorting DB
- ✓ Data Mining
- Expert Consultation
- Field Monitors
- Survey
- Other:

Analytic Methods

- Case Studies
- ✓ Modeling
- Sampling
- ✓ Statistical Analysis
- Other:

Nature of Research

- ✓ Applied
- Basic
- Consultation
- Coordination/Integration
- Education
- Hybrid Basic—Applied
- Hybrid Applied—Consultation

Deliverables (other than publications and reports listed below)

Visual Analytics application for analyzing healthcare, social media, and weather data to assess emerging health threats.

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Technology Transitions (describe any products/technologies in process or that have completed transition to commercialization; include actions and progress to date)

N/A

Additional Funding Sources Leveraged: include amount, source of funding, PI and period of performance

N/A

Collaborating Partners (academic Co-PI's, businesses, or other government funding agencies)

Collaborating End-Users (specific DHS operating components such as FEMA, TSA, Coast Guard or federal, state, local law enforcement, fire, emergency management, etc.)

Please provide name of agency, contact name and email address.

N/A

Collaboration with other VACCINE project teams, national labs, and other Homeland Security Centers of Excellence (CREATE, NCFPD, START, PACER, ALERT, NCBSI, MIREES, ZADD, CHC and NTSCOE).

Describe purpose and nature of the collaboration and any follow-up to the discussion, if applicable.

N/A

Project Period (only complete if different than 4/1/12-6/30-13)

N/A

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

Project Outcomes (Publications, Presentations, etc., based on this VACCINE-funded project)

Peer-Reviewed/Refereed Publications, Journals, Conferences: list only citation below, must also provide/attach electronic copy of all individual publications to VACCINE

If additional space is needed, please attach a separate Word document listing relevant materials.

Submitted:

N/A

Accepted:

N/A

Other Reports (including white papers, book chapters, manuscripts submitted, in revision or accepted/in press [not including those in preparation], other publications)

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Presentations (include title, presenter, date, meeting, location. Attach PowerPoint if available). If additional space is needed, please attach a separate Word document listing relevant materials.

Temporal/geo-spatial analytics of epidemic data and forecasting epidemic spread, Shehzad Afzal, 08-05-2014. First International and Interdisciplinary Workshop on the Ecology, Evolution and Dynamics of Dengue and other Related Diseases, Arizona State University.

Patents/Copyrights (List names)

Applications: N/A

Awarded: N/A

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Summary of Outcomes and Impact of Project

N/A

Impact or success story associated with project

N/A

Issues Encountered, if applicable: intellectual property, data sensitivity, publication of high risk/sensitive/proprietary findings, institutional collaboration and relationships, etc.

N/A

VACCINE Annual Report – Year 7

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If any item does not apply to your project, please indicate "NA" under the heading

Changes in research plans, if applicable: describe any major changes in the project's plans or objectives, such as initiatives added or omitted, compared to those outlined in the original, funded proposal.

N/A

Supporting Documentation: list items and attach electronically, including survey instruments, photos, models, letters to participants, or other unique documentation.

N/A

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Institution: Purdue University

PI and/or Co-PI: Dr. David S. Ebert

Project Name: Success Visualization

Academic Disciplines:

Keywords associated with project: Data Visualization

Theme for Research Projects (Check all that apply)

If this is not a research project, indicate "NA" below

	Public Safety Coalition Projects (state or local law enforcement, fire, emergency management, etc.)
	Federal Operating Component Projects (TSA,FEMA, Secret Service, ICE, CBP, USCIS, Coast Guard)
	Enterprise Resiliency Environments
	Event Evacuations
	Visual Analytics for Security Applications
V	International Collaborations

Theme for Education Projects (Check all that apply)

If this is not an education project, indicate "NA" below

	Minority or Underserved Programs
	Undergraduate and Graduate Education Program
	Professional Education and In-Service Programs
V	N/A

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Students Supported on Project

Graduate Research Assistants (include name(s), university and department)
Jun Xiang Tee, MS, Purdue University, Computer Science

0

0

Undergraduate supported students (need number only) 0

Other Graduate Students (non-supported) involved in project (need number only)

Research Problem /Abstract (in 200 words or less, provide a summary of the project goals and objectives, **in simple language understandable to someone outside the project's field).**

This project aims to present the information of all the research/projects that have been conducted in VACCINE Center using data visualization methods. In this project, different perspectives of the individual projects are visualized along with their temporal evolution. Users can investigate the man power, funding, and achievements of different projects visually and interactively.

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading.

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

Technical Approach (Check all that apply)

Data Collection Methods

- Compiling & Sorting DB
- Data Mining
- Expert Consultation
- Field Monitors
- Survey
- Other:

Analytic Methods

- Case Studies
- Modeling
- Sampling
- Statistical Analysis
- Other:

Nature of Research

- Applied
- Basic
- Consultation
- Coordination/Integration
- Education
- Hybrid Basic—Applied
- Hybrid Applied—Consultation

Deliverables (other than publications and reports listed below)

N/A

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

Technology Transitions (describe any products/technologies in process or that have completed transition to commercialization; include actions and progress to date)

N/A

Additional Funding Sources Leveraged: include amount, source of funding, PI and period of performance

N/A

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

Collaborating Partners (academic Co-PI's, businesses, or other government funding agencies)

Collaborating End-Users (specific DHS operating components such as FEMA, TSA, Coast Guard or federal, state, local law enforcement, fire, emergency management, etc.)

Please provide name of agency, contact name and email address. N/A

Collaboration with other VACCINE project teams, national labs, and other Homeland Security Centers of Excellence (CREATE, NCFPD, START, PACER, ALERT, NCBSI, MIREES, ZADD, CHC and NTSCOE).

Describe purpose and nature of the collaboration and any follow-up to the discussion, if applicable. N/A

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

Project Period (only complete if different than 4/1/12-6/30-13)

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

Project Outcomes (Publications, Presentations, etc., based on this VACCINE-funded project)

Peer-Reviewed/Refereed Publications, Journals, Conferences: list only citation below, must also provide/attach electronic copy of all individual publications to VACCINE

If additional space is needed, please attach a separate Word document listing relevant materials.

Submitted: N/A

Accepted: N/A

Other Reports (including white papers, book chapters, manuscripts submitted, in revision or accepted/in press [not including those in preparation], other publications)

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

N/A

Presentations (include title, presenter, date, meeting, location. Attach PowerPoint if available). If additional space is needed, please attach a separate Word document listing relevant materials.

N/A

Patents/Copyrights (List names)

Applications: N/A

Awarded: N/A

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Summary of Outcomes and Impact of Project

This project provides a web-based visualization interface that provides the information of projects/research that have been conducted in VACCINE Center. Man power, funding amount and major achievements are visualized in the system.

Impact or success story associated with project

N/A

Issues Encountered, if applicable: intellectual property, data sensitivity, publication of high risk/sensitive/proprietary findings, institutional collaboration and relationships, etc.

N/A

Changes in research plans, if applicable: describe any major changes in the project's plans or objectives, such as initiatives added or omitted, compared to those outlined in the original, funded proposal.

N/A

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

Supporting Documentation: list items and attach electronically, including survey instruments, photos, models, letters to participants, or other unique documentation.

N/A

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Institution: Purdue University

PI and/or Co-PI: Dr. David S. Ebert

Project Name: VALET : Visual Analytics Law Enforcement Toolkit

Academic Disciplines: Computer Engineering

Theme for Research Projects (Check all that apply)

If this is not a research project, indicate "NA" below

X	Public Safety Coalition Projects (state or local law enforcement, fire, emergency management, etc.)
	Federal Operating Component Projects (TSA,FEMA, Secret Service, ICE, CBP, USCIS, Coast Guard)
	Enterprise Resiliency Environments
	Event Evacuations
	Visual Analytics for Security Applications
	International Collaborations

Theme for Education Projects (Check all that apply)

If this is not an education project, indicate "NA" below

	Minority or Underserved Programs
	Undergraduate and Graduate Education Program
	Professional Education and In-Service Programs
X	N/A

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Students Supported on Project

Graduate Research Assistants (include name(s), university and department)

Abish Malik, Purdue University, Electrical and Computer Engineering

David Wiszowaty, Purdue University, Computer Science

Guizhen Wang, Purdue University, Electrical and Computer Engineering

Hanye Xu, Purdue University, Electrical and Computer Engineering

Siqiao Chen, Purdue University, Electrical and Computer Engineering

0

0

Undergraduate supported students (need number only)

0

Research Problem /Abstract (in 200 words or less, provide a summary of the project goals and objectives, **in simple language understandable to someone outside the project's field).**

The exploration of criminal incident reports for detecting trends, discovering anomalies and evaluating resource usage is an ever-expanding issue for law enforcement agencies. Tools need to be developed that assist law enforcement officials in their analysis in order to take preventive measures and judiciously allocate available resources. In order to better facilitate crime incident analysis, the Visual Analytics Law Enforcement Toolkit (VALET) provides a comprehensive visual analytics system for both PCs and mobile devices which provides police officials with access to their data on the fly. Our system allows users to visualize data geo- spatially on a map and provides filtering tools that filter crime by the type of offense committed. The crime being visualized can additionally be filtered by time to analyze the correlation of different crimes with time. Our system enables users to view a history of previous crime incidents and forecast a pattern of crime using automated algorithms. Moreover, the users have the ability to receive immediate feed of events.

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Technical Approach (Check all that apply)

Data Collection Methods

- [ ] Compiling & Sorting DB
- X Data Mining
- X Expert Consultation
- [ ] Field Monitors
- [ ] Survey
- [ ] Other:

Analytic Methods

- [ ] Case Studies
- X Modeling
- X Sampling
- X Statistical Analysis
- [ ] Other:

Nature of Research

- X Applied
- [ ] Basic
- [ ] Consultation
- [ ] Coordination/Integration
- [ ] Education
- [ ] Hybrid Basic—Applied
- [ ] Hybrid Applied—Consultation

Deliverables (other than publications and reports listed below)

The desktop and mobile application released to the various public safety agencies.

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading.

Technology Transitions (describe any products/technologies in process or that have completed transition to commercialization; include actions and progress to date)

N/A

Additional Funding Sources Leveraged: include amount, source of funding, PI and period of performance

N/A

Collaborating Partners (academic Co-PI’s, businesses, or other government funding agencies)

Collaborating End-Users (specific DHS operating components such as FEMA, TSA, Coast Guard or federal, state, local law enforcement, fire, emergency management, etc.)

Please provide name of agency, contact name and email address.

Ohio Homeland Security. POC: Thomas J. Gerber, Deputy Chief of Operations (Law Enforcement), ThJGerber@dps.state.oh.us

Lafayette Police, IN. POC: Pat Flannelly, Chief of Police, pjflannelly@lafayette.in.gov

Purdue Police, West Lafayette, IN. POC: John Cox, Chief of Police, jkcox@purdue.edu

Evansville Police, IN. POC: Alan Yeager, AYeager@evansvillepolice.com

Collaboration with other VACCINE project teams, national labs, and other Homeland Security Centers of Excellence (CREATE, NCFPD, START, PACER, ALERT, NCBSI, MIREES, ZADD, CHC and NTSCOE).

Describe purpose and nature of the collaboration and any follow-up to the discussion, if

applicable N/A

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

Project Period (only complete if different than 4/1/12-6/30-13)

N/A

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Project Outcomes (Publications, Presentations, etc., based on this VACCINE-funded project)

Peer-Reviewed/Refereed Publications, Journals, Conferences: list only citation below, must also provide/attach electronic copy of all individual publications to VACCINE

If additional space is needed, please attach a separate Word document listing relevant materials.

Submitted:

G. Wang, A. Malik, S. Chen, S. Afzal, D. S. Ebert. A Client-based Visual Analytics Framework for Large Spatiotemporal Data under Architectural Constraints. IEEE Symposium on Large Data Analysis and Visualization.

Accepted:

Other Reports (including white papers, book chapters, manuscripts submitted, in revision or accepted/in press [not including those in preparation], other publications)

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

N/A

Presentations (include title, presenter, date, meeting, location. Attach PowerPoint if available). If additional space is needed, please attach a separate Word document listing relevant materials.

N/A

Patents/Copyrights (List names)

Applications: N/A

Awarded: N/A

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by August 7, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Summary of Outcomes and Impact of Project

The VALET application has been deployed to several law enforcement agencies, and we keep getting more requests from other users as well.

Impact or success story associated with project

N/A

Issues Encountered, if applicable: intellectual property, data sensitivity, publication of high risk/sensitive/proprietary findings, institutional collaboration and relationships, etc.

N/A

Changes in research plans, if applicable: describe any major changes in the project's plans or objectives, such as initiatives added or omitted, compared to those outlined in the original, funded proposal.

N/A

Supporting Documentation: list items and attach electronically, including survey instruments, photos, models, letters to participants, or other unique documentation.

N/A

University

Of

Oxford

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by July 30, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Institution: University of Oxford

PI and/or Co-PI: Professor Min Chen and Mr. Frank Egerton

Project Name: Measuring and Visualizing Information Trustworthiness using Visual Analytics

Academic Disciplines: Computer Science / Visual Analytics / Data Science

Keywords associated with project: trust, CV, multivariate features, glyph-based visualization

Theme for Research Projects (Check all that apply)

If this is not a research project, indicate "NA" below.

	Public Safety Coalition Projects (state or local law enforcement, fire, emergency management, etc.)
	Federal Operating Component Projects (TSA,FEMA, Secret Service, ICE, CBP, USCIS, Coast Guard)
X	Enterprise Resiliency Environments
	Event Evacuations
X	Visual Analytics for Security Applications
X	International Collaborations
	N/A

Theme for Education Projects (Check all that apply)

If this is not an education project, indicate "NA" below.

	Minority or Underserved Programs
	Undergraduate and Graduate Education Program
	Professional Education and In-Service Programs
X	N/A

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by July 30, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Students Supported on Project None

Graduate Research Assistants (include name(s), university and department)

Dr. Simon Walton, Oxford e-Research Centre, University of Oxford

Undergraduate supported students (need number only)	0
Other Graduate Students (non-supported) involved in project (need number only)	1

An MSc student was involved in a related research topic, but not aware of the details of this project

Other Undergraduate Students (non-supported) involved in project (need number only)	0

Student Thesis in 2015 (include name, thesis title, university, department, degree, date)

Vivek Kothari, Visual Analytics Methods for Image Classification, University of Oxford, Department of Computer Science, MSc thesis, November 2015. (Note the work was one of the two case studies in a paper accepted by IEEE VAST 2016.

Research Problem /Abstract (in 200 words or less, provide a summary of the project goals and objectives, **in simple language understandable to someone outside the project's field).**

The aim of this project is to study the feasibility of a visual analytics methodology for measuring and reasoning about trust. Given a specific type of textual information, such as curricula vitae, it usually requires a highly complicated process to determine if any part of the information may not be reliable. Our main hypothesis is based on the concept of "literary shapes", which scholars in creative writing use to categorize different fictions. Although a piece of text is commonly considered by many as unstructured, it is possible to identify a collection of features from the text. Such features can be visualized using glyphs, and hence metaphorically "shapes". Furthermore, the collection of glyphs representing different features can also be viewed as a "shape". A piece of text can therefore be represented by multiple levels of "shapes". This naturally leads to a number of research questions:

Q1. How can one represent a piece of text, such as a CV, using glyphs? Q2. Can human analysts make observations through such shapes?

Q3. What will be the benefits of using such visualization, in comparison with (a) reading the text directly, or

(b) relying on automated text analysis?

Q4. What would be an appropriate process for creating such a visual representation from the raw text? Q5. What would be the directions for future technology developments?

In this project, we focused on Q1 through data collection, feature identification, visual design, and software development, and addressed other questions through observations and discussions.

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by July 30, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Technical Approach (Check all that apply)

Data Collection Methods

X Compiling & Sorting DB (small scale)

Data Mining

Expert Consultation

Field Monitors

Survey

Other:

Analytic Methods

X Case Studies

Modeling

Sampling

Statistical Analysis

X Other: Visualization

Nature of Research

X Applied

Basic

Consultation

Coordination/Integration

Education

Hybrid Basic—Applied

Hybrid Applied—Consultation

Deliverables (other than publications and reports listed below)

Research Questions Q1 and Q4

1. We designed a template for feature extraction, which enabled the visual design and software development.

2. We designed a set of glyphs for conveying features as "shapes".

3. We manually extracted features from a collection of CVs.

4. We developed a piece of software for visualizing these CVs using their feature

shapes. Research Questions Q2, Q3 and Q4

5. We made our observations and drew our conclusions about these research questions based on our experience.

Technology Transitions (describe any products/technologies in process or that have completed transition to commercialization; include actions and progress to date)

We have not made any concrete step in this direction as the idea featured in this project is very new, and our development is likely to be among the first of such experimentations and developments. We hope to revisit this in the future.

Additional Funding Sources Leveraged: include amount, source of funding, PI and period of performance

We have not used any additional funding sources. We did arrange for an MSc student (self-funded) to conduct on an MSc project, working on a feature-based calcification problem with sparse data. The application domain was to classify visualization images (also considered as unstructured data). This experience helps us to address research questions Q3 and Q5.

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by July 30, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Collaborating Partners (academic Co-PI's, businesses, or other government funding agencies)

Mr. Frank Egerton, Bodleian Library, University of Oxford (line managing 22 staff)
Also a novelist and a lecturer on Creative Writing.

Collaborating End-Users (specific DHS operating components such as FEMA, TSA, Coast Guard or federal, state, local law enforcement, fire, emergency management, etc.)

Please provide name of agency, contact name and email address.

None.

Collaboration with other VACCINE project teams, national labs, and other Homeland Security Centers of Excellence (CREATE, NCFPD, START, PACER, ALERT, NCBSI, MIREES, ZADD, CHC and NTSCOE).

Describe purpose and nature of the collaboration and any follow-up to the discussion, if applicable. Professor David Ebert, VACCINE Purdue, oversees the project.

Project Period (only complete if different than 4/1/12-6/30-13)

1/7/2014 - 30/06/2015

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by July 30, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Project Outcomes (Publications, Presentations, etc., based on this VACCINE-funded project)

Peer-Reviewed/Refereed Publications, Journals, Conferences: list only citation below, must also provide/attach electronic copy of all individual publications to VACCINE

If additional space is needed, please attach a separate Word document listing relevant materials.

Submitted:

None

Accepted:

G. K. L. Tam, V. Kothari, and M. Chen. **An analysis of machine- and human-analytics in classification**. To appear in *IEEE Transactions on Visualization and Computer Graphics*, 23(1), 2017. (To be presented in IEEE VIS 2016.)

This paper reports two case studies, one of which was carried out by Kothari at the early stage of this project. For an understandable reason, he did not work on CV data directly. Nevertheless, the finding of this paper is forms part of the goal of this project.

Other Reports (including white papers, book chapters, manuscripts submitted, in revision or accepted/in press [not including those in preparation], other publications)

Project Report (In preparation)

Shapes of CV – Measuring and Visualizing Information Trustworthiness using Visual Analytics

Paper (Planned with a Provisional Title)

Shapes in Text Analysis

Presentations (include title, presenter, date, meeting, location. Attach PowerPoint if available). If additional space is needed, please attach a separate Word document listing relevant materials.

Kothari's case study will be presented (briefly) by Tam in IEEE VAST 2016.

The work on glyph-based visualization was just completed and no presentation has been given.

Patents/Copyrights (List names)

Applications: None

Awarded: None

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by July 30, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Summary of Outcomes and Impact of Project

1. We have applied the "bag of features" approach to CV analytics, and developed a set of glyph representations for summarize the features of CVs, facilitating external memorization and juxtaposed comparison. The glyph representation offered a hierarchical perception of features, which we metaphorically referred to as "shapes".
2. We established that the cost of manually extracting features from a CV is on average between 15-30 minutes per CV. Some of the extraction effort (e.g., word counting) can easily be automated. Some (e.g., identifying career gaps) can potentially be automated subject to a set of robust conditions. At least in the short term (e.g., 1-2 decades), humans' involvement will be unavoidable. Nevertheless, the cost is not excessive and creating a CV repository supported by feature-based visualization is achievable.
3. We conducted a comparative study on constructing feature-based classification models using automatic algorithm (machine-centric) and parallel coordinates plots (human-centric). The work was carried out before CV collection and feature extraction, and thus was set in a different application domain. The conclusion suggests that the construction of classification models using features extracted from CVs is feasible and it is necessary to adopt a visual analytics approach by keeping humans in the loop.

Impact or success story associated with project

The main part of project (glyph-based visualization) was just completed and we will assess its impact in the near future.

The subsidiary part of the project (feature-based classification) has led to an information-theoretic analysis of machine-centric and human-centric processes, and the quantitative finding was unexpectedly in favor of human-centric processes.

Issues Encountered, if applicable: intellectual property, data sensitivity, publication of high risk/sensitive/proprietary findings, institutional collaboration and relationships, etc.

CV data is highly sensitive and we have so far kept the data assessable to the three researchers only (Chen, Egerton, and Walton). That is another reason why Kothari's MSc project avoided the reference to CVs as the thesis would be in the public domain.

Changes in research plans, if applicable: describe any major changes in the project's plans or objectives, such as initiatives added or omitted, compared to those outlined in the original, funded proposal.

1. There were some major delays of activities in November and December due to the family illness and grievance of the co-I, and in January and February due to the family illness and grievance of the PI.
2. The original plan to develop a system based on ViTA was dropped mainly because the analytical capability of ViTA would only applicable to relatively low-level feature analysis, and it would be better to focus on high-level features. Building a system on the top of ViTA may also potentially encounter an open source requirement, which we did not feel ready to address. Hence, ViTA was

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by July 30, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

not featured in the development.

Supporting Documentation: list items and attach electronically, including survey instruments, photos, models, letters to participants, or other unique documentation.

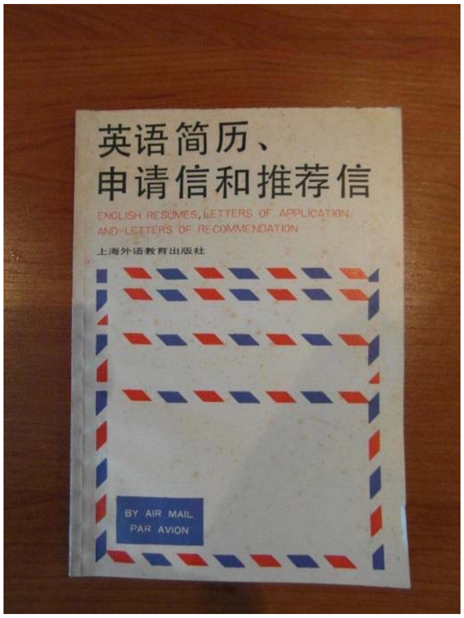
We will submit a separate project report very soon. Below we attach a photograph of a source of data, and a glyph-based visualization of 16 CVs.

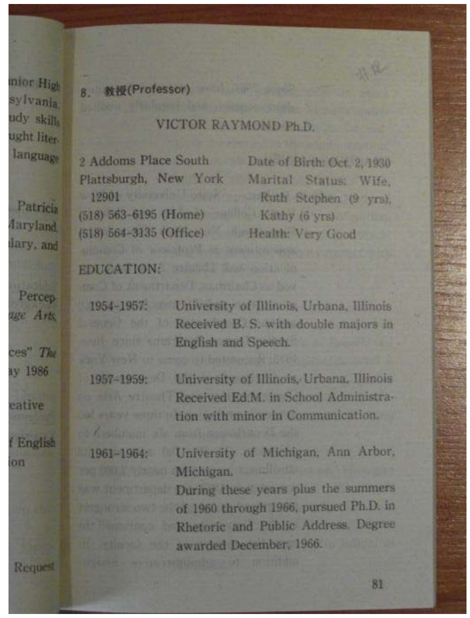
VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by July 30, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading





8. 教授(Professor)

VICTOR RAYMOND Ph.D.

2 Addoms Place South
Plattsburgh, New York
12901
(518) 563-6195 (Home)
(518) 564-3135 (Office)

Date of Birth: Oct. 2, 1930
Marital Status: Wife,
Ruth Stephen (9 yrs),
Kathy (6 yrs)
Health: Very Good

EDUCATION:

1954-1957: University of Illinois, Urbana, Illinois
Received B. S. with double majors in English and Speech.

1957-1959: University of Illinois, Urbana, Illinois
Received Ed.M. in School Administration with minor in Communication.

1961-1964: University of Michigan, Ann Arbor, Michigan.
During these years plus the summers of 1960 through 1966, pursued Ph.D. in Rhetoric and Public Address. Degree awarded December, 1966.

81

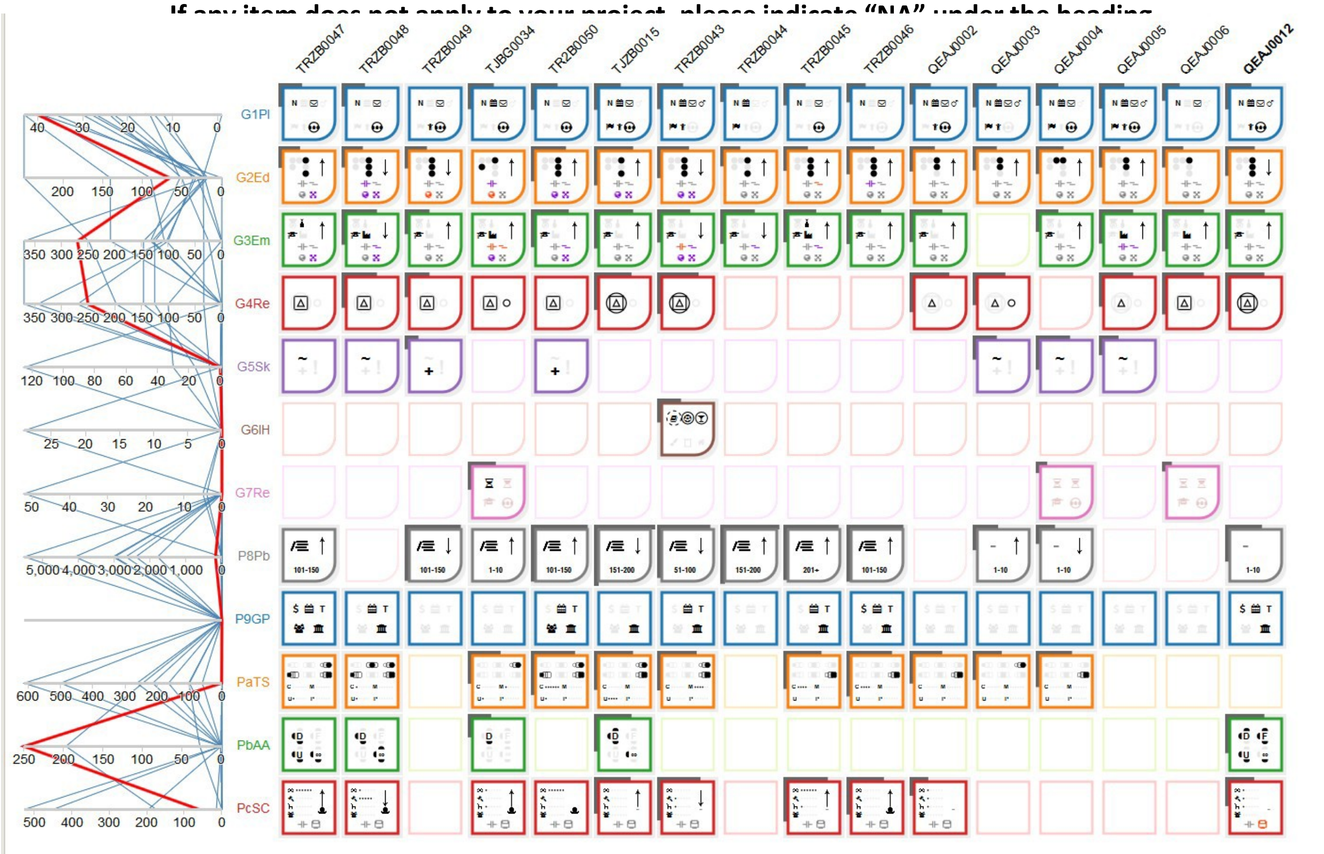
A CV printed in a book
(QEAJ0012)

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by July 30, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading



Glyph-based visualization of 16 CVs

University

of

North Carolina

at Charlotte

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by July 30, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Institution: University of North Carolina at Charlotte

PI and/or Co-PI: William Ribarsky, PI; William Tolone, co-PI; Isaac Cho, Investigator

Project Name: Multimedia, Social Media, Text, and Emergency Response Analytics

Academic Disciplines: Visual analytics, unstructured content analysis, decision-making, social analysis

Keywords associated with project: interaction, visualization, analytics, critical infrastructure, financial

Theme for Research Projects (Check all that apply)

If this is not a research project, indicate "NA" below.

X	Public Safety Coalition Projects (state or local law enforcement, fire, emergency management, etc.)
	Federal Operating Component Projects (TSA,FEMA, Secret Service, ICE, CBP, USCIS, Coast Guard)
X	Enterprise Resiliency Environments
X	Event Evacuations
X	Visual Analytics for Security Applications
X	International Collaborations
	N/A

Theme for Education Projects (Check all that apply)

If this is not an education project, indicate "NA" below.

	Minority or Underserved Programs
X	Undergraduate and Graduate Education Program
X	Professional Education and In-Service Programs
	N/A

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by July 30, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Students Supported on Project

Graduate Research Assistants (include name(s), university and department)

Todd Eaglin, UNC Charlotte, Computer Science

Undergraduate supported students (need number only)

O**ther Graduate Students** (non-supported) involved in project (need number only)

Other Undergraduate Students (non-supported) involved in project (need number only)

Research Problem /Abstract (in 200 words or less, provide a summary of the project goals and objectives, **in simple language understandable to someone outside the project's field).**

The project applies visual analytics methods to a range of problems of significance to DHS. In each case one or more tools or products are produced. In several instances, the tools are deployed to stakeholders. Capabilities produced include:

- A system of systems model has been set up for investigating a regional electric smart grid infrastructure under duress from natural or man-made disasters. This system can investigate weak points and cascading effects due to failures in an overall infrastructure including electrical, water, transportation, food distribution, and other components. A Web service was set up so that onsite managers could access the results of these large scale simulations on mobile devices such as a laptop or tablet computer, providing the capability to determine what will happen, when and where it will occur, and who and what infrastructures will be affected so that immediate, appropriate action can be taken. Work is being done with NC government partners, utility companies, and VACCINE colleagues.

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by July 30, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Technical Approach (Check all that apply)

Data Collection Methods

X	Compiling & Sorting DB
X	Data Mining
X	Expert Consultation
	Field Monitors
	Survey
	Other:

Analytic Methods

X	Case Studies
X	Modeling
	Sampling
X	Statistical Analysis
	Other:

Nature of Research

	Applied
	Basic
	Consultation
X	Coordination/Integration
	Education
X	Hybrid Basic—Applied
	Hybrid Applied—Consultation

Deliverables (other than publications and reports listed below)

- Stand-alone, modular modeling system for time-dependent, cascading critical infrastructure outages at the front of large scale weather events (e.g., hurricanes). This system can also be inserted into a comprehensive system such as the VASA workbench.
- Urban Emergency Response search and command capabilities developed based on discussions with UNC Charlotte Police and Public Safety Department. Consultation on tools with Charlotte Mecklenburg EMS.

- A set of social media visual analytics tools to investigate the narrative arc of social movements by following relevant topics, events, and social networks.

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

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If any item does not apply to your project, please indicate "NA" under the heading

Technology Transitions (describe any products/technologies in process or that have completed transition to commercialization; include actions and progress to date)

A stand-alone version of our critical infrastructure modeling system plus our collection of cascading breakdown results for a large ensemble of hurricane paths has been deployed. The visualization interface is accessible as a Web service by a range of devices anywhere on the Internet. A robust Web server connects the interface in a secure fashion to a compute and data intensive back-end. The ensemble results are organized on the back-end for interactive recall and immediate display in the visual interface. Visual interfaces in use include desktop, laptop, and mobile (iPad). We are running case studies for Charlotte Mecklenburg EMS and NC Public Health and Preparedness. The goal is improved delivery of critical public health services in the face of a wide spread weather disaster.

The partnership with the Electric Power Research Institute (EPRI) continues. We have now developed a prototype situationally aware control and analysis system for the distribution system of the future (DSOF). The DSOF will be very sensor-rich with new opportunities to analyze and control at all levels (including at the home or business site). Our critical infrastructure work contributes to this work. We are setting up the prototype to respond to the effects of large storms as they develop. The new sensor data is giving us results to extend our critical infrastructure model deep into the distribution system and to prepare for response under the DSOF. Funding from the Department of Energy and other sources is being sought

Additional Funding Sources Leveraged: include amount, source of funding, PI and period of performance

William Ribarsky and Wenwen Dou, $50,000 Army Research Office, through October 31, 2016.

William Ribarsky, $20,000, EPRI, through October 31, 2015.

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by July 30, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Collaborating Partners (academic Co-PI's, businesses, or other government funding agencies)

David Ebert, Purdue University, ebertd@ecn.purdue.edu
Daniel Keim, University of Konstanz, keim@uni-konstanz.de

Chris Sechrest, Duke Energy, ~~Chris.Sechrest~~@duke-energy.com
Douglas Dorr, EPRI, ddorr@epri.com

Bob Hay, Chattanooga EPB, hayrw@epb.net

Collaborating End-Users (specific DHS operating components such as FEMA, TSA, Coast Guard or federal, state, local law enforcement, fire, emergency management, etc.)

Please provide name of agency, contact name and email address.

Chief Jeffrey Baker, UNC Charlotte Police, 704-687-8300, jbaker88@uncc.edu

Jeff Stovall, CIO, City of Charlotte, jstovall@charlottenc.gov

Henry James, Associate Vice Chancellor for Risk Management, Safety & Security, UNC Charlotte, 704-687- 8454, hjames1@uncc.edu

Jon Studnek, Charlotte-Mecklenburg Emergency Management System, jonst@medic911.com

Regina Godette-Crawford, Chief, NC Office of Emergency Medical Services, 919-855-3935

Collaboration with other VACCINE project teams, national labs, and other Homeland Security Centers of Excellence (CREATE, NCFPD, START, PACER, ALERT, NCBSI, MIREES, ZADD, CHC and NTSCOE).

Describe purpose and nature of the collaboration and any follow-up to the discussion, if applicable.

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by July 30, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Project Period (only complete if different than 4/1/12-6/30-13)

VACCINE Annual Report – Year 7

Please complete **ALL** fields.

This form must be emailed to Mary Padget at padget@purdue.edu **by July 30, 2016.**

If any item does not apply to your project, please indicate "NA" under the heading

Project Outcomes (Publications, Presentations, etc., based on this VACCINE-funded project)

Peer-Reviewed/Refereed Publications, Journals, Conferences: list only citation below, must also provide/attach electronic copy of all individual publications to VACCINE

If additional space is needed, please attach a separate Word document listing relevant materials.

Submitted:

1. Todd Eaglin, William Ribarsky, and Isaac Cho. Space-Time Kernel Density Estimation for Real-Time Interactive Visual Analytics. Submitted to Hawaii International Conference on Systems Science (HICSS 2017).
2. Isaac Cho, Wenwen Dou, and William Ribarsky. CrystalBall: A Visual Analytic System for Future Event Discovery and Analysis from Social Media Data. Submitted to IEEE Trans. on Visualization and Computer Graphics.
3. Alex Endert, William Ribarsky, Cagatay Turkay, Ignacio Blanco, and Fabrice Rossi. The State of the Art in Coupling Machine Learning with Visual Analytics. Submitted to Computer Graphics Forum.

Accepted:

Other Reports (including white papers, book chapters, manuscripts submitted, in revision or accepted/in press [not including those in preparation], other publications)

Presentations (include title, presenter, date, meeting, location. Attach PowerPoint if available). If additional space is needed, please attach a separate Word document listing relevant materials.

Patents/Copyrights (List names)

Applications:

Awarded:

Summary of Outcomes and Impact of Project

- We have collected and integrated a large amount of infrastructure data for North and South Carolina (electrical, water, roads, key buildings, etc.). We have run ensembles of simulations for different hurricane paths with a distribution of widths, strengths, and detailed paths. This permits a probabilistic analysis of outcomes and identification of parts of the infrastructure plus key served components (e.g., schools, hospitals, etc.) that are most at risk. We have developed a set of visual interfaces that run on a range of devices, including iPads. The goal is to provide emergency responders or planners at any level a picture of what will happen, when it will happen, and at what locations. We have developed a scalable, stand-alone, Web service-based system to determine the effects of large scale weather or other events on critical infrastructure breakdown. We have also integrated this system of simulations and the VASA Workbench,.
- We developed very general text and event (location, time) analysis tools. The combined text and entity extraction tools have been applied most recently to predictive identification of future events via streaming social media analysis.
- In collaboration with the Electric Power Research Institute (EPRI) and utlity company partners, we have now developed a prototype situationally aware control and analysis system for the distribution system of the future (DSOF). Use of the system will result in a more resilient and optimally run electric power system.

Impact or success story associated with project

- We have made the complete set of critical infrastructure data for North and South Carolina available to both German and American VASA partners. These data plus the critical infrastructure modeling environment are now being used on a project with EPRI to create capabilities for the distribution system of the future.

- We have written joint papers on the collaborations with VACCINE and other collaborators.
- Using the critical infrastructure breakdown system we set up during this project, we have continued working with Charlotte and state emergency management personnel, public health officials, Duke Energy and other utility companies, on infrastructure resiliency and effective response efforts.
- With our college and the College of Business, we developed and continued to participate in the MS Degree in Data Science and Business Analytics. Examples from this project are used in the certificate and degree courses

Issues Encountered, if applicable: intellectual property, data sensitivity, publication of high risk/sensitive/proprietary findings, institutional collaboration and relationships, etc.

Changes in research plans, if applicable: describe any major changes in the project's plans or objectives, such as initiatives added or omitted, compared to those outlined in the original, funded proposal.

Supporting Documentation: list items and attach electronically, including survey instruments, photos, models,