CCICADA
Command, Control, and Interoperability Center for Advanced Data Analysis
A Department of Homeland Security Center of Excellence

Using advanced data analysis to protect the American people from natural and man-made threats!

"I never guess. It is a capital mistake to theorize before one has data. Insensibly one begins to twist facts to suit theories, instead of theories to fit facts".
Sir Arthur Conan Doyle

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CCICADA—The Command, Control and Interoperability Center for Advanced Data Analysis – consists of 17 partner universities and companies working with the U.S. Department of Homeland Security (DHS) and related agencies to develop data tools and systems to anticipate and respond to threats to the safety and security of the American people.

Founded in 2009 as a DHS University Center of Excellence, CCICADA turns massive amounts of unstructured data into useful information to mitigate the effects of natural disasters and protect the U.S. from terrorism at home and abroad. CCICADA has achieved an impressive track record in a short time, using its data extraction, analysis, modeling, simulation, and decision making capabilities to:

- Collaborate with FEMA and other agencies to mitigate the effects of flooding, hurricanes, and other natural disasters;
- Enhance the ability of U.S. Customs officials to identify and inspect incoming shipments of vessels or vehicles containing illegal or lethal cargo;
- Help the U.S. Coast Guard more efficiently patrol the nation's coastal borders and protect the nation's $24 billion domestic fisheries industry from illegal harvesting;
- Protect millions of sports fans from potential harm with enhanced inspection and evacuation systems at stadiums and other sports venues;
- Enable diverse law-enforcement agencies to solve serious crimes and prevent human trafficking and related abuse of women and children; and
- Identify potential cyber-attacks at an early stage.

These are just a few of the examples of data-intensive projects undertaken by CCICADA to protect the American public from homeland security threats.

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The lead university in the CCICADA partnership is Rutgers University, the State University of New Jersey. The director of CCICADA is Dr. Fred Roberts, Professor of Mathematics at Rutgers and Director Emeritus of the Center for Discrete Mathematics and Theoretical Computer Science. Dr. Roberts has many years of experience running large, complex organizations and projects.

Roberts gives credit for CCICADA's achievements to the researchers and students of Rutgers and its partner institutions – Carnegie Mellon University, City College of New York, Howard University, Morgan State University, Princeton University, Rensselaer Polytechnic Institute, Texas Southern University, Tuskegee University, University of Illinois at Urbana-Champaign, University of Massachusetts-Lowell, and University of Southern California - as well as to the collaboration of CCICADA's non-university partners - Alcatel-Lucent Bell Labs, Applied Communication Sciences, AT&T Labs, Regal Decision Systems, and TerraGo Technologies, and various state and federal government agencies.

Fred S. Roberts
Rutgers University
Director of CCICADA

"What gets measured, gets managed"
Peter Drucker

In today's technological world, sustaining science as a source of new knowledge and innovation has become as important to modern society as maintaining the nation's capabilities in manufacturing, trade, and defense.

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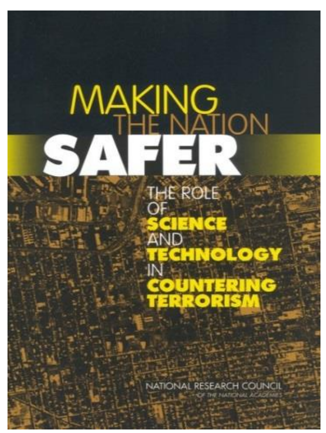
In 2002, under the Homeland Security Act, DHS began its operations, unifying 22 legacy agencies within a single department with a common mission: to safeguard America and integrate our Nation's capabilities to prevent, protect against, respond to, and recover from threats and disasters of all kinds.

Within DHS, the Science and Technology Directorate (S&T) manages science and technology research to protect the homeland. S&T's mission is to strengthen America's security and resiliency by providing knowledge products and innovative technology solutions for the Homeland Security Enterprise.

In the report *Making the Nation Safer – the Role of Science and Technology in Countering Terrorism*, the National Research Council (NRC) of the National Academies, also in 2002, laid out a set of important technical initiatives. These include such things as prioritized lists of initiatives for the *immediate application of existing technologies*, and initiatives for *urgent research* needed.

In part, as a direct response to the NRC technical initiatives, the DHS S&T Directorate Office of University Programs (OUP) was formed. OUP taps the expertise of the nation's colleges and universities to address pressing homeland security needs through unique programs, by establishing the Centers of Excellence (COEs), which engage the academic community to deliver tools, technologies, knowledge products, training and talent to enhance DHS's capabilities. CCICADA is one of these COEs.



The ability of decision makers to retrieve and extract useful information in real time faces a precipitous decline unless new, more powerful methods are developed.

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Academia, industry, and Local, State, Regional, Tribal, Territorial and Federal agencies, are interdependent partners in knowledge creation and acquisition, but they are also partners in the use and management of the products resulting from such knowledge and processes created from that knowledge.

Secretary Janet Napolitano, the third Secretary of Homeland Security, said this about the COE program:
"The DHS Centers of Excellence are a cornerstone of the Department's effort to engage the best and brightest minds at our nation's universities to help solve our homeland security challenges. We must continue to expand our collaboration with the science and engineering communities to address the evolving homeland security threats we face."

CCICADA was created in 2009 as one half of a COE in Command, Control and Interoperability to build the mathematical and computational foundations for obtaining knowledge and practical understanding from massive amounts of unstructured data. CCICADA focuses on data sciences (data analytics), while the other half of this center, VACCINE, based at Purdue University, focuses on visualization sciences (visual analytics). CCICADA includes 17 partner institutions led by Rutgers University, and together CCICADA and VACCINE with their partner institutions form the center, which is now called CVADA, the Center for Visual and Data Analytics.

"If you do not know how to ask the right question, you discover nothing."
W. Edward Deming

Data arrives at lightning speed, in great volume, from disparate sources, subject to error and uncertainty, and is easily manipulated.

Virtually all of the activities in the homeland security enterprise require the ability to reach conclusions from massive amounts of data. CCICADA uses data analytics to assess the massive flows of data to gain awareness, identify new and potential threats, and assist the homeland security community to work more efficiently. In addition, CCICADA provides powerful analytical tools to facilitate information sharing, collaboration, and data-driven decision support for a diverse workforce - now and for the future. Homeland security personnel, from first responders to administrators, are more effective at their jobs when floods of data can be turned into actionable information. The public is the ultimate beneficiary of effective, science-based solutions to complex problems, whose solutions are designed to mitigate the effects of natural and man-made disasters and protect the homeland from terrorism at home and abroad. Identification of possible threats is key to having immediate rapid responses to such threats.

Economic development and stability depend on security of the homeland, which in turn depends on knowledge, and those who are involved in the knowledge processes: individuals, industry, academia, and the government. This knowledge supply chain includes research/education centers like CCICADA that generate new knowledge and transfer and distribute knowledge, and industry and government agencies that apply the knowledge, and the public that benefits from the products produced. Traditionally, industry, academia, and the government have not viewed one another as

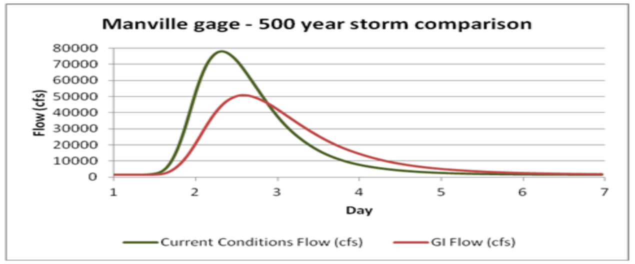
A rapidly changing knowledge-based economy that is secure from natural and man-made disasters depends on the interactions of government, industry, academia, and the public.

partners in the same integrated processes of knowledge development and transfer. However, today, these historical attitudes have changed under a common unifying purpose of homeland security and stability. Industry and government's problem-solving approach depends on fundamental research, yet basic research is often initiated in response to the need to solve important real problems.

CCICADA believes for knowledge transfer to take place, it is not sufficient to conduct research, develop new technologies, and help implement these technologies; it is imperative that CCICADA play a part in creating the next generation of researchers, technicians, and practitioners who are able to use new tools and solve new problems that will inevitably arise. For this to work, students, faculty, researchers from academia and industry, and practitioners all learn together and solve important problems together at CCICADA.

Ashley Crump
Undergraduate Participant in
CCICADA Research

The practitioners are part of the CCICADA process, from posing the problems that they would like to see solved, to helping find solutions, to implementing these solutions. CCICADA is working extensively with many components of the Department of Homeland Security at the state and federal level including FEMA, the Coast Guard, Transportation Security Administration, Customs and Border Protection, Citizenship and Immigration Services; with the Departments of Justice and State, the U.S. Army, the Centers for Disease Control and Prevention; and with police departments, homeland security offices, and offices of emergency management throughout the U.S.



How do we collect and manage tons of data so that we can integrate it with other data and ask important questions of the data now and in the future?

Gathering, Extracting and Managing Data

Science itself is a living enterprise. With few exceptions, acquisition of scientific knowledge is a cumulative process that depends on one's continuing ability to collect, to manage, and to share data. Though these might seem like simple tasks, there are many challenges related to each task. Collecting data involves both generating new data and accessing existing information often buried in large quantities of data. This data may be in text, in large databases, in various media formats, or contained in the vast array of social media sites. Extracting this data and the information it provides is a daunting task.

Prevention of Human Trafficking is one of CCICADA's application areas. Human trafficking is the illegal use of people, often women and children, for the profit of others. CCICADA is helping law enforcement by compiling and correlating data from open sources about the trafficking and abuse of women and children, and integrating this information with data from law enforcement sources to build a system that identifies likely minors. Statistics are computed to help focus law enforcement actions. Tools developed to solve problems in the prevention of human trafficking have applications to work done by agencies such as the Microsoft Digital Crimes Unit and the FBI, and in the analysis of escort services at places like the Super Bowl.

New techniques and resulting knowledge, applied to the development of new tools to solve a specific problem, can be applied to solve other problems that may be vastly different from the original one.

Disease Surveillance, or the early identification of newly emerging or re-emerging diseases is critical to the ability to control potentially devastating epidemics such as various forms of pandemic influenza that have led to large numbers of fatalities in the past. As part of its program on bio-surveillance, designed to get early warnings of disease outbreaks, CCICADA has explored novel methods ranging from the use of non-standard data, such as text from remote newsletters, to the use of tools of information theory. CCICADA researchers applied the information-theoretic concept of entropy (a measure of the unpredictability of an outcome or its information content) to transform data about the number of new disease cases into a disease surveillance signal. The use of such signals led to new tools for disease outbreak identification that could detect outbreaks earlier and more accurately than other methods currently in use.

Collaborating with colleagues at the Centers for Disease Control (CDC), CCICADA faculty and students explored algorithmic tools for pre-processing disease incidence data to make the data more readily amenable to detecting outbreaks. Levels of disease incidence were classified into "bins" to create a smaller number of categories to be processed, thus speeding up data analysis. Collaboration with another DHS COE, the Center for Foreign Animal and Zoonotic Disease Defense (FAZD), provided a vehicle to analyze these methods further. Early detection, such as that enabled by CCICADA tools, is a key component of effective disease containment.

Edward Hovy
Research Director
Carnegie Mellon University

Statistical Analysis shows that the differences are much greater than can be explained by random chance. How much of these differences can be attributed to environmental factors such as weather, time pressure, or others?

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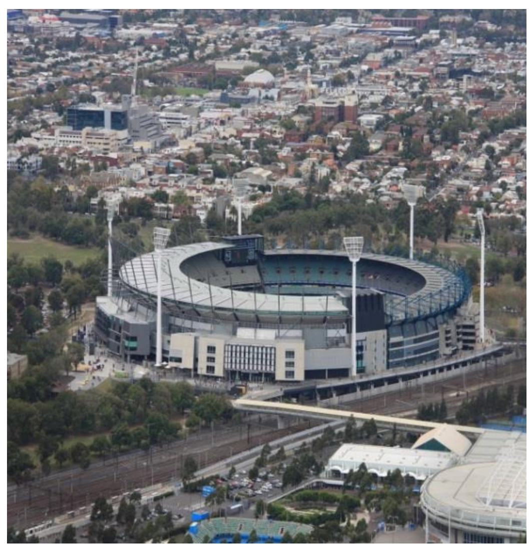
Safety of Sports Stadiums is critical to the millions of people who attend events at these venues**.** Since 9-11, large venue sites across the country have been considered targets for terrorist activity. The Boston Marathon bombings of April 2013 highlighted the urgency of finding methods to better protect sports venues, and other inside and outside entertainment venues. One of the most important and extensive projects that CCICADA has taken on in the last few years involves stadium security. When the National Football League (NFL) asked all stadiums to wand 100% of the spectators before stadium entry, the lines got long and some fans could not get into the stadium near kickoff time. CCICADA undertook a project to analyze patron inspection methods at stadiums. Data was collected at a variety of venues using video analysis and onsite observations and included, not only football games, but soccer games, monster truck events, and rock concerts. Inspection methods, such as bag checks, pat-downs, and wanding, were compared.

Statistical analysis of data showed that there were significant differences in inspection times depending upon the procedure used, the location of the gate, who was doing the inspection, and how long before game time the inspection took place, and that the differences observed were much greater than could be explained by random chance. There were also major differences for the different types of events. This work has led CCICADA to engage with all major sports leagues, and professional, college and minor league stadiums to plan for fan inspections using these tools.



Far-reaching changes involving complex technical, economic, and legal issues have begun to alter the conditions for exchange of data among scientists, especially across national boundaries.

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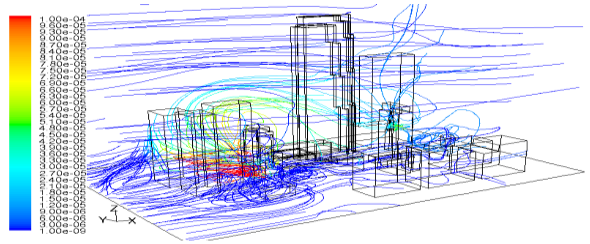
Stadium evacuation is a component of stadium security where best practices depend on large amounts of data. How can a large sports stadium be evacuated quickly in the event of a terrorist attack or natural disaster like Hurricane Sandy or the Moore, Oklahoma tornado? CCICADA, with its partner Regal Decision Systems Inc. and stadium management and security from a variety of sports leagues, has developed sophisticated tools for simulating the evacuation of stadiums. The simulation tools calculate the time required to move people to a safe place as well as the benefit of sheltering the patrons in place. Evacuation routes from different stadium sections, location of security personnel during an evacuation, physical obstacles, and likely crowd dispersions are all part of the model developed before simulations are run. CCICADA has developed training materials for stadium operators for implementing the evacuation plans. The results of this work were found useful and important during a lightning storm emergency at an NFL stadium.

The evacuation model and subsequent simulations provide everyone with information well beyond such things as how long it will take to evacuate a full stadium. The behavioral aspect and its potential impact was one thing not incorporated in the original models and subsequent planning processes. Now the model needs to include such things as the desire to wait for friends, the possibility of getting lost, deliberate motion in a different direction than intended, emotion of the game and the chaos at the scene. CCICADA is developing new models to take these factors and others into account.

"The analysis you and your team of experts presented to our security staff at the NFL office was very well received. Thank you for giving us the opportunity to see how valuable computer modeling can be in evaluating more effective and efficient technologies to secure our stadiums".

Raymond J. DiNunzio
Director of Strategic Security Programs
National Football League



Modeling involves abstraction, simplification, and formalization, in light of particular methods and assumptions, in order to better understand a particular part or feature of data.

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Managing Data During Emergencies is one of the biggest challenges facing law enforcement and homeland security. Data analytical tools are needed to understand the nature of an event, support field decisions, and prioritize activities and resources. Event information, including activities, content, and spatio-temporal analysis, are all needed. CCICADA tools make use of multiple media to gain situational awareness and enable collaboration in complex environments. For example, the system GeoXray, developed by CCICADA partner TerraGo, links multimedia data to an image in an area of concern by identifying the geographic features shown, and then using information retrieval techniques, such as used in search engines, to find texts associated with the data that best match the specific objects (e.g.., buildings or roads) within an image. The system is in use in California, by the Air Force, Army and the U.S. Geological Survey. The Hippocrates system developed by the New Jersey Department of Health and Senior Services is used for monitoring and responding to health-related emergencies. CCICADA assisted in establishing the Hippocrates system on smart phones, making it usable by first responders in the field.

Data during emergencies is often inconsistent and conflicting. This includes data gathered to prevent human trafficking, crime data and disease data. Inconsistencies can be due to simple noise in the data or a malicious intent to deceive. CCICADA develops computational tools to address the problem of trustworthiness. The development of precise definitions of the factors that contribute to trust, including accuracy, completeness, bias, and others, are necessary. Once definitions are made precise, metrics measure the accuracy, possible biases, and completeness of the extracted data.

A model represents the system and simulation predicts the operation of the system over time. A simulation uses the model as a base.

Data Driven Modeling and Simulation

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The scale of the problems CCICADA is trying to solve and the large amount of data that is acquired require researchers and others to develop tools to simplify the data and create models of the component parts. Modeling tools assist analysts in arriving at possible options or decisions that they must make so that they might better understand the consequences of these actions. Once models are created to represent the key characteristics or behaviors of the system or process, then simulations that imitate the operation of the process or system over time are performed. Simulations can be used to show the eventual real effects of alternative conditions and courses of action. Simulations are also used when the real system cannot be engaged because it may not be accessible, or it may be dangerous or unacceptable to engage, or it is being designed but not yet built, or it may simply not exist.

Port and Border Security provide an example of how CCICADA uses modeling and simulation. It exhibits how CCICADA works with the U.S. Coast Guard and U.S. Customs and Border Protection (CBP) on a variety of problems such as inspection of containers in large transport vessels in the Port of New York and New Jersey. One of the primary responsibiities of CBP is the protection of U.S. borders by inspecting incoming shipments for illegal and/or potentially lethal cargo. However, it is impossible to inspect all incoming shipments. CCICADA has developed sophisticated models of port operations to determine the best approach to conducting container inspections.

The key to progress has been the extent of collaboration that has occurred. CCICADA has remained receptive and flexible throughout the process.
Commander Kevin Hanson of the Coast Guard

Protecting the key areas of the high seas is an important mission for the United States Coast Guard and this includes enforcing US domestic fisheries laws.

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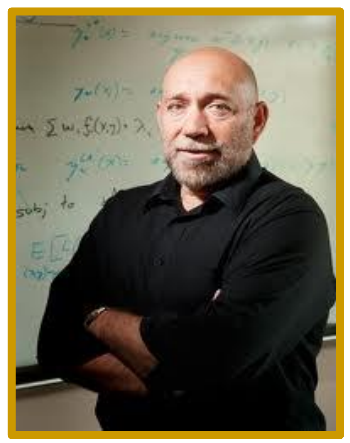
A key task was to establish current baseline measures to compare new approaches. Such new approaches now include using offsite reviews of container contents in warehouses removed from the port of entry, allowing more efficient use of CBP inspectors.

CCICADA also works with CBP's Office of Border Patrol (OBP) to model the placement of unaccompanied minor children who are caught trying to enter the U.S. OBP works with Immigration and Customs Enforcement and the Office of Refugee Resettlement in the Deparment of Health and Human Services to place these children into apparopriate shelters where they can be taken care of until placed with relatives or appropriate families. The placement problem requires major modeling and simulation efforts.

Fisheries Law Enforcement is aided by CCICADA's use of modeling and simulations which help the U.S. Coast Guard use their law enforcement resources more efficiently. The Coast Guard is tasked to ensure the sustainability of the domestic 24 billiion dollar fisheries industry. To do so the Coast Guard is tasked to enforce the Fisheries Management Plans in the sea. NOAA, the National Oceanic and Atmospheric Administration, enforces these plans on shore. In addition to enforcement of the Fisheries Management Plans, the Coast Guard enforces laws to protect marine mammals and endangered species, and enforces international fisheries agreements. A primary activity is the sighting and boarding of vessels of commercial fishing fleets.



Dan Roth
Research Director
University of Illinois
Urbana/Champaign

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The Coast Guard developed a scoring system to determine which commercial fishing vessels it should board to look for fishery violations. Features included in their scoring system include outcomes of prior boardings and the presence of up-to-date safety inspection stickers. The Coast Guard's question to CCICADA was whether it could increase the percentage of times a boarding leads to discovery of a fisheries law violation by making use of sophisticated data analytics tools. Using Coast Guard supplied data, CCICADA determined which factors might provide better predictors of success.

Flood Mitigation is an increasingly important problem. Hurricanes Katrina and Sandy have accentuated the immediate need to mitigate against floods. How do we develop a model for determining the most cost-efficient flood mitigation investments? Can a model enable us to simulate realistic floods? Once we have such a model, how does it drive decision making?

CCICADA developed a general model for flood mitigation investment and decision making in its work with the Raritan River flood issues in New Jersey. Tools developed for the tasks included a hydrological model to measure the impact of various mitigation strategies on peak flow. These strategies included more catch basins, cisterns, green spaces, flood buy-outs, and various flood warning systems. Another model related peak flow and total flow over flood level to property damage and insurance claims, and additional strategies were developed.

FEMA Regions

Hurricane Sandy emphasized the need for the U.S. and states to engage in the rigorous development of flood mitigation strategies and disaster planning tools, to analyze the risks of an event and provide possible risk reduction strategies.

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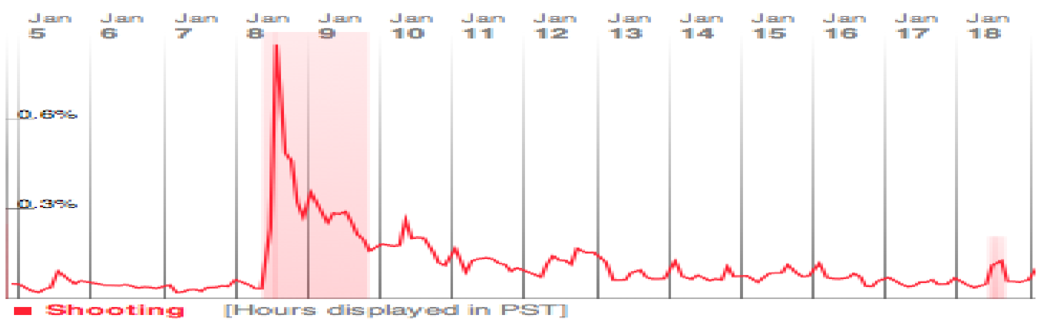
The two flood models were combined to see how much could be saved from employing each of the strategies or combinations of strategies. Inherent in each of these models is baseline data on seasonality, ground cover, average soil moisture content, "normal" river heights at various points and average precipitation and duration for different times of year. This work in flood mitigation on the Raritan River was in collaboration with the DHS National Transportation Security Center of Excellence at Rutgers University.

There is a great deal of data that arrives in planning for emergencies and during them. How does such data arrive during a disaster and how is it organized so that analysis can take place? Can learning tools and computer tools be developed so that analyses don't have to be done over and over again? Because information gathered is too huge or too complex for humans to handle and organize, and conclusions that could be drawn are not immediately obvious, ways of clustering the data, and organizing it must be developed. A central CCICADA tool is to represent such data in networks, where the data flows between nodes in the network, and where the nodes are people, sensors, databases, or almost anything. This representation enables the discovery of trends and inferences.



People are everywhere connected around the world. Can we find out when events such as earthquakes tsunamis, hurricanes, tornadoes and other disasters occur and how they develop and proceed by watching Twitter streams?

Information Networks, Analysis, and Learning

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Social Media Networks can be used during emergencies as potentially critical tools. CCICADA researchers chose 50 topics, such as earthquake, tsunami, foreshocks, epicenter, magnitude, and others on Twitter. They learned the "topic signatures" that indicate an event is occurring or has occurred. In particular, bursts of occurrence in a particular timespan allow them to monitor the event as it unfolds and begins to dissipate.

Social media are also fundamental tools in emergency response planning. CCICADA researchers obtained over 1 billion tweets collected by Twitter during an earthquake event. These tweets were in addition to a variety of communications on other social networks. They found that there is great diversity in types of communication networks and the spread of information on these networks. People, including first responders, follow typical sequences when communicating during emergency situations. Any anomaly in these communication sequences can be quickly identified when the data can be processed quickly.

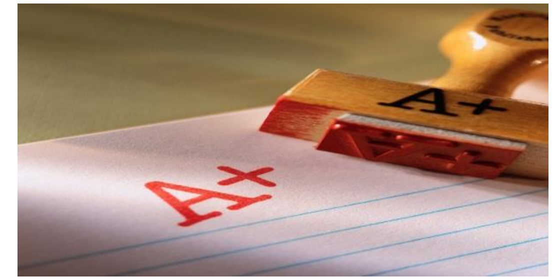
Use of social network data is challenged by the trustworthiness of the data and issues of privacy and security. A major CCICADA research area is how best to preserve privacy while enhancing security. CCICADA researchers are developing sophisticated data-scientific methods to address issues of privacy while strengthening security.

Paul Kantor
Research Director
Rutgers University

The devastation and psychological impact of a successful bomb attack on America, even a small one, is dramatic. The 2013 Boston Marathon bombing proved we must find new ways to detect bomb-making materials, whether from improvised explosive devices or radiation-emitting materials.

Methods of Nuclear Detection have formed the basis for several CCICADA projects that have made use of new tools in data science. Recently, the Domestic Nuclear Detection Office (DNDO) Test and Evaluation Divisiion approached the center with the following question: We have many procedures (algorithms) for identification of threat radioactive isotopes and for distinguishing them from non-threat ones such as medical isotopes. How can we pick a portfolio of best procedures? There are many criteria that must be considered – accuracy is of course one, as is usability, but so too are efficiency, minimizing false alarms, cost, and others. This is a heavily data-intensive task and provides the opportunity to work with a sister DHS center of excellence CREATE, the National Center for Risk and Economic Analysis of Terrorism Events, in gathering the full set of criteria from various stakeholders. The initial phase of the project is to find a full set of criteria and then to create metrics for measuring each criterion. Next, scoring systems must be developed that can be used to combine the measures under each criterion into a score to assign to each procedure or algorithm. Finally, experiments must be designed to test these algorithms when the large number of possible combinations of relevant criteria make it infeasible to make all desirable comparisons.

Earlier work with DNDO involved the desire to get an early warning of risky ship containers before their arrival in the U.S. U.S. Customs and Border Protection (CBP) collects information at overseas points of embarkation, using a variety of customs forms,



Machine learning focuses on prediction of occurrence, based on known properties of the data learned from training data. For example, a machine learning system can be trained to distinguish email spam from non-spam and kick out the spam emails.

including a ship's manifest and its bill of lading. This information is used to determine if the ship poses a potential risk. CCICADA has developed sophisticated methods of statistical analysis, machine learning, and data visualizaton to develop risk scores that inform CBP as to the need for enhanced inspections to find dangeorous cargo such as nuclear or radiological materials.

Detection of radiation-emitting material can be accomplished by locating radiation sensors, but where should these sensors be placed? In some cases, such as ports and border crossings, checkpoints provide logical locations for the sensors. It is not at all obvious where sensors should be put in outdoor settings like the Boston Marathon or in the middle of Manhattan. One option is to put the sensors in random places, or move them randomly. This type of randomization can create uncertainty in an adversary, raising their cost of an attack. Randomization can also be achieved by placing sensors in police cars. CCICADA research with DNDO led to the conclusion that the number of police cars might not be sufficient to provide a high enough probability of detection, but using taxicabs might.

Is there a conflict between freedom of economic activity and increased security? This potential conflict is most appparent in urban areas like Lower Manhattan. How do we manage these sometimes conflicting goals?

Data-Driven Decision Making

Now that we are finding ways to gather, extract, organize and manage large amounts of data, create models of the problems we wish to solve, run simulations that show us what might happen if we implement an alternative, and develop tools to aid in the solutions, how do we make decisions based on all of this information? This is a major task of CCICADA and other DHS university centers, working alone and with each other.

The Urban Commerce and Security Study (UCASS) is a project that couples CCICADA, the CREATE COE based at the University of Southern California, and The National Transportation Security COE based at San Jose State University to develop a support tool that planners and decision makers can use to make choices about security initiatives and countermeasures, while taking into account the potential impact of those countermeasures on economic activity. This data-driven decision making tool initially is not a real time tool, but is a tool to be used in planning. In particular, the planning tool compares security measures as to risk and economic consequences in an urban area. A prototype of the tool has been developed and presented to homeland security partners.

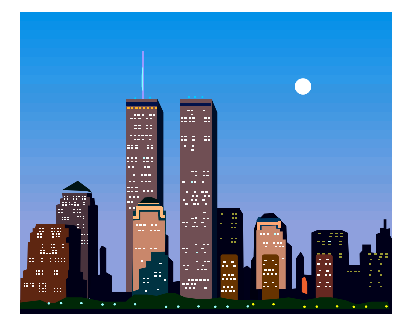
UCASS began in Lower Manhattan, near the new World Trade Center site, where the desire to keep things safe is sometimes seen as conflicting with the desire to enhance economic activity. Numerous stakeholders have security/economic goals in big cities. In Lower Manhattan, these include the NYPD, NYC Department of Transportation, local and state agencies, the 9-11

"Defeating insurgents and terrorists is not based on traditional war tactics; it encompasses a national strategic effort that employs all elements of national power".

9-11 Commission Report

Memorial, real estate firms, development corporations, residents, and others. Information needs to come from many different sources – video cameras, screeners at subway stations, security checkpoints, police departments, store owners, and more. In addition, data on the costs of countermeasures has to be acquired – capital and operating costs, costs of delays, inconvenience costs, environmental costs and more. The complexity of finding ways to quantify these costs and gathering opinions about them from stakeholders like residents, workers, tourists, and businesses is mind-boggling. Besides all of these challenges, how are metrics established for such things as inconvenience and indirect inpacts?

Enter the modeling/simulation phase. Tools were needed to model and simulate security initiatives. Students walked the streets of Lower Manhattan to conduct surveys and take counts to populate a model. Information about the probability of different behavior in response to various scenarios – e.g., what happens when a pedestrian sees a street blocked, or patrons see a restaurant entrance with a metal detector – was gathered. Based on such data, the CCICADA-developed simulation determines the change in economic activity level after an hour, a day, a month. CCICADA simulated all pedestrian life – workers, tourists, shoppers and pedestrians – with a focus on commercial life. Closing streets, placing bag checkpoints on one side of a street or in subway entrances, placing more security cameras on streets are simulated. Output from the simulations is produced online and offline, and in animation formats. All of the economic and simulation data feeds into a "computable general equilibrium" model of Lower Manhattan developed by CREATE.



Al Qaeda spent roughly half a million dollars to destroy the World Trade Center and cripple the Pentagon. The cost to the United States estimated by a survey done by *The New York Times* is $3.3 trillion.

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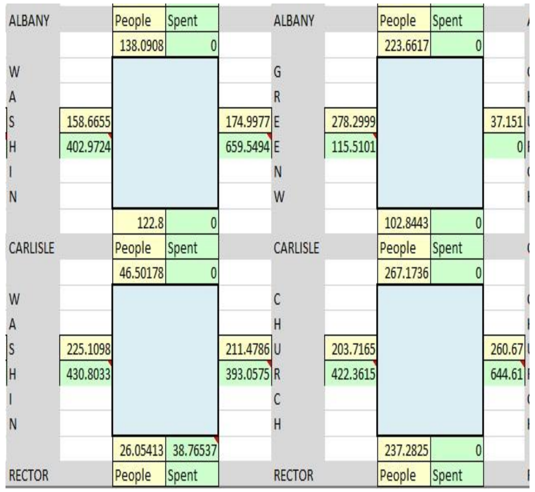
This model can be used to calculate spillover economic effects in larger regions as well as to feed CREATE's risk models. Using all of the data, models, and simulations, CCICADA hopes that users will be able to create portfolios of security initiatives that are usable, efficient, and most of all will help to prevent terrorism with minimal impact on the local economy.

Quite a few other types of decisions could be aided by building on the UCASS tools:



Which areas or facilities should be opened first after a snow storm, massive fire, or other disaster to assure the quickest economic recovery?

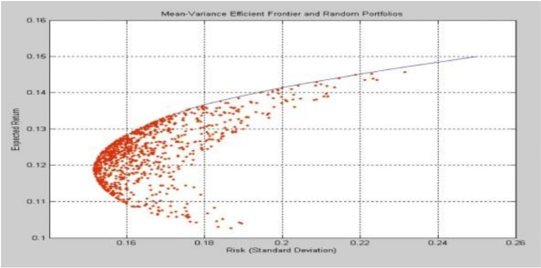
What is the impact at an airport of opening one runway compared to another after the airport has been shut down?

Which neighborhood should get power back first, second, etc., after a storm like Hurricane Sandy?

What security initiatives will keep mall customers safe while getting as many people into the mall as possible?

What is the economic impact on a region if the Coast Guard Captain of the Port raises the maritime security level or implements a transportation worker identification credential program?

Deriving knowledge, information, and practical understanding from massive amounts of unstructured data, through partnerships and collaboration.



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Resource Allocation is another way to look at the economics of homeland security by analyzing the costs of utilizing limited resources and finding ways to utilize these resources more efficiently. This was the goal of a project with the U.S. Coast Guard that was aimed at assisting in the allocation of boats to boat stations. The CCICADA Boat Allocation Module (BAM) tries to find an assignment of available Coast Guard vessels of different types to the many Coast Guard boat stations around the country so that vessels are assigned to stations where their capabilities best match the mission requirements of the station. The overall goal in developing this model is to inform senior Coast Guard leaders' decisions regarding asset capabilities, acquisitions, and allocations; unit locations; policies and concepts of operations; and mission tradeoffs.

The BAM project had two objectives: a) to efficiently meet the required mission hours and station requirements, while staying within a given budget and b) to satisfy all of the station and mission requirements, while minimizing the total budget amount. Emphasis was on the first objective. The model developed by CCICADA, in close collaboration with the Coast Guard, has sufficient flexibility to change certain inputs in order to test possible scenarios and their impact on the overall objectives. For example, the Coast Guard management might ask what would be the impact on unmet mission hours if the budget is reduced by 5%. Or, if the Coast Guard allows boats to operate for 10% more hours before scheduled maintenance, and desires to meet the mission hour requirements, how is the budget impacted? The BAM tool is currently installed on Coast Guard computers. This BAM model shows a potential savings of nearly 120 million dollars over a 20 year period.

"The goal is to turn data into information and information into insight".
Carly Fiorini, former CEO of Hewlett Packard

To prevent terrorism, we need to identify the terrorists and their tools whether they be on fishing boats or transport vessels, attending football games, or just attempting to cause harm.

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Data about immigration forms collected by the U.S. Citizenship and Immigration Service (USCIS) is crtiical for that agency to plan its workforce deployment and budget. The many immigration forms received by USCIS range from applications for green cards to requests for asylum. The USCIS Volumes Projection Committee compares the number of forms received in previous years, as well as factors affecting applications, such as changed immigration regulations or economic or political events in other parts of the world, in order to project the number of forms expected in the next time period. With this information USCIS is able to make better decisions on their resources, such as allocation of staff and expenditures. CCICADA researchers are using new tools of data science, such as time series analysis from statistics, to assist USCIS in making their projections more accurate.

The Arctic is a major area of concern for the Coast Guard because of rapidly changing climate, resulting impact on ice conditions, and stress on other Coast Guard areas of responsibility. CCICADA's Dynamic Modeling for Arctic Resource Allocation project is formulating models to analyze and support decisions concerning current, anticipated, and proposed operations of the Coast Guard in the Arctic. It initially focuses on resource allocation modeling/logistics for oil spill response in remote Arctic environments.

Barrow Sunset

The transfer of technologies to applications usable by practitioners provides an engine to drive increased security, innovation, and economic growth.

Technology Transfer

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The goal of the CCICADA Technology Transfer Program is to transition CCICADA data analysis technologies into practical applications usable by first responders and Homeland Security practitioners. CCICADA wants to see that its work is never far from the practical problems impacting homeland security. One way to accomplish this is to rapidly assemble and configure a range of prototypes tailored to specific homeland security challenge areas and problems. To do this CCICADA's research is especially sensitive to the following key requirements: analysis and synthesis (and visualization) of large volumes of data; operation in real time; security of systems and information; and evaluation of system performance. Technology transition enters at the early stages of each project.

The GeoXray technology mentioned earlier has been transitioned to multiple users, and CCICADA's work on the Hippocrates situational awareness tool has been transitioned to first responders through smart phones. CCICADA's tools for solving Coast Guard boat allocation problems have been transitioned to work on Coast Guard computers. CCICADA's higher order learning tools have found multiple users, including numerous police departments, an Air Force Base, and Bloomberg News; and the CCICADA tools for natural language processing are in use at Semantica, the Mayo Clinic, and other places.

Director of Transition
Bill Pottenger
Rutgers University

CCICADA
Command, Control, and Interoperability Center for Advanced Data Analysis
A Department of Homeland Security Center of Excellence

It is not enough to simply develop solutions and tools to solve important problems. We must educate and train technically knowledgeable people of all ages to use the tools to solve new problems.

Knowledge Transfer

Knowledge transfer comes in two forms – education of the next generation workforce and transitioning knowledge into technologies for wide use. CCICADA believes for knowledge transfer to take place it is not sufficient to conduct research, develop new technologies, and help implement these new technologies. It is critical that CCICADA and all of its partners play a key part in developing the next generation of researchers, technicians, and practitioners.

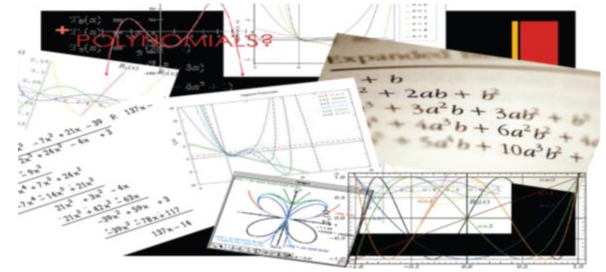
To produce a new generation of researchers and practitioners well equipped to create and implement innovative new solutions to important problems, CCICADA provides education and training to students, faculty, professional analysts, and first responders. These students, faculty, practitioners, and others from a broad set of disciplines centered on data acquisition, analysis, management, and decision making participate on all of the research teams and projects.

CCICADA undergraduate, graduate, and 9-12 education programs include:

- Research Experiences for Undergraduates (REUs)
- Workshops and Tutorials
- Graduate Student Training & Development
- Reconnect (to Current Research)
- Student Internships at Agencies
- Courses and Materials Development
- Minority-serving Institution Summer Research Programs

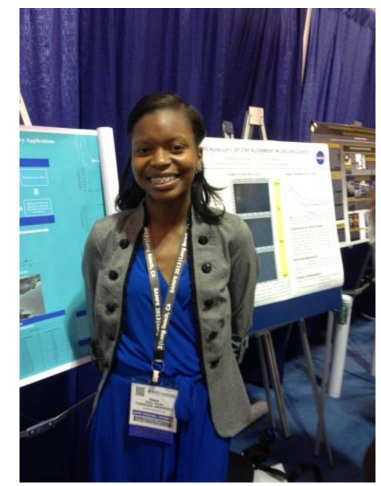
Brian Thompson
Graduate DHS Fellow

CCICADA is committed to building pioneering education programs that integrate research and education and sow the seeds for a robust, diverse homeland security workforce in the future.

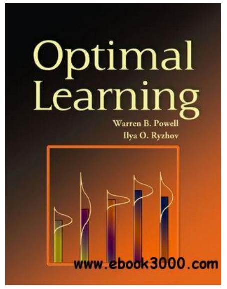


Graduate students are key players in all CCICADA programs – both research and education. There are over 40 affiliated graduate students at CCICADA partner organizations per year. They are heavily engaged in CCICADA projects, e.g. stadium security, CBP container inspection, and UCASS among others. They are also heavily engaged in education programs as assistant mentors in REU, and as lecturers/role models for undergraduate programs, especially the programs aimed at encourging minorities to enter STEM disciplines.

The Summer Research Experiences for Undergraduates Program (REU), housed at Rutgers University, provides advanced undergraduates from around the country with an exciting research experience as part of CCICADA research teams working on such problems as stadium evacuation, prevention of human trafficking, detection of adverse disease events, and many more. Each student has an individual mentor and each student has multiple opportunities to present their results during the summer. Diane Render, shown to the right, was a student from Albany State University in Georgia in the REU program in 2010 and is now finishing her Ph.D in Materials Science and Engineering at Tuskegee University. James Manning, from the University of South Carolina, REU student in 2010, is completing his Law Degree at the University of Virginia. REU students are introduced to industrial research in addition to research important to the homeland security of our country.



Diane Render
REU Student 2010
Tuskegee Ph.D student



CCICADA Education Principles:
- **Rapid transition of research into education**
- **Timely and evolving content**
- **Model programs and curricula that can be widely disseminated and replicated nationwide**

Course and Materials Development is an important component of knowledge transfer. CCICADA-developed materials and courses are able to provide new knowledge to tens of thousands of students and practitioners nationwide. CCICADA emphasizes modules based on CCICADA research and the research of other Centers of Excellence. They are classroom tested, widely used, cover 5 to 8 days of instruction, and have impacted over 5,000 students to date. Books have been developed related to homeland security and the work of CCICADA, for example: *Optimal Learning*, by Warren Powell and Ilya Rhyzov, and *The Mathematics of Encryption – an Elementary Approach* by Margaret (Midge) Cozzens and Steven Miller.

A Sample of university courses developed so far include:

Optimal Learning (Princeton),
Privacy-preserving Technologies (Texas Southern),
Encryption for Criminal Justice and Political Science (Rutgers/Williams),
Visual Analytics (UMass-Lowell),
Visual Analytics of Massive Graphs (UMass-Lowell),
Internet and the Information Environment (Rutgers),
Game Theory and Homeland Security (West Point).

Andrew Rodriquez
Graduate Student

CCICADA is surveying cyber security education and training programs for government, undergraduate and graduate students, and industry, and designing materials to train people to deal with the rapidly-changing enviornment of cyberthreats and responses.

The knowledge supply chain includes research that generates new knowledge and teaching to transform and distribute this new knowledge.

Workshops and Tutorials are designed for a variety of audiences, through new shortcourses in the CCICADA Data Science Summer Institute, and in specialized meetings designed to develop a dialogue and/or introduce participants to topics such as urban planning for climate events, Hurricane Sandy research, cascading changes in power transmission systems, reliability and resiliency of networks, and risk-averse decision making.

CCICADA's **RECONNEC**T Workshops are week-long workshops to involve faculty teaching undergraduates and other professionals in new research topics in the mathematical and computer sciences related to homeland security. They develop modules related to these research topics to take back to their own classrooms, and they make them available for use nationwide. Faculty and other professionals come from all over the country and include many faculty from minority serving institutions.

Reconnect 2013
at Morgan State University

Topics over the past few years have included *Privacy*, *Text Extraction*, *Water Infrastructure Contamination and Risk Analysis, Game Theory*, *Visual Analytics*. and *Biosurvellance*. Many new courses have resulted from these Reconnect Workshops, and have reached over 30,000 students.

Note: The pictures included in this brochure were found in clip art, in the public domain through Wikepedia Commons, provided by CCICADA researchers, and ten were purchased from Getty Images (those occurring on pages 2*, 7, 8*, 11, 16*, 17, 18, 21*, 28* and the cover, where * denotes top picture).