Hurricane Irene is just the latest major storm to damage infrastructure across a large region of the United States. While Hurricane Katrina left the lasting image of people on the roofs of their homes, Hurricane Irene left millions without electricity, and has damaged the nation’s transportation infrastructure along the Atlantic coast, closing mass transit in New York and Philadelphia, blocking Amtrak lines, washing away historic bridges in Vermont and stranding small towns throughout the mountainous state.

Transportation is the essential infrastructure for all emergency response. Articles about Irene in the New York Times and Los Angeles Times pointed out that roads are essential to the provision of all other emergency services. In Vermont “goat tracks” had to be created with storm debris and gravel to support the weight of emergency vehicles, even while the state capital itself was under flood watch for the Winooski River. All terrain vehicles (ATVs) were used on temporary roads to move sick people out of disaster areas, and food and pharmaceuticals into empty local stores in isolated towns. The damaged electrical grid could not
be restored because bucket trucks could not access isolated areas, so they arrived instead in ATVs using temporary roads.

For two years researchers at Mineta Transportation Institute (MTI) have been working with the California Department of Transportation (Caltrans) to develop a continuity of operations/continuity of government (COOP/COG) planning and training program that builds on Caltrans' 2006 COOP/COG plan. Using enhancements from the Continuity Guidance Circulatrs 1 and 2, the COOP/COG plan bases a complete Continuity Branch on the Caltrans essential functions, including an Emergency Relocation Group (ERG) comprised of a Human Capital Unit, Relocation Unit and Essential Functions Unit. The team created position descriptions for all branch personnel. The most unique feature of the new COOP/COG plan is its development of a relationship between the existing emergency management structure and its emergency operations center with the COOP/COG Branch and its functions.

California has been called “America’s disaster theme park.” Tsunami damage from the Japanese earthquake was just the latest challenge to the highway infrastructure of the state. A forty vehicle accident with fatalities caused by rain unexpectedly turning to snow, and a freeway overpass destroyed by a tanker truck fire are two recent examples of no-notice events that required uninterrupted response by Caltrans. To enhance Caltrans’ internal emergency response capabilities that support the field response to the public, MTI staff provided Incident Command System/National Incident Management System (ICS/NIMS) introductory training, and an 8-hour scenario-based emergency operations center (EOC) course. This training is intended to ensure that Caltrans has a robust basis for emergency response to any event.

However, COOP/COG is required when the disaster not only overwhelms a state’s internal emergency response capabilities, but also involves aspects of the headquarters in a disaster. For example, a power outage in the capital, flooding of the capital city, or a terrorist threat to the state capital might require the opening of the alternate facility, as well as an alternate EOC.

Caltrans' COOP/COG plan was written following Hurricane Katrina in 2006, with an emphasis on its information technology needs. Over the past several years exercises and real events have demonstrated the need to better document the role of the ERG, the interface between the EOC and the alternate continuity facility where essential functions are being maintained, and the role of the Caltrans headquarters in delivering emergency response services in the field, while also supporting the Governor’s Office and other executive functions of state government. MTI’s researchers have updated the threat assessment on which emergency planning is based, worked with Caltrans staff to better document interfaces, researched ERG responsibilities, looked for best practices, and developed transportation department-specific COOP/COG training for the ERG members, including a tabletop exercise for the ERG to refine their checklists and “drive away” kits.

After completing the work for Caltrans, which includes a number of state-specific aspects, the team undertook the creation of a generic version of the COOP/COG Plan, which can be used by any state-level transportation agency. The generic plan has sections that are applicable across all states, and other segments that are examples to be replaced with state-specific material. The Generic COOP/COG Plan for State Level Transportation Agencies has been published by MTI at www.transweb.sjsu.edu. While the publication can be downloaded as a pdf, a URL is also available to download a Word version that can be easily modified by any other state.

The second phase of the COOP/COG project was the creation of a research report, and training materials to support the creation of a robust state-level transportation agency emergency response and COOP/COG capability, entitled COOP/COG Handbook for State-Level Transportation Agencies, which is also on the MTI website. The first section is the research report, which includes information on their research on the role of a state-level transportation agency COOP/COG program, the interface between the EOC and the COOP/COG Branch, and ERG staffing, development and deployment.

Two complete sets of training materials are also included in the Handbook. The first set provides EOC training supported by PowerPoint Notes pages, scenarios, and student handouts. It includes a complete set of EOC position descriptions for an EOC modeled on the FEMA IS-775 "ESF" organization structure, which brings the ICS into the EOC.

The second set of training materials focuses on training the COOP/COG Branch staff. It includes PowerPoint Notes pages, student handouts, a set of basic ERG position descriptions, and a set of model ERG position checklists.
The lessons of Hurricane Katrina were cautionary, leading to a reinvigoration of the COOP/COG program nationwide. The lessons of Hurricane Irene, including rapid debris removal and road access development, reinforce the importance of planning and training. Keeping the roads open - even in a disaster - is a critical emergency response element for any state. The Generic COOP/COG Plan and COOP/COG Handbook materials, developed by MTI NTSCOE researchers, are designed to support all state-level transportation agencies in organizing their resources to ensure that roads will be open to support the rapid response to any disaster, even when the headquarters itself is a victim.

**NTSCOE – P: Petrochemical Incident Location System (PILS)**

NTSCOE – P at Texas Southern University (TSU) recently completed the 1st iteration of the Petrochemical Incident Location System (PILS), a historical database of hazardous materials spills viewed via a GIS base.

The Petrochemical Incident Location System (PILS) analyzes the statistical patterns of petrochemical incidents in relation to transportation security and provides a database of hazardous materials incidents throughout the country by displaying this information on a Geographical Information Science (GIS) map. “PILS provides the information that helps future policy makers or route planners in improving the efficiency and security of petrochemical transportation routes. This work addresses the Department of Homeland Security (DHS) priority research areas of transportation systems vulnerability, strategic studies of transportation infrastructure and integrated technological solutions to protect transportation infrastructure.”

The PILS database covers over 200,000 incidents from 1993 – 2008. This enables DHS stakeholders and emergency responders to observe clusters and patterns in a way that will improve response and recovery, and to illuminate non-routine occurrences involving petrochemicals. This research focuses on the inventory of hazardous materials incidents and assembles a relevant database to increase the resilience of the nation’s multimodal infrastructure and analyze threats to the delivery of petrochemicals.

To create PILS, NTSCOE- P researchers and graduate students collected raw data from the Pipeline and Hazardous Materials Safety Administration (PHMSA). A computer information system was used to analyze, data mine, and extract information from the space of petrochemical manufacturing and hazardous materials. The data are used to analyze patterns of incidents for the different modes of transportation and identify the frequency of accidents, locations of accident and reasons why such accidents happened. Using PILS, the researchers can collectively research events and incidents with an eye to future proactive prevention.

PILS has progressed into a newly funded project named **PILS: Implementation and Optimization for Mobile Devices or PIOD.** This funding includes building a mobile application for PILS and training of a select group of first responders. Training will emphasize device operation, as well as solicit feedback and suggestions for making it more user friendly. The Jackson, Mississippi and Houston/Harris County Fire Departments will have separate sessions on training and analysis options in early 2012.

Texas Southern University (TSU) provides hands on research to undergraduate and graduate student in relation to Transportation Security under the Department of Homeland Security’s National Transportation Security Center of Excellence. With a concentration on petrochemicals, students are able to interact with local stakeholders to view important real world scenarios and exposure to current industry trending topics. The items include, but are not limited to: organizing and hosting the annual advisory board meeting; researching and analyzing data gaps in system reporting structures; and creating web based Graphical User Interfaces (WebGUI). As students matriculate through the program, their research continues to evolve and garner more depth. Students are encouraged to publish and present work for various conferences and journals.

Each year the NTSCOE –P sends a student representative to the National Transportation Summer program at Texas Southern University (TSU) (and satellite program schools) to teach high school students about the Geographic Information System and how it relates to homeland security and transportation. The curriculum encourages high school students to explore careers in transportation and its subcomponent elements.

**UConn NTSCOE: Multi-University Team Developing Materials for Blast and Fire Protection of Infrastructure**

On August 21, 2002, the National Institute of Standards and Technology (NIST) announced its building and fire safety investigation of the World Trade Center (WTC) disaster. They found that: “In the absence of structural and insulation damage, a conventional fire substantially similar to or less intense than the fires encountered on September 11, 2001, likely would not have led to the collapse of a WTC tower.” Since the 9/11 attack, research to develop materials and concepts for both blast and fire protection of infrastructure has been accelerating. Until recently, however, research that simultaneously addresses both
concepts that would focus on developing entirely new materials. Riman from Rutgers University’s department and Professor Richard Mechan Engineering University of Rhode Island’s Professor Arun Shukla from the Engineering department; UConn’s Civil & Environmental un university team led by researchers from the University of Connecticut (UConn) and including researchers from the University of Rhode Island (URI) were assembled to address this challenge. Professors Rainer Hebert, George Rossetti and Bryan Huey of UConn’s Chemical, Materials & Biomolecular Engineering department; Professor Jeong-Ho Kim from UConn’s Civil & Environmental Engineering department; Professor Arun Shukla from the University of Rhode Island’s Mechanical Engineering department and Professor Richard Riman from Rutgers University’s Material Science department, began working together to develop entirely new material concepts that would focus on combined blast and fire resistance.

Dr. Hebert and his team are working to determine whether layered corrugated or tubular structures with graded mechanical properties for blast absorption are more effective when exposed to blast waves. In addition, they are experimenting with oxide materials to increase fire resistance after explosion, the aim being production of blast and fire resistant structural retrofits for older infrastructure or elements built into new structures. Using sophisticated computer models, Professor Kim can predict how these structural materials will behave based on mechanical properties, without expensive and time-consuming physical testing.

When this research began, the UConn team was conducting tests with ordinary steel, but in the meantime, the team has included an ASTM 913 grade 65 steel that is used for many new tall buildings, including the new One World Trade Center. The 913 grade 65 steel is currently being tested by Dr. Hebert’s team using elevated temperatures, high strain rate and explosive loading. This type of testing is a first for these materials and the properties of the steel under these conditions are unknown. The team will use the data to develop models that could be used in the future by structural engineers. Once examined, the results will therefore be beneficial for stakeholders that utilize this steel in building large infrastructure.

Dr. Riman (Rutgers), a specialist on ceramic and oxide materials, has a novel way of making customized oxide materials that can be made in fairly large sizes and quantities. He is developing bonding strategies for oxide/metal interface and combining metals with oxide materials to bond to the metal for increased fire and ballistic impact protection. In place of the concrete that is currently used, these oxides would be far superior for fire protection in the case of an explosion. Uniquely, the team is looking at purely metallic and oxide materials, as other research in this area has used textile or polymeric materials that cannot survive the temperatures of 800-900 degrees Celsius that might be encountered in the instance of explosion and fire.

At the University of Rhode Island, Dr. Shukla has a unique testing facility where the materials produced at UConn and Rutgers are tested under high strain rate deformation and shock loading. Using a shock tube, the materials are exposed to shock waves, generated to emulate explosion. Taking advantage of this facility, the team learns from the material transformation they observe and can develop their new materials to withstand greater blast loads and higher temperatures.

While catastrophic events are inevitable, Dr. Hebert and his team of experts are working to produce products and new material concepts that can improve the blast and fire protection has been minimal.

In early 2010, a multi-university team led by researchers from the University of Connecticut (UConn) and including researchers from the University of Rhode Island (URI) and Rutgers University were assembled to address this challenge. Professors Rainer Hebert, George Rossetti and Bryan Huey of UConn’s Chemical, Materials & Biomolecular Engineering department; Professor Jeong-Ho Kim from UConn’s Civil & Environmental Engineering department; Professor Arun Shukla from the University of Rhode Island’s Mechanical Engineering department and Professor Richard Riman from Rutgers University’s Material Science department, began working together to develop entirely new material concepts that would focus on combined blast and fire resistance.

Dr. Hebert and his team are working to determine whether layered corrugated or tubular structures with graded mechanical properties for blast absorption are more effective when exposed to blast waves. In addition, they are experimenting with oxide materials to increase fire resistance after explosion, the aim being production of blast and fire resistant structural retrofits for older infrastructure or elements built into new structures. Using sophisticated computer models, Professor Kim can predict how these structural materials will behave based on mechanical properties, without expensive and time-consuming physical testing.

When this research began, the UConn team was conducting tests with ordinary steel, but in the meantime, the team has included an ASTM 913 grade 65 steel that is used for many new tall buildings, including the new One World Trade Center. The 913 grade 65 steel is currently being tested by Dr. Hebert’s team using elevated temperatures, high strain rate and explosive loading. This type of testing is a first for these materials and the properties of the steel under these conditions are unknown. The team will use the data to develop models that could be used in the future by structural engineers. Once examined, the results will therefore be beneficial for stakeholders that utilize this steel in building large infrastructure.

Dr. Riman (Rutgers), a specialist on ceramic and oxide materials, has a novel way of making customized oxide materials that can be made in fairly large sizes and quantities. He is developing bonding strategies for oxide/metal interface and combining metals with oxide materials to bond to the metal for increased fire and ballistic impact protection. In place of the concrete that is currently used, these oxides would be far superior for fire protection in the case of an explosion. Uniquely, the team is looking at purely metallic and oxide materials, as other research in this area has used textile or polymeric materials that cannot survive the temperatures of 800-900 degrees Celsius that might be encountered in the instance of explosion and fire.

At the University of Rhode Island, Dr. Shukla has a unique testing facility where the materials produced at UConn and Rutgers are tested under high strain rate deformation and shock loading. Using a shock tube, the materials are exposed to shock waves, generated to emulate explosion. Taking advantage of this facility, the team learns from the material transformation they observe and can develop their new materials to withstand greater blast loads and higher temperatures.

While catastrophic events are inevitable, Dr. Hebert and his team of experts are working to produce products and new material concepts that can improve the blast and fire protection has been minimal.

In early 2010, a multi-university team led by researchers from the University of Connecticut (UConn) and including researchers from the University of Rhode Island (URI) and Rutgers University were assembled to address this challenge. Professors Rainer Hebert, George Rossetti and Bryan Huey of UConn’s Chemical, Materials & Biomolecular Engineering department; Professor Jeong-Ho Kim from UConn’s Civil & Environmental Engineering department; Professor Arun Shukla from the University of Rhode Island’s Mechanical Engineering department and Professor Richard Riman from Rutgers University’s Material Science department, began working together to develop entirely new material concepts that would focus on combined blast and fire resistance.

Dr. Hebert and his team are working to determine whether layered corrugated or tubular structures with graded mechanical properties for blast absorption are more effective when exposed to blast waves. In addition, they are experimenting with oxide materials to increase fire resistance after explosion, the aim being production of blast and fire resistant structural retrofits for older infrastructure or elements built into new structures. Using sophisticated computer models, Professor Kim can predict how these structural materials will behave based on mechanical properties, without expensive and time-consuming physical testing.

When this research began, the UConn team was conducting tests with ordinary steel, but in the meantime, the team has included an ASTM 913 grade 65 steel that is used for many new tall buildings, including the new One World Trade Center. The 913 grade 65 steel is currently being tested by Dr. Hebert’s team using elevated temperatures, high strain rate and explosive loading. This type of testing is a first for these materials and the properties of the steel under these conditions are unknown. The team will use the data to develop models that could be used in the future by structural engineers. Once examined, the results will therefore be beneficial for stakeholders that utilize this steel in building large infrastructure.

Dr. Riman (Rutgers), a specialist on ceramic and oxide materials, has a novel way of making customized oxide materials that can be made in fairly large sizes and quantities. He is developing bonding strategies for oxide/metal interface and combining metals with oxide materials to bond to the metal for increased fire and ballistic impact protection. In place of the concrete that is currently used, these oxides would be far superior for fire protection in the case of an explosion. Uniquely, the team is looking at purely metallic and oxide materials, as other research in this area has used textile or polymeric materials that cannot survive the temperatures of 800-900 degrees Celsius that might be encountered in the instance of explosion and fire.

At the University of Rhode Island, Dr. Shukla has a unique testing facility where the materials produced at UConn and Rutgers are tested under high strain rate deformation and shock loading. Using a shock tube, the materials are exposed to shock waves, generated to emulate explosion. Taking advantage of this facility, the team learns from the material transformation they observe and can develop their new materials to withstand greater blast loads and higher temperatures.

While catastrophic events are inevitable, Dr. Hebert and his team of experts are working to produce products and new material concepts that can improve the
predict strength evolution with time. Using automated unconfined compressive strength equipment purchased through DHS funds, the team tested hundreds of samples mixed with the different stabilizers at various water contents and times of reaction. In addition, using X-ray diffraction equipment at UConn’s Institute of Material Science (IMS), they studied the evolution of soil components in the soil in order to correlate the products of chemical reactions with the macroscopic strength gained.

After 18 months of research, they have a methodology that can be used in one pure type of soil and can be applied to anything that needs soil stabilization: levees, dams, tunnels or roads. Dr. Chrysochoou and her team of students have demonstrated that it is possible to quantitatively analyze soil microstructure and link it with macroscopic behavior. In the future, they hope to expand this research to a broad range of soil types and, ultimately, to develop a design guide that can be used by the Federal Highway Administration (FHWA), Local Departments of Transportation and the US Army Corps of Engineers for rational design of chemical soil stabilization in applications such as road subgrades and levee construction.

**UCONN NTSCOE: Ultra-High Performance Fiber Reinforced Concrete for Resilient Transportation Infrastructure**

According to a recent report of the American Society of Civil Engineers, approximately 25% of the bridges on the U.S. highway system are classified as “structurally deficient” and the average U.S. bridge is only 7 years away from its useful life of 50 years. The study also examines the economic consequences associated with aging U.S. surface-transportation systems and reports that failing transportation infrastructure cost U.S. businesses and households an estimated $130 billion dollars last year alone. One of the most promising approaches to address these problems is to develop and utilize advanced construction materials to revitalize our nation’s aging infrastructure. Researchers at the University of Connecticut are studying new advanced concrete materials to address knowledge gaps that hinder their widespread utilization.

Ultra-high performance fiber reinforced concrete (UHP-FRC) is an innovative construction material known for its superior mechanical properties and excellent durability. Both characteristics are inherited from an optimized particle packing density. The addition of metal fibers increases its strength compared to standard concrete. Under elevated temperature, high particle packing density unfavorably leads to a vapor barrier, which results in significant strength reduction before the material can be fully utilized. Professor Kay Wille and his team at the University of Connecticut (UConn) are working to characterize the material behavior under elevated temperature with respect to both chemical changes and physical effects. Although much research work has been carried out to characterize traditional concrete under elevated temperature, research results for UHP-FRC under these conditions are still very limited.

The UConn team has achieved preliminary results for thermal behavior of a commercially available UHP-FRC, Ductal®, developed by Lafarge. Fundamental thermal parameters such as coefficient of thermal expansion and thermal conductivity have been obtained using thermo-mechanical analyses. Thermo-gravitational analyses and differential scanning calorimetry have been performed to quantify the temperature range for chemical and physico-chemical changes of the material. The results of the previous tests are being analyzed to characterize the thermal behavior of UHP-FRC. In order to separate the effects of vapor pressure and chemical decomposition, research has been initiated to heat cylindrical specimens very slowly to prevent spalling. After specimen drying, they are exposed to different temperatures in the range of 100°C and 900°C. Their residual mechanical properties at different temperature, such as compressive strength and elastic modulus, are investigated to conclude the portion of material decomposition.

This fundamental work on material characterization under elevated temperature allows the researchers to assign temperature-dependent material properties in their structural analysis and design software. Based on their research results, the ability of a structure, such as a bridge or tunnel, to withstand high temperatures due to a fire can be evaluated. The time that a structure can withstand fire exposure depends on several parameters, like material behavior, structural design and the amount of loading applied. Enhancements in structural integrity will allow for more resilient bridges and tunnels and give first responders more time to rescue people trapped in emergency situations.

Ultimately, Dr. Wille and his team plan to successfully apply UHP-FRC solely or in composition with common steel reinforcement in tunnel linings with potential cost reduction in comparison to conventional methods.
Please contact the following individuals for additional information about the NTSCOE:

**MACK BLACKWELL RURAL TRANSPORTATION STUDY CENTER AT THE UNIVERSITY OF ARKANSAS**
Heather Nachtman, Ph.D.
hln@uark.edu
Letitia Pohl, Ph.D.
lpohl@uark.edu

**CENTER FOR RESILIENT TRANSPORTATION INFRASTRUCTURE AT THE UNIVERSITY OF CONNECTICUT**
Michael Accorsi, Ph.D.
accorsi@engr.uconn.edu

**HOMELAND SECURITY MANAGEMENT INSTITUTE AT LONG ISLAND UNIVERSITY**
Vincent E. Henry, Ph.D.
Vincent.Henry@liu.edu

**CENTER FOR TRANSPORTATION SAFETY, SECURITY AND RISK AT RUTGERS, THE STATE UNIVERSITY OF NEW JERSEY**
Michael Greenberg, Ph.D.
mrg@rci.rutgers.edu
Henry Mayer, Ph.D.
hmayer@rutgers.edu

**MINETA TRANSPORTATION INSTITUTE AT SAN JOSÉ STATE UNIVERSITY**
Rod Diridon
rod.diridon@sj-su.edu
Brian Michael Jenkins
brian.jenkins@sj-su.edu

**TEXAS SOUTHERN UNIVERSITY**
Carol Abel Lewis, Ph.D.
ntscoep@tsu.edu

**TOUGALOO COLLEGE**
Eduardo Martinez
emartinez@tougaloo.edu

ACKNOWLEDGEMENT & DISCLAIMER
This research is supported by the United States Department of Homeland Security, Science and Technology Directorate, Office of University Programs. This material was developed based on research and collaboration with the National Transportation Security Centers of Excellence (NTSCOE) at the Mack-Blackwell Rural Transportation Center, University of Arkansas; Center for Resilient Transportation Infrastructure, University of Connecticut; Homeland Security Management Institute, Long Island University; Center for Transportation Safety, Security & Risk, Rutgers University; Mineta Transportation Institute, San Jose State University; Texas Southern University; and Tougaloo College. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the US Department of Homeland Security.