Third-Year RESCUE Annual Report – 2005 to 2006

Responding to Crises and Unexpected Events

ITR

Collaborative Research: Responding to the Unexpected

National Science Foundation Award Numbers:

IIS-0331707, University of California, Irvine

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June 30, 2006

Table of Contents

EXECUTIVE SUMMARY

Following RESCUE's NSF site visit in June 2005, the team restructured the project to refine and redefine the goals which will enable us to focus on our mission of dramatically improving the ability of emergency response organizations to gather, process, manage, use and disseminate information during man-made and natural catastrophes. A new strategic plan outlining the milestones and deliverables for the remainder of the project, which will end in September 2008, was developed, submitted and presented to NSF at a reverse site visit in November 2005.

The strategic plan details our reorganization of the project team, including the reaffirmation of our community advisory board (CAB) and the formalization of a technical advisory committee (TAC).The CAB provides invaluable feedback on our research activities from the perspective of the first-responder community; they also assist with joint research efforts between ourselves and government partners. The TAC provides technical guidance on specific scientific and research topics; formalizing the committee helps ensure the depth and breadth of our research.

Five major multidisciplinary research projects have been identified. As a whole, they enable the RESCUE team to pursue our mission; individually, they focus our research. The five projects are: Situational Awareness from Multimodal Inputs (SAMI); Robust Networking and Information Collection; Policy-Driven Information Sharing Architecture (PISA); Dissemination in the Large; and Privacy Implications in Technology.

The four testbeds continue to evolve as living laboratories in which to test, validate and define our research: the Transportation testbed; the CAMAS testbed at UC, Irvine Campus; the San Diego Gaslamp Quarter (GLQ Testbed); and the partner site at Champaign, Illinois. The Transportation testbed has evolved into an integrative simulation environment, referred to as MetaSIM. These testbeds have been active in the last year, with activities including the following: building a realistic, detailed disaster scenario to act as a motivating use case for PISA's policy-driven information-sharing architecture in Champaign; a full-scale deployment and implementation of the GLQ Testbed during Mardi Gras festivities in San Diego; evacuation drills run on the CAMAS testbed at UC Irvine; and integration of key components of MetaSIM.

We continue to develop and build derivative system artifacts based on our research efforts that have direct value to response organizations, as follows. The artifacts 1) provide focus and context for research and expose new research challenges at interdisciplinary boundaries; 2) provide concrete mechanisms for collaborations amongst PIs; 3) engage input from the user community in all phases of research; and 4) enable exploration of technology transfer opportunities. Ultimately, they will serve as a legacy of the RESCUE program beyond the five years of funding of the project. All artifacts have associated partners from the user community. The partners serve as advisors, early adopters and testers, and in some cases, participate in the artifact development itself.

Through the testbeds and artifacts, we have continued to strengthen our partnership with the first-responder community. Our partners have participated in our testbeds, helped orchestrate drills, and have provided valuable, candid feedback on the usefulness and usability of new technologies. They have pushed researchers to consider issues relevant to real-world crisis and disaster response that may not have otherwise been apparent.

The following report is an overview of our research activities, findings, and achievements for the past year.

1. PARTICIPANTS

1.1 PEOPLE WHO HAVE WORKED ON THE RESCUE PROJECT

Below is a listing of all RESCUE project personnel at UCI and UCSD. The tables separate primary personnel from senior personnel and others who have worked on the project. In addition to listing affiliations, the role of each investigator or participant is given. All participants have generally worked at least 160 hours on this project.

1.1.1 RESCUE Primary Personnel

Name	***Role(s) on Project***	***>160 hrs***	***Work on project***
Sharad Mehrotra	Principal Investigator & Project Director Privacy Project Leader	Yes	***Data Management:*** Dissemination PISA Privacy SAMI Networking Testbed: CAMAS, MetaSIM
Ramesh Rao	Principal Investigator	Yes	***Wireless Applications:*** Networking Privacy Testbed: GLQ, MetaSIM
Carter Butts	Co-Principal Investigator	Yes	***Social Phenomena:*** Dissemination PISA Privacy
Ronald T. Eguchi	Co-Principal Investigator Transportation Testbed Leader	Yes	***Loss Estimation:*** Testbed: Transportation, MetaSIM
Nalini Venkatasubramanian	Co-Principal Investigator Dissemination Project Leader	Yes	***Middleware:*** Dissemination Privacy SAMI Networking Testbed: MetaSIM
Marianne Winslett	Co-Principal Investigator PISA Project Leader	Yes	***Trust Negotiation:*** PISA Testbed: Champaign
Bhaskar Rao	Co-Principal Investigator	Yes	***Voice Recognition:*** Networking SAMI Testbed: GLQ
Mohan Trivedi	Co-Principal Investigator	Yes	***Image Processing:*** Networking SAMI Testbed: GLQ

1.1.2 Other RESCUE Senior Personnel

Additional people (excluding UCSD – see Section 1.1.3) who contributed to project and received a salary, wage, stipend or other support from this grant.

Brigham Young University

Name	***Role(s) on Project***	***>160 hrs***	***Work on Project***
Robert Bradshaw	Undergraduate Student	No	***Trust Management:*** PISA
Jim Henshaw	Graduate Student	No	
Jason Holt	Graduate Student	Yes	
Travis Leithead	Graduate Student	Yes	
Kent Seamons	Senior Personnel	Yes	***Trust Management:*** PISA Testbed: Champaign
Tim van der Horst	Graduate Student	Yes	

ImageCat, Inc.

Name	***Role(s) on Project***	***>160 hrs***	***Work on Project***
Beverley Adams	Researcher	Yes	***Remote Sensing:*** Testbed: MetaSIM
Paul Amyx	Researcher	Yes	***Software Development:*** Testbed: MetaSIM
Sungbin Cho	Researcher	Yes	***Transportation Analysis:*** Testbed: MetaSIM
Howard Chung	Researcher	Yes	***Image Processing:*** Testbed: MetaSIM
Charles Huyck	MetaSIM Project Leader	Yes	***GIS Applications:*** Testbed: MetaSIM
Michael Mio	Researcher	Yes	***Software Development:*** Testbed: MetaSIM

University of Colorado, Boulder

Name	***Role(s) on Project***	***>160 hrs***	***Work on Project***
Christine Bevc	Graduate Student	Yes	***Organizational Networks:*** Dissemination Testbed: Champaign
Sophia Liu	Graduate Student	Yes	
Jeannette Sutton	Post-doctoral Researcher	Yes	
Kathleen Tierney	Senior Personnel	Yes	***Organizational Networks:*** Dissemination Privacy Testbed: Champaign

University of Illinois, Urbana-Champaign (UIUC)

Name	***Role(s) on Project***	***>160 hrs***	***Work on Project***
Mike Rosulek	Graduate Student	Yes	***Trust Management:*** PISA Testbed: Champaign
Lars Olson	Graduate Student	Yes	
Jintae Lee	Graduate Student	Yes	

University of Maryland, College Park (UMD)

Name	***Role(s) on Project***	***>160 hrs***	***Work on Project***
Peter Chang	Senior Personnel	Yes	***Bridge Sensor Development:*** Testbed: MetaSIM
Ke Liu	Graduate Student	Yes	
Bryce Lehman	Graduate Student	No	

University of California, Irvine (UCI)

Name	***Role(s) on Project***	***>160 hrs***	***Work on Project***
Mohanned Alhazzazi	Programmer	No	***Video Applications:*** Dissemination Testbed: CAMAS
Kemal Altıntaş	Graduate Student	Yes	***Spoken Language Understanding:*** SAMI
Alfred Anguino	Undergraduate Student	No	***Human-as-sensor:*** Dissemination Testbed: CAMAS
Naveen Ashish	SAMI Project Leader	Yes	***Situational Awareness:*** SAMI
Vidhya Balasubramanian	Graduate Student	Yes	***Spatial Representation and Navigation:*** Project 2: MetaSIM Testbed: CAMAS
Quent Cassen	Project Manager	Yes	Project Management
Stella Zhaoqi Chen	Graduate Student	Yes	***Data Cleaning:*** SAMI
Jean Chin	Project Support	Yes	Project Management
Jonathan Cristoforetti	Graduate Student	Yes	***Evacuation Simulation:*** MetaSIM Testbed: CAMAS
Nicolas Demaegdt	Graduate Exchange Student	No	***Networking:*** Testbed: CAMAS
Mahesh Datt	Graduate Student	Yes	***Privacy and Data Collection:*** Privacy
Chris Davison	Technology Manager CAMAS Testbed Leader	Yes	Technology Manager Testbed: CAMAS
Rina Dechter	Senior Personnel	Yes	***Probabilistic Modeling and Reasoning:*** SAMI
Mayur Deshpande	Graduate Student	Yes	***Peer-to-Peer Dissemination:*** Dissemination
Vibhav Gogate	Graduate Student	Yes	***Activity Modeling and Bayesian Inference:*** SAMI
Priya Govindarajan	Graduate Student	Yes	SAMI
Ramaswamy Hariharan	Graduate Student	Yes	***GIS Modeling:*** SAMI
Bijit Hore	Graduate Student	Yes	***Privacy and Data Collection:*** Privacy
Jon Hutchins	Graduate Student	Yes	***Data Mining/Occupancy Modeling:*** SAMI
Hojjat Jafarpour	Graduate Student	Yes	Dissemination
Ravi Jammalamadaka	Graduate Student	Yes	***Secure Data Warehousing:*** Privacy
Lorien Jasny	Graduate Student	No	***Information Dissemination:*** Dissemination
Shengyue Ji	Graduate Student	Yes	SAMI
Dmitri Kalashnikov	Post-doctoral Researcher	Yes	***Data Cleaning, Spatial***

Name	***Role(s) on Project***	***>160 hrs***	***Work on Project***
			Uncertainty: SAMI
Parin Kenia	Graduate Student	Yes	***Privacy & Data Collection:*** Privacy
Ali Khoaedi	Graduate Student	Yes	***Spatial Representation and Navigation:*** SAMI
Jihye Kim	Graduate Student	Yes	Privacy
Iosif Lazaridis	Graduate Student	Yes	***Quality Aware Querying:*** Networking
Chen Li	Senior Personnel	Yes	***Data Integration:*** Privacy
Jay Lickfett	Programmer	Yes	SAMI
Ben Lind	Graduate Student	Yes	***Data Analysis:*** Organizational Networks
Yiming Ma	Graduate Student	Yes	***Data Filtering:*** SAMI
Samuel Mandell	Undergraduate Student	No	Dissemination
Daniel Massaguer	Graduate Student	Yes	***Evacuation Simulation:*** Testbed: CAMAS
Mirko Montanari	Graduate Exchange Student/Programmer	Yes	***Crisis Alert System:*** Dissemination
Rabia Nuray	Graduate Student	Yes	***Data Cleaning:*** SAMI
Miruna Petrescu-Prahova	Graduate Student	Yes	***Data Analysis:*** Dissemination
Charlotte Petyt	Graduate Exchange Student	No	***Networking:*** Testbed: CAMAS
Anton Popov	Undergraduate Student	No	***Indoor Autonomous Mobile Sensing Platform:*** SAMI Dissemination Testbed: CAMAS
Titus Sanchez	Undergraduate Student	No	***Video Based People Counting:*** SAMI Privacy
Nitesh Saxena	Graduate Student	Yes	***Group Admission Control:*** Privacy
Dawit Seid	Graduate Student	Yes	***Graph-Based Querying Language:*** SAMI
Houtan Shirani-Mehr	Graduate Student	Yes	Privacy
Michal Shmueli-Scheuer	Graduate Student	Yes	***Data Dissemination Architecture:*** Dissemination
Padhraic Smyth	Senior Personnel	Yes	***Data Mining Techniques:*** SAMI
Claudio Soriente	Graduate Student	No	Privacy
Gene Tsudik	Senior Personnel	Yes	***Security:*** Privacy
Jinsu Wang	Graduate Student	Yes	***Distributed Data Collection:*** Networking
Jehan Wickramasuriya	Graduate Student	Yes	***Access Control and Privacy:*** Privacy
Bo Xing	Graduate Student	Yes	***Cellular Networks:***

Name	Role(s) on Project	>160 hrs	Work on Project
			Dissemination
Xingbo Yu	Graduate Student	Yes	***Distributed Data Collection:*** Networking

1.1.3 UCSD Senior Personnel

People from UCSD who contributed to the project and received a salary, wage, stipend or other support from this grant:

University of California San Diego (UCSD)

Name	Role(s) on Project	>160 hours	Work on Project
John Miller	Senior Development Engineer	Yes	***GIS Applications*** Networking; SAMI
Ganapathy Chockalingam	Principal Development Engineer	Yes	***GIS Applications, Software Development*** Dissemination Testbed: GLQ
Babak Jafarian	Senior Development Engineer	Yes	***Wireless Applications*** Networking MetaSIM Testbed: GLQ
John Zhu	Senior Development Engineer	No	***Wireless Applications*** Testbed: GLQ
BS Manoj	Post-doctoral Researcher	Yes	***Networking*** Testbed: GLQ
Sangho Park	Post-doctoral Researcher	No	***Computer Vision*** SAMI Networking Testbed: GLQ
Stephen Pasco	Senior Development Engineer	Yes	***Software Systems and Architecture*** Networking PISA Privacy Testbed: Champaign, GLQ
Helena Bristow	Project Support	Yes	***Administrative Support***
Alexandra Hubenko Baker	Project Manager	Yes	***Project Management***
Raheleh Dilmaghani	Graduate Student	Yes	***Network optimization and modeling*** Networking SAMI Testbed: GLQ
Shankar Shivappa	Graduate Student	Yes	***Speech Recognition*** SAMI Testbed: GLQ
Wenyi Zhang	Graduate Student	Yes	***Speech Recognition*** SAMI Testbed: GLQ
Vincent Rabaud	Graduate Student	Yes	***Computer Vision*** SAMI Testbed: GLQ

Name	***Role(s) on Project***	***>160 hours***	***Work on Project***
Aaron Jow	Graduate Student	Yes	***Platform Development*** Networking
Javier Rodriguez Molina	Hardware development engineer	Yes	***Software and Hardware Device and Applications*** Networking Testbed: GLQ
Stephan Steinbach	Undergraduate student	Yes	***Computer vision, mobile applications*** Networking SAMI Testbed: GLQ
Rajesh Hegde	Postdoctoral Researcher	Yes	***Speech Recognition*** Networking SAMI Testbed: GLQ
Rajesh Mishra	Senior Development Engineer	Yes	***Networking*** Testbed: GLQ
Brian Braunstein	Software Development Engineer	No	***Networking*** Testbed: GLQ
Ping Zhou	Graduate Student	No	***Networking***

1.2 ORGANIZATIONS THAT HAVE BEEN INVOLVED AS PARTNERS

Government Partners:

- **California Governors Office of Emergency Services:** *Kevin Miller – GIS Analyst, Paul Veisze – GIS Manager, and Rebecca Wagnor – Manager Technical, Assistance Branch.* Beta testing and providing feedback on InLET**;** *Jim Goltz –OES Earthquake and Tsunami program.* Primary contact for rapid seismic alert system.
- **City of Champaign:** *Steve Carter – City Manager, Fred Halenar – Director of Information Technology.* Carter has been the impetus for the City of Champaign being involved with RESCUE. Halenar is the main contact with the city for RESCUE testbed activities. He attended our most recent RESCUE All Hands Meeting in San Diego and is now serving on our Community Advisory Board. Halenar has been instrumental in expediting the flow of resources to RESCUE from the city, and to the city from RESCUE (e.g., his group is currently experimenting with 4 RESCUE-produced CalMesh nodes).
- **Champaign Fire Department:** *Steve Clarkson – Deputy Chief (and EOC head), Brad Bone – Lieutenant, John Barker – Captain, Dena Schumacher – Public Information Officer (and EOC Public Information Officer).* Our contacts in the Champaign Fire Department helped us procure two years of 911 call database entries for RESCUE and 50 audios of the fire department responding to incidents over the past few years (7 GB of data). They identified key stakeholders for Marianne Winslett to interview, granting us valuable insights into first responder organizations. They also worked closely with Winslett to develop the derailment scenario resulting in a chemical spill.
- **Federal Emergency Management Agency:** *Doug Bauch – Mitigation Specialist.* Beta testing and providing feedback on InLET.
- **Federal Highway Administration:** *Ke Liu.* Peter Chang is working with Liu on a strategic emergency evacuation traffic simulation.

- **City of Los Angeles:** *Ellis Stanley, General Manager, Emergency Preparedness Department.* Providing feedback on InLET and Chair of the Community Advisory Board (CAB).
- **City of Ontario Fire Department (OFD):** *Jacob Green.* The City of Ontario Fire Department (OFD) is one of RESCUE's Community Advisory Board (CAB) members. The OFD has very actively championed one of the SAMI (Situational Awareness from Multimodal Inputs) artifacts, namely the Ontario Emergency Information Portal (OEIP). To date, SAMI members (the project leader and staff members) have had several meetings (including some onsite at the OFD), mainly on the development of the OEIP. A prototype OEIP is in place with discussions now focused on pilot testing and evaluation. The OFD, particularly their analyst (Jacob Green) and members of their IT department have provided valuable input and guidance on capabilities for an emergency information portal and have also provided data and databases for the assembly of the portal.
- **San Diego Police Department (SDPD):** *Bill Maheu – Chief, Sergeant Phil Terhaar – SDPD Critical Incident Management Unit (CIMU), Officer Lance Dormann – SDPD Critical Incident Management Unit (CIMU), Officer John Graham.* The San Diego Police Department has been an active collaborator in field trials that are being conducted for the Networking Project. They have also been GLQ testbed participants. The RESCUE networking group collaborated with the San Diego police by setting up audio and visual sensors, and a wireless network infrastructure during the February 28, 2006 Mardi Gras festival in downtown San Diego.
- **Orange County Fire Authority (OCFA):** *Rich Toro.* Toro is a member of RESCUE Community Advisory Board. SAMI investigators and staff have had three visits and meetings with OCFA to identify areas of collaboration. To date, the OCFA has provided SAMI with a dataset of an audio collection of recorded 911 calls to OCFA, which SAMI researchers are using to work on event extraction and situational understanding from conversations.
- **U.S. Geological Survey:** *David Wald and Paul Earle – Seismologists.* Integration of ShakeCast into InLET; testing and providing feedback on InLET

Community Partners:

- **UCI Environmental Health and Safety,** *Linda Bogue, Emergency Management Coordinator; and EH&S first responder team.* Bogue and the EH&S team have been working with UCI researchers to incorporate simulations into actual drills, and have assisted in the design and execution of drills as well as providing input for technology development in CAMAS testbed. They have also been instrumental in allowing us to participate in drill activities, providing information on community events, helping to "reality test" project ideas, verify technologies, and provide important feedback on technologies' ease of use and applicability in real situations.
- **UCSD Environmental Health and Safety:** *Phillip Van Saun – Manager, UCSD Emergency Services; Tod Ferguson – HazMat Business Plan Manager.* Van Saun and Ferguson are UCSD's main contacts for emergency management drills, campus drill activities, and technology feedback.
- **UCSD Police:** *Dave Rose - Lieutenant.* Lieutenant Rose is a CAB member, as well as an active collaborator in UCSD campus drills and technology trials, including the UCSD campus drill in November 2005, and Mardi Gras in downtown San Diego in February 2006.

- **Champaign Unit 4 Schools:** *Ecomet Burley – Deputy Superintendent.* Marianne Winslett's interviews with Dena Schumacher (Champaign Fire Department) and Burley exposed the two weakest points in the city's and schools' response plan to the derailment scenario.
- **PISA Project Collaborators:** Five people from the nearby Red Cross chapters, one from ham radio, three from the local ambulance companies, one from METCAD (911), one from MTD (the Champaign bus system), two from the police department, plus the city's directors of transportation, finance, neighborhood services (shelters). Each of these people has been extremely helpful in participating in the interviews and in helping to pull the scenario together.
- **UCI Calit2 Administration and Building Facilities:** Supporting the instrumentation of the Calit2 building and providing a pervasive application environment for testing and validation of research. Also part of the CAMAS testbed.

Academic Partners:

- **CalState Monterey**: *Miguel Tirado,* collaborator on inter-organizational communication and technology issues related to the Hurricane Katrina response. Tirado has provided RESCUE researchers with unique field data collected immediately following the event.
- **MCEER, NSF-sponsored earthquake engineering research center:** Integration of existing advanced technology toolsets.
- **University of British Columbia:** *Stephanie Chang - Associate Professor***.** Use of InLET in classroom environment as instructional tool.
- **UCI Center for Unconventional Security Affairs:** *Paul Dourish, Richard Matthews;* collaborators on privacy-related topics.
- **UCI NACS, Technologists.** Aided in the overall design and integration of the CAMAS testbed within the larger academic computing infrastructure.
- **UCI Information and Computer Science:** *Stas Jarecki and Michael Goodrich;* collaborators on privacy-related topics.
- **UCI TeamXAR, Undergraduate Student Collaborators**. Designed an autonomous guided vehicle as a mobile sensing platform as well as a small (RC vehicle) version for the same purpose; to be deployed in CAMAS testbed
- **University of Maryland:** *David Lovell*. Peter Chang is working with Lovell on a strategic emergency evacuation traffic simulation.
- **University of Southern California/ISI:** *Clifford Neuman and Tatyana Ryutov.* Kent Seamons is cooperating with Neuman and Ryutov to allow trust negotiation facilities to be used with GAA-API. The combination produces a flexible, adaptable framework to rapidly changing conditions.
- **University of Naples:** *Piero Bonatti.* Marianne Winslett is working with Bonatti on the theoretical underpinnings of the security infrastructure of PISA, and will spend next year visiting him in Naples.
- **San Diego State University Visualization Laboratory:** *John Graham, Steve Birch, Eric Frost***.** Collaborators in Gaslamp Quarter (GLQ) Testbed Mardi Gras deployment – assisted with camera placement, VPN, and networking concerns.
- **UCSD Supercomputer Center/Calit2 UCSD Division:** *Erin Kennally.* Collaborator on privacy-related topics

- **Wireless Internet Information System for Medical Emergency Response in Disasters (WIISARD):** *Les Lenert, MD – Principal Investigator.* WIISARD is a project at UCSD sponsored by National Library of Medicine/National Institutes of Health for developing medical emergency response applications. Prof. Ramesh Rao, PI of the UCSD Division of RESCUE also co-directs the WIISARD project. RESCUE's interaction with WIISARD results in a valuable field partner for evaluating the Robust Networking products. RESCUE's CalMesh ad-hoc mesh networking system provides the backbone on which WIISARD's devices operate. The RESCUE networking group along with WIISARD project participants participated in the full scale home land security drill conducted by the San Diego county in November 2005, and will participate in a UCSD /San Diego Metropolitan Medical Strike Team (MMST) drill in the Calit2 building on UCSD's campus in August 2006.
- **WHYNET:** *Principal Investigators: Rajive Bagrodia, Babak Daneshrad, Michael Fitz, Mario Gerla, Mani B Srivastava).* WHYNET is an NSF-funded Wireless Hybrid Network testbed to facilitate detailed study of cross-layer interactions in mobile communication technologies all the way from the application layer to physical devices interactions and their impact on application level performance in heterogeneous wireless systems. The Robust Networking and Information Collection project is collaborating with them on cellular network research and modeling.

Industry Partners:

- **Convera Inc.:** We are initiating collaboration with Convera Inc., a Carlsbad-based company which is a leading provider of knowledge management and semantic search solutions. In the coming months, we will be actively collaborating on the development of a national-scale disaster portal that will provide useful online information in events such as hurricane or other disaster. Specifically, Convera will be providing SAMI and RESCUE industry strength tools for assembling a national scale disaster portal application. This effort also involves ImageCat Inc., which will provide its expertise in the disaster management information analysis area to guide the design of such a disaster portal application.
- **DigitalGlobe:** *Brett Thomassie, Director, Civil Government Programs.* DigitalGlobe has provided satellite imagery for several recent natural hazard events, including the 2003 Bam, Iran earthquake, Hurricane Charley in 2004, 2004 Indian Ocean earthquake and tsunami, and the 2004 hurricanes, including Hurricane Katrina.
- **Gaslamp Quarter Association:** *Jimmy Parker – Executive Director, Dan Flores – Senior Marketing Manager.* GLQ testbed partners.
- **Gatekeeper Systems:** *(Developers of ShakeCast) Philip A. Naecker, Programmer.* Significant dedication of resources integrating USGS real-time ground motions into InLET.
- **IBM:** *Hakan Hacigumus – IBM Almaden, Bala Iyer – IBM Santa Teresa Labs.* Worked on joint publications on a novel data sharing architecture based on remote hosting.
- **Mushroom Networks:** *Cahit Akin, Mustafa Arisolyu.* Mushroom Networks is a Calit2 UCSD Division startup and they collaborate with the UCSD Networking group on many activities, including GLQ testbed and field trials.
- **SkyRiver Communications:** *Ron D'Alleva, Paul Miller, Mike Williams.* Skyriver Communications is a wireless service provider that supports the GLQ testbed with bandwidth connectivity in downtown San Diego.

- **The School Broadcasting Company:** *Evan Arguelles and Jeff Briggs.* Working with RESCUE on information dissemination to schools.
- **Qualcomm**: Invited member of Industry Affiliates Group; collaborators on Location Based tracking on the cellular platform project.

1.3 OTHER COLLABORATORS AND CONTACTS

- **Caltrans:** Ganz Chockalingam of UCSD and Ron Eguchi of ImageCat are collaborating with Caltrans in their research.
- **CAMAS Industrial Testbed Partners:** Canon (Visualization equipment, SDK), The School Broadcasting Company (School based dissemination), Ether2 (Next-generation Ethernet), Boeing (Testbed research partners, Apani Networks (Data security at layer 2), 5G Wireless (Broad-range IEEE 802.11 networking), IBM (Smart Surveillance Software and 22 e330 xSeries servers), AMD (Compute servers), Microsoft (Software), ImageCat, Inc., (GIS technologies and loss estimation for emergency response), Printronix (RFID technology), and Walker Wireless (People-counting technology).
- **GLQ Testbed Partners:** The following owners/managers from Gaslamp Quarter locations and businesses provided access to their facilities to enable us to deploy a camera mesh network for Mardi Gras 2006 (in collaboration with San Diego Police): Old City Hall Building, Ostera Fish House, Martini Ranch, Buca del Beppo, Aubergine, Dustin Arms, Dussini and USA Hostels 726 5th Ave.
- **KPBS Radio:** There is a link to http://traffic.calit2.net on the San Diego local public broadcasting station's website.
- **Lab9 Software:** Provided the UCSD speech recognition group with a beta version of their large vocabulary speech software developer kit (SDK) for an HP iPAQ device (an NDA was signed with them in May 2006). This SDK will enable the team to test speech recognition algorithms on mobile devices.
- **Lumen Vox:** A San Diego-based company working with the UCSD Speech recognition group. An NDA was signed in March 2006.
- **National ICT Australia (NICTA):** A Center of Excellence in the area of information and communication technology formed by the Federal Government's Department of Communications, Information Technology and the Arts and the Australian Research Council. NICTA's consortium partners are the Australian Capital Territory Government, the New South Wales Government, the University of New South Wales, and the Australian National University. NICTA's research thrusts are in the area of situational awareness and trusted networks which complement nicely research being conducted in the RESCUE project. The RESCUE team has had significant interactions with Chris Scott who heads the Brisbane labs of NICTA (that focuses on homeland security motivated IT challenges) and plans are underway to form a international consortium of researchers in this area.
- **SDSU Homeland Security Master's Program:** *Bob Welty* – Collaborator on GLQ testbed Mardi Gras activity.
- **Voxeo:** Provides an interactive voice recognition platform for the San Diego Traffic report, and the peer-to-peer based traffic/incident reporting system which will be piloted in summer 2006.

1.4 RESCUE PROJECT MANAGEMENT

The RESCUE project has been re-organized in order to focus research activities towards fewer but higher impact efforts, and to achieve more robust interactions with emergency response organizations and industry. Part of the re-organization strategy has been to create two new internal RESCUE committees that will ensure stronger connections with the scientific and end-user communities: Technology and Artifacts Steering Committee, and External Interactions Steering Committee. In addition to these two new internal project committees, the Executive Committee of RESCUE has formed a second oversight committee – the Technical Advisory Committee (TAC) – to help guide and validate the efficacy of our research. The TAC will work along side with the Community Advisory Board (CAB) to ensure that measurable progress is made towards the objectives identified at the beginning of this strategic plan. Figure 1 shows the current members of both oversight committees. The role of major each major committee and oversight group is described below:

- **Executive Committee:** 1) Review annual research plan to ensure progress towards project goals; 2) set policy that guides the development of system artifacts and maximizes collaborative research; and 3) work with oversight committees to identify opportunities for groundbreaking scientific research and to secure meaningful end-user collaboration.
- **External Interactions Steering Committee:** 1) Serve as primary link to first-responder community; 2) track other synergistic research activities that help to facilitate interactions with the first-responder community; and 3) monitor testbed development and progress to ensure that they adequately engage researchers as well as government partners.
- **Technology and Artifacts Steering Committee:** 1) Identify cross-disciplinary research opportunities that can lead to 'big science'; 2) guide the development of RESCUE artifacts; and 3) working with the External Interactions Steering Committee, identify opportunities to test and validate technologies.
- **Technical Advisory Committee**: 1) Contribute to the development of a RESCUE strategic plan for the remaining three years of the project; 2) provide feedback on annual RESCUE research plans; 3) on an as needed basis, provide advice and guidance on specific technical issues as they relate to the RESCUE project in general or to specific research projects, 4) help identify gaps in research approach and unique new opportunities, 5) make recommendations on program adjustments, and 6) serve as emissaries of RESCUE to a broader scientific community.
- **Community Advisory Board:** 1) Provide feedback on ongoing research; 2) help set research priorities from the standpoint of first-responder needs; and 3) facilitate joint projects and/or internships with government partners and organizations.
- **Research Project Leaders:** 1) Develop annual research plan for their respective projects; 2) work with individual researchers to develop detailed task plans; and 3) monitor the progress of each task to ensure that they contribute to project goals and objectives.

Technical Advisory Committee

Rakesh Agrawal
Microsoft Fellow

Louise Comfort
Professor of Public and Urban Affairs
University of Pittsburgh

Mario Gerla
Professor of Computer Science
University of California, Los Angeles

Fred Juang
Motorola Foundation Chair
Georgia Research Alliance Eminent Scholar
Georgia Institute of Technology

David Kehrlein
Environmental Science Research Institute (ESRI)

Dick Kieburtz
Professor Emeritus
OHSU/OGI School of Science and Engineering
Pacific Software Research Center

Raghu Ramakrishnan
Professor of Computer Sciences
University of Wisconsin-Madison

Community Advisory Board

City of Champaign
Fred Halenar

City of Irvine
Dawna Finley
Eileen Salmon

City of Los Angeles
Ellis Stanley

City of Ontario
Jacob Green

City of San Diego Police Department
Karen Butler
William Maheu

Governor's Office of Emergency Services
James Watkins (retired)

Los Angeles County Office of Emergency Management
Bob Garrott

Orange County Fire Authority
Rich Toro

SPAWAR
Paulette Murphy

UCI Environmental Health and Safety
Marc Gomez

UCSD Campus Police
David Rose

Figure 1. RESCUE's Technical Advisory Committee (TAC) and Community Advisory Board (CAB)

Figure 2 shows the new management structure after reorganization. Listed in Figure 2 are the various oversight and management committees, and the five new projects (Situational Awareness from Multimodal Inputs (SAMI), Robust Networking and Information Collection, Policy-Driven Information Sharing Architecture (PISA), Customized Dissemination in the Large, and Privacy Implications of Technology). The research leaders for each project are also listed in Figure 2.

For purposes of explaining the project organization changes made after input was received from NSF, the new elements of the project management chart are highlighted in yellow. RESCUE plans on selecting the chair of the Technical Advisory Committee by mid-summer.

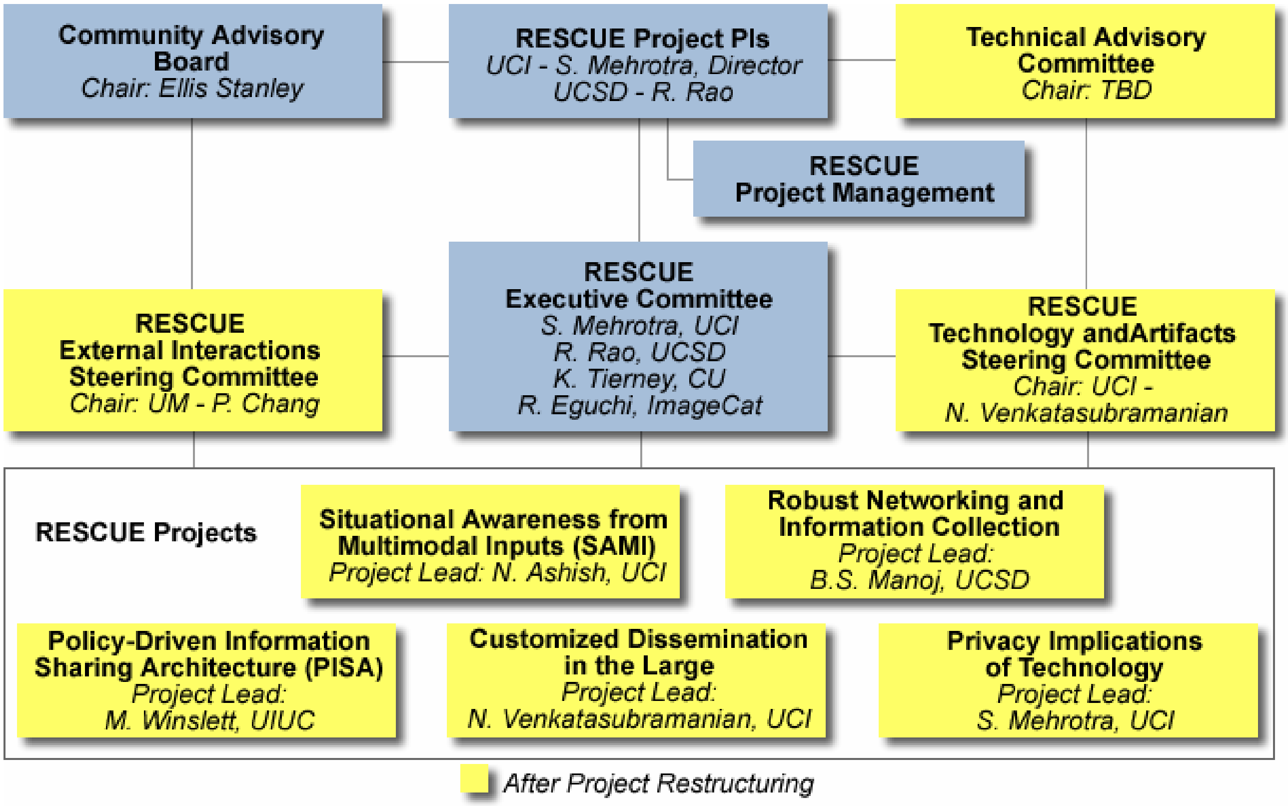

Figure 2. New RESCUE Project Management Organization

To maximize the project's potential for achieving 'big science,' the Technology and Artifacts Steering Committee is working directly with the Technical Advisory Committee. The first meeting between TAC and RESCUE's project leaders took place at our annual meeting in January 2006. Here, each project's strategic plan and progress was presented and reviewed. In addition to valuable feedback on the specific projects, on TAC's suggestion, the simulation and testing efforts were consolidated into MetaSim.

The External Interactions Steering Committee met with the Community Advisory Board in January 2006 to ensure that end-user needs and priorities are considered in the development the annual research plan. To date, CAB members have been working with the individual projects on their research efforts: the Dissemination project has been working with our CAB members from UCI EH&S and California OES; Networking with UCSD Police, San Diego Police, and City of Champaign; SAMI with the City of Ontario and UCI EH&S; PISA with the City of Champaign; and Privacy with UCI EH&S.

Figure 3 shows a schedule of key milestones for the RESCUE project. These milestones are divided into two major categories: management and technical. The management milestones describe key actions or activities leading to the development of a Year 3-5 strategic plan, and subsequent partnerships with government and industry organizations. The culmination of the RESCUE project will highlighted by a government and industry conference where RESCUE artifacts will be showcased to a broader audience and where strategic partnerships with government and industry will be unveiled. The technical milestones involve the development of testbeds and artifacts, and programs to validate artifact development.

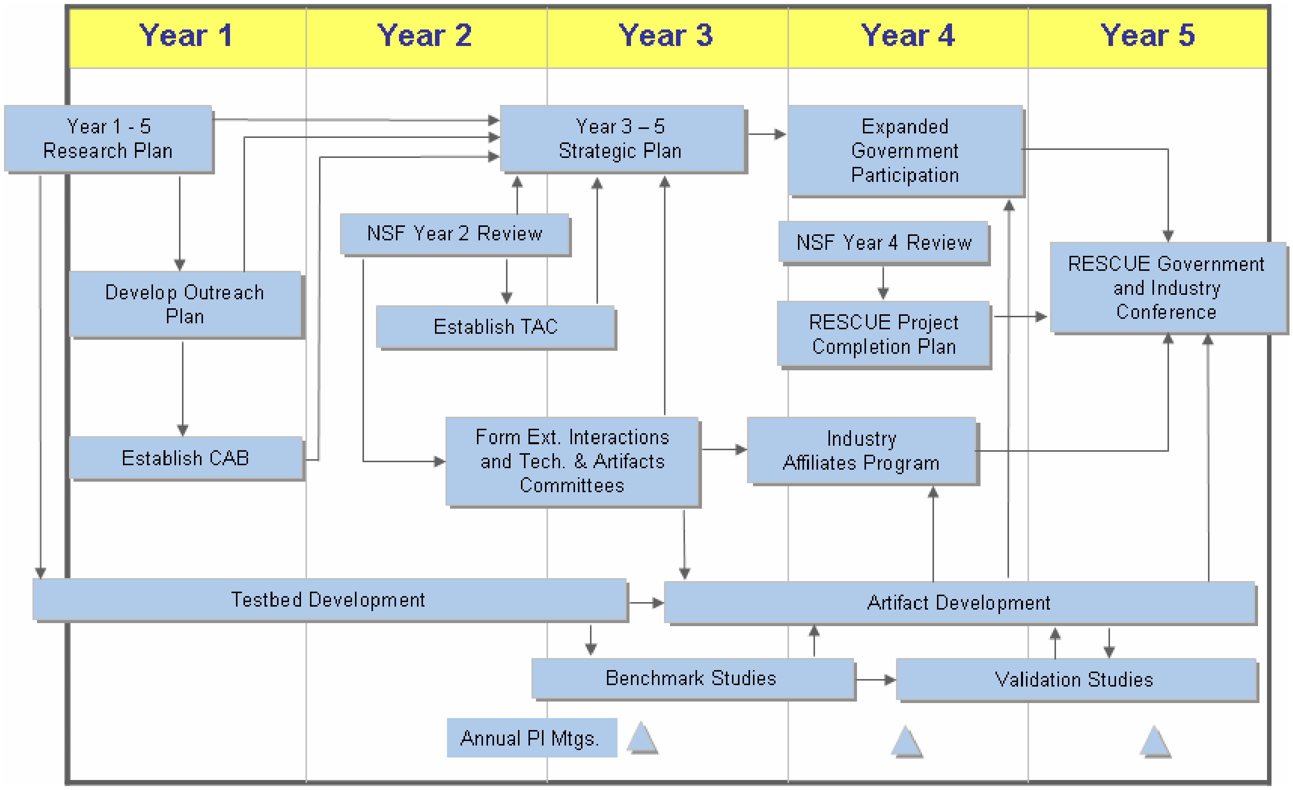

Figure 3. Key Management and Technical Milestones for the RESCUE Project

2. ACTIVITIES AND FINDINGS

The mission of RESCUE is to enhance the ability of emergency response organizations and the public to mitigate crises, save lives, and contain secondary and indirect human and economic loss. RESCUE is carrying out this mission by radically transforming the ways in which these organizations gather, process, manage, use and disseminate information during man-made and natural catastrophes.

The RESCUE project is built around three major components: integrative research projects, artifacts, and integrative testbeds. The *integrative research* program allows RESCUE to leverage the project's resources to explore and develop holistic solutions to complex, crisis response issues. By implementing a multi-disciplinary approach to solving these problems, the RESCUE project is able to address the socio-political and organizational contexts in which critical decisions are made during a crisis. Multi-disciplinary collaboration also makes it possible for RESCUE to address other challenges, such as those associated with public warnings during crisis conditions. Holistic solutions to crisis response challenges are needed if the project is to have a broad impact on current practices in emergency response. In order to ensure broader impacts, RESCUE has committed significant resources to the development of project *artifacts*. These artifacts are in many cases the result of multi-investigator collaborations. Within the vision of RESCUE, these products constitute the legacy of the RESCUE after the project ends. Finally, to validate the efficacy of our research, we have developed a set of large-scale *testbeds* that will test and evaluate our research findings in different crisis response settings. We are able to simulate disasters within the context of large regional events, e.g., an earthquake, as well as localized disasters that may occur as a result of a terrorist attack.

Together, these three components form the basis for achieving groundbreaking research, developing validated solutions to complex crisis response issues, and providing for a legacy that lives beyond the five-year life of RESCUE. Below we discuss progress in Year 3 along each of the major components of RESCUE.

2.1 MAJOR RESEARCH AND EDUCATIONAL ACTIVITIES, INCLUDING MAJOR FINDINGS

2.1.1 Integrative Research Projects

Five major multidisciplinary research projects have been established that together enable the RESCUE team to pursue focused research that supports our mission of *dramatically improving the ability of emergency response organizations to gather, process, manage, use and disseminate information during man-made and natural catastroph*es. The five projects are: Situational Awareness from Multimodal Inputs (SAMI); Robust Networking and Information Collection; Policy-Driven Information Sharing Architecture (PISA); Dissemination in the Large; and Privacy Implications in Technology. These projects are a new element of the RESCUE program; created to address NSF's recommendation to focus RESCUE on a few large innovations. Our objective in these projects is to explore novel interdisciplinary research ideas that have the possibility of "high impact" – approaches that are usually difficult to follow when PIs work in isolation along narrowly defined disciplinary boundaries. The specific objectives, grand challenges, broader impact opportunities, and expected results, as well as concrete tasks and timelines for each of these projects can be found in the RESCUE strategic plan submitted to NSF. We next report progress, activities, and findings over the past year in each of the projects.

2.1.1.1 Project 1: Situational Awareness from Multimodal Inputs (SAMI)

Goals:

Our objective in SAMI is to design and develop technologies that can create actionable situational awareness from the avalanche of heterogeneous multi-modal data streams (audio, speech, text, video, etc.) including human-generated input (e.g., first responders' communications, field reports, etc.) during or after a disaster. Such technologies are of profound importance to first responders since response activities that occur as the disaster unfolds are decision-centric and decisions in our view depend directly on the situational awareness available. Awareness of the situation (past, present, and predicted future) which constitutes information about people (their vulnerabilities, location, demographics), resources (food, water, shelter) and progression of the event and activities (plume spread, storm track, evacuation progress) as well as implications of actions or inactions are amongst the most important factors that influence the quality of such decisions and hence efficacy of the response. From a technology perspective, we see limitations in two major areas for situational awareness, namely information and data management technology and in signal analysis, interpretation, and synthesis; we aim to significantly advance these technologies in SAMI. Our approach is based on the notion of *events* as fundamental building blocks in situation awareness applications. Our research and development efforts in SAMI will cover 3 areas - situational information management, signal analysis and synthesis of situational information, and also an analysis environment for SA applications. The grand challenge in this project is to develop general-purpose tools/technologies/methodologies for building situational awareness applications across a wide variety of domains. Today, such applications are built in-house using a variety of data and knowledge management technologies and signal analysis techniques integrated in an ad-hoc way. In SAMI, we are undertaking an event-oriented approach to building situational awareness. Such an approach has several advantages: events provide a natural way to abstract situational information from lower-level signal data; it supports a clean separation between media-level and application level (semantic) events; it enables incorporation of semantics and context when analyzing multimodal data and reasoning about situations; and it provides a generalized abstraction for situation representation that can be used to build data management technology for situational awareness applications. Our research will explore how events can be used as a fundamental abstraction for each of these component systems.

Deliverables and Milestones:
From a technology perspective, we had identified 3 principal components for a comprehensive *situational information management system* that prototypes the above mentioned situational awareness capabilities. These components, as stated in our strategic plan, are 1) A situational data management system for managing situational information 2) A component for signal interpretation, analysis and synthesis, and 3) Analyst tools over the integrated information.

The deliverables and milestones for Year 3 in these areas, as stated in the strategic plan are the following:

Signal Interpretation, Analysis, and Synthesis
1. Robust speech recognition
2. Video-based event detection
3. Event extraction and synthesis from text
4. Semantic extraction for quality improvement
5. Exploiting multi-modal information in extraction

Situational Data Management
1. Situational data modeling and representation
2. Situational data querying

Analyst Tools
1. Graph analysis
2. GIS querying and visualization
3. Information reliability
4. People awareness and predictive modeling
5. Emotion detection

Activities and Findings:

Signal Interpretation, Analysis, and Synthesis
Situational information is crisis response resides in a variety of modalities. Our work in this area focuses on developing robust technologies for extraction of information from all modalities and exploiting multimodality and contextual knowledge for the extraction of situational information. We are developing approaches for both extraction of information from independent single modality streams as well as extraction of information from multi-modal information streams about a situation.

Robust Speech Recognition

Multi Microphone Speech Processing: Research in this area is focused on developing robust speech processing and recognition techniques, particularly in noisy conditions. Multi microphone techniques provide an efficient framework for canceling out ambient stationary (car, aircraft noise) and non stationary interference (door slams, sirens) coming from different directions and mixing eventually with the speech signal of interest. Beamforming algorithms detect the direction of arrival of the speech signal of interest and cancel out the undesired interference coming from other directions which in turn improves speech recognition performance significantly in noisy conditions.The major findings and contributions include development of a robust broadband adaptive beamforming algorithm. Inherently beamforming algorithms assume the look direction of the desired speech signal to be perfectly known but in practice there is some uncertainty. We have developed a robust broadband adaptive beamforming algorithm, which combines the robustness of the delay and sum (DS) beamforming in the look direction uncertainty with the high interference rejection capability of the conventional adaptive beamforming algorithm. In addition, we have developed a corresponding robust narrowband adaptive beamforming algorithm to address computational complexity issues. The proposed robust broadband adaptive beamforming algorithm is robust to the spatially spread source. Other activities have included design of a handheld two-microphone array system; real data from this system has been recorded in the command center at an earthquake drill and also in the RESCUE command center in the GLQ Mardi Gras drill. Finally, we have studied the approach in the context of the real world recorded Multi-channel Overlapping Numbers Corpus (MONC).

Single Channel Auditory Stream Segregation, Speech Enhancement, and Robust Speech Recognition: Major findings and contributions to date include a scheme for detecting undesired stationary, non stationary events, multiple speakers has been formulated using single channel speech data, as single channel speech stream segregation and speaker separation is important in significantly improving speech recognition performance in noisy conditions. Sinusoidal modeling is conventionally used in speech modeling and coding of a single speech source. This technique models harmonics of the speech source as 3 components: amplitudes, phases and frequencies. This technique has been used to model and separate speech and non speech (noise) sources as well as multiple speech sources (speakers). Sinusoidal plus residual modeling and auditory grouping has been used to separate multiple speech sources with well separated pitch. Constrained iterative sinusoidal analysis and synthesis of noisy speech has been formulated using residual interpolation and robust pitch tracking for single channel speech enhancement.

Video-based event detection for enhanced situational awareness

Our work is centered around “homography", which in computer vision denotes a linear projective transformation that relates two different views of a scene. Representation of objects in the "homography domain" referes to this warped representation of the given object. Usually, the three-dimensional objects violate the constraints of planar points and are warped by the homography transformation. This warped representation of objects can provide very useful information when multiple homography representations are combined together. Combining multiple homography relations from multiple cameras significantly enhances robustness in image segmentation. Our work is a novel approach to track people and vehicles in crowded scenes using multiple cameras. Camera calibration is not needed in our approach to extract the world coordinates of objects. Our study shows that object representation and tracking in the homography domain, independent of detailed appearances of the objects, are efficient and robust way of handling visual events. Semantic understanding of visual events is achieved by spatio-temporal analysis of the objects in the multiple homography representations.

Event extraction and synthesis from text

Our work in event extraction from text is driven by the end applications of triaging and analysis of the extracted event information. We are interested in the extraction of 'events' from situational text data from both corpuses of documents (such as a collection of new stories) as well as real-time event extraction from transcribed audio streams. We have developed architecture for an end-to-end event extraction system driven by predicate logic based extraction rules. The architecture includes the definition of individual components and their interaction, and the detailed specification of the rule language for performing the extraction. One of the unique advantages of this architecture is that the extraction rules can capture and exploit text and sentential features of various types including data or knowledge based features, features obtained from linguistic analysis, and statistical features. We have initiated an implementation of an end-to-end event extraction system based on this architecture. We are building this system by utilizing off-the-shelf components such as text classifiers, machine learning toolkits and rule based inferencing systems and also open source text extraction platforms such as GATE.

Semantic Extraction for Quality Improvement

Text extraction systems today have limitations in terms of the quality of the data that they can extract from text. For instance extractors may not be able to recognize when two instances of an extracted item actually refer to the same entity. Extractors are also not able to infer the values of certain fields to be extracted if the values are not explicitly mentioned in the text. Our work on semantic extraction aims at improving the quality of such extraction by developing techniques to address problems such as object disambiguation or extracted value inference as mentioned above. We start with the entity disambiguation problem. There are two types of disambiguation problems, studied most frequently in the literature: fuzzy lookup and fuzzy grouping. We have developed a *domain-independent* solution for both of these problems which are composed of new algorithms and methodologies that are based on a new paradigm that we have proposed. They improve disambiguation quality by taking into account the relational nature of many datasets and analyzing connections of entities via relationships. For fuzzy lookup, we have developed a comprehensive and principled solution, which converts the problem into solving an optimization OR problem (nonlinear programming). We recently have proposed initial algorithms for making the lookup approach self-tunable to the dataset being processed. During the last year, we also have made several important adjustments to the base algorithms employed by the lookup solution; in particular, we have reworked some of the objective functions used by the NLP optimization problem. For fuzzy grouping, we have developed two new clustering algorithms, which take into account the information about entity and relationships. One is based on agglomerative clustering and the other one is based on correlation clustering. A method for calibrating the approach to datasets being analyzed has been proposed. The other problem we are working is that of Web page disambiguation where our goal is, given a set of Web pages (from a standard search engine in response to a keyword search for a person name) to cluster and disambiguate the Web pages according to the actual (real-world) entities (i.e., persons) that they represent. Our framework is capable of analyzing word distributions over webpages, weblinks and emails. It also extracts locations, organizations, and people names and constructs a graph out of this information, which the framework is capable of analyzing. We have also devised an initial solution for incorporate *ontologies* in our framework, as well as started initial research on proper *modeling* of web-pages, which will allow us to associate the right references with the right entities and relationships. The initial findings are quite encouraging. Several of our algorithms have been redesigned to work with the problem of Web Disambiguation; in particular we have developed a new algorithm that is based on correlation clustering.

Exploitation of multi-modality and semantics for extraction and synthesis
In this area we have successfully designed and implemented a simple system that detects fundamental events from audio-video data in a meeting room. Our emphasis has been on the real-time operation of the system (synchronizing capture and processing of audio and video data). Participation in drills and real life events has played a major part in broadening our research. Our participation in the Mardi Gras event in Downtown San Diego (March 2006) is one example where RESCUE was able to collect audio and video information from the RESCUE command center for extraction and synthesis. These drills and events also enable us to study system deployment issues to capture synchronized audio and video data

Situational Data Management
Our goal in this area is to develop database technologies to represent, store, and manage situational data and to be able to support analyses and applications. Today situational awareness applications are built in an ad-hoc and hard coded fashion; our aim is to provide a general purpose data management system with an even centric model and representation that facilitates building such applications. The system will represent activities – their spatial and temporal properties, entities associated with the activities, and events that constitute the activities, and support languages/mechanisms/tools to query and analyze such situational data to facilitate building situational awareness applications

Situational data modeling and representation
Event Model: We have developed E, a multimedia event model. E is generic and offers expressive primitives for capturing the basic aspects of event description for any kind of event from any source and at any level of abstraction. These include freely definable event types, properties, tags, and n-ary relationships between events. E permits one to capture uncertainty at the level of events as well as at the level of individual event properties. E allows events to refer to all documenting media and sensor data available on them, thereby providing a unified index onto media and sensor data. As a first application, E has been successfully applied for the representation and analysis of outdoor reconnaissance patrol events gathered from wearable sensors and cameras. We have also implemented the EDB event store for storing events based on E. EDB provides basic event storage and navigational event access services on top of a relational database management system via a web service API. We are still in the process of defining an event ontology language and developing event retrieval algebra.

Multimedia Event Stream Processing System: We have implemented CAMAS VM, a distributed sensor data processing and transformation infrastructure. It features the concept of sensor data processing nodes. These can be installed on the machines of a network, take an arbitrary number of raw and structured sensor data streams as inputs, apply injectable sensor data transformation function code on the input streams, and deliver an output stream as a result. CAMAS VM nodes can be connected to form arbitrarily complex sensor data transformation topologies. We have defined an initial set of basic sensor data transformation function code, covering acquisition of sensor data from video cameras and people counters and the synchronization of different sensor data streams. A registry has been implemented for CAMAS VM. The registry maintains information of the CAMAS VM nodes installed, the various types of sensors available, information about the network topology, as well as the sensor data transformation code available for injection. Finally, we have defined and implemented a sensor data acquisition and transformation language (SATLite). SATLite allows developers to declaratively specify sensor data transformation topologies at an abstract level. These are processed by a query processor which in cooperation with the registry, instantiates these topologies on the nodes of the network. We have implemented a translator for translating an essential subset of CQL to SATLite. Thereby, we have proven the expressiveness of our approach.

Situational Data Querying

We have focused on the spatial aspect of events in the area of event data querying. We are working on multiple aspects of the problem including the extraction of spatial expressions and references from free text, the interpretation of spatial expressions in a probabilistic manner, and indexing mechanisms for efficient querying of the spatial references given complicated probabilistic representations. We have developed a new end-to-end situational awareness architecture that is specifically tailored towards the emergency management requirements. The framework uses human reporters (first responders, concerned citizens etc.) as sensors to gain raw information. The framework currently deals with free text inputs -- one of the major input modalities in almost all the emergency management applications. In the past one year, we have focused on the spatial reasoning and querying components that are commonly used in the applications. Reasoning or querying directly on the raw input often fails to achieve the desired retrieval quality. To attain a higher level of spatial knowledge, we have implemented a spatial information extractor based on various existing spatial Gazetteers, and represent the extracted knowledge as spatial expressions for our modeling tools. To capture the uncertainties in the spatial expressions, we have proposed a novel modeling process to convert the spatial expressions to probabilistic representations. By analyzing the emergency management query requirements, we defined formal semantics of the commonly used spatial queries given probabilistic data representations. To speed up the query response time, we have proposed a set of novel indexing structures based on a Grid indexing framework. We have extensively tested our approach on a real emergency response data set, and demonstrated the effectiveness and efficiency compared to the current state-of-art.

Analyst Tools

Our objective is to design analysis tools for situational awareness over situational data extracted and represented by technologies described in the previous two sections. The analyst tools being developed fall in two broad categories: domain-specific analysis tools (such as the people awareness and GIS tools described below) and analysis or decision support tools that can be applied across domains (such as the graph analysis and information reliability tools described below).

Graph Analysis

We have completed the design of GAL (Graph Analysis aLgebra), a semantic graph query algebra that enables to query text-extracted data about events and their relationships. Our work on GAL is motivated by the observation that semantic graphs provide a unified representation of data, domain semantics, knowledge, and context extracted from structured, semi-structured as well as free text sources. Our GAL algebra, which is implemented as a middleware between data sources and front-end applications incorporates a number of novel operators and semantics including graph grouping, graph aggregation, semantic joins, inference and multi-structural composition. We believe (and are working on demonstrations) that these features offer new possibilities of event analysis and mining applications. The preliminary performance experiments we conducted on GAL have provided positive results generally showing that the rate of growth of query runtimes is almost linear with the size of the database. Included in this design, was a development various optimization techniques for efficient execution of GAL. Since we implemented GAL by translating it to SQL, the optimization techniques are aimed at two aspects of the translation: (1) achieving the generation of efficient SQL, and (2) for the operations (like sub-graph extraction) which the relational engine evaluates using inefficient plans, we have developed better techniques for plan costing and join ordering.

GIS querying and visualization

The second thrust is on GIS data, specifically searching (hidden) GIS data on the Web. We are developing ways to more effectively collect, represent and index the, often "hidden" or deep-Web GIS datasets present on the Web, so that search for such datasets becomes more effective. Current technologies make use of high level metadata, compiled manually, for searching certain published GIS sources. However, this mechanism has the limitations of incomplete understanding of how the real GIS data looks like and what exactly or approximately it contains. Our solution to these limitations was to develop a novel GIS data integration technique that incorporates the spatial analysis of query rectangle, thereby combining the best among top ranked sources. The main intuition is that a list of top-*k* data sources for a given spatial query is not enough as each of the data sources may partially satisfy the query. Therefore, the algorithm incorporates space partitioning techniques to incrementally improve the quality of answers to spatial queries.

As part of the research process for searching GIS data, we have identified and collected publicly available GIS data sources which include around 7500 GIS layers from around 350 servers. These datasets have been cleaned, getting rid off the original schema, and incorporated into a uniform schema which contains only geography and keywords from each dataset. We are now in the process of developing a framework to represent and index terabytes of GIS data so that search can be done on such datasets.

People awareness and predictive modeling

There are two ongoing activities within this area. The first is the development and implementation of an approach to detecting (anomalous) events from sensor data. The aim is to identify abnormal or anomalous behavior patterns from time series sensor data. The approach has been implemented and evaluated in the specific domain of detecting anomalous events from traffic highway loop-sensor data. We have developed a new probabilistic framework that can learn to recognize abnormal behavioral patterns from time-series of sensor data related to human activity (e.g., people-counter sensors in buildings and loop-sensor data for freeway traffic). Our approach is based on a novel hidden Markov Poisson model that can be learned automatically from data, separating the predictable hourly/daily/weekly rhythms of human behavior from abnormal events. In addition, we have tested and validated the methodology on several months worth of (a) people-counter data from the UCI Calit2 building, and (b) loop-sensor traffic data from Los Angeles freeways. The experimental results showed that our new approach can accurately detect events that are atypical (e.g., meetings in the Calit2 building or large sporting events in the evenings or on weekends in traffic data). In systematic comparisons with a more standard baseline approach (using a thresholded Poisson statistic), our new method had average accuracies of between 90 and 100% in detecting known events compared to between 70 to 80% on average for the more traditional baseline method.

The second project in this area focuses on "people forecasting" where we are developing an approach for posterior estimation based on probabilistic network analysis. Included in this are novel parameterized importance sampling algorithms for posterior estimation in probabilistic networks having a large number of zero probabilities. Our sampling algorithms operate on a framework of mixed networks introduced in our previous work (see RESCUE publications list). We have also developed a novel approximate reasoning class of algorithms that integrate search with importance sampling. These algorithms were able to find better approximations of posterior beliefs than the state-of-the-art algorithms on many large benchmark instances.

Information reliability

We are developing techniques for representing and incorporating information reliability measures in environments where information is collected and aggregated from multiple information sources with varying degrees of reliability at both the level of the information source as well as the information report. We have identified some specific information collection and aggregation tasks, useful for analysts during a disaster and have designed an information pipeline for obtaining this information in an automated fashion through our disaster portal. The information is obtained from a variety of internet information sources as well as television sources by access to close-caption content. We are currently implementing this information pipeline and also developing information reliability measures for the information obtained through this pipeline.

There are also other possibilities in consideration for incorporation of information reliability in SAMI. One is the development and demonstration of reliability and confidence measures for *assertions* made by people in an environment such as a public information portal which also allows for posting of messages. We may evaluate this in the context of the Ontario information portal. Other possibilities, in the context of applicability to information dissemination are also being discussed.

Emotion Detection from Speech signals for Enhanced QOS in Emergency Networks: Emotion Detection from speech signals is a challenging area which looks at how the emotional state of a person (happy, sad, angry, etc.) can be detected automatically from the speech signal.

Our work on emotion detection is focused on automatically detecting the state of the speaker/caller (Distressed or Normal) from the speech signal, without manual intervention. We have developed emotion detection techniques using novel features extracted from the speech signal, and techniques for feature selection for pruning less discriminative features. Working with the networking researchers we explored how emotional content from the human speech can be used to provide Quality of Service (QoS) in a wireless mesh network. We investigated the possibility of detection of distress (distress is defined in this context as the emotion content such as fear) in human speech and developed a theoretical model for classifying the speech into either a distressed call or a normal call. Once a call is identified as a distressed call, the voice packets generated by that call are marked in order to indicate the source's distressed status. The voice packets originated by a distressed or highly-agitated caller are treated in a differentiated manner by the distributed wireless mesh network in order to provide better QoS. We developed a non-binary-based adaptive back-off mechanism to provision differentiated QoS for the voice packets generated by the distressed or highly agitated sources in comparison with the normal voice sources. The developed solution provides an average distress detection probability of 60% to 80% and an average end-to-end delay performance advantage of about 60% at very high load. With three traffic classes such as normal traffic, moderately-distressed traffic, and extremely-distressed traffic, the obtained accuracy of recognizing the emotion content in speech is about 60-75%. The emotion detection accuracy went up to 80-85% when there were only two classes for detection: i) normal traffic and ii) distressed traffic. Additional findings made by our experiments include that the use of a non-binary based adaptive back-off algorithm could provide about 60% reduction in the end-to-end delay for the calls originated by a distressed or highly agitated source. As part of the knowledge base creation, we conducted a detailed study on issues and solutions in wireless mesh networks and load balancing techniques in wireless mesh networks. The findings from these studies have developed into two separate invited textbook chapters.

Cross Project Opportunities

The CAMAS project, in itself, is highly multidisciplinary bringing together researchers from various area of computer science: computer vision, speech processing, text analysis, data management, distributed computing with researchers from social science and disaster science. While the SAMI artifacts (described in the Artifact section of this report) highlight cross disciplinary synergies more explicitly, interactions have also resulted at basic research level leading to new innovative research. The project on emotion detection in speech for QoS provisioning in wireless networks is an example of such a cross-disciplinary interaction that brings together researchers in speech analysis with networking researchers. Besides such interactions, CAMAS researchers have worked extensively with researchers in Dissemination – the GIS query and analysis techniques form the basis for implementing the customizations required in dissemination. Furthermore, the surveillance system built using the multimedia event streaming system and situational awareness technologies are the basis for the case study and privacy explorations in RESCUE (see privacy section of this report). Finally, , situational awareness technologies developed as part of SAMI are the key component of the CAMAS testbed and will be deployed in the PISA testbed.

2.1.1.2 Project 2: Robust Networking and Information Collection

Project Summary:

The Robust Networking and Information Collection project focuses on three important aspects of RESCUE. First is the robust networking infrastructure - the Extreme Networking System (ENS), - which provides computing, communication and to some extent, database resources, on site at ground zero in the event of an emergency. Given the possible environmental constraints, such as lack of electric power, partial or full unavailability of fixed communication networks, and the presence of heterogeneous communication technologies, creating an ENS is a challenging task. The second important research aspect is to make today's networks capable of surviving disasters. Devising new radio resource management and network survivability schemes for existing cellular networks is one part of this. Finally, the third important focus area is dynamic information collection in the same context as above. In order to collect multi-dimensional information, the information collection mechanisms need to be integrated with the networking elements. Once the data is collected, usually in an imprecise format, a set of intelligent and adaptive data inference schemes are employed to obtain the necessary and legible data which will be used by other projects under RESCUE. For example, cellular phones will be used as multi-dimensional sensors to collect a variety of data, such as location of users, user reports, civilian occupancy in a given area, and progress of evacuation. These focus areas are organized into three subprojects under the Robust Networking and Information Collection: a) Extreme networking system, b) Adaptive cellular networking system and, c) Adaptive information collection system. In addition, after the annual all-hands meeting in January 2006, we developed two project themes which span across all the subprojects. These are 1) theoretical research, and 2) project integration.

Challenges: The grand challenge in this project is to make today's communication networks robust enough to handle crises. Three branches of this challenge are the following: i) develop a network infrastructure form to facilitate the post disaster communication requirements by providing a quickly deployable, rapidly reconfigurable, and high performance communication network in the event of full destruction of existing communication networks, ii) devise mechanisms on today's communication networks to make the networks adaptable and reconfigurable to survive partial or full destruction, to counter the rapid and unmanageable increase in network traffic, to aid the first-responders in handling crises, and to get *a priori* information about impending crises, and iii) develop intelligent data collection mechanisms on today's networks which glean information for aiding response activities from communication networks pre, during, and post crises.

The major thrust areas are the following: i) development of a hybrid wireless networking system, ENS, for aiding the post disaster operations, ii) developing solutions to make communication networks survive and adapt to the crises situation by incorporating new research solutions, and iii) making today's network able to deliver additional information which will aid emergency management. The development of ENS has the following tasks a) architectural design for a hybrid wireless network, b) protocol design for MAC, routing, and other higher layers, c) provisioning essential network services, d) performance evaluation and deployment schemes, and e) higher-layer solutions for enhanced robustness. The addition of robustness to today's communication infrastructures such as cellular networks is carried out by a variety of methods such as developing a) new radio management schemes that can take the extremity of disaster situation into account, b) survivable network routing schemes which can help the disaster management scheme, and c) other untraditional communication methods such as interoperability of communication across heterogeneous networks. In order to make today's network to deliver additional information to mitigate and handle disasters, novel approaches are being employed in building additional hardware or software in communication equipments and networks.

Year 3 Deliverables and Milestones:

Extreme Networking System: The ENS project focuses on developing the following: hybrid network architecture, robust routing protocols for ENS system, a robust MAC layer protocol for crisis situations, design and development of management utilities for ENS, and development of essential services for ENS. In order to make these happen, we plan to focus on the following over the next 12 months:

1. A modular mesh networking system which is a software solution to enable network protocol researchers and developers to easily test their protocols on a real mesh networking deployment, such as CalMesh.
2. A path-diversity-based routing protocol and adaptive medium access control protocol for wireless mesh networks that increases the performance of wireless mesh networks during extreme situations.
3. Development of a scalable mesh network protocol using the modular mesh test-bed.
4. Implementation of the hot-swappable network protocol on the modular mesh test-bed
5. Development of essential services for ENS.
6. Development of service reliability mechanisms for ENS, service discovery protocol, and management Interface for ENS.
7. Development of a heterogeneous MAC for ENS.
8. Investigation of schemes for capacity improvement using routing, MAC, and other protocol modifications for ENS.
9. Development of application survivability solutions for ENS.

Adaptive Cellular Networking System: In the next three months, our primary objective is to investigate the capabilities of the OPNET simulation platform for research into adaptive cellular networking system. The deliverables for the next 12 months include the following:

1. Integration of OPNET with other simulators.

2. Interaction with an external database, so that the simulation results can be read iteratively by other simulation functions.
3. Accept agent location from DrillSIM iteratively.
4. Specification of all input and output file formats as well as timing for information exchange.
5. Study of different crisis situations and their influence on the cellular infrastructure.
6. Obtaining the location of cell sites (collaboration with carriers).
7. Integration of real-time measurements (TEMS) into OPNET-based cellular simulator

Adaptive Information Collection System: In accordance with the strategic plan, our main research directions are to develop a cell phone-based sensor system and cell phone-based location tracking. In order to achieve the objectives, we plan to complete the following in the next 12 months:

1. Incorporate the first version of the peer-to-peer (p2p) system into the production system available at http://traffic.calit2.net.
2. Implement other trust algorithms and validate them using the production system.
3. Development of solutions for supporting different wireless sensors such as that for video, into the cell phone-based sensor platform.
4. Integration of Bluetooth-based GPS for the cellular-based location tracking system.
5. Spam proofing of cell-phone-based traffic notification and peer-to-peer incident dissemination system by historical analysis of usage patterns.
6. Development of new validation algorithms needed to validate the incidents reported by the users for the adaptive information collection system.
7. Development of a full scale cell phone-based location tracking system.
8. Develop a full-scale adaptive information collection system based on a cellular phone based sensor system that can locate user, gather incident information, collect, organize, and disseminate to a select set of interested parties.

Activities and Findings:

Extreme Networking System. The Extreme Networking System (ENS) is critical to the information collection, management, and dissemination processes, which are essential components for creating situation awareness. Thus ENS is an enabler for the higher-layer functions that support situational awareness that are being developed as part of RESCUE. A three-level hierarchical network architecture has been developed and deployed as part of this project. The first level is formed by the user's or responder's devices which, to accommodate the needs of first responders, should be quite heterogeneous. The second level is formed by a wireless mesh network platform which can provide high reliability and fault tolerance. The third level is formed by a variety of multiple long haul backbone networks, such as cellular and satellite networks. The gateway nodes act as the bridge between the wireless mesh platform to the backbone networks. In addition to the three levels of networking modules, ENS bundles a set of application layer solutions for information collection, management and intelligent dissemination. A portable ENS node, a CalMesh node, is the major component of ENS. A CalMesh node can incorporate multiple technologies and interfaces to support the other two hierarchies in addition to performing its primary task as the wireless mesh network plane. Each CalMesh node has the capability to provide additional information such as geo-location information which helps in generating situational awareness and contextual information. The ENS also provides localized, customized information management and maintenance resources such as localized web services at ground zero. ENS has the built-in capability of providing adaptive content processing and information dissemination to the first responders and the victim population. The current version of the ENS architecture has been used and tested in several trial experiments.

The ENS architecture differs from other network architectures as it utilizes several advanced features such as Always Best Connected (ABC) paradigm, bandwidth aggregation techniques, load balancing mechanisms and localized web-based information collection, management, maintenance, and intelligent dissemination system, besides being an example of a next generation hybrid wireless network architecture. Some of the development directions are discussed below.

CalMesh: The CalMesh platform is a wireless mesh networking platform which provides a mobile, instant deployment mesh network. Every CalMesh node has been installed with a durable, portable, 12VDC (battery) or 120VAC (wall) powered nodes. No existing infrastructure is needed to deploy a wireless mesh network using a CalMesh platform. Each node is able to provide a wireless networking "bubble" to client devices that use IEEE 802.11 technology. Each CalMesh node is also capable of merging its bubble with other nodes in order to increase the physical size of the network, enabling client devices to communicate over long distances by creating a "bubble of bubbles," a multihop wireless network. The CalMesh is designed to be able to distribute existing Internet connectivity within the created bubble. In order to use the CalMesh network across a set of heterogeneous networks, the networking group also developed a VPN overlay network. This overlay network, used successfully during the Mardi Gras 2006 deployment which is described in the Gaslamp Quarter (GLQ) testbed section.

The ENS research group made several interesting findings as a result of a number of Homeland Security drills conducted as part of Rescue. Some of these observations are already published in research papers. The important findings are briefly stated here.

We developed a sophisticated fully-distributed addressing scheme for the ENS nodes. This research output resulted from our experiments with commercial wireless mesh client nodes such as Tropos Networks wireless mesh nodes in which the DHCP-based addressing scheme is centralized. During crisis situations, a centralized DHCP server is vulnerable to the following issues: i) single point failures, ii) increased delay in obtaining an address, and iii) failure of address allocation at times of extremely high contention. Contention refers to the channel access attempts by the wireless mesh nodes to transmit their packets. When the load is high or the number of nodes is high, the contention increases. Our fully distributed DHCP based addressing scheme implements a DHCP server in every ENS node that is part of the ENS system. Such a solution improves the speed of obtaining an address in addition to providing high reliability in addressing.

We also developed a dynamic address mobility management scheme for the ENS system. According to this scheme, when an ENS client node moves from the ENS access point to which it is registered to another access point, due to either mobility, failure of access points, and network partitions, the dynamic address mobility management scheme is executed. Based on this approach, the new access point, upon successful completion of the association process for the mobile ENS client node, initiates a proactive ARP-REPLY packet which contains the new MAC address to IP address resolution information. The ENS client nodes which were using the previous ARP-table entries could update its ARP table entries with new and updated information from new access point in a pro-active manner. This scheme better supports highly mobile nodes in an ENS environment.

Gateway redundancy is another significant contribution of ENS project where existing wireless mesh networking solutions utilize only one of the multiple gateways (the ENS node which has connectivity to the external wired network or the Internet). We introduced the capability to utilize multiple heterogeneous gateway nodes simultaneously in the ENS. Unlike the existing wireless mesh network technologies; these gateway nodes in ENS can utilize a variety of networks such as wired networks, wireless LANs, cellular networks, and satellite networks. Our approach to utilizing multiple gateway nodes also included a variety of novel approaches such as Always Best Connected (ABC) and Bandwidth Aggregation (BAG) in addition to load balancing.

The ENS also provided a highly enhanced bridging metric where we defined every wireless link with a specific value derived from the signal strength. This bridging metric is then used to build a spanning tree which provides a much better end-to-end throughput performance when compared to the traditional hop-length based bridging metric. We further improved the performance of our bridging metric by eliminating the rapid fluctuation of the bridging metric.

We also studied the important parameters that influence the throughput capacity of a string topology of wireless mesh networks. We used the parameters such as number of collisions, mean periodicity of transmission attempts, and the average contention window. The behavior of number of collisions followed a convex shaped pattern with maximum collision at the center of the string topology; whereas the mean periodicity of transmission attempts followed a concave pattern with minimum mean period at the center of the string. In addition, the most important observation was made on the variation of the average contention window as a function of hop length. The average contention window has been found to be varying almost linearly with a negative slope with hop length. The slope of this variation is also found to be influencing the end-to-end throughput achieved. For example, when we increased the slope of mean contention window with hop length when compared to the slope of the mean contention window variation with IEEE 802.11 DCF, we found a decrease in end-to-end throughput. Learning from this, we inverted the slope of the variation of the mean contention window to make it almost a positive slope, we obtained throughput increase. We also noted that the end-to-end throughput increased with the slope of the mean-contention window variation with hop length.

Adaptive Cellular Networking System. The main products created out of this project is a cellular simulator which can interact with other simulators for inputs such as mobility and damages to infrastructure in order to provide analytical outputs in terms of the wireless coverage and capacity for the system as a whole. This simulator is also a part of the METASIM simulator.

A prototype was developed for all four simulation modules, and serves as a test of many key issues, such as timing, file transfers, and the ability to call the various components as external modules. Detailed Investigation of Opnet capabilities is scheduled to be completed by end of June 2006. This includes different interfaces and databases that can be useful for other simulators. The investigation has already started and few of the format and interfaces have been identified. A test simulation for UMTS network has been conducted and the capabilities of Opnet have been tested.

Adaptive Information Collection System. The result of this project is the development of a fully automated peer-to-peer system that can collect and relay disaster-related information to the general public and the first responders. Though government agencies and the private sector have some of the basic data needed for effective disaster prevention and management, the means to effectively disseminate the data in an intelligent manner (i.e., delivery of relevant and timely information to the right target population) is lacking. Typically, the data is disseminated in a broadcast mode, which could create an unnecessarily chaotic or highly distressed situation. Also, in many situations, there is significant lag in the collection of crisis related data by the government agencies. This lag can be eliminated by empowering and training the general public to report relevant information.

We have used San Diego as a testbed to develop, deploy and test this system to empower the general public (in particular, the commuters) of the county to act as human sensors and relay information about incidents ranging from wild fires, mudslides and other major accidents to the general public and to the 911 control center. The system can be accessed simply by making a phone call and will be based on speech recognition. We have learned from past experience, that the general public will not adopt such a system if you inject a new phone number during the time of a disaster (such as the San Diego wild fires). The system should be available on a regular basis, disseminating information that is valuable to the public on an every day basis.

We are using the traffic notification system we developed; it has been operational for the past two years and is used by thousands of San Diego commuters every day as the basis for prototype. The system currently provides personalized real-time traffic information to the commuters via cell phones (http://traffic.calit2.net). We have modified this system so that commuters can report incidents 24x7, including the time, location, severity and the urgency of the event. We will analyze the data for validity and populate the events in a GIS database. Other commuters calling in, hear these events if they happen to fall within their previously input commute segment. Also based on the severity of the incident, we can notify all or part of the users via voice calls and text messages in a parallel and scaleable manner. We will create a hierarchical voice user interface that will accommodate the severity of the incidents being reported. Examples of scenarios are the following. In the simplest case, a commuter might see a major accident that has closed several lanes of a highway. He or she can report this incident via the system and other users who are calling in for traffic information will hear this event. An example of a more severe case would be the San Diego wild fires spreading to I-15 resulting in a shutdown of the freeway. If one reports such an event, the severity of the event will trigger an alert to all the users, to avoid that region of the freeway.

Cellular Location Tracking System: The main research focus areas are: i) GPS based tracking, a BREW-based software for mobile phone to perform GPS fixing and networking for data exchange with server, ii) a server for GPS position, speed, and mobile identity, iii) a desk-based map view to display real-time position, speed of travel, and identity of tracked objects, and iv) a mobile client and server working together as a complete solution for object tracking. The GPS data used by our system includes the latitude, longitude, horizontal speed, heading, and altitude. The system will be integrated with Microsoft Map Point mapping engine to display a more sophisticated street map. The system can also work with any third-party client.

The most compelling aspect of the Adaptive Information Collection system is the requirement that the information is to be collected and disseminated in an adaptive and targeted manner to people, with minimal delay. For example, today, commuters on freeways call 911 if they see a severe accident and that information never cascades to other commuters other than through a vague traffic report on the radio which are generally disseminated after a long delay. In our Adaptive Information Collection system, we found a very novel peer-to-peer based information collection mechanism which can also ensure quick dissemination. According to our peer-to-peer based traffic information collection and notification system, a community of freeway users is formed to efficiently collect, process, and empower targeted dissemination. Another critical issue we resolve with this system is anomalous information collection. We can detect abnormalities based on the volume of calls received in any hour. The anomalies such as a spike in volume of the calls can be used to understand that something must be wrong on the freeways. Indirectly, the commuters are acting as sensors by calling in. It is essential that we determine the location of the problem, by the highway and the location in the highway they are requesting information for. Implementation of a rating system which allows only regular users of the system to report incidents may be helpful initially. Others will not have sufficient privileges in the beginning and as time proceeds, every genuine user will be given a chance to improve their rating. One important finding we made is the relation between the acceptability and adoptability of this system for general public. With just 10-20% of the population adopting the system, it can serve as a powerful tool for the general public to relay, share and disseminate all types of critical information. In the case of cellular phone-based location tracking system, we observed that the standard GPS does not work indoors; in addition, the accuracy range obtained by the AGPS turned out to be around 50-100 meters.

System Integration. In the system integration project, several important factors affecting project integration were learned. The RESCUE team utilizes a standards-based approach using an Enterprise Service Bus (ESB). The purpose of the ESB is to facilitate application and process integration by providing distributed processing, intelligent routing, security and dynamic data transformation. In an ESB, these services are infrastructure services so each application does not have to implement these requirements independently and in a proprietary manner. The ESB addresses the disadvantages of existing solutions by creating a standard infrastructure for integration. Point-to-point solutions, where each of n components requires n-1 interfaces for full communication, are replaced by a bus solution where each component requires a single interface to the bus for global communication. An ESB provides distributed messaging, routing, business process orchestration, reliability and security. It also provides pluggable services and, because of the use of standards, these pluggable services can be provided by third parties and still interoperate with the bus.

The main research directions of the system integration project are i) an Enterprise Service Bus (ESB) for integrating the different networking modules in RESCUE and ii) a sophisticated web portal-based front-end for the Enterprise Service Bus. This website can be accessed at www.dsscc.com. This site was developed to serve as a front end for the Enterprise Service Bus.

Cross Project Opportunities. The ENS project interacts with two other projects within RESCUE. First is the CAMAS testbed where the ENS is used as an infrastructure for their experiments. Second is the Champaign testbed where the ENS provides the network infrastructure. The adaptive cellular networking system group is closely working with several of the projects within RESCUE. An example of such collaborative projects is METASIM. METASIM is aimed at integrating a number of domain-specific simulation testbeds such as CellSim, DrillSim, INLET, and CAMAS in order to create a Meta simulator that could provide much better insights into the issues involved in emergency response. We plan to develop a software simulation tool for developing and studying the survivability of cellular networks during large scale disasters such as earthquake. This software simulation tool will be integrated with earthquake simulators such as INLET to study different networking solutions for disaster response. For the information collection solutions, we plan to develop a series of software solutions which will be used in real situations for collecting and collaborating user inputs. For example, the cellular phone based location tracking system is under test for tracking the campus bus transportation in UCSD.

In addition to research projects within RESCUE, the ENS project collaborates with the NSF-sponsored infrastructure project, Responsphere, in order to build a networking infrastructure for emergency response. Several of the research ideas are implemented with infrastructure funding support from Responsphere. The ENS project closely interacts with WIISARD, a medical response application that can use the ENS infrastructure. During several major drills in which UCSD division participated, WIISARD and the ENS project collaborated successfully. The primary reason behind the success of collaboration between WIISARD and RESCUE is the fact that these two projects are complementary to each other. WIISARD is an IT system for medial emergency response whereas ENS in RESCUE is a robust networking project for emergency response. Adaptive cellular networking research interacts with the WHYNET project on deriving the realistic traffic parameters from cellular networking research which can be used by the cellular network simulator.

2.1.1.3 Project 3: Policy-driven Information Sharing Architecture (PISA)

Project Summary:

The objective of PISA is to understand data sharing and privacy policies of organizations and individuals; and devise scalable IT solutions to represent and enforce such policies to enable seamless information sharing across all entities involved in a disaster. We are working to design, develop, and evaluate a flexible, customizable, dynamic, robust, scalable, policy-driven architecture for information sharing that ensures the right information flows to the right person at the right time with minimal manual human intervention and automated enforcement of information-sharing policies, all in the context of a particular disaster scenario: a derailment with chemical spill, fire, and threat of explosion in Champaign, Illinois.

Year 3 Deliverables and Milestones:

1. Port Enterprise Service Bus (ESB) to small-organization environment.
2. Focus group discussions with stakeholders for target scenarios.
3. Interviews with emergency management to obtain detailed understanding of information sharing policies.
4. Identify information sources for target scenario.
5. Model information sharing policies.
6. Express policies using existing policy languages.
7. Design needed extensions to policy languages.
8. Scalability and availability work on policy engines and trust management infrastructure.
9. Develop information broker to facilitate sharing.
10. Integrate broker with SAMI and message bus.

Activities and Findings:

As described in the Champaign Testbed section of this annual report, during the past year we completed the construction of the derailment scenario that is the focus point for PISA (Milestones 3 and 4 above). As described in the PISA Artifact section of this report, we identified the RESCUE research that is relevant to the scenario. With the scenario in place, we began to identify the requirements for PISA in the context of the derailment. We also prepared for the sociology focus groups (milestone 2), planned for August 2006.

The most significant change from our initial plans is that the U.S. Government's Disaster Management Information System (DMIS) may serve as the underlying infrastructure for PISA (Milestone 9), with policy management facilities layered atop DMIS. It is possible that DMIS may play the role we intended for ESB (Milestone 1); we will be examining this point during the summer. Once this question is resolved, we can move on to integrating ESB and DMIS, if appropriate (Milestone 10). It is clear now that SAMI will play a relatively minor role in the scenario (Milestone 10), so we anticipate delaying the integration of SAMI with DMIS/ESB and instead concentrating on the addition of flexible authorization facilities to DMIS/ESB, as described below.

The information sharing policies that we have identified for the derailment scenario are relatively straightforward, i.e., they can be expressed in any reasonable policy language (Milestones 5, 6, and 7). We are investigating the possibility of layering them on top of DMIS. We have also determined that DMIS has rigid security requirements that may limit its effectiveness in a crisis. We plan to work to integrate RESCUE research on flexible authorization systems into DMIS over the coming year, and on trustworthy audit logs.

During the past year, we have developed a number of approaches to enhance the availability of trust management infrastructure, even under attack and flash crowd conditions (Milestone 10), and published those results in SATMAT06. We will be implementing those approaches in the coming year.

In parallel with the above activities, we continued our research on flexible authorization systems, which will serve as the building blocks for the flexible authorization facilities that we plan to demonstrate in the context of DMIS/ESB (and resulting in nine conference publications over the past year). To this end, we have been re-architecting TrustBuilder, our runtime system for authorization in open systems. **TrustBuilder 2** will build on our insights obtained from using TrustBuilder over the past several years, by redesigning it to be more flexible, modular, extensible, tunable, and robust against attack. The design of TrustBuilder 2 is complete, and we are in the midst of implementation.

The hurdles hindering PKI deployment are also a huge obstacle to the deployment of some trust management solutions. We have begun exploring more lightweight mechanisms for establishing trust across security domains. Many crisis response organizations have limited information technology resources and training, especially in small to mid-size cities. We are giving more consideration to practical approaches for these environments.

We have developed **Thor**, a hybrid repository for storing and managing digital credentials, trusted root keys, passwords, and policies that is suitable for mobile environments. A user can download the security information that a device needs to perform sensitive transactions. The goals are ease of use and robustness. Our long-term goal is an architecture that emergency personnel will find easy to use to securely access sensitive data during a crisis.

We have completed the first integration of trust negotiation with a DBMS. The database system is aligned with a proxy that authenticates strangers outside the security domain according to rules and roles defined in the database system. This is a first step toward an information sharing architecture where organizations can use policy-based mechanisms to specify and control who has access to what resources.

We have developed **LogCrypt**, which supports tamper evident log files using hash chaining. This system provides a service similar to TripWire, except that it is targeted for log files that are being modified. Often, an attacker breaks into a system and deletes the evidence of the break-in from an audit logs. The goal of LogCrypt is to make it possible to detect an unauthorized deletion or modification to a log file. Previous systems supporting this feature have incorporated symmetric encryption and an HMAC. LogCrypt also supports a public key variant that allows anyone to verify the log file. This means that the verifier does not need to be trusted. For the public key variant, if the original private key used to create the file is deleted, then it is impossible for anyone, even system administrators, to go back and modify the contents of the log file without being detected. During this past year, we completed experiments to measure the relative performance of available public key algorithms to demonstrate that a public key variant is practical. This variant has particular relevance in circumstances where the public trusts government authorities to behave correctly, and also benefits authorities by giving them a stronger basis for defending against claims of misbehavior. This technology may have relevance to more secure auditing during a crisis.

We are currently developing **Nym**, an extremely simple way to allow pseudonymous access to Internet services via anonymizing networks like Tor, without losing the ability to limit vandalism using popular techniques such as blocking owners of offending IP or email addresses. Nym uses a very straightforward application of blind signatures to create a pseudonymity system with extremely low barriers to adoption. Clients use an entirely browser-based application to pseudonymously obtain a blinded token which can be anonymously exchanged for an ordinary TLS client certificate. We designed and implemented a Javascript application and the necessary patch to use client certificates in the popular web application MediaWiki, which powers the popular free encyclopedia Wikipedia. Thus, Nym is a complete solution, able to be deployed with a bare minimum of time and infrastructure support. Nym currently authenticates clients based on their IP address. As part of a companion NSF project, we are beginning to explore how to leverage email authentication as a lightweight mechanism to authenticate and easily share information outside the local security domain. We should have results by the end of this year of the project, and it may provide a useful alternative for easy, policy-based sharing across organizations.

We continued our work on **hidden credentials**, which allow a service provider to send an encrypted message to a user in such a way that the user can only access the information with the proper credentials. Similarly, users can encrypt sensitive information disclosed to a service provider in the request for service. Policy concealment is accomplished through a secret splitting scheme that only leaks the parts of the policy that are satisfied. Hidden credentials may have relevance in crises involving ultra sensitive resources. They may also be able to play a role in situations where organizations are extremely reluctant to open up their systems to outsiders, especially when the information can be abused before an emergency even occurs. We have observed on the UCI campus that some buildings have lock boxes that are available to emergency personnel during a crisis. The management of physical keys is a significant problem. Hidden credentials have the potential to support digital lockboxes that store critical data to be used in a crisis. The private key used to access this information during a crisis may never have to be issued until the crisis occurs, limiting the risk of unauthorized access until the crisis occurs.

Cross-project Opportunities. In future years, PISA will continue to include investigators Winslett (security), Seamons (security), Tierney (sociology), and Pasco (software engineering). In addition, through insertion of their technology into PISA, we expect the following investigators to become PISA participants: Ashish (SAMI), Davison (MetaSim and Responsphere), Eguchi (loss estimation), Li (information integration), Mehrotra (privacy), Rao (extreme networking), and Venkatasubramanian (information dissemination). These investigators can bring the following technology to PISA: MetaSim, extreme networking, dissemination (donations, family reunification, language/mode, and flash dissemination), social networking, InLET evacuation/loss estimation tool, ManPacks and EvacPacks, CAMAS mobile cameras, information integration

2.1.1.4 Project 4: Customized Dissemination in the Large

Project Summary:

This project will focus on information that is disseminated to the public at large specifically to encourage self-protective actions, such as evacuation from endangered areas, sheltering-in-place, and other actions designed to reduce exposure to natural and human-induced threats. Specifically, we will develop an understanding of the key factors in effective dissemination to the public in various disasters and design technology innovations for conveying accurate and timely information to those who are actually at risk (or likely to be), while providing reassuring information to those who are not at risk and therefore do not need to take self-protective action. The ultimate objective is a set of next generation warning systems that can bring about an appropriate response, rather than an under- or over-response. To lend focus to the project, we will address the above challenges in the context of the following two case studies that represent two extremes along the time spectrum. The first case study is on real-time seismic alerts which are very short term alert technologies such as those currently being studied in the State of California where timelines range from minutes/seconds before impact to hours after impact. The second case study involves longer-term warnings for hurricanes and techniques to reach highly diverse populations effectively when ample warning time (days) are available. For these scenarios, the scientific grand challenges that will be addressed in our efforts are as follows:

1. *Understanding dissemination scenarios:* by identifying and studying the role of factors involved in decision making to enable decisions regarding when, what and whom to warn to avert the usual problems of normalcy bias and over-response.
2. *Supporting customization needs:* through flexible, timely, and scalable technologies including peer-based publish/subscribe architectures.
3. *Scalable, robust delivery infrastructure:* to build highly scalable, reliable and timely dissemination services from unstable and unreliable resources using a peer-based architecture for both wired and wireless dissemination.

Year 3 Deliverables and Milestones:

Key milestones for Year 3 as outlined in the strategic plan for dissemination research have been organized into three main sub-thrusts.

1. Complete work on understanding responder networks (using WTC disaster) and initiate work on modeling information flow through organizational and public disaster networks. Initiate work on understanding specific scenarios.
2. Work on customizable dissemination in pervasive spaces and lead into research on rapid publish-subscribe in peer-based networks.
3. Complete work on basic flash dissemination in peer-based networks and push-pull based dissemination. Initiate work on reliable, prioritized flash dissemination and dissemination in wireless networks.

Activities and Findings:

During the second year of this project, we introduced a new form of dissemination that arises in mission critical applications such as crisis response, called flash dissemination. In the third year, in addition to expanding the initial effort on flash dissemination, we introduced new efforts that represent a more holistic approach to public dissemination as outlined in the strategic plan. This includes a focused effort in the social science arena on understanding the specific chosen dissemination scenarios (Subthrust 1). Efforts include (a) determining dissemination factors for the real-time seismic alert and longer term warning scenarios and (b) investigating information diffusion both in interpersonal networks and across emergent multi-organizational networks. An understanding of such network structures and information flow through people in these networks guides the development and deployment of IT techniques for customized dissemination in wired/wireless networks. We also initiated efforts to understand and enable customized and personalized dissemination (Subthrust 2) more formally. We have explored problems and developed solutions to deliver customized information public at large (to individuals and organizations) through a peer-based publish-subscribe framework. Progress in Subthrust 3 (robust and scalable delivery) included the development of algorithms/protocols/systems for scalable and reliable flash dissemination in large spaces with heterogeneous devices, networks, users and information. We have also initiated a project on scalable and reliable information dissemination using heterogeneous communication networks (telephony, cellular, WiFi, mobile ad-hoc etc.) in addition to our effort in delivering information over traditional Internet based technologies. We describe in more detail the specific projects classified under the three main dissemination subthrusts below.

Understanding Dissemination Scenarios

a. Earthquake Information Dissemination Scenario: On May 26, 2006, RESCUE, assisted by the Natural Hazards Center, hosted an Earthquake Early Warning (EEW) Workshop at the UCI Campus. The purpose of this meeting was to update researchers and stakeholders on the state of the art developments in earthquake alert and warning since the conclusion of the TriNet study (2002); to introduce and explain the goals and plans for public information dissemination within RESCUE; and to discuss issues pertaining to public information dissemination from the fields of earthquake engineering science, social science, information technology, state and local policy-makers, emergency managers, schools/school districts, parents and community members, and private industry partners. Each participant was asked to describe their discipline-specific role as it related to the warning cycle for earthquake hazards. This cycle includes data collection and analysis, warning decision, warning content, warning dissemination, public perception, confirmation, and self protective action. Each participant provided brief presentations summarizing their areas of expertise leading to an afternoon discussion on the feasibility and barriers to public earthquake information dissemination.

Key findings include the following: 1) Many accomplishments were made through the TriNet project specifically in seismological studies, including the ShakeMap technology. However, the pilot project, which was promised, was never undertaken, partly due to the lack of an IT infrastructure for enabling this. The workshop revealed that RESCUE dissemination technologies can play a significant role in enabling such a pilot project. 2) There is a need for a federal agency to step forward and take the lead on earthquake early warning. The lead agency will be protected from liability issues under federal mandate should legislation on EEW be created.

These findings apply to dissemination of information to the public in multiple ways. First, there is a clear indication that earthquake early warning is possible with the technologies that can now be made available. Second, we are more aware of the organizational issues surrounding information dissemination. For instance, it will be imperative that in the event of a quick onset hazard with little warning, information must reach individual users rather than get tied up in bureaucracy and organizational hierarchy. Additionally, we recognize that there will be various phases of hazard impact and therefore customized messages will need to be developed that address protective measures that can be taken at different points of time prior to and post impact. This affirms the role of IT techniques for customization in this scenario. In addition to the various key findings, this workshop afforded an opportunity for graduate and undergraduate student researchers to learn about the various aspects of earthquake early warning systems. They were introduced to the complexity of the problem which extends beyond technological capabilities to the social aspects of policy development and liability issues.

b. EMONS in Crisis: In the wake of disasters, previous researchers have identified emergent systems among groups and organizations. Due to phenomena such as mass convergence to the impact site, the need for improvisation in a changing environment, and the presence of conditions that exceed the capabilities of the pre-existing response system. When existing organizational networks are unable to cope with an event, emergent multi-organizational networks (EMONs) develop to meet the needs of the affected community. Relatively little is known, however, regarding the structure of such networks, or the determinants of interaction with them. Using data collected from the Sept 11th WTC attacks, this effort analyzes the multi-organizational networks that formed after the WTC attacks and develops a methodology for extracting EMONS that can be applied in practice. Such analyses apply to dissemination of information to the public since they help explain which organizations have the greatest ability to distribute information to the community at large due to their role and place in the network structure. For instance, specific non-profit or non governmental organizations can serve to link local organizations with diverse constituencies and vulnerable populations that otherwise would not be reached through more traditional channels.

Following the September 11 attacks on the World Trade Center, data was collected from situation reports, status updates, newspaper articles, news transcripts and field notes to document emergent multi-organizational networks (EMONs) which developed in response to the WTC disaster. These field documents and newspaper articles were coded and recorded to represent the more than 6,600 records of interaction between organizations involved in the initial 12 days following the event. The resulting data set represents one of the largest efforts ever undertaken to capture EMONs in the immediate post- disaster environment.

In our work, we examine the probability of interaction between organizations based upon attribute data, including type (i.e., government, non-profit, profit, collective), scale of operation, and degree of autonomy. Using exponential family models, we estimate the extent to which organizations work with similar versus dissimilar alters (i.e. non-profits working with non-profits or government organizations working with for-profit organizations). In addition, we investigate the question of whether these effects differ depending upon the functional tasks in which the organizations are involved. These results shed light on the emergence of coordination among organizations of various types in this post-disaster environment of September 11. Our work also presents a step-by-step methodology to measure and extract EMON's using qualitative data for quantitative network analysis. This methodology addresses issues related to data sources, coding, network extraction, and analysis. Issues related to data sources include common sources and their properties, sampling issues, and data management, including cataloging and archiving data. Data coding and network extraction will be concerned with the identification of vertices and their relationships, or edges. Finally, considerations for analysis will address measurement constraints and errors.

Using information based on WTC and other previous EMON research, the knowledge obtained can *inform the design of customized information dissemination systems* for different types of crises. For events with longer warning periods, such as hurricanes, EMONS would be more readily identifiable where networks emerge to provide assistance to potential victims in the hazard path. For instance, a network of organizations could provide transportation to persons without vehicle access, or they could help evacuate persons who were immobile or disabled. Alternatively, networked organizations might band together to spread the word on protective actions that might be taken using various modes of technology for information dissemination. In quick onset events, such as earthquakes, the warning period may range from a few seconds to a minute or two before the impact of an event. In these cases, traditional networks of dissemination, such as mainstream media, reverse 911, and emergency broadcast networks, have very limited use in disseminating effective and customized information. However, knowledge of EMONs can be applied to the design of early warning systems. For example, while EMONs typically develop in response to events, existing research would inform the identification of strategic organizations in an EEW system. The system would then help create emergent relationships between organizations that might not typically interact with each other on a day-to-day basis, such as the US Geological Society (USGS) and a school-driven dissemination platform (provided by private agencies such as the School Broadcasting Company) to disseminate earthquake information to schools in a specific area to allow them to take immediate protective action. In this case, the relationships emerge during the design of the warning system as opposed to the response phase of an event. This research will help demonstrate that EMONs are not phase-specific, but may occur at any time during the disaster cycle.

c. Diffusion of Crisis Information through Interpersonal Networks. The goal of this effort is to understand the information diffusion process on hypothetical population of persons within a region. In this preliminary work, the network is loosely typical of what one might expect from telephone contacts; vertices are scaled by the expected completeness of the information they would be expected to receive from a serially transmission process (e.g., word of mouth) in which each concept has a chance of being lost during each iteration. Factors studied include the number of steps from the point of origin and the time to first contact the node. Interesting observations include:

1. Spatial character of the process: We observed that the movement of information seems to be much more uneven than might be expected from a purely spatial model: information does occasionally "tunnel" to spatially remote parts of the network, where spatially local clusters of informed actors often emerge. Within regions which are generally well-informed, one generally finds a few "stragglers" who are notified very late in the diffusion history. One expects that this effect would be amplified by additional sources of heterogeneity (e.g., age, race, language, etc.), but it emerges even without those complicating factors.
2. *Path lengths:* Information often takes a fairly circuitous route in reaching its destination. Even where network diameters are on the order of 3-4, realized path lengths of 12-14 (or longer) may be observed. This has important implications for the nature and quality of information which is received by individuals in the network.
3. *Notification time:* Information quality declines in first notification time, spatial distance from the origin, and social distance from the origin. Simple signals may persist over fairly long chains, but detailed information is likely to be concentrated within a reasonably narrow socio/spatio/temporal envelope around the originating individual.

Our preliminary efforts indicate that the behaviors are consistent with the field literature on initial propagation of information during crises of various sorts. A potential application of this study in the context of dissemination are in Reverse 911 systems for mass dissemination where one could exploit the natural process of information diffusion by strategically placing reverse 911 calls (or other alerts) so as to maximize the diffusion of accurate information within a target population.

d. Citizen Communications in Disasters: Recent crisis events around the world have drawn new attention to the role information communication technology (ICT) can play in improving warning and response activities. ICTs are enabling emergency responders as well as members of the public to develop new ways in which to respond to a crisis. Members of the public (through ICT) are not only playing a more active role in seeking information but also in providing information to each other and to formal crisis response and management teams. Drawing on disaster social science research, we consider the role of public participation in disaster and how ICT is extending this participation, particularly in the form of citizen-to-citizen communications. We reviewed information dissemination and consumption activities in cases of recent disasters, showing how low- and high-tech citizen communications vary in part depending on the physical, temporal, and spatial characteristics of disaster. We characterized three primary types of those communications, and consider how they map to formal response efforts, and, in so doing, raise questions about the ability of command-and-control organizational response models to support these important activities. Our work argues how information science can contribute to a complex domain with thoughtful technological innovation and knowledge about the interaction between ICT and organizations. Our plans are now to build an analytical framework for describing public communications following a disaster through remote and in-field ethnographic studies of real disaster events. Examining both low- and emerging high-tech forms of citizen communications, we will develop prototypes for peer-to-peer, location-aware, and hybrid digital-physical technologies that support different forms of information seeking, provision and personal expression.

Supporting Customization Needs

a. Customized Dissemination via Peer-Based Publish/Subscribe Frameworks. Our efforts in understanding the dissemination scenarios have revealed the need for customized dissemination. Our work investigates the use of a distributed publish/subscribe based infrastructure as a suitable platform using which customization needs can be captured and explored. The underlying pub/sub model consists of a set of pub/sub servers (brokers) connected to each other through an overlay network. Publishers and subscribers connect to one of the brokers to send or receive publications and subscriptions. The main goal of most existing pub/sub approaches is to increase scalability of the pub/sub system through reducing each broker's load; for example, techniques have been developed to reduce the total cost of matching and routing events. A common approach is to construct a spanning tree on the pub/sub overlay network to forward subscriptions and publications. This allows avoiding diffusion of content in parts of the pub/sub network where there are no subscribers and prevent multiple deliveries of events.

However, in the case of emergency warnings, notification dissemination time, the time between publishing a notification and delivering it to all of the interested subscribers, also plays a critical role. We use content-based pub/sub as a communication infrastructure for a customized alert dissemination system. While existing content-based pub/sub systems can scale reasonably well and disseminate notifications with reduced communication cost, timely notification has not been addressed. The primary goal of our work is in timely (and customized) dissemination of notifications to interested receivers.

To achieve this, we need to address the factors that are involved in the notification dissemination process and exploit all the available resources. We have initiated work on HiPub, a framework for exploiting publish/subscribe overlay network for content routing through the shortest path which results in scalable and high speed dissemination. HiPub also incorporates support for multidimensional indexing for content and subscription representation which results in reduced subscription maintenance load and high speed content matching. More specifically,

- We proposed a new approach to content-based pub/sub that disseminates messages from publishers to subscribers along a source-based shortest path (in contrast to spanning tree based approached proposed earlier). By using the shortest path, our approach is able to significantly reduce the delivery time of notifications under diverse load. Besides improving dissemination speed, our approach naturally exploits the inherent parallelism of the overlay network and reduces the likelihood of links becoming bottlenecks by distributing the notification dissemination task to a larger number of links as compared to the existing approaches.
- We develop two main approaches both of which use shortest path for message delivery. These approaches differ in the techniques used to prune the content dissemination tree to prevent forwarding published content towards part of the overlay network where there are no subscribers. Our first approach, LACRA, aims to reduce subscription maintenance by aggregating subscriptions in every broker based on the link that the subscriptions are received from. The second approach, BACRA, aims to accurately route content by having subscriptions broadcast to all brokers. We proposed and evaluated a family of techniques for content and subscription routing based on BACRA and LACRA. Through comprehensive simulation studies, we show that our proposed approach significantly speeds up the content dissemination process while the dissemination traffic is less or at most the same as the existing systems.
- We also proposed a novel approach for content representation which exploits subscription covering and merging and speeds up the matching operation. This is done by applying multidimensional indexing techniques in pub/sub system. Our simulations show that content representation technique that we propose can achieve considerable reduction in subscription maintenance and content matching load.

b. Push-Pull Based Customized Dissemination of Dynamic Information. In this work, we explore customized delivery of information in a client/server context. Applications that need to disseminate dynamic information from a server to various clients can suffer from heavy communication costs. Customized information needs of clients can influence whether information must be pushed to the client or pulled from the server. Data caching at a client can help mitigate these costs, particularly when individual push-pull decisions are made for the different semantic regions in the data space. The server is responsible for notifying the client about updates in the push regions. The client needs to contact the server for queries that ask for data in the pull regions. We call the idea of partitioning the data space into push-pull regions to minimize communication cost data gerrymandering. In this study, we present solutions to technical challenges in adopting this simple but powerful idea. We give a provably optimal-cost dynamic programming algorithm for gerrymandering on a single query attribute. We propose a family of efficient heuristics for gerrymandering on multiple query attributes. We handle the dynamic case in which the workloads of queries and updates evolve over time. We validate our methods through extensive experiments on real and synthetic data sets.

Scalable and Robust Delivery Infrastructures

a. Flash Dissemination in Heterogeneous Networks. The goal of Flash Dissemination is rapid distribution (over the Internet) of varying amounts of data to a large number of recipients in as short a time period as possible. Given the unpredictability in its need, the unstable nature of networks/systems and the varying characteristics of delivered content, flash-dissemination has different concerns and constraints as compared to traditional broadcast or content delivery systems. First, the underlying protocols must be able to disseminate as fast (or faster) as current highly optimized content delivery systems under normal circumstances. In addition, such protocols must be highly fault-resilient under unstable conditions and adapt rapidly in a constantly changing environment. In this study, we have developed a minimum-state gossip-based protocol called CREW. We implement the protocol in a framework that we call RapID that provides key building blocks for P2P content delivery systems. Extensive experimental results over an emulated Internet testbed show that CREW is faster than current state-of-art dissemination systems (such as BitTorrent, Splitstream and Bullet), while maintaining the stateless fault-tolerance properties of traditional gossip protocols. Further, we have also investigated centralized, global-knowledge protocols for dissemination. These protocols are much faster than localized randomized protocols and may be useful in situations where network and systems are stable and dissemination may be repeated multiple times to the same set of recipients, thus amortizing the knowledge collection and dissemination plan generation costs. Our key findings are as follows:

- Gossip-based protocols are inherently simpler to design and more fault-tolerant and hence they can achieve (and even better) the performance of optimized dissemination systems without compromising on their fault tolerance properties. CREW is a gossip-based protocol. Thus, CREW has dual advantage of lower maintenance of system code and higher resilience during crisis scenarios while still being able to disseminate data very quickly. Two key factors are needed to make gossip-based protocols achieve fast dissemination. First is the reduction in data overhead and second is high concurrency. Low data overhead can be achieved using two techniques. First meta-data needs to be used so that nodes only get information that they are missing. A more novel finding is the use of random walks on overlays to achieve a near real-time constant overhead membership service. High concurrency can be achieved by making all nodes active as soon as possible (high inter-node concurrency) and by using a high-performance and scalable middleware layer to achieve high intra-node concurrency.
- We have tested various dissemination systems and protocols on our Internet testbed. The systems include BitTorrent, Bullet, Splitstream and lpbcast. The first three systems are highly-optimized systems for large content delivery in heterogeneous networks. Lpbcast is a gossip-based protocol more geared towards fault-tolerance. In comparison to these systems, CREW, our flash-dissemination protocol achieved much faster dissemination, under various heterogeneity settings such as heterogeneous latencies, bandwidths and packet loss rate.
- High concurrency leads to congestion in the network slowing down dissemination. Thus high concurrency needs to be autonomically adaptive. We implemented a congestion recognizer and back-off mechanism in CREW using theory from random sampling to achieve this. Experimental results show that this combination of high concurrency coupled with intelligent back-off results in CREW's superior performance.

- We have developed centralized dissemination heuristics that can outperform randomized approaches when global knowledge is available. These heuristics can be employed in situations where dissemination needs are known beforehand.
- We have started investigating how overlay properties affect dissemination speeds. Preliminary investigation shows that highly skewed overlays can significantly impact the dissemination speed. Making dissemination systems agnostic to overlay properties is an important step for several reasons. It opens up new possibilities in design of overlay construction which has implications for constructing fault-tolerant overlays. Also, it has implications in the use of dissemination protocols in other systems where the overlay is beyond the control of the dissemination protocol.
- We will also investigate how the dissemination protocols behave in highly dynamic environments where a large number of nodes can join and leave simultaneously. This will be used to extend our work into building a 'catastrophe tolerant' flash dissemination system (necessary for crises) to building a P2P web-server for handling large unpredictable flash crowds (common in a variety of situations including disasters).

b. Information Dissemination in Heterogeneous Wireless Environments. Wireless networks (e.g., cellular, Wi-Fi) extend wireline networks in warning and notifying large number of people (both the public and first responders) in crisis situations. People with handheld devices (e.g., cell phones, PDAs) not only receive emergency alerts, but also share warnings and other related information between each other via ad hoc networks. In this work, we study fast, reliable, and efficient dissemination of application-generated data in heterogeneous wireless networks. We consider coverage (the percentage of intended recipients that receive the information), redundancy (the time it takes for people to receive the information) and energy consumption (on handheld devices) as the primary metrics. We develop efficient dissemination strategies that are not only fast and reliable, but also resilient to network congestion and recipients' mobility. We propose protocols that manage the dissemination of data with large size. We also investigate exploiting multiple radio interfaces, hybrid networks as well as mobility for faster dissemination. Key findings include:

- We have obtained a more concrete understanding of the distinct needs of application-level data dissemination in wireless networks, i.e., high coverage (reaching the maximum number of recipients), and low latency (within shortest possible time), etc. We have pinpointed the advantages and drawbacks of existing dissemination schemes, and have reexamined the well-known broadcast storm problem from the perspective of application-data dissemination. We have found that blind flooding is often effective since it achieves high coverage and low latency.
- We have reexamined the network stack for application data broadcast, and evaluated the choices of primitives on each layer, for instance, MAC-broadcast Vs MAC-unicast at the MAC layer, empty routing Vs on-demand routing at the network layer, etc..Through experimental studies, we have shown the performance tradeoffs between using MAC-broadcast and MAC-unicast as the primitives for wireless data broadcast. Specifically, MAC-broadcast-based dissemination approaches have better performance in terms of high coverage and short latency, whereas MAC-unicast-based dissemination approaches save energy.
- We have briefly studied the power properties of wireless interfaces in MAC-broadcast and MAC-unicast transmissions, including how they consume energy in transmitting, receiving, idling as well as in reduced-power state, etc.. We are exploring the use of random unicast-based background protocols to save battery on participating handheld devices during

disseminations. Unicast transmissions can put neighboring nodes into reduced-power state, in which less energy is consumed .

- We have shown the good performance of single-spanning-tree-based dissemination schemes, and the nice property of a center-rooted spanning tree. We have developed a distributed center-finding algorithm, which quickly finds the approximate central node of a network using small amount of messages.
- We have initiated work to exploit cellular/Wi-Fi combined networks to achieve quick, scalable and location-aware critical-information dissemination, using new technologies such as cell broadcasting and Wi-Fi cell phones. We have shown the feasibility and advantages via a simulation-based demo.

Cross Project Opportunities. The work described above has connections to the PISA, SAMI, privacy and networking projects. For instance, a policy-based infrastructure is being developed for organization-based public dissemination platforms; we are planning to explore commonality of policy specification mechanisms also being studied in PISA. The public information portal being developed in the SAMI effort will serve as the basis for development of the peer-based hurricane warning platform for the public at large. Privacy issues arise in customized dissemination over pervasive spaces and in wireless/cellular networks. Finally, the work on dissemination over heterogeneous wireless networks will cover the mesh network substrate being developed as part of the extreme networking project.

2.1.1.5 Project 5: Privacy Implications of Technology

Project Summary:

Privacy concerns in infusing technology into real-world processes and activities arise for a variety of reasons, including unexpected usage and/or misuse for purposes for which the technology was originally not intended. These concerns are further exacerbated by the natural ability of modern information technology to record and make persistent information about entities (individuals, organizations, groups) and their interactions with technologies – information that can be exploited in the future against the interests of those entities. Such concerns, if unaddressed, constitute barriers to technology adoption or worse, result in adopted technology being misused to the detriment of the society. Our objective is to understand privacy concerns in adopting technology from the social and cultural perspective, and design socio-technological solutions to alleviate such concerns. The project is exploring the “grand challenge” of whether Information Technologies can be designed with “knobs” that can control disclosure of information amongst entities (individuals, organizations, government) and whether such privacy knobs coupled with a set of “best practices” can be used to empower technology adopters to fit the technology into existing (and possibly dynamically evolving) societal and cultural expectations with respect to privacy.

To bring focus, the project is exploring privacy challenges in the context of a set of chosen technologies we are developing in RESCUE and their usage scenarios.

1. *Observation systems for situation monitoring:* we will explore privacy concerns in using multimodal pervasive infrastructure (consisting of video, audio, motion tracking, RFID, etc.). The infrastructure is being developed for variety of purposes including monitoring and recording emergency drills to building surveillance application.

2. *Customizable information dissemination technologies:* We will explore privacy concerns in using scenarios such as real-time seismic alerts to schools and organizations in California, and hurricane warning systems to provide customized warning to a large population. The scenarios mentioned are being studied in Customized Dissemination in the Large project of RESCUE and we will leverage such studies to understand privacy challenges that arise.

3. *Technologies for inter-organizational data sharing:* As part of the PISA project, we are exploring information exchange and interaction needs amongst various organizations at Champaign in case of a derailment with a chemical spill. Privacy and confidentiality challenges will also be studied in that context leading to development of policy languages and novel privacy preserving architectures.

Year 3 Deliverables & Milestones:

We expect to gain deep insight into privacy concerns in infusing technologies into real-world activities in general. Furthermore, we expect to very significantly advance state-of-the-art in privacy technologies. Based on these advances, we expect to design at least one information technology solution (viz. multimodal observation systems) with appropriate privacy "knobs" to control the amount of information collected disclosure and to explore the resulting privacy versus utility tradeoffs. An additional result is a shared common vocabulary to express privacy concerns, and a set of "best practices" that can be adopted to limit or eliminate a broad range of privacy concerns in technology usage. Specific deliverables and milestones for Year 3 of RESCUE are at two levels: Case studies to understand privacy concerns & challenges, and technology solutions for privacy preservation.

Case Studies:

1. Initiate study of privacy challenges in building observation systems
2. Initiate study of privacy challenges in data sharing in the Champaign testbed
3. Initiate study of privacy concern in information dissemination systems

Technology Milestones:

- Quantifying privacy & privacy preserving mechanisms
  -Techniques for location privacy
  - Information hiding by anonymization and data perturbation
- Privacy preserving observation systems
  - Privacy preserving architecture & solutions
- Privacy preserving data sharing system
  - Initiate work on privacy policy enforcement
  - Initiate work on privacy realization in data outsourcing architecture

Activities & Findings:

Case Study: Understanding Privacy Concerns in Surveillance. The RESCUE team, working in collaboration with Erin Kenneally at UCSD, who specializes in law & digital forensics, launched a one-year study of Privacy and Utility for Emerging Surveillance Technologies. Surveillance technology automates human perception capabilities in a manner that alleviates the constraints of the physical world. In other words, it facilitates time-, space-, and cognition-shifting in ways that can both greatly enhance capabilities as well as being exploited to violate privacy rights and expectations. There are opposing arguments as to whether the benefits of such technologies outweigh the costs. Among these considerations, the real and potential privacy risks are paramount and often define the course and scope of surveillance technology deployments. Specifically, the battle is often fought between the privacy rights lobby and government/law enforcement and corporate entities. This study will inform the cost-benefit debate by assessing how surveillance technologies can be designed and deployed to minimize the potential privacy- invasive applications of surveillance technology, while simultaneously realizing it's utility.

Building the Infrastructure to Study Privacy Concerns in Situation Monitoring. Significant advances were made in deployment of the Responsphere infrastructure (GLQ and CAMAS testbeds) and building of a multimedia event streaming system that serves as a CAMAS Virtual Machine. The infrastructure deployed and the corresponding software forms a fertile ground for a privacy implication study in Year 4 of the project.

Systematic Search for Optimal k-Anonymity. An approach to ensuring privacy in data publishing & sharing applications is to anonymize the data by removing identifying attributes and generalizing the quasi-identifying attributes such that the released information cannot be used to distinguish an entity within an anonymity group of K. To anonymize data, a family of generalization schemes is considered and an optimal generalization that meets the anonymity requirement (viz. anonymization size is at least K) and minimizes information loss is chosen. Previous approaches have considered generalizations that split attribute values independently. By visualizing the k-anonymity problem as multidimensional binning/histogramming, we developed an approach to k-anonymization that allows any hierarchical partitioning of space to be considered in the solution set. Our approach ensures k-anonymization with much lower information loss compared to existing approaches by considering a much larger class of generalizations. Nonetheless, better solution comes with an additional cost of enumerating additional generalizations. Intelligent enumeration strategies coupled with highly effective techniques to prune the search space significantly reduce the additional overhead. Using these techniques, we designed a search strategy that is progressive: it offers good solutions with bounds on quality quickly – one can stop the search when the solutions are “good enough” or continue the search process to get the optimal solution. Furthermore, our strategy generalizes to work with a large class of cost functions and privacy constraints.

Location Privacy. We examined privacy in the context of location-based services where location information is required by the service provider to render appropriate service. Previous work in this context has focused on techniques to anonymize user requests using a location proxy to prevent a service provider to gain insight into the identity of the requestor. Such models work well when the setting is fully anonymous and where service requests by the same entity are independent – that is, the service provider need not know connect subsequent requests of the same individual. A large class of location-based services is either non-anonymous or pseudo-anonymous in which service provider can know (either deterministically or probabilistically) if two requests are by the same person. In such a setting, inference attacks can be launched based on constraints on location data (e.g., limits on how much a person can travel in a given period of time). Such constraints can be used to launch correlation-based attacks. In this work, we identify how correlation analysis can lead to information disclosure about location and identity of subjects. We develop information hiding techniques that can withstand such correlation based attacks. Using our technique, we can protect location privacy against attacks launched by an adversary based on not only background knowledge but also correlation analysis.

Privacy-Preserving Observation Systems (P^3). Building on the work done in the PaDOC system (video surveillance), we derived insights into the nature of privacy preservation in pervasive environments. Specifically, we achieved the following: i) extended the basic model for specifying certain types of policies in pervasive spaces to support more complex policies that rely on historical user-data gathered in the pervasive space; ii) studied this from the point-of-view of specific scenarios on-site (smart office-space/coffee room); iii) proposed an event automaton-based execution model for user-specified policies; iv) proposed a system architecture and designed communication protocols for detection of events; v) proposed a very specific notion of privacy in the context of the architecture – i.e. anonymity; and vi) determined channels of inference in the proposed system that may lead to privacy violations; vii) identified the various constraints that need to be imposed on data representation and communication protocols to ensure individual's privacy in such a system; and viii) modeled the system design problem (privacy-performance) as a constrained optimization problem and proposed some heuristic solutions for the same. Experimentation on the proposed protocols under varying conditions (e.g. levels of anonymity, structure of composite events, etc.) is currently underway. Once the CAMAS-VM testbed is complete, we hope to incorporate our privacy preserving techniques for validation and performance.

In a related effort, we designed and built a practical, novel and secure system "Loud-and-Clear" (L&C). L&C provides human-assisted secure pairing for previously unassociated devices, e.g., cellphones, laptops, printers, PDAs, etc.

Privacy-Preserving Data Sharing Systems**.** Protecting Individual Information against Inference Attacks in Data Publishing: In many data-publishing applications, the data owner needs to protect sensitive information pertaining to individuals, such as the disease of a patient. Meanwhile, certain information is required to be published. The sensitive information could be considered as leaked, if an adversary can infer the real value of a sensitive entry with a high confidence. There are various methods using which the adversary can infer sensitive values. In this work, we study how to protect data when an adversary can do inference attacks using association rules derived from the data. We formulate the inference attack model, and develop complexity results on computing a safe partial table. We classify the general problem into sub-cases based on the requirements of publishing information, and propose the corresponding algorithms for finding a safe partial table to publish. We have conducted an empirical study to evaluate these algorithms on real data.

pVault/Delegate. We explored architecture for achieving secure mobile access to personal data. In this architecture the users outsource their personal information to a remote service provider who is in charge of providing storage and data access services. The heterogeneous personal data of users is captured in the form of XML documents. The service provider itself is untrusted and therefore the data is encrypted before being outsourced. This architecture allows the user to access their data from any trusted computer connected to the internet. This architecture was implemented as a software artifact called Pvault. Pvault has been running successfully for over a year.

Furthermore, we proposed a new architecture for accessing websites securely from untrusted machines. Accessing the Internet to perform sensitive transactions from the computers outside one's administrative control is risky. The untrusted nature of these machines creates a target rich environment for identity thieves. We designed a proxy-based architecture called Delegate that enables a user to access websites without disclosing any personal information to the untrusted machine. In addition, Delegate enforces rules at the proxy to detect and prevent session hijacking attempts. The architecture requires no special software at Web servers or the untrusted machine, but assumes the user possesses a trusted hardware device like a cell phone. Delegate is designed to strike an appropriate balance between ease of use and security. If concepts from the proposed architecture were supported by Web servers, then some of the same protections Delegate affords to users of untrusted machines could be realized by users on trusted desktop computers when their machines fall prey to spyware or other malware.

***Privacy Preserving Authentication*.** Much progress has been made in designing novel techniques for privacy-preserving authentication (secret handshakes) and information delivery (OSBE). Several efficient and secure protocols have been developed and research began into the area of privacy-preserving group authentication (GSH). Furthermore, 2nd release of BOUNCER package for secure membership management in dynamic peer groups has been released. BOUNCER includes a number of innovative protocols for fully distributed admission (and eviction) of group members.

2.1.2 Testbeds

In RESCUE, we have created four testbeds for the purpose of evaluating RESCUE research. (1) The Transportation Testbed, led by ImageCat, simulates an evacuation activity in case of a large regional disaster (such as earthquake in the Los Angeles area). Online software called InLET (Internet-based Loss Estimation Tool) has been developed that enables researchers to quantify the efficacy of various IT solutions by examining the impact on highway performance both with and without improved information technology. This year witnessed a major evolution of the transportation testbed into an integrative simulation environment referred to as MetaSIM. MetaSIM is the result of integration of diverse simulation capabilities being developed by different RESCUE partners into a single integrated system. In particular, MetaSIM is an amalgamation of the transportation simulation with micro-level agent simulator (DrillSim being developed at UCI) and a cellular infrastructure simulator being developed at UCSD. MetaSIM provides RESCUE researchers a mechanism to test and validate IT solutions in a very rich set of scenarios which neither of the three simulators could provide individually. (2) The UCI CAMAS testbed creates a campus level pervasive environment that supports a variety of networking and sensing capabilities. The pervasive infrastructure enables monitoring, instrumentation, and recording of campus level drills as well as testing technologies in that context. A multi-agent response activity simulator (DrillSim), fully integrated with the pervasive infrastructure has been built both as a training tool and a tool for what-if analysis. (3) The GLQ testbed at San Diego serves as a living laboratory for deploying and testing variety of communication technologies such as hybrid wireless mesh network connected to the Internet over multiple long-haul point-to-point wireless links. The infrastructure offers not only crucial data on the pattern of user traffic over a wireless mesh network but also a wideband Internet access infrastructure to public and law enforcement agencies. (4) Finally, the Champaign, Illinois Testbed – a result of active participation of user community in RESCUE research – consists of a set of response organizations willing to serve as a testbed for deployment, testing, and validation of RESCUE research focusing on secure data sharing. It provides an opportunity to explore challenges and study the efficacy of IT research and solutions in a smaller-city setting. Our ongoing discussions with multiple response organizations in Los Angeles, Orange County, and San Diego County will provide additional opportunities to test technologies from multiple perspectives.

2.1.2.1 MetaSIM Testbed

Testbed Summary:
Many project efforts within RESCUE include a simulation component, and integration of the various simulators has a potential for synergy. Given this opportunity, the transportation testbed platform was expanded in scope to encompass existing simulation efforts at multiple research sites and became project MetaSIM. MetaSIM is a natural extension of the ongoing collaboration between universities and researchers forged by Project RESCUE, and the transformation of the transportation testbed into MetaSIM formalized efforts to address issues surrounding model integration. This section of the annual project report describes the purpose of the MetaSIM testbed, and the current status.

MetaSIM is envisioned as a web-based collection of simulation tools developed to test the efficacy of new and emerging information technologies within the context of natural and manmade disasters, where the level of effectiveness as measured by reduction in expected losses, evacuation times, and other impacts can be determined for each technology developed. Outside of the research community, MetaSIM will prove useful to emergency managers and first responders by providing centralized and wireless dissemination of disaster simulation data and information. Before an event, disaster simulations of probable events will aid in the prioritization of mitigation activities and increase preparedness through training scenarios. Immediately after an event, MetaETASIM will aid in situational awareness and resource deployment. During the recovery phase, MetaSIM will help assess long-term shelter and public assistance requirements. MetaSIM will be a highly-distributed collection of simulation models connected by a series of translators that access a common database. Simulation models running on computers at different locations are connected together to create a meta-simulation capability that allows the assessment of the larger impacts of a disaster. Models simulating various aspects of a complex event do not have to coordinate data transfer with each other, but are able to share simulation results through a common enterprise database. A standardized communication protocol is envisioned to allow other simulation models to be incorporated without system redesign. Through the web interface, a basic user would be able to run each module as needed, whereas researchers could incorporate meta-simulations into their own projects by calling individual models as a computer service. By utilizing this distributed simulation environment, METASIM has the potential to become a comprehensive modeling platform for simulating the effects of large disasters.

End users of the envisaged system are: 1) engineers and scientists, sociologists, geographers, computer scientists, and other domain experts; 2) civil, structural and transportation engineers; and 3) emergency management professionals. Anticipated applications include: 1) testing emerging technologies; 2) training based on probable scenarios; 3) drills from probable scenarios, such as those conducted in emergency operation centers (EOC); 4) post-event loss estimation and impact analysis; 5) post-event simulation of cascading events; 6) “plug and play” integration of additional simulation tools; and 7) assessing disaster mitigation strategies and alternatives.

Year 3 Milestones and Deliverables:
The following features represent the major elements of MetaSIM. In total, these features represent the main deliverables for Year 3.

Modularity and extensibility. MetaSIM will serve as a common database for visualizing the results of the various modules and as a communication hub, storing and facilitating the translation of data between individual components. This communication portal will not serve as a centralized database for all the individual models. Each model is likely to have specific data requirements that may or may not correspond with other models. The scalability of MetaSIM will depend on each individual model sharing a reasonable amount of data through the centralized system.

Ultimately, MetaSIM will be a collection of plug-and-play simulation tools connected by a series of translators and a database. With proper definition of inputs, outputs, timing, and scale, the results of each simulation component could be available for iterative use by each of the other simulation models. Registering and synchronizing transactions between various simulation engines and assuring proper use of scale will require tight integration.

Integration of key components. MetaSIM will consist of a suite of simulation tools. Given that there are likely to be many overlapping features in the various simulators, such as an interface, a method to view results, and a database, many of the components of a given simulator will not be used, and advanced users may want to use the various simulation engines outside of MetaSIM.

Analysis at multiple scales. The various simulation tools will integrate results from micro-simulations of very small areas to large-scale statistical models covering very wide regions. A key component of MetaSIM will be the integration of these various levels of analysis, so that micro-scale benefits are extrapolated to regional effects, and regional effects are used to inform micro-simulations.

Simplified user interfaces. Each simulation component of MetaSIM draws from many disciplines, and expert use requires extensive study. However, the vision of MetaSIM is of a product that can be used with very little, if any, expertise in the science or technology that supports MetaSIM. This will be accomplished through extensive use of defaults, so that users can adjust a minimal number of parameters of interest without dedication of significant resources. Table 1 illustrates how this goal is accomplished through a series of "user levels".

Table 1: Preliminary identification of anticipated users of DrillSim within MetaSIM, indicating the expected level of effort and data requirements to complete an analysis.

Level	Who	Time Required	Input	Results
L1	Emergency Manager	Minutes	Whether or not to run various modules	Default output from each model at some level of aggregation, with IMS or other interface to detailed results
L2	Researcher Response Personnel	Hours	Select from various predefined options, representing a baseline, and the integration of technology.	Comparison of various outputs with and without integration of technology.
L3	Advanced Research	Days	Define custom input, integrating a new suite of technology.	Comparison of various outputs with and without integration of technology with new technologies analyzed.
L4	RESCUE Researchers	Weeks	New regions, models, or geography.	Comparison of various outputs with and without integration of technology, analyzing a new area.

For MetaSIM to achieve the ultimate goals of modularity and extensibility, many integration issues must be resolved. MetaSIM will address these issues through leveraging existing resources within the RESCUE project, and focusing on a key application: modeling the benefits of integrating cellular technologies during evacuation. This application will address four simulation modules currently being developed and/or used within the RESCUE project. The crisis simulator (InLET) will provide initial estimates of damage throughout a region. Based on the estimated damage to buildings and the cellular infrastructure, DrillSim will model evacuation of the UCI campus. This evacuation will consider a default occupancy level for the campus, for every floor of every building, and will be modeled both with and without IT technologies or hardening of the cellular infrastructure. As evacuation occurs at a building level, evacuees will enter an out-door campus level evacuation, from which they will continue to an automobile-based evacuation using the transportation model. A cellular simulation tool will consider how to optimize the remaining cellular load to facilitate evacuation. The vision of this initial deployment project has evolved amongst project team members, given the capabilities and limitations of existing models. A common, application-based focus is emerging that will provide a concrete deployment challenge to address issues of modularity and extensibility.

Activities and Findings:

The Transportation Simulator. The transportation simulator provides a platform for testing the assumption that rapid and accurate information conveyed to drivers can significantly improve the performance of a transportation system when viewed within the context of evacuation. Drivers weigh information reliability for: 1) understanding the status of an event; 2) assessing the expected duration of disruption; and most importantly; 3) determining the best action to take to minimize the impact. With additional and more accurate information, it is expected that drivers will behave in a more predictable manner and generally follow instructions and directions from ITS (Intelligent Transportation Systems), and thus will be able to reduce average travel times during an emergency. The transportation module consists of an integrated model of simplified quasi-dynamic traffic assignments, and a destination choice model. In the last year, information that will become available through IT solutions has been synthesized through parameters, such as information reliability, rapidness of dissemination, penetration rate and degree of customization, to reduce uncertainties associated with decision making when evacuating a congested network.

In the current proof-of-concept, three parameters characterize the type of information that might be provided to drivers. The *reliability* of information indicates "how much" the drivers trust the warning given to them for evacuation. The more reliable the information, the more people depart sooner. The *timing* identifies the lag between the disaster and the notice to evacuate. The *customization* refers to the degree of information specificity with regard to their current geographic location. If no customization is applied to the evacuation notice, people in a given block will all receive the same messages. However, if an IT solution can detect the location of a cellular phone, it may be possible to give individuals very specific routing information.

The trip generation model allocates population within the exposed area over time, depending on *Reliability* and *Timing*. In the current model, network congestion is not considered in trip generation. Given *Reliability*, r, and *Timing*, T, trip generation at any given simulation time period t, g_t is calculated by Equations 1 and 2. By the warning given at time T, the population moves at its maximum rate $g_{\max}$. Equation 1 specifies a linear relationship between reliability and the maximum generation rate. The model assumes a gradual increase in the number of evacuees over time, according to Equation 2. The key parameters are available as adjustable inputs to the model, for users to assess the efficacy of different methods of integrating IT into emergency response. The module has been tested with various small scale evacuation scenarios.

$$g_{\max} = \alpha + \beta \cdot r \quad (1)$$

$$g_t = \begin{cases} g_{\max} \cdot t/T \ , \ if\ t < T \\ g_{\max} , \ if\ t \geq T \end{cases} \quad (2)$$

The transportation model used to assess route choice for evacuation consists of a series of database queries. The basic algorithm implemented is detailed below. Drivers continuously depart from an initial location (Step 2), and take the best route at that instance (Steps 5 and 6). On each route, traffic is assumed to be continuous with uniform density. Step 7 counts how many drivers are exiting the evacuation area within each time period. Residual evacuation demand is added to the trip generation module for the next time period, and is factored into the congestion calculations in Step 3. The simulation is repeated for a predefined number of time periods.

Step 0: Initialize: Clear storages for intermediate calculations
Step 1: Estimate trip generation in each time period
Step 2: Increase simulation time period by one
Step 3: Update congested link travel time based on traffic volume on the link
Step 4: Calculate path travel time between all zone-pairs, by aggregating link travel times in each route
Step 5: Choose best travel route-destination from each origin to destination-route combination according to the level of customization.
Step 6: Assign the trips to routes based on the allocated demand to the links in the selected path
Step 7: Calculate evacuated trips and evacuation demand in the system
Step 8: Evaluate stopping criterion. Stop analysis if current time period reaches the simulation duration

Resolving changes in driving behavior and IT solutions is still problematic. A premise for the transportation testbed is that IT solutions may improve disaster response. By providing means for rapid assessment of the situation and optimal plans, online tools should improve emergency responses extensively, but the link between IT and behavior is currently left to conjecture. This will be addressed in Year 4 through integration with MetaSIM. Additionally, for better representation of drivers' mobility, the transportation module will be modified to incorporate meso or micro scale traffic dynamics.

DrillSim. DrillSim is designed as a multi-agent crisis response activity simulator which has plug and play capabilities. The goal of DrillSim is to test IT solutions in the context of disaster response. The activity is modeled at an individual level, and software agents model humans. A neural network based decision making system models the human decision making in our system. DrillSim version 1.0 which simulates an evacuation within a building has been developed, and DrillSim version 2.0 which simulates an evacuation at a campus level is being implemented currently. Interfaces to input data for the DrillSim and a visualization interface have been developed. Virtual reality-augmented reality integration is being pursued currently, and an initial level integration has been achieved by sending the output of DrillSim to a real person carrying a PDA or a mobile computer.

In the past year, models for representation of space and the impact of different phenomenon on space have been studied. The models are at different resolutions to capture accurately the impact and also keep the system scalable. Planning over multiple resolutions of spatial data, and efficient data management techniques exploiting the multiple resolution representation of space is currently being explored.

The software agents, which model human beings in DrillSim, are the information processing entities. Each agent has a view of the world, based on which it makes decisions, and plans to execute them. The decision making process is modeled using a neural network. The behavior of agents form the basis of the activity modeling, and it provides a flexible way to implement different activities by just modifying behavior. Agents also assume different roles, and the behavior is dependent on the roles. DrillSim has the facility to edit existing roles and also add new roles into the system.

Additional progress includes the creation of base data sets, which are being used by DrillSim and other projects within Rescue. Maps and GIS data for the entire UCI campus, and detailed building CAD maps have been analyzed and stored in the database. These datasets support a geographical model for DrillSim. Data of drills (video of drill, questionnaire etc) conducted in UCI have also been stored. DrillSim activity modeling is being calibrated using data from these drills.

Designing agents that realistically model human beings is the primary challenge in DrillSim. In general, humans use information and knowledge to take decisions, which are rarely simple and independent from decisions made by others. Additionally, when faced with identical information, a group of individuals may decide to react differently, based on knowledge. Factors like social network, risk adversity, resources, and how people react to technology impact the decision making process. Work is being done to improve the behavior of agents in DrillSim.

DrillSim models activity at the individual level, and since every agent makes a decision at every instance that impacts the output of the simulation, there is a significant scalability issue. Research into scalability solutions has included modifying the scale of resolution of data and interspersing macro-level modeling with micro level activity modeling. In Year 4, DrillSim version 2.0 will be deployed for campus level evacuation, and integrated into actual CAMAS drills. Interfaces for DrillSim will be designed and integrated, and the simulation module will be integrated with MetaSIM

Crisis Simulator (InLET). In the years following the 1994 Northridge earthquake, many researchers in the earthquake community focused on the development of loss estimation tools, such as HAZUS (HAZards-US). Advances in GIS technology, including those associated with desktop GIS programs and robust application development languages enabled rapid scenario generation that previously required intensive data processing work (in many cases, manual activities.) In some cases, these programs were linked with real-time earthquake information systems, such as the Caltech USGS Broadcast–of-Earthquakes (CUBE) system, or ShakeMaps (USGS) to generate earthquake losses in real-time. The Federal Emergency Management Agency (FEMA) funded the development of a high-profile and widely-distributed loss estimation program called HAZUS (HAZards-US). Because of its flexibility in allowing users to import into the program custom datasets, the use of HAZUS in real events (e.g., 2001 Nisqually, Washington earthquake) sometimes resulted in conflicting results, especially when different users were involved in modeling the same event.

This issue (i.e., conflicting results) highlighted the need for a centralized system where data and model updates could cascade to multiple users. In the past year, a successful implementation of the Internet-Based Loss Estimation Tool (InLET) was achieved. InLET is the first known web-based massive simulation program that incorporates: 1) an earthquake-based disaster simulation module; 2) building and infrastructure damage estimation routines; 3) socio-economic loss estimation models, and 4) a transportation routing and evacuation module. Currently, the model works on a database for Los Angeles and Orange Counties. The program has a mapping interface with standard GIS functionality such as re-center, and zooming in and out. Additionally, the basic framework easily supports overlaying various vector and raster data, including points of interest, data gleaned through online searches, or satellite imagery and aerial photography. Development has progressed as planned, and the product has been demonstrated for use by multiple end users at one time.

A primary challenge has been structuring large database files used for computation so that the results are usable by multiple users over the web concurrently. Additionally, allowing multiple users to access the system for extensive analysis makes the scalability of InLET an issue. The models are mainly based on computationally intensive SQL queries. Over a series of improvements, InLET is being migrated to a robust analytic system that is based on a SQL Server. The queries are being formatted to simultaneously work for multiple users. Primary functionality is being built to incorporate USGS ShakeMaps and ShakeCast results.

InLET is designed to be used by first responders, planners, and anyone involved with emergency response. It is a tool that can be used to estimate the amount of damage that has occurred in a large disaster (e.g., earthquake), to examine likely areas of impact, and to assess the impacts of different response and recovery decisions. In Year 4, InLET will be modified to accommodate multiple users simultaneously in a simulation capacity. The backend database will be migrated to SQL Server to provide a more robust architecture.

2.1.2.2 CAMAS Testbed

Responding to natural or man-made disasters in a timely and effective manner can reduce deaths and injuries, contain or prevent secondary disasters, and reduce the resulting economic losses and social disruption. Organized crisis response activities include measures undertaken to protect life and property immediately before (for disasters where there is at least some warning period), during, and immediately after disaster impact. One of the major objectives of the RESCUE research program is to radically transform the ability of organizations to gather, manage, analyze and disseminate information when responding to man-made and natural catastrophes. This testbed focuses on the design and development of a multi-agent crisis simulator (DrillSim) for crisis-activity monitoring as well as the instrumentation of approximately 1/3 of the UCI Campus known as the “Smart-Space.” The Smart-Space contains state of the art technologies such as Wi-Fi, RFID, people-counters, video and acoustic sensors, as well as a number of other sensors and devices.

Testbed Summary:

The objective of the testbed is to be able to play out (either through actual drills or through DrillSim) a variety of crisis-response activities such as evacuation, medical triaging, firefighting, or reconnaissance. This serves multiple purposes such as IT solution integration, training, testing, decision analysis, impact analysis, etc. The testbed personnel provide a number of drills (i.e., “drills on demand”) throughout the year for such testing as well as access to the datasets and metrics that result from the drills, with proper approval (e.g., IRB). The researchers invite other academic partners, industry, government, and First Responders partners to partake in the drills and technology testing. It is the researcher's desire that the CAMAS testbed become a proving ground for the investigation, verification, and interoperability testing of disruptive information technologies.

Year 3 Milestones and Deliverables:
During Year 3, the CAMAS testbed designers finished the instrumentation of the Cal-IT2 building and began the Phase 2 (outdoor) instrumentation in earnest. The research team made a significant investment in long-range IEEE 802.11G Wi-Fi technology. An entire response Zone (e.g., set of UCI buildings designated under the command of one set of 1st Responders; approximately 1 square kilometer) was instrumented with this technology. Planning is underway for Phase 3 (administration buildings) instrumentation.

Also during Year 3, the CAMAS designers deployed RFID technology, more people counting technologies, a large 8-processor/64-bit Solaris machine, as well as Wi-Fi mesh routers (created by the UCSD team) within the UCI testbed. On an additional note, all of the RIFID equipment was generously donated by the Printronix Company for use in the CAMAS testbed. It will be used for a variety of research purposes including localization and privacy preservation work.

Activities and Findings:
2005: Instrumentation of EH&S Biohazard Training. The team tested a handheld PDA information collection/dissemination/communications platform, 802.11 bridging into open networks, video streaming to EOC centers, and remote monitoring of incident sites.

2006: Evacuation of Cal-IT2 building. The team tested the video/acoustic sensors, remote monitoring of the building, DrillSim integration into the "real world" response activity, data set collection. The social scientists conducted experiments with regard to information networks as well as instrument design.

2006: Evacuation of Zone 3. The team tested the EvacPack platform, the CAMAS Virtual Machine (CAMAS VM), sensor streaming over unstable networks, data set collection, and mobile camera utilization. The social scientists in the RESCUE Project conducted experiments on noise-level to crowd density correlations as well as on-site versus remote crowd estimations.

2.1.2.3 GLQ Testbed: Gaslamp Quarter Mardi Gras Deployment

Testbed Summary:
A mobile communications and sensor network was designed, built and installed in the GLQ testbed for the Gaslamp Quarter (GLQ) Association's 2006 Mardi Gras event on February 28, 2006. The basis of the infrastructure was a wireless network mesh connecting sensors and access points to each other and to the Internet, as well as streaming data back to the San Diego Police Department (SDPD) Critical Incident Management Unit command post and the UCSD Technology Operations Center.

The communications network infrastructure consisted of a CalMesh network, Tropos wireless access points, satellite dish deployment and a Mushroom network. VPN nodes fitted with cameras were connected to the mesh. The Tropos system and the CalMesh nodes were the foundation of the networking infrastructure for this installation. The Mushroom network provided redundancy and was available to replace a failure of the back haul (which was not needed).

The team successfully integrated different access technologies and networks to create a single, more reliable network. Functional capabilities were examined; experiments were conducted and performance measurements were taken on multiple parameters of the network and on the various deployed sensors. Numerous field trips were made to the GLQ to study and take measurements on the topology of the area, locations for placement of equipment, signal strength and other factors. Nearly 30 people were involved overall, with a core group of a dozen or so researchers who actually made the experimental and operational platform work. Researchers from the WIISARD project, Responsphere and other groups were also involved.

The Mardi Gras deployment gave the researchers an opportunity to test their technologies and products in real time, under field conditions and importantly, to assess their performance and usefulness when integrated together. Following is a brief overview of the deployment. More general information is available at: http://www.calit2.net/newsroom/article.php?id=810.

Activities and Findings:

Communications Network Configuration and Testing

The Gaslamp Quarter is an approximately three-by-eight square block area from 4th Street to 6th Street (west to east) and E Street to L Street (north to south) in downtown San Diego, CA. Both the SDPD command post and the UCSD Tech Ops Center were located inside the event perimeter at a hotel near the southern end of the covered area.

The Tropos network system consisted of five Tropos 5110 outdoor routers, five outdoor remote controllable on/off switches and five Tropos power cords; these were installed five days in advance of Mardi Gras (and still remain in the testbed). The system included one gateway node which was connected to a 3 Mbps wireless backhaul. This gateway node was installed on the roof of a two-story business building. The other four Tropos nodes were installed on street-corner lamp posts. CalMesh networking nodes were used to extend the coverage of the wireless network: Three CalMesh nodes were deployed to connect the command center and southern-most camera to the satellite internet connection.

VPN clients, built by reconfiguring CalMesh boxes, were deployed at the scene. The VPN server was located at UC San Diego. Five VPN nodes were built with cameras hardwired as clients. Port forwarding was then set up on the VPN nodes to enable connectivity (and therefore access to the cameras from other VPN clients). Several Windows and Linux laptops were used for this. Four of the VPN nodes were set up to use the Tropos network; the fifth was set up to use the CalMesh network. Internet connectivity was provided by a service provider, SkyRiver Communications. The Tropos gateway node was connected to the SkyRiver network via point-to-point microwave link. Only the Tropos network remained installed at the scene, all other parts were mobile and thus, uninstalled following the Mardi Gras event.

Measurements of network traffic flows were taken (the VPN boxes were assigned static IP addresses in the Tropos system). Three of the nodes and the SDPD command post served as the main locations from which data samples were collected during the Mardi Gras celebrations. (Additional preliminary measurements were taken in the area during preparation for and installation of the Tropos network.)

Measurement samples were taken intermittently from different locations in the Mardi Gras area during the festivities. Packet delays for the camera nodes to the VPN server were around 50-100ms. Throughput of the VPN connections going through the CalMesh network was around 200kbits/sec. Because the VPN runs on TCP, TCP traffic constituted a large amount of the entire traffic measured, 86.54%; UDP traffic accounted for 10.81% of the traffic. Sample results in bytes transferred at the 5th and E streets corner at 8:25 pm for 15 minutes were as follows:

VPN node/camera IP address (number of bytes): 10.100.10.120 (10025033), 10.100.10.116 (895549), 10.100.10.118 (34808) and 10.100.10.112 (20428).

The highest observed traffic flow during the Mardi Gras originated at VPN box 10.100.10.120 (located at 5th and E streets) during a sampling period of about 900 seconds at approximately 10 PM. During the observation period, this VPN client had two separate connections in time. This may be due to a dropped first connection, followed by the initiation of another connection. The traffic variation with respect to time at 5th and G streets was rather different compared to that observed at 5th and E. Here, the traffic sample (5th and G) was stable without breaks. Also of note, for every TCP connection pair, a large bi-directional traffic difference was noted.

For a variety of reasons the current installation of the Tropos network in the GLQ is not optimal for ongoing measurements and testing during non-event periods (i.e., day-to-day testing). Therefore, the network is currently accessible only by password, which reduces the traffic substantially (and there is no 'ordinary' traffic of the type we wish to assess on the network). Issues include local businesses and hotels providing Wi-Fi to paying customers (competition concerns) and the City of San Diego is having significant electrical problems in the downtown area. The Gaslamp Quarter is an historic part of downtown with an aging civil infrastructure on which they are working. We are currently drawing up plans to develop an additional venue outdoors where such testing can take place, as well as working to resolve problems in the Gaslamp to enable a reliable testing platform situation. It is noteworthy to point out that the barriers which interfere with ongoing, extended testing of regular traffic flows would not exist in a real emergency or disaster.

Summary and Brief Discussion of Technologies Tested during Mardi Gras

A mesh network with full functionality and remote monitoring has been installed and tested in the GLQ testbed. The network was tested under different conditions resulting in multiple sets of data collected on the behavior of the network. The team successfully integrated different access technologies and networks to create a single, more reliable network. Various subsystems were deployed and made to interoperate to produce a cohesive whole. Many lessons were learned in the course of successfully achieving this deliverable.

The Mardi Gras deployment gave researchers across multiple disciplines an opportunity to test their technologies and products in real time, under field conditions and importantly, to assess their performance and usefulness when integrated together. The communications and sensor network was also used to support the SDPD in their management of the traditionally very large (tens of thousands) and rowdy crowd of party-goers. The deployment was a step towards the more chaotic environment seen in real emergencies and disasters.

Throughout the evening several representatives of the SDPD came over from their command post to visit the UCSD Tech Ops Center, including the police chief and officers from the SDPD Critical Incident Management Unit. They were given demonstrations of the technologies deployed and each was discussed. The police chief commented that what he saw was quite promising and there is a possibility of additional collaborations in the future.

Among the many applications and technologies used and tested were: a video stream over a cell phone system, location-based tracking system, cameras over a virtual private network (which included two cameras streaming video into the SDPD command post).

An enterprise service bus was successfully integrated with the location-based tracking system which demonstrated the ease with which communication between two disparate systems on a network can be established. Cell phone performance testing using a CDMA air interface tester was performed both during the Mardi Gras festival (heavy load scenario) and on an ordinary day, close to midnight in the GLQ testbed area, 10 days later for comparison purposes.

A previously established system "call-to-collaborate", which is designed for relaying information and instructions en masse via cell phone was tested in the very noisy, outdoor, environment. As a proof of concept, the Mobile Vision (MoV) Project built a prototype mesh node which had a MoV board with the goal of enabling the mesh board in the VPN clients to download from the camera to a local storage device.

Synchronized audio-video measurements, designed to provide a panoramic representation of human interactions in a command center environment, were taken in the UCSD Tech OPS Center. Legal issues unfortunately prevented this from being conducted in the police command post (the original target location). A small network of two Mushroom boxes was deployed and various tests were performed regarding the performance of the spatial diversity feature of the system.

The datasets from these numerous applications and the network measurements are not posted for public use, due to the nature of the data and possible privacy issues. However, the data is available to outside researchers via email request.

Creation of 'turnkey' systems for deployment of the communications and networking technologies are being developed, including integration protocols. Performance metrics per configuration choices are being captured as tests are run. Parameters and instructions are under development and lists of all needed equipment from the sophisticated to the mundane have been drawn up for many of the technologies.

2.1.2.4 Champaign Testbed

Testbed Summary:

The Champaign Testbed is a partnership between the RESCUE project, the City of Champaign, and first responder organizations in Champaign.

The Champaign Testbed provides an opportunity to explore challenges in crisis response and study the efficacy of IT disaster research and solutions in a smaller-city setting. More precisely, this testbed provides:

- Opportunities to experiment with artifacts from the RESCUE project.
- Opportunities to study organizational decision-making in crises that occur in a medium-size city.
- First-responder input into requirements for RESCUE artifacts.

Our primary focus this year has been on building a realistic, detailed disaster scenario to act as a motivating use case for PISA's policy-driven information-sharing architecture, for the sociology focus groups planned for Champaign, for potential use in tabletop exercises conducted by the City of Champaign, and as a source of potential applications of RESCUE artifacts.

Year 3 Milestones and Deliverables:

1. *Sociological studies:* We plan to run three sociology focus groups in Champaign in August 2006, discussing the disaster scenario described below.
2. *Requirements for chemical spill scenario*: During the past year, we created the chemical spill scenario described below.

Activities and Findings:
During the past year, we worked with emergency response organizations to develop a disaster scenario focusing on a train derailment in Champaign with an associated chemical spill and danger of explosion. This scenario will serve as the topic for the sociology focus groups in Champaign, as a source of potential applications for RESCUE artifacts, as a focusing scenario for PISA, and as the expected basis for tabletop exercises with city agencies over the coming year.

The Champaign Fire Department and Champaign Emergency Operations Center worked with us to put together an initial 8-page version of the scenario. Then we met with over a dozen stakeholders from the set of first responders for the scenario, including city officials (shelters, finance, and transportation), fire department and EOC administrators (fire lieutenant, hazmat specialist, public information officer, EOC head), police department, Red Cross (Champaign and Peoria chapters, and ham radio organization), medical responders (two local ambulance companies and the local Level 1 Trauma Center mass casualty coordinator for Carle Hospital), MTD (transit district), METCAD (911), and Unit 4 (school district, for evacuation aspects of the scenario). The meetings were conducted one-on-one with each organization. The resulting notes have been distilled into a detailed version of the scenario and shared with PISA project participants and with the city of Champaign.

We analyzed the detailed scenario, looking for gaps in the response to the crisis, and wrote up our findings. We have shared those findings with the city of Champaign. We also looked for opportunities for technology insertion, wrote up those findings, and shared them with PISA project participants. A number of these opportunities are good matches for artifacts being developed by the RESCUE project.

In addition to the scenario-related activities, Champaign has shared a portion of their library of fire calls and of 911 calls with the RESCUE project, for use by researchers throughout the project. In addition, the RESCUE project has given the city three network-in-a-box nodes, which the city plans to use in conjunction with its new high-tech mobile networking trailer to extend networking out into the field during disaster response.

As is clear from the description above, the Champaign Testbed has a very strong community outreach component. We could not have put together the derailment scenario without extensive involvement from the community. At the same time, the process of putting together the scenario has uncovered several problems in the way that first responders in the City of Champaign would respond to such a disaster, in the form of gaps between responders' expectations of one another and what can actually be delivered. The city's eventual resolution of these problems will be a benefit that accrues to the city in return for the effort that the city put into assembling the scenario. The city also plans to benefit from the scenario by using it as the basis for tabletop exercises with city agencies over the coming year.

The sociology focus groups in Champaign will explore certain aspects of the response to the derailment scenario. In addition to serving its intended purpose of providing interesting fodder for analysis of the results by RESCUE sociologists, the discussion that takes place at the focus groups will benefit the city, as the Champaign city manager is very interested in being prepared for a possible derailment in Champaign.

2.1.3 Integrative Artifacts

While each one of the research projects described in Section 2.1.1 involves long-term research explorations, we are making a concerted effort to build derivative system artifacts of direct value to response organizations. Building such artifacts serves multiple purposes: (1) they provide focus and context for research and expose new research challenges at interdisciplinary boundaries, (2) they provide concrete mechanisms to create and sustain collaborations amongst PIs, (3) they help to engage input from the user community in all phases of research: design, prioritization, testing, and validation, (4) they provide natural conduits to explore technology transfer opportunities, and (5) they can serve as a legacy of the RESCUE program beyond the five years of funding of the project. Artifacts chosen have an associated partner from the user community who will serve in an advisory capacity and/or participate in the artifact development and will also serve as early adopters and testers.

SAMI Artifact – EvacPack Reconnaissance Artifact. This artifact is a system for reconnaissance information capture. Our goal is to develop and demonstrate an end-to-end system for multi-modal situational information capture, with the eventual goal of the multi-modal data captured being useful for real-time situational awareness analysis or for post situation analysis and assessment.

This artifact is actually the integration of two efforts that were initiated, originally independently. One is an “EvacPack” (a mobile information capture platform using which a responder can capture and transmit real-time text, audio, and video situational information) which has been developed at UCI. We are integrating this EvacPack with VIEWS, a software system that has been developed and used extensively by ImageCat for reconnaissance data analysis (such as damage assessment tasks).

For the EvacPack, we have completed the development of a mobile, wearable hardware sensor platform, with the following features and capabilities: audio and video information capture, GPS and other positioning indicator capture, heading and acceleration sensors, and video goggles, which will aid in visualization for a mobile user wearing the system. We are also currently developing a software infrastructure to manage multiple mobile sensor sources. This infrastructure includes: streaming (text data, audio, and video), data storage / management, temporal synchronization of various data, and visualization for analysts or people working in an EOC

Multiple possibilities are under consideration at this point for the integration of some of the research thrusts into the EvacPack artifact; namely, the integration of the E event database with the EvacPack. The event database will serve to model and store the multi-modal data collected by the EvacPack. We have already made progress on this and a first integration of the E event database with the EvacPack will be deployed and evaluated as part of the June 22 UCI Calit2 Drill. A second effort involves audio event extraction. We will apply research results from the audio event extraction thrust to extraction of events from the audio information captured by the EvacPack (deployed in planned drills and exercises). In the area of text extraction, we will apply research results from work on event extraction from conversations to (transcribed) conversations captured by the EvacPack. Given the early stage of the conversation extraction work, it may be more realistic to consider this integration at a later stage. Finally, we plan to demonstrate the effectiveness of the spatial reasoning and indexing in the context of location references captured by the EvacPack in drills and simulations.

Note that we see possibilities for connection to research thrusts beyond SAMI as well for the EvacPack artifact. For instance we can foresee problems that will need to be addressed in areas such as multi-modal information transmission and distribution where the EvacPack may be deployed in environments with partial network coverage and low network bandwidth. This is a possible connection to some of the research in the Dissemination Project which may be applicable here.

Researchers at UCI have been working with ImageCat, developer of VIEWS software, who have direct experience in reconnaissance data gathering and processing and knowledge of real-world disaster issues. We will continue our integration with VIEWS software, an industry tool currently in real-world use, and are engaging active participation of ImageCat to guide the reconnaissance artifact development to demonstrate its value to alleviating the problems associated with reconnaissance data processing.

SAMI Artifact – Ontario Portal. This artifact is a portal website which allows the Ontario Fire Department (OFD) to provide informational and interactive emergency management-related communication with Ontario residents. Our goal is to work with emergency response organizations to prototype a web information portal where we can 1) provide simple but very useful and much desired capabilities to citizens, analysts, and responders during local disasters., and 2) use the implemented portal as a conduit for evaluating some of our advanced research, for instance in areas such as traffic event detection from loop sensor data, reliability measures for assertions in (portal) online postings etc.

We have completed implementation of capabilities for announcements/instructions, interactive easy to use maps with situational information, and integration of emergency shelter information with a database of shelter information with an easy-to-use map oriented interface; and a database for tracking disaster evacuees. We are also currently working on developing a preparedness guide, an online donation management capability and on the integration of damage reporting tools into the Portal. The Portal is designed with the intention that it could be easily adapted for use by other municipalities or organizations. A beta is available at http://www.disasterportal.org/ontario

The Ontario Portal artifact holds multiple possibilities for research integration which are under consideration at this stage, including text extraction and refinement, where we can demonstrate the effectiveness of research in text extraction and information refinement to create structured (event) data sets from raw online text sources of information; GIS data search, to demonstrate the effectiveness of research on GIS data search and integration in the context of the Ontario Portal; and finally, predictive modeling, which will demonstrate the effectiveness of research on event detection from traffic loop sensor data in the portal context using actual local traffic data.

The Ontario Portal also holds possibilities for research connections beyond SAMI. It was expressed to us by the OFD personnel that they also have a critical need for a system that can alleviate the high volume of 911 calls they receive during a local disaster. They would also like more scalable means to notify people or specific groups of people (say parents of children of a particular school) with status and/or instructions in such situations. Such problems relate directly to the research in the Dissemination Project.

There are connections to research in the Information Privacy project. The privacy of information belonging to individuals is of prime importance at all times, including disaster situations, and a balance needs to be struck between information that is released (in a situation such as individuals are trying to trace family members or relatives), and information that is preserved. Another privacy aspect arises because this portal may actually have multiple categories of users, such as lay citizens and people in an official capacity such as responders and analysts. We may need to provide mechanisms to control what information can be accessed by whom in that case. We will explore these possibilities in detail in Year 3.

The Ontario Portal has a strong collaboration with the City of Ontario Fire Department (OFD), which is the agency that initiated and championed this artifact in the first place. We have had regular visits and meetings with the OFD including their analysts, deputy chief and IT and GIS support staff. The OFD is playing a key role in defining the key capabilities being developed in the portal.

The OFD is expected to play a key role in the continuation and outreach activities for the Ontario Portal. The City of Ontario will be the first testbed for the portal deployment. Through the OFD, we also have plans to integrate the Portal with other government information sources through WebEOC – a commercial data integration software product currently in widespread use and adoption by emergency organizations throughout the United States. As the Portal reaches maturity, plans for transition into a deployable system by the City of Ontario and beyond are also under discussion.

SAMI Artifact –The Hurricane Portal. We have recently initiated the development of a national-scale Hurricane Portal in collaboration with Convera Inc. and ImageCat Inc. Our goal is to develop a portal for disasters (such as hurricanes) for real-world and large-scale use by exploiting the industrial strength search engine development technology provided by Convera Inc. We aim to provide 'faceted' navigation and search capabilities to analysts and post disaster information gathered from online information sources.

Even at this early stage, we are seeing connections of this artifact with a couple of research thrusts in SAMI. For example, in the area of exploratory event analysis, the Hurricane Portal is intended as a tool for analysts who are interested in specialized navigation and query retrieval. Our work on graph analysis over events and relationships could be applied here. In considering information reliability, we are finalizing a plan where we will use this Portal to gather, extract and integrate data (from online sources) to help answer a specific end user damage assessment query. We are considering incorporating information reliability and certainty measures in the information pipeline.

We have a strong collaboration with Convera, a leading knowledge management company which will be providing us with industrial strength tools and products for web data crawling, indexing, and faceted search. We are also collaborating with ImageCat who will serve as domain experts for the definition of ontologies covering the specific domain of interest and that will be exploited in the end user search and navigation.

Robust Networking Artifact – Extreme Networking System (ENS). The Extreme Networking System (ENS) is the artifact from the robust networking and information collection project and the ENS system is a robust networking infrastructure which provides computing, communication, and intelligent information collection, management, and maintenance systems, for use on site at ground zero, in the event of emergencies. Given the possible environmental constraints such as lack of electric power, partial or full unavailability of fixed communication networks, and the presence of heterogeneous sets of communication technologies, designing an ENS is a challenging task yet ENS is critical to information collection, management, and dissemination process, which are essential components for creating situation awareness. Thus ENS is an enabler for the higher-layer functions that support situational awareness that are being developed as part of this project.

The primary goal behind the artifact is to provide an efficient, reliable, and scalable network infrastructure for aiding the emergency response activities when the existing networking infrastructure fails or becoming non-functional. Other objectives of this artifact it to make the application of research ideas developed as part of the robust networking and information collection research project in RESCUE. A more detailed discussion of this artifact can be found under Project 2 (Robust Networking and Information Collection) activities, Section 2.1.1.2.

For Year 4, the artifact development plans are the following: i) to develop modular networking system for flexible and hot swappable networking protocols, ii) development of advanced medium access control protocols, iii) development of high reliability routing protocols, iv) development of network management system. In addition to the above mentioned action items, we also plan to develop a robust version, UrbanMesh, of the ENS artifact in order to utilize in urban wireless mesh networking. The initial design for the UrbanMesh has been initiated and is expected to be completed within Year 4.

Enterprise Service Bus Artifact. The enterprise service bus (ESB) serves many functions, one of which is to loosely couple disparate systems. It also allows logic encapsulated in components to be loosely coupled to the ESB, so that logic can be applied to incoming and outgoing data. It provides a range of functions to offer more flexible and manageable ways to enable a disparate range of applications to work together. The central element to an ESB is a message bus that is used to ‘wire’ different components or applications to the bus. In particular, the ESB allows the developer to rapidly and flexibly create business processes based on the resulting architecture configurations. The goal of employing an ESB is to provide a unified method of interacting with data from disparate sources without encumbering the developer with the details about how the data is sent or received or the protocols involved.

During the Mardi Gras event that took place in downtown San Diego (GLQ Testbed), one aspect of the Location Based Tracking (LBT) system was to collect GPS data from cell phones and record this information to a database. The ESB took an active part in this scenario and was configured to frequently poll the LBT system for updated cell phone locations. GPS enabled cell phones were deployed and the whereabouts of the cell phones were tracked on a Google map as pin points, shown on a screen in the UCSD Tech Ops Center.

HTTP was chosen as the protocol between both systems and XML as the messaging format. HTTP was selected because the LBT system already had an exposed HTTP interface. The ESB supports FTP, email, file, Multicast, SMTP, Soap, TCP, UDP, Pop3 and HTTP. Since the LBT had an available HTTP interface, we chose it as the protocol between both systems. XML was selected as the messaging transport because it is a standardized means to sending messages between heterogeneous systems. An XML request and response model was collaboratively agreed upon and utilized. The ESB requested information from the LBT by sending an XML request over HTTP. The LBT would handle the request then return an XML response also over HTTP. The requests made by the ESB were synchronous. The user interface (UI) dynamically generated the cell phone locations on a Google map.

The integration implementation between the ESB and the LBT system was a success. Both systems were able to exchange data throughout the entire event without any issues and for the entire length of the event. This was due mostly to the stability of both systems and the network.

Next Steps: Future plans for the ESB include integrating Tropos and CalMesh nodes to collect node metrics; provide objects within a boundary given GPS location, boundary type and boundary radius; and integrate 'Call to Collaborate' and integrate speech recognition. The web portal based front end for the Enterprise Service Bus can be accessed at http://www.dsscc.com.

Policy-based Information Sharing Architecture (PISA) Artifact. This artifact is intended to embody the research results of the PISA thrust along with other artifacts from throughout RESCUE, all focusing on a single disaster scenario: a train derailment with chemical spill, fire, and danger of explosion in Champaign.

Research to be integrated into the Artifact: As described elsewhere in this report, during the past year, we have worked with organizations in the city of Champaign to develop a detailed version of the derailment scenario and identify opportunities for RESCUE technology insertion. With the scenario in place, we have identified the artifacts and research from elsewhere in RESCUE that are relevant to the scenario. It is not yet clear whether this research should be integrated into a *single* artifact, as the derailment scenario has multiple distinct populations of potential IT users (e.g., first responders and evacuees), and their needs may be best served by separate artifacts. The relevant research:

1. *Information dissemination and next-generation 911 services*.
2. *Information integration*. RESCUE technology for information integration is needed to help with the problem of proliferation of family reunification and disaster welfare inquiry web sites. The tasks include: automatically find such sites, parse their interfaces, extract information from the databases behind them and from free-text entries (including tasks such as entity and relationship identification), integrate the information gleaned from multiple reunification web sites and make it available through a single one-stop-shopping interface.
3. *Privacy*. Family reunification web sites raise interesting privacy issues, a topic of interest in RESCUE.
4. *Extreme networking*. RESCUE's network-in-a-box technology can allow responders in the field to transmit pictures and video of the derailment scene to the EOC, and for other purposes.
5. *Computer security*. Champaign has been experimenting with the US government's Disaster Management Information System (DMIS) for cross-organizational information sharing during crises. DMIS is cumbersome to set up and its security is rigid enough to limit its use in a crisis. Extensions to DMIS are likely to become the core of the artifact produced by the PISA project, and possibly for integrating MetaSim as well.
6. *Event analysis*. SAMI may be useful for plume analysis, filtering out an overload of information arriving over DMIS, and possibly in evacuation planning.
7. *InLET loss estimation tool*. If the derailed tank cars explode, InLET's loss estimation capabilities can give a quick estimate of the dollar magnitude of the destruction.
8. *Sensors and sensor data analysis and reduction*. The fire department is interested in RESCUE "manpack" technology, which equips firefighters with sensors, a computer to process data from the sensors, and the capability to send the resulting summaries over the internet. This information could be fed into DMIS.

Government and Industrial Partners: Our partners are the city of Champaign, the Champaign Red Cross, and Champaign ambulance companies. Details are available in the discussion of the Champaign Testbed.

Plans for Continuation and Outreach via Artifacts: We will continue our partnership with the organizations mentioned above as we work to design the PISA artifact over the coming year.

Artifact Plans for Year 4: With the derailment scenario now in place, we have moved on to formulating requirements for the PISA artifact. Our focus in the next year will be on the design of the artifact and on working with researchers throughout RESCUE whose research will be represented in the artifact.

MetaSIM Artifact – DrillSim. DrillSim is designed as a multi-agent crisis response activity simulator focusing on evacuation which has plug and play capabilities. The software will live beyond Project RESCUE as a tool to assess the integration of various technology solutions for evacuation. DrillSIM is discussed extensively in the MetaSIM Testbed section.

MetaSIM Artifact – InLET. InLET is designed to be used by first responders, planners, and anyone involved with emergency response. It is a tool that can be used to estimate likely levels and locations of damage and how one might plan critical response activities. Outreach activities have involved city, county, state, and federal emergency management agencies. InLET simulates crisis after a disaster as part of MetaSIM, but stands alone as a real-time, online loss estimation system for Los Angeles and Orange counties in California. InLET is discussed extensively in the MetaSIM Testbed section of this annual report, see Section 2.1.2.1.

MetaSIM Artifact – Transportation Simulator. In addition to simulating an evacuation activity in case of a large regional disaster, the transportation simulator can be used to assess various evacuation schemes for tsunami or hazardous materials release. The transportation simulator is currently being evaluated by Caltrans for use in their District 7 traffic operations. The transportation simulator is discussed in the MetaSIM Testbed section, see Section 2.1.2.1.

Dissemination Artifact: A Real-Time Crisis Alert System. In Year 3, we initiated within RESCUE, the development of a "Real-Time Crisis Alert System". Its goal is to create an automated system to disseminate information to a variety of organizations and to the public in the event of a disaster, particularly focusing on rapid delivery of critical information to schools and parents of children in schools. The dissemination will be done by exploiting the organization's emergency plans by sending, for every event, the right information to the person in an organization that, according to the emergency plan, should receive it. The information is also customized to accommodate the modality via which individuals in the organization choose to receive the message (Internet, telephony, radio etc.). The primary advantage in leveraging existing emergency plans of organizations is that they can now have increased utility since participants in the response plan (including the general public) have updated, relevant and customized information easily available to them. Our initial focus is on developing a seismic alert and warning system for K-16 schools.

As discussed in our strategic plan, our rationale for choosing the real-time seismic alert warning scenario has been articulated earlier in the research plan. Our undertaking of the development of the real-time alert artifact is based on several considerations, including:

- Our familiarity and access to the scientific, technological, and policy issues associated with issuing such alerts.
- Renewed interest in developing techniques for earthquake prediction and early warning in California, stemming in part from new scientific discoveries and actual predictions. Since RESCUE is currently in the process of devising technologies for rapid alerts, RESCUE can contribute to the implementation of systems that the state might develop.
- Schools were always considered by the state of California as participants in the real-time alert system. RESCUE has the opportunity to conduct pilot studies with schools in order to test prototype flash dissemination systems. Moreover, RESCUE has recently forged relationships both with school systems in the greater Irvine area and with the School Broadcasting Company, a technology company that specializes in customized information dissemination systems for schools. The School Broadcasting Network already has in place procedures for disseminating information from schools to parents during non-disaster times. This would, then, constitute a "dual use" system with which parents are already familiar.
- Access to individuals who are closely involved with policy development and planning for real-time alert systems are in the Southern California area including potential users, such as the City of Los Angeles.
- The location of the greater Irvine area is in an ideal geographic position to benefit from real-time warnings associated with earthquakes on the southern San Andreas Fault.
- Reuse possibility since once a prototype school-based system is developed for one hazard, it can be further adapted to multi-hazard contexts, particularly those involving very short or no warning periods (e.g., terrorist bombings, tornadoes).

The architecture of school crisis alert system is organized as shown in Figure 4. The dedicated content server, using a software module called Content Generator, receives the critical information from official entities, such as earthquake information from USGS through the ShakeCast protocol, or through manual notification/insertion of events, for example, by emergency personnel. From the description of the event, according to a predefined but modifiable policy, it is decided which type of schools should receive the notification and the kind of message that should be sent to them. The notification has usually the form of an action to take (evacuate, contact the emergency personnel) but it can be also informative (how to recognize and treat for exposure to a particular chemical, up-to-date information on road blockages in the vicinity of the school, etc). The type of events handled by the system and the policy definition is flexible: the form of notification can depend on the type of event, the kind of school and its location and the presence of nearby facilities, e.g. chemical facilities, and any related information that the system can maintain access to. Each combination of parameters is called *organization selection predicate.* Different schools can receive different notifications that inform them about the particular dangers that they will face during the crisis. For example, a school in a area strongly hit by an earthquake probably will need information about the nearest hospital and information about the state of the transportation network to be able to get the kids outside and drive the injured ones to a nearby hospital; a school near a chemical facility probably will need information about the type of chemical with which the facility is working and how to eventually treat an intoxication by it. The policy does not define a complete message; it is a template that describes which information is needed by an organization. The instantiation of this information into actual data is done by the next module, the Organization Message Generator.

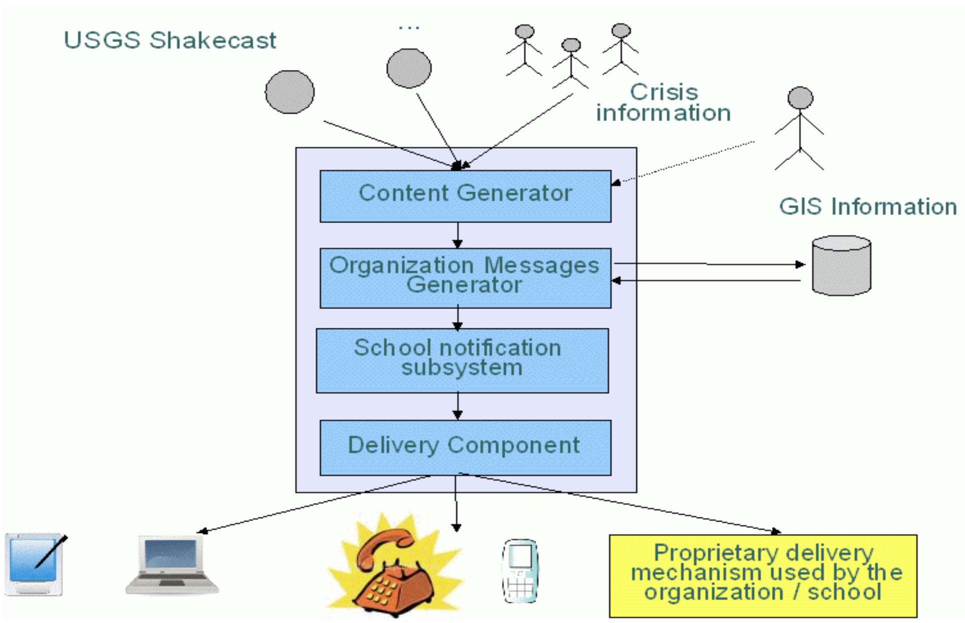

Figure 4: System Architecture

The *Organization Message Generator* evaluates the organization selection predicate on the GIS data to obtain the list of schools involved in each notification. The message can be personalized for each specific entity, according to type, location and other school's characteristics. Examples of personalization are a detailed map of the area near the school, location and contact information of the nearest shelters and hospitals or the state of the transportation network, like bridges and roads.

The new messages are then sent to the specific *School Notification Subsystem* that implements the emergency notification procedure of each school. To be able to deal with different organizations other than schools, the system permits the definition of other subsystems to accommodate personalized emergency procedures. This module individualizes the actual recipients of the message according to the local school's policy. Each recipient can define how he/she prefers to receive the notifications: different modalities are integrated in a seamless way, so it's possible to receive the messages as special notifications on a computer, as a text messages or a call on a phone or on a PDA.

The list of recipients and the messages are then elaborated by the *Dissemination Module*. It implements the actual communication mechanism used to deliver the messages. Specific mechanisms can be Internet through the use of the RAPID dissemination system (developed within the RESCUE project), a innovative P2P technology for flash dissemination of information that is fast and scalable to thousands of nodes , a message on a PDA or a notification through the standard phone infrastructure (phone call, text message). If the school or organization has already enacted a notification infrastructure (for example an automatic dialer that calls a predefined set of numbers), it can be integrated into the system as a proprietary delivery mechanisms to leverage the existing and working infrastructure.

In Year 3, we have developed an initial prototype of such a system and demonstrated it to our government partners at the Earthquake Information Dissemination Workshop held in Irvine in May 2006. While this is a preliminary version of the system, it has generated significant interest amongst our partners and our plans are to significantly enhance the prototype into a deployed implementation in collaboration with our industry and government partners in Year 4. Our implementation platform leverages computing, communication and storage facilities in the Responsphere infrastructure and CAMAS testbed.

2.2 OPPORTUNITIES FOR TRAINING AND DEVELOPMENT PROVIDED BY THE PROJECT

In addition to the primary emphasis of graduate level education, our RESCUE students are encouraged to take advantage of myriad training and development opportunities made available by the program. These include serving internships in industry, presenting papers at technical conferences, and participating in weekly and monthly meetings.

Because all members of the research team are working on closely-related problems, by necessity diverse areas of expertise are united by a common task set. We expect students supported by this grant to develop more diverse skill sets, to obtain familiarity with a wider range of scientific literature, and to be better able to bridge disciplines in their own work than their traditionally trained peers. This group of younger researchers form a community that is held together not only by the high scholarship expected of post-graduate researchers but also by a shared bond of applying scientific and technological methods to deal with the universal sense of horror that the events of September 11th unleashed. Outside of their own scientific domains, we expect this unique experience to motivate our students to serve in the community as scholar-citizens who can articulate modern approaches to understanding vulnerability and threats and responding to crises, and in doing so help reduce the public anxiety about rare, unexpected events. Some of the specific activities which promote training and development opportunities are listed below:

Student Research Exchange Program – Internships

Shankar Shivappa, UCSD: internship at AT&T Research Labs, summer 2005. Shankar Shivappa (UCSD) worked during the summer of 2005 on an internship with AT&T Research Labs. His work there focused on using multiple feature extraction techniques and information fusion techniques for large vocabulary continuous speech recognition (LVCSR) tasks. Though Mel-frequency cepstral coefficients(MFCC) are the most commonly used speech features in LVCSR tasks today, other features like the Perceptual linear predictor(PLP) coefficients and Minimum variance distortion less response(MVDR) coefficients have been shown to be equally effective or superior to MFCC. The project involved the comparison of different feature extraction techniques on the SwitchBoard task. All three features were found to perform equally well. A method of regularization of the clean-speech-trained Gaussian mixture models (GMM) for use with noisy speech was also investigated and found to be effective. The method was based on the relaxation of the GMM covariance matrices. He also attempted the high-level fusion of the speech recognition results obtained by using different feature sets. This did not yield significant improvement. By conducting a detailed analysis of the results, he deduced that the MFCC, MVDR and PLP feature sets do not provide complimentary information as far as speech signals are concerned. This explained the lack of improvement due to information fusion.

Mirko Montanari, UCI: Graduate Exchange Student: *University of Bologna*. Mirko Montanari was an exchange student at UCI from September 2005 to March 2006. During which he worked on a preference enabled analysis process which provided an interactive way of finding the best matched record in a database according to a user's preference. Montanari impressed the RESCUE team so much that we asked him to extend his stay with us until December 2006 as a programmer. He is currently working under the Dissemination Project, designing the real-time alert system in collaboration with our partners, The School Broadcasting Company.

Nicolas Pawlaczyk: Nicolas is a student from Telecom Lile in France. He instrumented the CalIT2 building with sensors that communicate over the existing powerlines (i.e., copper-based power grid system). The goal is to provide low bandwidth sensor information over yet another layer 1 infrastructure. During a disaster event, this could provide a redundant source of information outside the normal layer 1 communications infrastructure.

Nicolas Demaegdt and Charlotte Petyt, UCI: Graduate Exchange Students. *University of Lille, Villeneuve d'Ascq, France.* Nicolas and Charlotte are doing an internship with the RESCUE project between June 2006 and Aug 2006. During their assignment, they have been working on networking projects within the CAMAS testbed which include working with the CalMesh routers. The also actively participated in the June 22, UCI Zone 3 drill.

Arn Womble, Texas Tech: Working with ImageCat as a Post-Doctoral student in defining hurricane building damage states from satellite photos.

Carol Friedland, Louisiana State University: Working with ImageCat, this PhD candidate is exploring how best to quantify building damage states from hurricane storm surge effects. An important aspect of this work is the use of remotely-sensed images for damage assessment and GPS-based technologies for post-disaster reconnaissance.

Orange County Fire Authority Internship: One internship project directly related to SAMI is proposed for the coming summer (2006). The project is to develop a prototype situational information dashboard for the Orange County Fire Authority (OCFA). The intended duration is June-Aug 2006. Alfred Anguiana is an undergraduate student being considered for this internship.

Dana Point Emergency Services Department Internship: Discussions for another proposed internship during summer 2006 have begun with the City of Dana Point Emergency Services Department. Initial project plans include database migration and coding. Shengyue Ji is a graduated student being considered for this internship.

Sophia Liu, University of Colorado, Boulder: Summer school program at Tilburg University in the Netherlands titled "Blended Crisis Response Teams: linking on-site teams and on-line communities" This Information Systems for Crisis Response and Management (ISCRAM) Community 2006 Summer School aimed to provide the participants with an intense interactive learning experience on the use of information systems and technology to support collaboration and decision making among 'real' or on-site crisis response teams and 'virtual' or on-line experts. The course was targeted to students in PhD programs in fields with research interests related to crisis management. It was a co-organization of the ISCRAM Community and the Dutch Chapter of TIEMS (The International Emergency Management Society).

Interactions with Government and RESCUE Partners:
Close and ongoing interaction between the research team and various public safety and emergency management organizations is essential to discovering the real needs, priorities, constraints and processes followed by crisis management personnel. Some examples of this type of interaction include:

- Monthly planning meetings with UCI Environmental Health & Safety and RESCUE researchers. Discussions are held regarding drill, infrastructure, and testbed planning.
- UCI RESCUE researchers also participated in the annual UCI first responder forum.
- Regular Environmental Health & Safety (EH&S) drills on the UCI campus that allow social scientists, computer scientists and IT specialists to observe emergency management in practice, and collect and process data used in information collection, analysis, sharing, and dissemination research.
- Collaboration with UCSD Campus Police to validate new technologies, learn more about their needs and gain exposure to other technology-related groups within the local San Diego first-responder community have continued; in addition, UCSD has strengthened the relationship with UCSD Emergency management and Environment, Health and Safety (EH&S) groups. We have participated in on campus drill (November 15, 2005) and are currently preparing for a large scale exercise in conjunction with UCSD disaster response projects, emergency management/campus police, and the San Diego regional Metropolitan Medical Strike Team (MMST), which till take place on August 22, 2006.
- UCSD researchers collaborated with the San Diego Police department to deploy a wireless network equipped with sensors in downtown San Diego for the February 28, 2006 Mardi Gras event. The objective was to better understand the technology requirements of the police and to see how we can help them enhance their situational awareness of crowded venues.
- The above examples and several others are explained in the Outreach section of this report.

Visits by Senior Officials:
UCSD: San Francisco Mayor Gavin Newsom and staff, 23 March 2006: tour of Rescue research facilities and demonstrations, particularly in the networking and traffic management areas

US-India Summit on Education, Research & Technology, 31 May 2006. Demonstrations of RESCUE research were presented, including a mesh networking demonstration, traffic management, and situational awareness to the following dignitaries from India: Honorable Kapil Sibal, Minister, Dept. of Science and Technology and Ocean Development; Avinash Dikshit, Personal Assistant to Mr. Sibal; S Bagchi, Delegate with Mr. Sibal; Kamal Dwivedi, Counsellor (Science and Technology), Embassy of India; V.S. Ramamurthy, Chairman, Indo-U.S. Science and Technology Forum; Arabinda Mitra, Executive Director, Indo-U.S. Science and Technology Forum; Smriti Trikha, Science Officer, Indo-US Science & Technology Forum ; Aruna Katara, Executive Chair, I2IT, Pune. The purpose of the summit, as described by Ramesh Rao, was "to explore new avenues for Indo-U.S. collaboration on education and research programs designed to improve science and engineering talent for corporations and universities in both countries." During the summit, 150 invited officials from industry, academe, government and non-governmental organizations in India and the United States met to explore strategic issues in high-tech research and education as they apply to those countries. Attendees included representatives form NSF: Kathryn Sullivan, Deputy Director of OISE (invited speaker); and Dr. Usha Varshney, Director, EECS.

Meetings and Workshops:
Weekly meetings. Weekly RESCUE meetings continue on both the UCI and UCSD campuses, allowing students, faculty, and government and industry partners to share in research findings, discuss possible implications of research, and identify additional opportunities to leverage

current research to address timely issues or problems. These meetings are very useful in educating our students and researchers about the field level reality from the emergency response perspective. Documentation from a selection of the weekly meetings, including presentation slides, can be accessed at http://www.itr-rescue.org/outreach/rescuemtg.php

Lecture Series. In pursuit of broadening the education of its students and creating opportunities for collaboration, the RESCUE project has hosted three sets of lectures series this year. These lecture series provide a chance for students to realize the applicability of their work in the real world, opens new directions for research, and introduces outside parties to the work being done in the project. More information about these lectures can be found at http://www.itr-rescue.org/outreach/seminars.php

RESCUE Seminar Series (2005-6)

- June 8, 2005 – Dr. Gopal Pingali, Research Staff member, Pervasive Computing Solutions, IBM T. J. Watson Research Center, presented the talk “Electronic Chronicles: Empowering Individuals, Groups, and Organizations”
- July 28, 2005 – Dr. Craig Knoblock, Senior Project Leader, Information Sciences Institute and Research Associate Professor in Computer Science, University of Southern California, presented the talk “Integrating Geospatial and Online Information Sources”
- August 22, 2005 – Dr. Arun Hampapur, Manager, Explorator Computer Vision Group, IBM T. J. Watson Research Center, presented the talk “Computer Vision Research at Watson: From VeggieVision to PeopleVision”
- August 31, 2005 – Dr. Arnon Rosenthal, Principal Scientist, Department of Cognitive Tools and Data Management, Center for Information Technology, The MITRE Corporation, presented the talk “Administration Challenges for Enterprise Data: Overview and Research Challenges”
- October 3, 2005 – Dr. Susanne Boll, Assistant Professor, Department of Computing Science, Multimedia and Internet-Technologies, University of Oldenburg, Germany, presented the talk “Context is King – or How Context Influences Multimedia Engineering”
- October 4, 2005 – Dr. J. Chris Scott, Director, Queensland Laboratory, National ICT Australia, presented the talk “Disaster Prediction Response and Recovery (DisPRR) – Australia coming to the RESCUE”
- January 12, 2006 – Dr. Raghu Ramakrishnan, University of Wisconsin, presented the talk “Discovering Interesting Subsets of Data in Cube Space”
- January 27, 2006 – Dr. Cyrus Shahabi, University of Southern California, presented the talk “GeoDec: Enabling Geospatial Decision Making”
- February 15, 2006 – Dr. Graham Campbell of Ether2 presented the talk “Distributed Que Switching Architechture”
- March 10, 2006 – Dr. Jerry Hobbs, Information Sciences Institute, University of Southern California, presented the talk “Ontologies for the Semantic Web”
- June 30, 2006 – Rich Toro, Orange County Fire Authority, presented the talk “Advanced Technology in Orange County Public Safety”

RESCUE Distinguished Lecture Series (2005-6)

- November 4, 2006 – Dr. Umakishore Ramachandran, Professor, College of Computing, Georgia Tech, presented the talk "DFuse and MediaBroker: System Support for Sensor-based Distributed Computing"
- April 21, 2006 – Erin Kenneally, M.F.S., J.D., Cyber Forensics Analyst, San Diego Supercomputer Center, UCSD, presented the talk "The Confluence of Technology on the Enforcement, Application and Interpretation of Law: Is the Tail Wagging the Dog?"

RESCUE Next-Generation Search Series (2005-6)

- April 12, 2005 – Dr. Claude Vogel, Chief Technology Officer, Convera, presented the talk "The Web You Trust: The Next Generation of Vertical Search"
- May 1, 2006 – Bradley Horowitz, Vice President, Product Strategy Group, Yahoo!, presented the talk "The Changing Face of Web Search"
- May 8, 2006 – Suranga Chandratillake, Chief Technology Officer and Founder, Blinkx, presented the talk "Context, context, context: the next law of search"
- May 15, 2006 – Dr. Marti Hearst, Associate Professor, School of Information, UC Berkeley, presented the talk "Faceted Metadata in Search User Interfaces"

Workshops:
On May 26, 2006 the RESCUE project hosted its first Earthquake Information Dissemination Workshop. Invited guests included representatives from schools, the California Office of Emergency Services and other government organizations, seismologists from CalTech and UC Berkeley, and industry. Through this workshop, we were able to gain valuable insights into what various organizations need in an information dissemination system and identified multiple opportunities for collaboration.

2.3 OUTREACH ACTIVITIES THE PROJECT HAS UNDERTAKEN

2.3.1 Outreach to the Scientific Community

The following workshops, keynote addresses, panels, demonstrations, and invited talks have been organized/delivered as part of the RESCUE outreach effort:

1. Charles K. Huyck, Solutions to Coastal Disasters 2005, keynote presentation: Use of Integrated GPS, Imagery, and Remote Sensing Following the Southeast Asian Boxing Day Tsunami and Niigata Ken Chuetsu Earthquake.
2. Charles K. Huyck, Managing Risk in the 21st Century: Creating the Global Earth Observation System of Systems – Balancing Public and Private Interests, Panelist.
3. Beverley J. Adams, Post-tsunami Urban Damage Assessment in Thailand, Using Optical Satellite Imagery & the VIEWS™ Field Reconnaissance System, November 4, 2005.
4. Beverley J. Adams, The Application of Remote Sensing Technology for Disaster Management & Response, Cambridge University, April 27, 2005.
5. Beverley J. Adams, Remote Sensing Technology for Response and Recovery, MCEER Annual meeting, Sacramento, CA, February 25-26, 2005.

6. Ronald T. Eguchi, MCEER Remote Sensing Research following the December 26, 2004 Asian Earthquake and Tsunami, MCEER Annual meeting, Sacramento, CA, February 25-26, 2005.
7. Ronald T. Eguchi, Remote Sensing and GIS in Disaster Management, 1st International Conference on Urban Disaster Reduction, Kobe, Japan, January 18-20, 2005.
8. Charles K. Huyck, Reconnaissance Technologies: Lessons from the Niigata Ken Chuetsu Earthquake and Southeast Asian Boxing Day Tsunami, EERI Annual Meeting, Mexico, February 2005.
9. Kent Seamons, Program Committee Chair, 5th Annual PKI R&D Workshop, NIST, Gaithersburg, MD, April 2006.
10. Kent Seamons, *2005 Web Policy Zeitgeist,* Invited panelist, The Semantic Web and Policy Workshop, Galway, Ireland, November 7, 2005.
11. Marianne Winslett, "Trust Negotiation: Ready for the Real World?" invited seminar at the University of Texas at San Antonio, May 12, 2006.
12. Alexandra Hubenko: Invited talk, "CalMesh: A Wireless Ad Hoc Mesh Network for Disaster Response". Microsoft/IAFC Fire Service Technology Symposium, Redmond, WA, December 6-7, 2005. This presentation has launched collaborations between UCI and Orange County, CA Fire Dept, and UCSD and Foster City, CA Fire Dept.
13. Jason Holt, Logcrypt: Forward Security and Public Verification for Secure Audit Logs, Australasian Information Security Workshop 2006, Hobart, Tasmania, January 2006.
14. Tim W. van der Horst, Short Paper: Thor -- The Hybrid Online Repository, First IEEE International Conference on Security and Privacy for Emerging Areas in Communications Networks, Athens, Greece, September 2005.
15. R. Hasan, "Synergy: A Trust-aware, Policy-driven Information Dissemination Framework", IEEE International Conference on Intelligence and Security Informatics (ISI 2006), San Diego, USA, May 23-24, 2006.
16. J. Lee, "Traust: A Trust Negotiation-Based Authorization Service for Open Systems," The Eleventh ACM Symposium on Access Control Models and Technologies (SACMAT 2006), June 2006.
17. J. Lee, "Virtual Fingerprinting as a Foundation for Reputation in Open Systems," The Fourth International Conference on Trust Management (iTrust 2006), May 2006.
18. J. Lee, "Traust: A Trust Negotiation Based Authorization Service," Demonstration Short Paper, The Fourth International Conference on Trust Management (iTrust 2006), May 2006.
19. J. Lee, "Open Problems for Usable and Secure Open Systems," Usability Research Challenges for Cyberinfrastructure and Tools, held in conjunction with ACM CHI 2006, April 2006.
20. L. Olson, "Trust Negotiation as an Authorization Service for Web Services," International Workshop on Security and Trust in Decentralized/Distributed Data Structures (STD3S) held in conjunction with IEEE ICDE 2006, April 2006.
21. C. Zhang, "PeerAccess: A Logic for Distributed Authorization." 12th ACM Conference on Computer and Communications Security (CCS '05), November 2005.
22. Researcher John Miller demonstrated ZigZag to a group of interested blind individuals on at the National Federation for the Blind (NFB) conference July 2, 2005 in Louisville, Kentucky. Zigzag is a sense of touch guiding system including a transmitter and a handheld guiding

device. Miller will be presenting his updated research (ZigZag 2) at the NFB conference in July 2006.

23. Raheleh Dilmaghani: "Performance Evaluation of RescueMesh: A Metro-Scale Hybrid Wireless Network" (R. B. Dilmaghani , B. S. Manoj, B. Jafarian, R. R. Rao. WiMesh-2005: First IEEE Workshop on Wireless Mesh Networks. Held in conjunction with SECON-2005 Santa Clara, CA, September 26, 2005 (This presentation has led to a partnership with a start-up company concentrating on ad-hoc mesh network deployments for emergency response).

24. Ramesh Rao, The First IEEE International Workshop on Next Generation Wireless Networks 2005 (IEEE WoNGeN '05) - held in conjunction with IEEE International Conference on High Performance Computing 2005 (IEEE HiPC '05) Goa, India, December 18-21, 2005. BS Manoj: workshop Co-Chair; Dr Ramesh Rao: Keynote talk, "Responding to Crises and the Unexpected"

25. G. Manimaran, Invited Seminar, Calit2, UCSD: "DoS Attacks and Countermeasures", Iowa State University. Hosted by BS Manoj, October 18, 2005:

26. Information Theory & Applications Center Inaugural Workshop, Calit2, UC San Diego, February 6-10, 2006

    BS Manoj, Chair, Session on Sensor Networks

    Bhaskar Rao, Chair, Session on MIMO

    Serge Belongie, Chair, Session on Bioinformatics

27. International Community on Information Systems for Crisis Response and Management (ISCRAM): Third annual ISCRAM Conference: May 13-17, 2006.

    BS Manoj and Alexandra Hubenko, workshop co-chairs: "Workshop on Future Communications Requirements for Emergency Response"

    BS Manoj and Alexandra Hubenko, session co-chairs: "Communication Challenges in Emergency Response"

28. Naveen Ashish, SAMI project leader is a featured speaker at the Institute for Defense and Government Analysis (IDGA) seminar on Joint Search and Rescue, July 25-26, Arlington, VA. He will provide a tutorial on situational awareness technologies being investigated and developed by SAMI.

29. Naveen Ashish is co-chair for the AAAI workshop on Event Extraction and Synthesis being held the National Conference on Artificial Intelligence (AAAI) 2006 in Boston, July 17th 2006.

30. Dr. B. S. Manoj co-chaired the International Workshop on Next Generation Wireless Networks 2005 (WoNGeN'05) [www.wongen.org] held along with IEEE Conference on High Performance Computing 2005 (HiPC 2005). This workshop focused on the key issues of Reliability, Availability, and Emergency Response in the design and development of next generation wireless networks. This successful and fully participated workshop had an acceptance rate of about 36% with participation from across the world.

31. Prof. Ramesh. R. Rao delivered the keynote talk titled "***Responding to the Crises and Unexpected***" during the opening ceremony of the International workshop on Next Generation Wireless Networks 2005 (WoNGeN'05).

32. Raheleh B. Dilmaghani presented her paper on "**Evaluation of a Metro-Scale Wireless Mesh Network**" in IEEE Workshop on Wireless Mesh Networks (WiMesh'05), held in conjunction with SECON-2005, Santa Clara, California, 26th September, 2005.

33. Raheleh B. Dilmaghani presented her paper on “**Emergency Communication Challenges and Privacy**“ at the International Conference on Information Systems for Crises Response and Management (ISCRAM 2006) [www.iscram.org] held during May 14th to May 18th at New Jersey Institute of Technology, Newark, NJ.

34. Rajesh Mishra presented a paper on “**Challenges in Using Distributed Wireless Mesh Networks in Emergency Response**“ at the International Conference on Information Systems for Crises Response and Management (ISCRAM 2006) [www.iscram.org] held during May 14th to May 18th at New Jersey Institute of Technology, Newark, NJ.

35. Dr. B. S. Manoj presented a seminar titled “**On the Evolution of MAC Protocols for Ad hoc Wireless Networks**,” on 10th December 2005, at Amrita University, Amritapuri Campus, Kerala, India. Amrita University is a partner in UCSD CalIT2’s international collaboration on education and emergency response.

36. Raheleh B. Dilmaghani presented her paper on “**Designing Communication Networks for Emergency Situations**“ at the International Symposium on Technology and Society (ISTAS '06) during June 9-10 at New York City, NY.

37. Dr. B. S. Manoj delivered another seminar titled “**On Using Multihop Wireless Relaying in Next Generation Wireless Networks**,” on 12th December 2005 at the Amrita University, Amritapuri Campus, Kerala, India.

38. Prof. Sharad Mehrotra organized the NSF Principal Investigators Meeting in 2005 for the Cybertrust Program. Cybertrust brings together researchers in security, database security, privacy, and cryptography together

39. Prof. Sharad Mehrotra served as the program committee co-chair of the IEEE Intelligence Security Informatics (ISI) Conference in May 2006. ISI is the study of the development and use of advanced information technologies, computer science, and algorithms for national/ international and homeland security related applications, through an integrated technological, organizational, and policy based approach.

40. Dr Ramesh Rao participated in “Strengthening the Scientific and Technical Responses to Hurricane Katrina: A Meeting of Experts”, convened at the National Academy of Sciences, Washington, DC, November 14-15, 2005.

41. Dr. Ramesh Rao chairs a study at the National Academies Computer Science and Telecommunications Board titled “Committee on Using Information Technology to Enhance Disaster Management.” This committee is studying the requirements for enhancement of crisis response, and will ultimately produce a report on how information technology can enhance crisis preparedness, response, and consequence management of natural and man-made disasters. The 18-month long study continues through October 2006

42. Butts, Carter T. (8/2006). Invited talk: ``Error and Missingness in Social Network Data: Problems and Palliatives.'' ASA Section on Methodology Invited Panel Session, ``Methods for Social Network Analysis.'' ASA Meeting, Montreal, Quebec.

43. Butts, Carter T. (5/2006). Invited talk: ``Dynamic Communication Networks During Extreme Events: an Intertemporal Analysis of Radio Communication During the World Trade Center Disaster.'' Invited Conference Presentation, NetSci International Conference and Workshop on Network Science. Bloomington, IN.

44. Butts, Carter T. (5/2006). Invited talk: ``Likelihood-based Network Comparison Using Permutation Models.'' Invited Workshop Tutorial, NetSci International Conference and Workshop on Network Science. Bloomington, IN.

45. Butts, Carter T. (5/2006). Invited talk: ``Modeling Communication Dynamics During Extreme Events: The Case of the World Trade Center Disaster.'' ``Age of Networks'' Speaker Series, Center for Advanced Study, University of Illinois at Urbana-Champaign. Champaign, IL.
46. Butts, Carter T. (12/2005). Invited talk: ``Extreme Networking: Communication and Coordination Networks During the WTC Disaster.'' Organizational Behavior Seminar Series, Graduate School of Business, Stanford University. Stanford, CA.
47. Butts, Carter T. Conference presentation: ``Cycle Census Statistics for Exponential Random Graph Models.'' (8/2006). ASA Meeting, Montreal, Quebec.
48. Petrescu-Prahova, Miruna and Butts, Carter T. Conference presentation: ``Emergent Coordinators in the World Trade Center Disaster.'' (8/2006). ASA Meeting, Montreal, Quebec.
49. Bevc, Christine; Butts, Carter T.; Liu, Sophia; and Tierney, Kathleen. Conference presentation: ``Predictors of Dyadic Interaction in Emergent Multiorganizational Networks Following the World Trade Center Attacks.'' (4/2006). 26th Sunbelt Network Conference (INSNA), Vancouver, BC.
50. Petrescu-Prahova, Miruna and Butts, Carter T. Conference presentation: ``Network Inference with Missing Data: A Performance Comparison of Existing Models.'' (4/2006). 26th Sunbelt Network Conference (INSNA), Vancouver, BC.
51. Chang, Peter. Conference presentation in the 2nd International Conference on Structural Health Monitoring of Intelligent Infrastructure, 16 – 18 November 2005, South China University of Technology, Shenzhen, China
52. Tsudik, Gene. Invited talk: “Next Generation Internet Security: The Clean-Slate Approach,” NSF Invitational workshop, CMU, August 2005
53. Tsudik, Gene. Panalist “Whither RFID Security?” IEEE Securecomm 2005, Athens, September 2005
54. Tsudik, Gene. Invited talk: “The Future of Internet Security,” National Research Council (NRC/NAS) study group on Power Grids, April 2006.

2.3.2 Outreach to the First-Responder, Government, and State Community

Drills

- *November 15, 2005:* UCSD Campus Exercise – RESCUE teams participated in this campus exercise, with researchers deployed both inside the emergency operations center (EOC) and in the field. Working with campus police, emergency management, and the HazMat team, researchers deployed several technologies, including video cameras to film building evacuations, a microphone array to record inside the EOC, and participated in general field observations to better understand response situations.
- *November 15, 2005:* MMST Drill at Del Mar Fairgrounds: http://www.calit2.net/newsroom/article.php?id=745
- *February 28, 2006:* Mardi Gras in the Gaslamp Quarter, San Diego: http://www.calit2.net/newsroom/article.php?id=810
- *June 22, 2006*: UCI Campus Zone 3 evacuation drill (1/5 of the UCI campus): - RESCUE teams participated in this exercise in collaboration with the UCI campus Environmental

Health and Safety office. This drill helped RESCUE researchers to study crowd dynamics, and the opportunity to test camera instrumentation, mobile 802.11 cameras, Evacpack, and DrillSIM.

- *August 22, 2006 (planned)* MMST Drill at Calit2/UCSD – RESCUE, WIISARD, Responsphere project teams.

Earthquake Professionals and California Government Emergency Responders: Demonstrations of InLET were made during the 8th National Conference on Earthquake Engineering, a 100th Anniversary of the 1906 San Francisco Earthquake Conference.

PISA and the Champaign Testbed has a very strong community outreach component. Our primary focus this year has been on getting a rock-solid disaster scenario to act as a motivating use case for PISA's policy-driven information-sharing architecture. We could not have put together the scenario that we have today without extensive involvement from the community. At the same time, the act of putting together the scenario has uncovered a number of problems in the way that first responders in the City of Champaign would respond to such a disaster. In particular, the interview phase of the scenario development has uncovered a number of learning opportunities for the city, by showing where gaps exist between responders' expectations of one another and the reality. The identification and resolution of these problems is a payback for the effort that the city put into helping us assemble the scenario---especially since the city chose the scenario theme (derailment with chemical spill) as a problem of particular concern to them.

This outreach activity will continue this spring and summer, as the sociology focus groups take place in Champaign. These groups will explore certain aspects of the response to the scenario that we have put together. The ensuing discussion will help the city to be ready for a derailment, and will also provide interesting fodder for sociological analysis of the results by Tierney's groups.

Outreach will continue for over the next 18 months, as the City of Champaign will be using our scenario as the basis for tabletop exercises and then, if appropriate, proceeding to a live exercise.

San Diego Police Department – Mardi Gras 2006. The San Diego Division of Rescue carried out an exemplary community support activity which involved two dozen Rescue researchers, San Diego Police Department, and the downtown San Diego community. Upon request from San Diego police to assist them, by using the experimental technologies developed as part of Rescue project, in their mammoth task of crowd control and monitoring the 25000-30000 strong crowds at the Gas Lamp Quarter of down town San Diego, the San Diego division carried out a wireless mesh network on a number of lamp posts and roof tops in order to provide network connectivity for the monitoring cameras. A brief report on the event is presented above in the testbed section.

E-newsletter

The RESCUE E-newsletter, begun in 2005, has continued in 2006. It features short descriptions of RESCUE developments of interest to the first-responder communities. In addition to our CAB members, distribution includes our industrial partners and Technical Advisory Committee members. The collection of E-news articles is available at the RESCUE web site at http://www.itr-rescue.org/enews

City of Ontario
The UCI RESCUE team met three times (October 10, 2005, and March 7 and April 10, 2006) with members of the Ontario (CA), Fire Dept. and Ontario IT Dept. RESCUE is developing a web portal for the city of Ontario in conjunction with our SAMI project. The portal is being designed to provide timely disaster-related as well as other pertinent information about the city, to the citizens of Ontario. Ontario emergency workers will be able to update the website with current information in near real time. This method of information dissemination is expected to have significant benefits over current sources such as TV and radio. On December 1, 2005, RESCUE staff members attended a hands-on demonstration of WebEOC at the Ontario Police Dept. WebEOC is software designed to provide real-time emergency information management to an Emergency Operations Center. This software has been purchased by the city of Ontario and many other communities across the country. The RESCUE/Ontario web portal will directly link to the WebEOC software deployed by the city of Ontario.

Orange County Fire Authority (OCFA)
UCI RESCUE researchers met with first responders from the Orange County Fire Authority (OCFA) at their new facility in Irvine on December 16, 2005, March 23, 2006 and June 7, 2006. Discussion outcomes include OCFA serves 22 of the 32 cities in Orange County with 400 fire vehicles. Rich Toro, OCFA Senior Fire Communications Supervisor, has agreed to be a member of our Community Advisory Board.

City of Dana Point
On June 12, 2006, representatives from the RESCUE project met with members of the City of Dana Point Emergency and Support Services office to discuss work being done at the RESCUE project. The City of Dana Point showed interest in testing out some of the artifacts the RESCUE project is currently developing including the EvacPack and a version of the Ontario Portal for their city. Discussions also led to establishing a summer 2006 student internship at Dana Point.

Long Beach and Los Angeles Port
In June of 2006, representatives from the RESCUE project were given a tour of the Port of Long Beach and Los Angeles. This tour allowed for some insights into the advanced technology incorporated into port operations, and introduced them to port security measures.

Research Demonstrations with First-Responder, Government, and State Community Groups:

- October 10, 2005. A RESCUE demonstration was presented to the City of Ontario Emergency Services group, resulting in a partnership and development of the Ontario Portal (see artifacts section for details)
- August 17, 2006 ZigZag sense of touch guidance system trials (including participation /input of UCSD HazMat team)
- January 10, 2006: RESCUE All Hands Meeting Community poster session and demonstration exposition: Participants included members of CAB, TAC, and community partners (UCSD Police, Emergency Management/EHS, and other disaster response community partners)
- In January 2006, RESCUE researchers presented the PaDOC Demo (Privacy-Preserving Video Surveillance) to Peter Freeman of NSF
- February 9, 2006: RESCUE researchers presented a demo to representatives from the California Governor's Office – David Crane, Special Advisor of Jobs and Economic Growth, and Mindy Fletcher, Deputy Chief of Staff for External Affairs.

- Calit2/UCSD-TUM Automotive Software Workshop, March 15-17, 2006, UCSD
- Demonstrations for San Francisco Mayor Gavin Newsom and staff, March 23, 2006
- On May 26, 2006 – Demonstration of the Real Time Crisis Alert System was given to members of the California Office of Emergency Services during the Earthquake Information Dissemination Workshop.
- On April 10, 2006 – RESCUE researchers demonstrated the first prototype of the Ontario Portal to City of Ontario Emergency Services.

2.3.3 Outreach to Industry

- **The School Broadcasting Company:** UCI RESCUE researchers met with Evan Arguelles and Jeff Briggs, principals of The School Broadcasting Co. on several occasions during the past year. The company provides local schools with a fast and reliable means to communicate more effectively with their students' parents and communities. As a result, schools are able to close the communication gap between school and home. In May 2006 RESCUE and The School Broadcasting Co. submitted a Calit2 proposal for a UC Discovery Grant award to supplement funding for RESCUE dissemination research.
- **Impinj, Inc.:** On September 19, 2005, UCI RESCUE researchers met with Vinay Gokhale of Impinj, Inc. to discuss applications of Impinj's RFID technology to RESCUE and Responsphere projects.
- **Asvaco:** UCI RESCUE researchers met on several occasions during the past year with members of Asvaco, a company committed to making America safer through technology, secured collaboration, interoperability and real-time management of disaster avoidance.
- **Cicso Systems, Inc.:** On November 1, 2005, discussions were held between RESCUE researchers and Cisco Systems, Inc. regarding the networking infrastructure needs of the project.
- **Boeing:** On December 8, 2005, and February 27, 2006, UCI RESCUE researchers met with members of the Boeing Homeland Security team to develop plans for collaboration on joint projects.
- **Ether2:** On December 9, 2005, UCI RESCUE researchers met with Graham Campbell and David Dietrich of Ether2. Ether2 recently unveiled a network protocol that can replace Ethernet.
- **AMD:** On December 20, 2005, RESCUE researchers met with representatives from AMD to discuss the computing needs of the project. This meeting eventually resulted in a generous price reduction on AMD product
- **Psion Teklogics:** On February 23, 2006, RESCUE researchers met with Psion Teklogics regarding the RFID infrastructure requirements for the CAMAS testbed.
- **IBM:** RESCUE researchers are currently negotiating a software donation from IBM in exchange for CAMAS testbed privileges. IBM's S3 software is a sophisticated surveillance technology that allows for an integrated awareness of an installation from a variety of sensors including video. IBM will donate this software in exchange for beta testing the software within CAMAS as well as allowing the company to conduct research within CAMAS.

- **Convera:** Discussions have been initiated regarding collaboration on text analysis, extraction, and querying techniques relevant to obtaining document and event level situational awareness during from web content. RESCUE will be developing a hurricane information portal using and extending Convera search technologies.

Research Demonstrations with Industry:

- In May 2005, RESCUE researchers met with **IBM** and presented demonstrations of advanced RESCUE technologies. Discussions were held regarding potential IBM donations to the project.
- On July 7, 2005, UCI RESCUE researchers conducted demonstrations of RESCUE and Responsphere projects for <u>Paul Mockapetris</u>, a graduate of UCI and Chief Scientist and Chairman of the Board at **Nominum, Inc.**
- On September 14, 2005, RESCUE researchers presented a demo to **Ether2**.
- On October 11, 2005, RESCUE researchers held its first meeting with **The School Broadcasting Company** (The SB Company) and presented demonstrations in the area of information dissemination. This meeting led to many more discussions between the project and The SB Company and eventually culminated into a joint UC Discovery Grant proposal in May 2006.
- On October 26, 2005, RESCUE researchers presented a demo to **5G Wireless, Inc.** Discussions were held regarding mutual research interest as well as infrastructure needs of the project.
- On December 13, 2005, RESCUE researchers presented a demo to **Asvaco** followed with discussions regarding mutual software research and potential software donations.
- On December 16, 2005, RESCUE researchers presented a demo to **Printronix, Inc.** which resulted in a generous gift of RFID equipment for the CAMAS testbed.
- On January 18, 2006, RESCUE researchers presented a demo to **Apani Networks, Inc**.
- On February 27, 2006, RESCUE researchers presented demos of Privacy, Human Activity Inference, DrillSim and SAMI to representatives from **Boeing**.
- On March 2, 2006, RESCUE researchers presented a demo to **JVC**.
- On April 3, 2006, RESCUE researchers presented a demo to Rick Dutta the CEO and founder of **Nexgenix**.
- On April 26, 2006, RESCUE researchers presented a demo to Michael Gonzales from **Apple** research.
- On June 28, 2006, RESCUE researcher presented a demo to **Vital Data Technologies**. Discussions were held regarding mutual research interests and testbed connections.

2.3.4 Outreach to the Community

Educational outreach:

<u>K-12 Outreach: Preuss School Interns</u>

UCSD's K-12 outreach activities included sponsoring a total of 4 student interns from the Preuss School, a charter school under the San Diego Unified School District whose mission is to provide an intensive college preparatory curriculum to low-income student populations and to improve educational practices in grades 6-12.

Winter 2006: Ashleigh Puente – project website development (mentor: A. Hubenko, H. Bristow)

Spring 2006: Erika Zepeda – hardware development (mentor: J. Rodriguez Molina)
Spring 2006: Giovanni Ibarra - software systems & integration (mentor: S. Pasco)

Undergraduate and Graduate Courses

UCSD, ECE 158 B: Dr. B. S. Manoj taught an undergraduate course on Data Networks II in which several protocols and architectures developed for high reliability networking was included. This course was partly sponsored by Department of ECE, UCSD. A total of 29 students, including senior ECE undergrads and graduate students undertook this course.

ECE 191, Winter 2006, UCSD: A Robust Multi Modal Speech Recognition System (mentors: Dr B. Rao, Dr. R. Hegde). This undergraduate project aimed to build an audio visual continuous speech recognition (AVCSR) system and address issues that are relevant in building robust speech recognition systems. The primary issues that will be addressed from a research perspective will be robust lip tracking, robust audio visual feature extraction and development of effective fusion mechanisms. Project was awarded "best project" of 15 projects undertaken during the winter 2006 quarter. http://www.calit2.net/newsroom/article.php?id=827
Class webpage: http://ece-classweb.ucsd.edu:16080/winter06/ece191/Group_list.htm

ECE 191, Spring 2006, UCSD: An Embedded Speech Recognition System (mentors: Dr B. Rao, Dr. R. Hegde) - The project aims at developing a robust embedded speech recognition in possibly in real time using a small wearable device. This kind of device will fit into the RESCUE theme which aims at focusing on robust speech recognition.
http://ece-classweb.ucsd.edu:16080/spring06/ece191/SP06Project_List.htm

ECE 191, Spring 2006, UCSD: Designing a High Capacity Wireless Mesh Network (mentor: Dr. BS Manoj, Dr. R. Rao) - this project aimed at developing new solutions and protocols for high capacity wireless mesh networks and these solutions are important for the wireless mesh networking research group working for the Rescue and Responsphere projects. The students came up with several interesting observations and potential solutions for increasing the capacity of a mesh networks having a string topology.

MAE 156, Spring 2006, UCSD: Mesh Network Antenna Caddy (mentor: D. Kimball): This project will focus on a stepping stone from our briefcase size mesh network boxes to our emergency response wireless mesh network distributor. The Mesh Network Antenna Caddy will provide limited mobility to increase the coverage and capacity of our existing mesh network.

ECE 291, Winter 2006, Spring 2006 UCSD: Zigzag Tactile Smart Pointer Guidance System for First Responders (mentor: Dr. J. Miller, Dr R. Rao). In a disaster situation, first responders may temporarily have no sense of vision because of a smoky environment or because they are visually distracted by other activities. The Smart Pointer system allows for the first responder quickly learning his location. The system will use the Rabbit 2000 microprocessor and 802.11 wireless LAN bridge to receive guiding instructions. The system will display on a web page hosted by the Rabbit 2000 microprocessor a waypoint in the direction pointed to by the device. An extension of the system receives inputs from a magnetic compass and from a GPS chip set. The Rabbit 2000 calls a simple function to select the waypoint from the database.

ECE 291, Engineering Group Design Project, UCSD, Spring Quarter 2006 Graduate student research project on Embedded Speech Recognition (mentors: Dr. R. Hegde and Dr. B.Rao)
Webpage: http://ece-classweb.ucsd.edu:16080/spring06/ece291/ECE291SPGROUPLIST.htm

CS 665, Advanced Computer Security, Winter Semester 2006, Brigham Young University, Instructor: Kent Seamons, Project: Access Control in Open Systems

CS 601R, Advanced Topics in Computer Security, Spring Term 2006, Brigham Young University, Instructor: Kent Seamons, Topic: Security and Usability.

Two completed MS theses: VisiRescue, from Ragib Hasan at UIUC; Traust, from Adam Lee; both are described under software artifacts heading

ICS 214A Principles of Data Management University of California, Irvine: (Winter 2006)

ICS 214B Transaction Processing and Distributed Databases University of California, Irvine: (Winter 2006)

ICS 215: Advances in Database Management System Technology (Spring 2006)
University of California, Irvine (approx 10 students); instructor: Sharad Mehrotra

ICS 243G: Network Security (Winter 2006)
University of California, Irvine (14 students); instructor: Gene Tsudik
Projects included: audio-based secure pairing of personal devices, privacy-preserving set operations, secure MANET routing, etc.

ICS 280: System Artifacts Geared Towards First Responders (Spring 2005)
University of California, Irvine) ; instructor: Sharad Mehrotra (approx. 15 students)

ICS 280: Secure Group Communication (Spring 2005)
University of California, Irvine; instructor: Gene Tsudik

ICS 280: Systems Support for Sensor Networks (Winter 2005)
University of California, Irvine; instructor: Nalini Venkatasubramanian

Courses that used CAMAS testbed:
UCI ICS 299, Loud and Clear Project, Tsudik, Summer 2005.
UCI ICS 214A, Principles of Data Management, Mehrotra, Fall:2005.
UCI ICS 214B, Distributed Data Management, Mehrotra, Winter: 2006.
UCi ICS 290, Research Seminar, Mehrotra, Winter, 2006.
UCI ICS 215, Advanced Topics in Data Management, Mehrotra, Spring: 2006.
UCI ICS 203A, Introduction to Ubiquitous Computing, Lopes, Winter: 2006.
UCI ICS 278, Data Mining, Smyth, Spring: 2006.
UCI ICs 199, Directed Research, Venkatasubramian, Fall, 2005.
UCI ICS 290, Research Seminar, Venkatasubramian, Winter 2006.

Other Educational Outreach:
University of British Columbia, Stephanie Chang, Associate Professor: Use of InLET in classroom environment as instructional tool.

Girls Inc: On two occasions over the past year UCI RESCUE students, in collaboration with Women in Computer Science, gave demonstrations of the RESCUE DrillSim project to Girls Inc., a national nonprofit youth organization dedicated to inspiring all girls to be strong, smart, and bold. With roots dating to 1864, Girls Inc. provides vital educational programs to millions of

American girls, particularly those in high-risk, underserved areas. Twenty-seven girls were present at the April 11, 2006, RESCUE demo.

UCI Native American outreach: In 2005, UCI RESCUE students presented a demo of DrillSim at the American Indian Summer Institute in Computer Science (AISICS), University of California, Irvine. AISICS is a unique comprehensive eight week summer outreach program developed and directed by computer science faculty at UCI and is in its eighth year of operation.

UCI Calit2 Summer Undergraduate Research Fellowship in Information Technology (SURF-IT) Projects: Naveen Ashish, UCI mentored a Research project for SURF-IT, 10-week summer research fellowship opportunity for UCI undergraduates to become immersed in IT-related research and applications. The research project topic is event detection from traffic sensor data (Summer 2006). SURF-IT is.

UCI Graduate Student Recruitment Day: In April 2006, RESCUE students and staff shared various aspects of the RESCUE project with potential graduate students. Presentations included an overview of the project, demos of EvacPack, DrillSim, Privacy Preserving in Media Spaces.

UCI Scholars Day: In March 2006, RESCUE students presented a project overview, DrillSim, and Anomalous Human Activity Detection to high school students participating in Scholars Day. Scholars Day is an invitation only one-day conference designed to introduce high-achieving high school seniors to the possibilities in information technology

Sally Ride Science Festival: In November 2005, RESCUE undergraduate student Alfred Anguiano presented his work with RESCUE in Sensor Instrumentation, Enhanced 9-1-1, and DrillSim. Sally Ride Science Festivals bring together hundreds of girls in grades 5 through 8, promoting interest in science and math.

Research Project Mentoring: In Spring 2006, Naveen Ashish of UCI directed a research project on information extraction from conversations originating in the UCI graduate database course in Winter 2005. The project dealt with event understanding from transcribed conversation data and led to a MS Thesis.

Edudyne: On January 23, 2005, RESCUE researchers designed an experiment to test Edudyne networking equipment within the CAMAS testbed. Edudyne is a non-profit organization specializing in community outreach and educational opportunities for the disadvantaged.

Research Demonstrations to the Community:

- On July 22, 2005, RESCUE faculty and members of the RESCUE DrillSim team conducted briefings and demonstrations for the Calit2 Advisory Board. This board is composed of prominent individuals in the engineering and computer science fields.
- October 28, 2005: Calit2 building dedication – posters and demonstrations of RESCUE artifacts and research
- On March 29, 2006, Research Demonstration was given to Beth Ford Roth, NPR reporter.
- On May 10, 2006, UCI RESCUE team members gave a briefing and conducted demonstrations for the UCI ICS Leadership Council. This council is composed of sixteen industry executives from Orange County and surrounding areas.

- On May 15, 2006, RESCUE staff met with faculty and students from Orange Coast College, a community college located in Orange County. Visitors included OCC's Dean of Technology.

3. PUBLICATIONS AND PRODUCTS

3.1 JOURNAL PUBLICATIONS AND CONFERENCE PROCEEDINGS

1. Adams, B. J., Huyck, C K., Gusella, L., Wabnitz, C., Ghosh, S., and Eguchi, R T. "Remote Sensing Technology for Post-Earthquake Damage Assement," *8th National Conference on Earthquake Engineering*, 2006.
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3.2 BOOKS OR OTHER NON-PERIODICAL, ONE-TIME PUBLICATIONS

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3.3 WHAT WEBSITES OR OTHER INTERNET SITES HAVE BEEN CREATED

1. Ontario Emergency Management Information Portal (beta site) http://www.disasterportal.org/ontario
2. TrustBuilder: http://dais.cs.uiuc.edu/trustbuilder/
3. *BYU Internet Security research lab: http://isrl.cs.byu.edu/*
4. Mobile vision database: http://rescue.calit2.net/mobilevision/data/
5. Mobile vision website: http://rescue.calit2.net/mobilevision
6. RESCUE Dataset Collection: http://rescue-ibm.calit2.uci.edu/datasets/ - details of this dataset are described in the “products” section
7. *INLET Online loss estimation tool:* http://rescue-ibm.calit2.uci.edu/inlet/.
8. CalMesh research: http://mesh.calit2.net
9. Enterprise Service bus portal: http://www.dsscc.com
10. PaDOC (A Framework for Privacy-Aware Data Collection) http://p3.ics.uci.edu
11. pVault (Secure Password Manager) http://www.itr-rescue.org/pVault
12. Call to Collaborate group messaging system: http://traffic.calit2.net/communicator
13. Earthquake Information Dissemination Workshop: http://www.itr-rescue.org/outreach/disseminationworkshop2006

3.4 SPECIFIC PRODUCTS DEVELOPED

Hardware/Software Products

Software Systems for Multi-perspective Video Analysis of Persons and Vehicles: Our software systems include robust background subtraction system, moving-object tracker system, multi-perspective homography mapping system, and data visualization and query system. The implementation involves development of robust background subtraction system. We have developed a codebook-based background subtraction module that is adaptive to environmental changes over time. The implementation also involves multi-perspective vision-based analysis of people and vehicle activities. Multiple perspective videos provide a useful invariant feature of object in image, i.e., the footage area on the ground. Moving objects are detected in image domain, and tracking results of the objects are represented in projection domain using planar homography. Spatio-temporal relationships between human and vehicle tracks are categorized to safe or unsafe situations depending on site context, for example, walkway or driveway sites. Crowd density and velocity are also estimated and archived online from the footage in homography plane.

Mobile vision software and hardware:

- Mobile (embedded) implementation of the License Plate Recognition System
  MoVs board – Texas Instruments OMAP 5912 devlopment kit outfitted with Linux, drivers, and the OpenCV libraries to support embedded implementations of Computer Vision software.
- MoZi prototype: collaboration with the ZigZag project has produced a two-servo system to be driven by the mobile vision project for guiding the visually impaired.
- MobileVision / Mesh prototype: Mobile Vision board embedded in a calmesh mesh network node, to add embedded computer vision capability to camera-enabled meshnodes.

PISA:

The following security software that can be used for the security infrastructure of the PISA artifact has been developed:

- Hidden Credentials – Credential system for protecting credentials, policies, and resource requests
- LogCrypt – Tamper evident log files
- Nym -- Practical pseudonymity for anonymous networks
- SACRED – Implementation of IETF SACRED (Securely Available Credentials) protocol
- Thor – Credential repository
- Traust -- An authorization server based on trust negotiation
- TrustBuilder – Trust negotiation prototype
- TrustBuilder 2 -- A complete re-architecting of TrustBuilder, currently under development
- VisiRescue -- GIS-based front end for first responders that uses trust negotiation for authorization

InLET:

Loss estimation tools have traditionally been highly customizable desktop programs, resulting in multiple users producing disparate results after an event. InLET (Internet-based Loss Estimation Tool), the crisis simulator for MetaSIM, is a centralized system where data, model updates and results cascade to end users. It is the first online real-time loss estimation system available to the emergency management and response community for Los Angeles and Orange Counties.

After a significant earthquake, Perl scripts written to respond to USGS ShakeCast notifications will call InLET routines that use USGS ShakeMaps to estimate losses within minutes after an event. As more functionality is integrated into MetaSIM, these tools will be tested and eventually released to the emergency management community, the research community, and the general public. InLET is now a fully functioning, online loss estimation tool, and many of the anticipated end users are currently beta testing and providing feedback. InLET can currently be tested at: http://rescue-ibm.calit2.uci.edu/inlet/.

Transportation Simulator:
The Transportation Simulator is a fully functioning online transportation routing tool that can be integrated into desktop applications and existing websites. The transportation simulation will analyze custom user-defined areas, and integrate assumptions of evacuation speed, routing, and notification. It is currently being modified to work in a multi-user environment within InLET.

DrillSim:
A prototype 2.0 of DrillSim, an agent-based evacuation model, is currently under development. A critical component of this expansion is a geographical hierarchy that will allow evacuation to be assessed at the campus level. Data is being collected from drills conducted at UCI. As drills are conducted, agent level information is being used to calibrate behavior models. The data is available at: http://rescue-ibm.calit2.uci.edu/datasets/.In addition to the independent models mentioned above, it is anticipated that MetaSIM will provide the capability for the integration of additional simulation tools.

CalMesh:
The CalMesh platform is a wireless mesh networking platform, which provides a Zero-infrastructure instant deployment mesh network. Every CalMesh node has been installed with a durable, portable, 12VDC (battery) or 120VAC (wall) powered nodes. No existing infrastructure is needed to deploy a wireless mesh network using CalMesh platform. Each node is able to provide a wireless networking “bubble” to client devices that use IEEE 802.11 technology. Each CalMesh node is also capable of merging it's bubble with other nodes in order to increase the physical size of the network, enabling client devices to communicate over long distances thereby creating a “bubble of bubbles”, a multihop wireless network. The CalMesh is designed to be able to distribute existing Internet connectivity within the created bubble. In order to use the CalMesh network across a set of heterogeneous networks, the networking group also developed a VPN overlay network.

VPN Overlay Network:
During the emergency drills carried out by the Robust Communications group, we learned several lessons working with a variety of networks. The VPN overlay network has the following features: (i) It creates a virtual private network across a heterogeneous set of physical networks, (ii) Enables Internet-infrastructure based applications running on mesh client devices to function, even while on separate mesh network partitions connected solely through the Internet, and (iii) it provides a VPN server with a fixed address on the Internet.

Cellular Simulator:
We have created a cellular simulator which can interact with other simulators for inputs such as mobility and damages to infrastructure in order to provide analytical outputs in terms of the wireless coverage and capacity for the system. This simulator is also a part of the METASIM simulator.

Call-to-Collaborate:
We have created a software infrastructure to allow distribution of a broadcast message to a geographically distributed team. The goal of these efforts is to develop a simple method for

communicating vital information (situational awareness, emergency warnings, etc) via voice to team members. Call to Collaborate enables users to create ad hoc groups via a Web browser interface and then call into a central voice server to record a message. This message is then instantaneously broadcast to all team members via phone. http://traffic.calit2.net/communicator

Video Streaming to Cell Phones:
During Mardi Gras, a live video stream was broadcast to cell phones. The system allowed the live stream to be viewed simultaneously over multiple handsets. In addition, the user can pick which camera to view. The ad-hoc system requires a laptop, an USB camera and a BREW-enabled cell phone. The stream can be viewed in public or private mode. It has a 5-to-10 second delay and a frame-rate of 5-10 frames/sec.

Peer-to-Peer Information Collection System:
We have developed a fully automated peer to peer system that can collect and relay disaster related information to the general public and to the first responders. Though government agencies and the private sector have some of the basic data needed for effective disaster prevention and management, the means to effectively disseminate the data in an intelligent manner (i.e, delivery of relevant and timely information to the right target population) is lacking. Typically the data is disseminated in a broadcast mode, which could create a situation of distress or nervousness among the general public, especially those who may not be affected by a particular broadcast. Also, in many situations, there is significant lag in the collection of crisis related data by the government agencies. This lag can be eliminated by empowering the general public to report relevant information.

Location Based Tracking System (LBT):
The mobile based tracking system is built with the latest Assisted GPS (AGPS) technology. Based on AGPS, a mobile phone is used to track the position and speed of objects. A real-time map is provided to view location, speed, and identity of objects. The system consists of a mobile client and a tracking/mapping server. Both client and server can work together as complete solution for object tracking. The GPS data used by our system includes the latitude, longitude, horizontal speed, heading, and altitude. The system will be integrated with Microsoft Map Point mapping engine to display a more sophisticated street map. The system can also work with a third party's mapping server as long as the server complies with the XML interface. The system is on 24x7; therefore it can be used anytime.

EvacPack:
This mobile sensing platform for 1st Responders utilizes 802.11, RFID, BlueTooth, Draeger multi-gas sensors, Sparton Avionics, wearable keyboard, wireless mouse, and a heads up display with an oboard computer. The EvacPack systems integrates into the DrillSim Project, Views (ImageCat Inc.) and provides a "human as a sensor" platform. Rescue Mobile Cameras are pan-tilt-zoom (PTZ). Linksys cameras are being used as a research platform for self-localizing cameras as well as virtual tele-presence research.

CAMAS Virtual Machine:
This project will provide a virtual interface into the CAMAS testbed. It will provide first responders and disaster response researchers a well-defined and easy to use window (virtual machine) into CAMAS.

Autonomous Vehicle Sensing Platform (AVSP):
There are two sets of AVSPs. The first is a two-passenger electric vehicle left over from the DARPA Grand Challenge project. The undergraduates running this project have agreed to

partner with Rescue to further develop the autonomous platform for first responders. The second AVSP is a small RC car used to provide reconnaissance information to 1st responders. Both platforms are instrumented with video, acoustic, and multi-gas sensors.

DrillSim:
DrillSim is a multi-agent crisis simulator that can play out the activities of the response (e.g., evacuation) during crisis from the perspective of IT solution integration. The simulator will model different response activities at both the macro and micro level, and model the information flow between different entities. IT solutions, models etc can be plugged in at different interfaces between these activities or at some point of the information flow in order to study the effectiveness of research solutions in disaster management and tested for utility in disaster response. In addition the simulator will also have capabilities to integrate real life drills into the simulated response activity using an instrumented environment with sensing capabilities.

pVault (Secure Password Manager): [http://www.itr-rescue.org/pVault/]
pVault is the software tool for password generation and protection. It provides a secure service for people to store their strong passwords encrypted on the third-party storage and retrieve them back whenever necessary. Decryption is done at a trusted machine thereby preventing even the remote server to have any knowledge about the user's passwords. When the user visits a webpage, pVault fetches all the passwords from the remote server and automatically fills in the required password on the web page. The user now has to remember only one password to authenticate with pVault. Since the passwords are stored at remote server it provides the user with mobile access to their passwords. pVault helps users during the registration process with a website by generating and filling the appropriate password textboxes with strong passwords.

RapID:
RapID is a peer to peer (P2P) application that provides for scalable distribution of data. A network of machines forms a RapID overlay network. A sender machine can then send data/content to all the other machines in a fast, scalable fashion. RapID is agnostic of the content being disseminated. It can be used to distribute any file. The file to be disseminated is input at a command line. The file is broken into chunks and 'swarmed' into the overlay. On the receiving end, the chunks are collected in the 'right-order' (using a 'sliding window') and sent to STDOUT. The output can be piped into another program or redirected into a file (to be stored).

Databases:
Speech Database collected from The Emergency Operations Centre at UCSD: Speech recordings were done at the EOC setup at UCSD police station during a mock earthquake drill conducted at UCSD. The data was collected to study the nature and feasibility of using speech recorded in real emergency situations at the command center for robust speech recognition research. The database was collected using single far field, dual channel lapel microphones, and a few wireless digital audio recorders. The data base is not put up for public use due to possible privacy issues. User accounts to access this information are available by request.

GLQ Mardi Gras command center Audio Visual database: An Audio-Visual recording system was deployed at the UCSD command center at the Coronado room of Hilton hotel, during the Mardi Gras. The setup was used as a demo to the SD police chief and other officers of SDPD. The System consisted of 2 video cameras and 2 3-element microphone arrays. The cameras were looking in from diagonally opposite corners of the room and there was one microphone array near each camera. User accounts to access this information are available by request.

Mobile Vision Database:

- Video footage during an experiment in the winter quarter of 2006, with a blind and blindfolded subject capturing video data of crossing the street. Available at http://rescue.calit2.net/mobilevision/data/
- Development enivornment tarball – simple freeze-dried development environment which can be unpacked in any unix environment to create the capability of building binaries for the mobile vision platform.

RESCUE Dataset Collection: http://rescue-ibm.calit2.uci.edu/datasets/: The RESCUE dataset collection contains a variety of text, audio, and video files collected by or for use in testing the RESCUE research projects. Disaster response data sets to be used by first responders as well as disaster response researchers are available here; user accounts to access this information are available by request.

- 9-11 NYPD Transcripts: Text transcripts of police reports obtained from Port Authority for use in testing event, spatial, temporal extraction.
- Orange County Fire Authority 9-1-1 Calls: Audio of 9-1-1 calls made to OCFA dispatch center.
- Champaign 9-1-1 Calls: 2 years of 911 call database entries; audio of 9-1-1 calls and responder radio traffic.
- Calit2 Building / UCI Campus Plans (images, CAD, GIS): Facilities information for testing evacuation simulator.
- Calit2 People Counter Logs: Sensor data for testing analysis/prediction tools.
- Champaign Truck Bomb Incident: Video, audio, still pictures of on-the-scene coverage of an apparent suicide truck bomb event. (training scenario)
- 7 GB of audio from Champaign Fire Dept incident responses
- TV Closed Captioning: Transcripts of closed captioning data from 2 local TV stations for testing extraction tools.
- UCI / UCSD Drills: Images, video, and related material from several evacuation and hazmat drills held on UCI and UCSD campuses.
- Boxing Day Tsunami: Collection of news reports, web information collected relating to tsunami events, with a GIS query interface.
- Hurricane Wilma: Images and video collected from areas damaged during this storm.
- Event Data Management: A generic database for the management of events and multimodal sensor and media data documenting these. It includes a web service for the event database; and a UI for the exploration and browsing of reconnaissance data based on the event database.

4. CONTRIBUTIONS

4.1 CONTRIBUTIONS WITHIN PRINCIPAL DISCIPLINES OF THE PROJECT

The central focus of the RESCUE project is to radically transform the efficiency (speed and accuracy) at which information flows through disaster-response networks. These networks span a multitude of response organizations as well as the public. The primary disciplines of research are information technology and social science. We summarize our contributions (current, ongoing and future) along both of these disciplines; however, we note that this research is multidisciplinary and thus transcends the traditional boundaries of these disciplines.

4.1.1 Contributions: Information Technology

The goal of our IT research is to provide seamless access to the right information by the right people at the right time. In this context, the *right information* refers to information, suitably customized/aggregated, that significantly enhances the decision-making capability of responding organizations/agencies/people. The *right people* refers to decision-making entities that triage information across organizational and system boundaries and to entities that utilize this information in making critical decisions regarding crisis response. The *right time* refers to time periods where effective decisions can either prevent the occurrence of secondary disasters, such as release of hazardous materials or minimize the initial impacts of the disaster through rapid and effective response, e.g., efficient deployment of emergency response resources.

To achieve the above goals, we envision information technology solutions that dynamically capture and store crisis-relevant data as it is generated, interpret and analyze these data in real-time, and triage critical information derived from these data to decision makers in forms that can easily be interpreted or used in making critical emergency-response decisions. Challenges in realizing such IT solutions arise due to the scale and complexity of the problem, the diversity of data and data sources, the state of the communication and information infrastructure through which information flows, and the diversity and dynamic nature of the responding organizations.

Diversity of Information Sources: Information needed for effective decision-making may be dispersed across a hierarchy of storage, communication and processing units – e.g., sensors (in-situ sensors, satellite imagery and other remote sensing technologies) where data are generated to form diverse and heterogeneous databases belonging to largely autonomous organizations. Critical information may reside across various modalities – e.g., field-observations communicated via voice conversations among emergency workers, video data transmitted from cameras carried by first responders, sensor data streams, and textual and relational information in databases.

Diversity of Information Users: Information may need to be shared across loosely coupled, diverse, and emergent multi-organizational networks in which different entities play different roles in response activities, have different needs and priorities, have different cultures, and may have vastly different capabilities with respect to technology utilization. These organizations may or may not have policies in place for data sharing and collaboration. Furthermore, these organizational networks may rapidly reconfigure in order to adapt to the element of surprise in a crisis event. Finally, different people/organizations have different needs and urgencies for the same information.

State of the Infrastructure: Information must be transferred across highly-distributed, mobile infrastructure consisting of heterogeneous communication channels and systems that are prone to failures and may be vulnerable to further damage or attacks during a crisis.

The RESCUE project is exploring both fundamental and applied research in information technology to overcome the challenges described above. We are making contributions to existing state-of-the-art IT areas at two different levels: systems-centric research and information-centric research.

In systems-centric research, we are exploring challenges in networking under extreme situations, technologies to maintain always-best-network connectivity, data management and middleware solutions for quality-aware dynamic data collection, data management approaches to store highly dynamic databases, technologies for representing and querying spatio-temporal events, approaches to seamlessly integrate databases "on the fly," open-distributed systems for trust establishment and management, systems to facilitate data sharing, and push-pull technologies for information dissemination.

With respect to information-centric research, we are exploring techniques for multimodal data analysis, including mechanisms for speech recognition in noisy distributed environments, video analysis including object recognition and tracking, models/methodologies for event extraction from multimodal data, techniques for event and entity disambiguation/resolution, methods for event tracking across multiple modalities, data interpretation techniques including probabilistic models for determining reliability of information, spatial and temporal localization of events, models for occupancy from various information sources, and visualization of spatio-temporal event-oriented data.

These diverse research activities are organized along four inter-related activities that together capture the information flow process during a crisis.

Information Collection: The objective of information collection is to bring relevant crisis-related information from a variety of information sources to decision makers in a timely and efficient manner. Our research addresses how large volumes of highly dynamic, multimodal information generated at various information sources can be effectively collected and stored over networks that might be unreliable and possibly insecure. Information sources include instrumented sensors, video cameras either embedded in civil infrastructures or dispersed at crisis sites for situation monitoring, remote sensing systems, field-based sensors such as seismic sensors, and sensor and video probes carried by first responders. Another important source of information is humans themselves. One of the key observations in our project is that first responders' observations and interpretations from the scene (given the benefit of human cognizance) can provide among the most vital and dependable sources of ground reality information during a crisis. Leveraged properly, it can result in much more accurate situation awareness and hence better response. Along the same line, eye-witness accounts from the public can also play an important role in situational awareness. Yet existing crisis-response systems do not systematically exploit such human input. An important thread of research in RESCUE is seeking scalable and robust IT solutions to enable the realization of humans as sensors. In the context of information collection research, our project is making specific contributions to Information Technology along the following directions:

- We are exploring integrated distributed systems, data management and networking research that enable information to seamlessly flow in real-time from these information sources to collection points over heterogeneous network channels that may be only sporadically available and are vulnerable to further hazards or attacks. In this context, we are specifically developing techniques for adaptive data collection from micro-sensors. Another critical contribution is exploring scalable techniques to collect localization (and other types of information) from cellular/mobile devices to enable a multitude of applications ranging from awareness of where people are (at an aggregate level) to support better disaster planning during a crisis, to cellular resource reallocation (e.g., bandwidth) to meet surge demands during crisis.
- Techniques to capture, analyze and process voice input from conversational speech in order to support the realization of the human-as-sensors concept. This effort, in

conjunction with the information analysis work described below, aims to extract meaningful events/information in real-time from transcriptions (possibly with the help of positioning technologies such as GPS, other sensor data and video feeds) and utilize the extracted information as input into situational monitoring, and damage and impact assessment systems.

- Another important contribution is exploring the privacy implications in the context of information collection with the objective of developing customizable solutions that explore a tradeoff between functionality and (the loss of) privacy. Spaces instrumented with video cameras, sensors, tracking systems based on RFID or similar technologies, while they facilitate surveillance and situation monitoring, leave a trace of people behind, whether this is acceptable to them or not. We envision data-collection mechanisms that are privacy-aware and adaptive. Such mechanisms will empower the users – to the extent possible – to control the acceptable loss of privacy, and adapt to the varying needs of the situation.

Information Analysis: A set of related research activities focus on extracting useful information (from the perspective of first-responders) from raw data (sensor data, text, voice and video streams) and assimilating or fusing data across multiple modalities to develop higher-level understanding. The information analysis component bridges the gap between raw data and semantically richer representations that are useful to humans in the context of their tasks (damage assessment, planning, situational awareness). A fundamental abstraction that permeates various aspects of information analysis is that of an "event." We define an event as a significant phenomenon or occurrence embedded in space and time. Events can occur at multiple spatial and temporal scales. For a field worker (e.g., a firefighter requiring fine-grained situation awareness), change in location of his team members at a given time might be an event. At a higher layer, relevant events may correspond to more aggregated information. For example, incident commanders monitoring the response at the city EOC (emergency operations center) may choose to focus on the total number of deployed firefighting or police units at a given region at a given time instead of detailed information about each individual/resource. Our work on information analysis is making contributions to the field of Information Technology along the following directions:

- Our research is exploring techniques for multimodal event extraction from mixed modality data streams (transcribed voice conversations in the context of human sensors, video feeds and various types of sensor data). Our research, besides developing robust technologies for speech recognition, video analysis and event extraction from text, is exploring approaches as to how multiples of such modalities analyzed together can result in improved awareness. Furthermore, approaches to improve extraction utilizing context and domain knowledge are also being designed.
- We are developing architecture for an event-based data management system for storing, representing and reasoning about situational information. In such a system, events are the basic level of data representation, much as tuples are in relational databases, or objects are in object-oriented systems. An event-based data management system we envision will provide a general event model, query languages, event-processing techniques, which form the core of the general-purpose event-based data management system. Such a system can then be used to build event-based situational awareness applications by specifying specific domain context, knowledge, etc. Our work so far has addressed challenges in building such a system – namely in the areas of event representation and event disambiguation.

- We are developing data analysis and interpretation techniques specially geared towards situational awareness. Specifically, we are exploring approaches to predict location and movements of people and groups utilizing lower level multi-modal sensor information, context, and knowledge. Such motion and location prediction can provide valuable insight into planning and resource scheduling during crisis.

Information Sharing: This area focuses on a set of related research activities that facilitate seamless sharing of information among decision-makers across organizational boundaries, especially across highly dynamic, emergent, virtual organizations. The crisis response environment is characterized by Dynamic and Evolving Virtual Organizations (*DEVOs)* in which participating organizations collaborate in the context of a variety of tasks related to disaster mitigation or response (e.g., rescue and evacuation, maintaining law and order). Seamless mechanisms to inter-organization information sharing can revolutionize how such emergent collaborations are established resulting in dramatic improvements to crisis response. Such information may have been dynamically collected and analyzed, or pre-existing in organizational knowledge and databases. Challenges in information-sharing across DEVOs arise due to frequent structural and functional changes (e.g. expansion, extension) within organizations, emergence of complex inter-organizational relationships, *lack of centralized control*, and an element of the surprise resulting in unexpected inter-organization relationships and data needs. Disaster response networks are characterized by heterogeneity in the nature of network relationships (e.g., command and control vs. voluntary coordination, formal or contractual vs. informal relationships) and shifting composition, as new organizational entities join the network in response to changing conditions and response to disaster-related demands.

- To address the information-sharing challenges in such virtual organizations, we are exploring an integrated approach to understanding information-sharing needs and optimizing organizational structures in the context of response coupled with technological innovations that facilitate their formation and functioning. From the IT perspective, we are making contributions towards developing an architecture, mechanisms, and technologies to enable "on-the-fly" information-sharing across diverse organizations that might or might not have prior plans for sharing information. Information sharing is among the most critical and immediate problems identified by the first-responder community and there is a very significant commercial as well as government funded-effort specifically in this area. An example is the Bionet program set up by DHS in which some of the members of our team participated. The Bionet program is seeking to develop architecture for data-sharing across public health organizations in the San Diego area for awareness in the context of a biological attack. Other related efforts include the DHS's efforts towards Disaster Management Interoperability system (DMIS). Instead of competing with or staying one step ahead of such efforts, our work is making contributions towards a few fundamental challenges that arise in information sharing in such domains. Specifically, our research is contributing to establishing trust, and trust negotiations in information-sharing systems.

Information Dissemination: Our goal is to address challenges associated with the timely dissemination of information to entities participating in disaster-response activities, to other organizations (e.g., mass media organizations), and to the general public. Information is one of the scarcest resources during a crisis and finding relevant, customized information is an even harder task. In this final area, our focus is on using IT to fill this void. Information as it becomes available (after collection and analysis) needs to be disseminated rapidly to end recipients. However, the information has to be customized keeping in mind various factors about the current context of the crisis, the state of the communication infrastructure and finally the intended impact it might have on the end recipients, and knowledge of social behaviors that emerge during disasters. For more than five decades, empirical social science research has focused on issues related to the dissemination of hazard-related information in both pre- and post-disaster contexts. We now have a good understanding of how crisis-relevant information can be effectively disseminated. However, a wide range of challenges and difficulties associated with communicating in turbulent, rapidly-evolving and uncertain environments still remain. Our focus in this research will be two-fold: (1) developing a structured approach to understand the dissemination process; and (2) designing advanced IT solutions that customize both dissemination strategies and message content to meet needs of diverse organizational actors and segments of the public. Our IT contributions in this thrust area are as follows:

- We are exploring how information (to be disseminated) can be customized on the fly with respect to dynamic conditions of the crisis, available communications infrastructure and the intended social impact. The goal is to take a variety of factors into consideration in coming up with a dissemination plan that can reach the most people with the most appropriate message. Starting with a conceptualization of information dissemination as a communication process consisting of four elements: (1) *Information sources; (2) messages; (3) dissemination channels; and (4) receivers of information*, we have started to build a holistic and structured framework of customized information dissemination that delves deeper into the various characteristics and interdependencies of these four elements.
- In this research, we address how computing and communication infrastructure can be used to achieve scalable dissemination which is among the most prevalent challenges when using IT for dissemination. How can any information source be able to disseminate information, in a scalable way, to a very large and dynamic set of end-recipients, especially under conditions of sporadic-available or totally-failed infrastructure? To this end, we are using the Peer-to-Peer paradigm to build dynamic infrastructures that can not only scale but also be able to reconfigure and dynamically adapt (with minimal management) to changing conditions seamlessly.
- A dissemination plan consists of either pushing the information to be disseminated to the recipient or alternatively by requiring that the information be pulled by the recipient. While traditionally disaster information is disseminated via a push mechanism using modalities such as television, radio, internet, etc. with the increasing prevalence of personal communication devices, pull technology (or a combination of push and pull) has become increasingly feasible. Pull-based technologies also provide for additional opportunities of customization since the context of the information seeker such as his/her location, and other information can be dynamically determined at the time. Our contribution in this area are formalizing the challenges, developing algorithms, and techniques to support best possible dissemination using a mix of push and pull technologies.

More specifically, primary contributions have been made in designing, developing and evaluating peer-based technologies for rapid emergency warning and alert systems. The contributions have been at multiple levels including the enabling of underlying systems infrastructures (wired and wireless) and customizing the delivered content to achieve the right level of response very rapidly from a large population. This work is been informed by an understanding of the sociological context in which such large-scale disseminations occur and determining how organizational and interpersonal networks evolve and interact in a crisis through analysis of prior disasters, field studies and workshops.

4.1.2 Contributions: Social Sciences

The contributions of RESCUE to work in the social sciences involve a range of topics, both basic and applied. A unifying theme across many of these topics is the emergence and adaptation of social networks under emergency conditions, which couple extreme environmental demands with intense time constraints. The social network field is a large and growing one, spanning disciplines ranging from sociology and disaster research to psychology and computer science (see, for example, Powell, 1990; Knoke and Guilarte, 1994; La Porte, 1996; Podolny and Page, 1998; Wasserman and Faust, 1994; Brandes and Erlebach, 2005). The extensive literature in this area focuses on a variety of issues, including structural features of networks, the consequences of structural position for individual network actors, network evolution and change, and the advantages of the network form of organization over other organizational forms—advantages that include the ability to foster adaptation and innovation. Among the many empirical studies on social and organizational networks, there has been almost no work on networks in disaster response. This gap in the literature exists despite the obvious applicability of network concepts, methodologies, and research findings to crisis response activities. A major contribution of the RESCUE project to the social sciences consists of work which fills this gap. Specifically, our work in this area is centered on three themes:

The Structure of Emergent Multi-Organizational Networks (EMONs)

During disasters, responding organizations rarely act alone; rather, they establish networks of interaction which allow for the pooling of knowledge and resources to assign and complete complex tasks. While efforts are often made to plan for coordination in advance, the highly contingent nature of disasters generally results in organizational behavior which emerges from idiosyncratic adaptation to local conditions (Dynes, 1970). A major topic of interest, then, is comprised of the causes and consequences of structural form within emergent multi-organizational networks. Prior research in this area (see Drabek, 2003) makes important conceptual and practical contributions to the properties of EMONs, but does not take full advantage of either advanced network-analytic methods or information technologies. Within RESCUE, we are employing novel, computationally intensive methods to the study of EMONs, as well as evaluating the implications of EMON structure for the design of information technology. These implications include challenges relating to the sharing of information across organizational boundaries, as well as interoperability requirements for information technology within response organizations.

Responder Communication Networks

Although practitioners in the emergency management field have long known that responder communication is crucial to effective response (Auf der Heide, 1989), very little is known about the structural properties of responder communication networks. In particular, no formal network analytic studies of communications among first-responders during the early hours of a disaster were available prior to the founding of the RESCUE project. Since information flow is of critical importance to task performance (Galbraith, 1977) as well as IT design, there are both practical and scientific reasons to characterize the emergence and behavior of responder communication networks. RESCUE researchers are making pioneering contributions in this area, including work on responder radio communications and in-person interactions during the World Trade Center disaster. This research helps lay the groundwork for new theories of emergent organization during times of crisis, while identifying important contextual factors which must be considered in the design of effective responder communication systems.

Techniques for Structural Analysis and Comparison

In order to study and evaluate EMON or responder network structure, one clearly must have tools which allow for the analysis and comparison of multiple networks. While the literature on social network analysis contains a range of such tools (see, e.g., Wasserman and Faust, 1994; Brandes and Erlebach, 2005), the particular substantive concerns addressed by RESCUE researchers cannot always be addressed using existing methods. For this reason, RESCUE researchers are also contributing to the social sciences by developing new tools and techniques for the comparative analysis of social networks. Examples of work in this area include novel methods for inferring networks from incomplete transcript data, and computationally intensive techniques for estimating the associations between multiple graph sets. In addition to facilitating empirical studies within the RESCUE project, this research contributes more broadly to work on problems of structural analysis in the social sciences.

In addition to research organized broadly around questions of social network analysis, RESCUE researchers are contributing to basic and applied research relating to organizational culture, technology and emergent behavior. Specific themes of this research include the following:

Technology Adoption and Deployment within Crisis Response Organizations

This research area focuses on the study of facilitating and constraining factors influencing the extent to which groups and organizations that participate in disaster-related preparedness and response activities can adopt and implement advanced IT solutions and share information across organizational boundaries. RESCUE-related research activities are predicated on the assumption that response activities will be more effective if accurate information is delivered to the appropriate organizational actors in a timely manner. However, yet to be determined is the extent to which such information flows will be facilitated or impeded by social and organizational factors. A partial list of such factors could include organizational cultures; resource constraints, including barriers related to both funding and available expertise; lack of interoperability among IT tools; security concerns for certain types of disaster events, such as terrorist attacks; legal constraints on information-sharing; issues of privacy and civil rights; proprietary attitudes toward data; and other factors. RESCUE researchers are contributing to work on these problems via field studies of response organizations, as well as participation with community partners in national, state, and local disaster drills.

Collective Behavior in Times of Crisis

Another area of emphasis within RESCUE concerns collective behavior in times of crisis. Both impending disaster threats and actual disasters generate a variety of collective behavior responses among the public and responding organizations (Tierney, Lindell, and Perry, 2001; Tierney, 2004). Such behaviors range from the highly altruistic and positive, such as mass volunteering, to more problematic behaviors, such as rumoring, large-scale convergence resulting in organizational "over-response," to crises, and spontaneous evacuations that may actually increase rather than reduce vulnerability. RESCUE-related social science research seeks to better understand and model these responses, with an emphasis on investigating how IT and network modeling techniques can assist with the early detection and amelioration of potentially dangerous and disruptive collective behavior responses.

Finally, it should be noted that a tertiary contribution of RESCUE to the social sciences lies in the generation of interdisciplinary collaboration between social scientists and IT researchers. Such collaboration accelerates the diffusion of problems and solutions between fields, contributing to the advancement of both parties. We believe that this interdisciplinary mixture results in dividends both now, and in the years ahead.

4.2 WITHIN OTHER DISCIPLINES OF SCIENCE OR ENGINEERING

Project-related activities in engineering focus on three distinct areas: monitoring the response or performance of critical infrastructure (such as bridges and highways), regional damage detection, and modeling of post-disaster traffic flows. These areas either support the various testbeds or provide methodologies for information collection, analysis, or dissemination.

Monitoring the Performance of Critical Infrastructure. Condition monitoring for bridges is traditionally performed using accelerometers. The advantage of this approach is that only a few sensors are needed at each location. Experience has shown that changes in the global characteristics of the bridge, however, are not sensitive to damage. Past research findings have shown that significant damage can manifest itself in changes that are smaller than those produced by noise in the signals. Alternative approaches have so far encountered problems that have yet to be resolved.

The approach taken by this RESCUE is to use long, continuous-strain gauges. If the type of deformation that contributes to deflection is known, then strain measurements can be used to determine the deflection of the bridge. Strain measurements based on point-wise measurement, however, is not altogether reliable since damage may not occur where the strain gauges are located. To mitigate this problem, a strain gauge that is designed to measure the cumulative strain over a distance is being developed. In this approach, any damage within the instrumented span will be captured.

The research above is part of the Transportation Testbed that has been created to evaluate the efficacy of information technology solutions to reduce or mitigate the effects of unreliable or unavailable information on the performance of large-scale infrastructure systems.

Regional Damage Detection. In a major disaster, effective response depends on quick and precise estimates of damage extent and magnitude. Loss estimates are critical in prioritizing the allocation of limited resources, as well as preventing cascading events that can exacerbate the initial effects of a disaster. With the recent emergence of loss estimation tools like HAZUS (Hazards US, a FEMA-sponsored effort), cities and communities are able to simulate the impacts of large disasters such as earthquakes, floods and hurricanes. These tools typically utilize large databases on hazards (location, extent and relative frequency), exposed populations and structures (detailed inventories), hazardous facilities (e.g., chemical processing plants), and critical infrastructure (e.g., highways and other lifeline systems). Hypothetical scenarios routinely provide results for emergency-response training exercises, response plans, and resource assessment. Advanced users use quantitative loss projections for planning purposes, including cost-benefit analysis of building codes and proposed mitigation efforts. After an event, loss-estimation programs provide answers at the critical time when damage extent and distribution is unclear.

Although these tools provide information that is useful for planning and response, they currently require expert users and are not very accessible after a disaster. Highly customizable and computation-intensive, they require GIS specialists or engineers to work with seismologists and geologists to create "study regions" where supplementary data are required for an accurate portrait of loss. Recent earthquake-response efforts have brought this modeling paradigm into question. After the 2001 Nisqually earthquake in the state of Washington, several different local, state, and federal entities took it upon themselves to produce estimates, which varied widely based on how the event was modeled. In the 2003 San Simeon earthquake in California, the sparse default data available in the rural area was not adequate to model the event accurately. These events illustrate the need for a web-based modeling environment, where important decisions concerning how the results are produced and presented can be controlled. Centralized and widely disseminated loss estimates will benefit response and planning efforts and will dovetail into various RESCUE products.

Development of a loss estimation tool for the Internet (a major focus of this research study) poses several technical and research challenges. Spatial database objects are being moved from a PC environment to a distributed database environment. Models that were initially developed in a single-tier format are being moved to a "three tier" web-based environment. This web-based program must integrate tools for complex spatial data-processing tasks. Each loss estimation module is being re-thought, restructured, and reprogrammed to generate results quickly with SQL queries. Complex models are being simplified and presented in a web environment. Currently, building loss and casualties are being calculated from predefined ground motions and building inventories. Next steps include query optimization, the coding of an attenuation function and integration of various transportation modules. Since GIS programs based on commercial software must frequently be modified for compatibility with new versions and new programming languages, all modules are being developed in freely available and OpenGIS compliant tools.

Modeling of Post-Disaster Traffic Flows: Many studies have focused on the flow of traffic during large-scale disasters. In most of these efforts, what is generally modeled is the efficiency in moving people from one area or region to another, often bypassing major areas of impact or disruption. In these cases, research issues that are addressed include: efficient construction of network models, adjustment of origin-destination algorithms accounting for traffic congestion and damage to buildings and infrastructure, and the fragility of key transportation components such as bridges, on- and off-ramps, and highway pavements. In RESCUE, our focus is on the rapid evacuation of people/drivers away from areas that have the potential for hazardous materials (chemical and biological) release. In this regard, a whole new set of research questions must be addressed. These include:

- Quantifying the number of drivers (and thus people) in highly concentrated areas, e.g., downtown and industrial areas, at any particular time. This information is critical in understanding the scope and magnitude of an evacuation effort. Current research is focused on innovative techniques for “counting” daytime traffic into these areas using “loop sensor” data. Several research tasks in RESCUE are focusing on better methods of quantifying area occupancy. These studies utilize video technology, advanced statistical techniques (such as Bayesian analysis), and image processing.
- Modifying conventional transportation models to address evacuation conditions. Important factors that will be addressed include: modification of micro-simulation models to more accurately reflect driver behavior; adjustment of transportation models to include accurate and inaccurate assessments of highway damage; and modeling of driver’s patterns with and without accurate traffic information. Collaborative research is being

conducted by teams of transportation specialists and social scientists to develop preliminary models for driver behavior. The results of this research are expected to benefit transportation modeling in general, and provide a new platform for modeling traffic patterns during large-scale disasters.

This research is part of the Transportation Testbed which is aimed at testing the efficacy of information technology solutions on a large regional scale. The improvements that are made to the transportation models described above will also help to improve the modeling of traffic flows under smaller incidents or events that occur on a more frequent basis.

4.3 WITHIN THE DEVELOPMENT OF HUMAN RESOURCES

The RESCUE project provides support for 31 faculty and senior personnel, and five full-time, as well as five part-time staff members, at five institutions. The project also supports 52 graduate students, whose involvement is central. Student engagement is facilitated by weekly group meetings, at which project members (both students and faculty) present current RESCUE-related research and discuss new directions. This collaborative environment provides a forum for mentoring and professional development while facilitating communication among research groups, in the best tradition of the research university.

RESCUE's contribution to education extends beyond mentoring of students in a research setting. RESCUE PIs Butts and Mehrotra have each designed and taught graduate seminars in the past year in the area of crisis response. These seminars featured coursework related to RESCUE research, but were available to students in the University of California generally; each combined practitioner materials from FEMA and other agencies with current scientific research in related fields. A major benefit of this educational effort has been the development of expertise in the areas of crisis management and disaster research among graduate students within the project, thereby facilitating the connection of basic research activities to real-world problems. Several students are following up on these initial experiences by field study with response organizations in Los Angeles (e.g., City of Los Angeles), thanks to agreements with our community partners. Such progress is in line with RESCUE's broader goal of serving as a catalyst for the integration of information technology research, social science and the crisis/disaster response fields.

In addition, RESCUE has committed to developing a long-term framework for this research project by ensuring the following activities:

At UCI, the RESCUE project has hired Quent Cassen to serve in the role of project manager, tasked to support the Principal Investigator for this research study (Mehrotra) and to facilitate interactions between key researchers and the first-responder community, the Community Advisory Board, and industry representatives. Jean Chin has been hired to serve as project coordinator in Irvine.

At UCSD, Alexandra Hubenko is serving as project manager, while Helena Bristow is working on project coordination and meeting/workshop organization. In addition (as specified in the original proposal), the Calit2 UCSD business office is financially managing the grant. Calit2 UCSD Division is also providing support in seminar organization and publicizing RESCUE functions and activities.

4.4 WITHIN THE PHYSICAL, INSTITUTIONAL, OR INFORMATION RESOURCES THAT FORM THE INFRASTRUCTURE FOR RESEARCH AND EDUCATION

With the resources that form the infrastructure for research and education, we have created a cross-disciplinary research laboratory at UCI that houses about 30 RESCUE students, faculty and staff from various disciplines. Weekly meetings generally attract over 25 participants from UCI, UCSD and ImageCat; these meetings facilitate multi-disciplinary/cross-disciplinary interaction, which helps to address technical, social and economic issues. As a result of these interactions, a number of joint research papers that demonstrate this commitment to multidisciplinary research have emerged.

A live campus-based testbed (CAMAS) for accurate situational awareness and monitoring by collecting, analyzing and triaging data in the context of a problem-reporting system is an example of a long-term commitment to form the type of infrastructure required to test various research innovations or solutions. The next generation of CAMAS will be integrated into a campus-level emergency drill at UCI to study the impact that such information-processing systems have on enhancing awareness in crisis response planning. The testbed also provides opportunities to enhance education by creating course projects that relate to the testbed. Specifically, IT courses such as data management, networks, middleware and multimedia will challenge the students to develop software artifacts that are tied to this testbed. Students taking data mining and social science courses (such as network analysis) will benefit from the data collected within this testbed.

To support this testbed, RESCUE has received additional funding from the National Science Foundation to develop *Responsphere*, which will serve as the basic infrastructure for CAMAS and other research efforts. *Responsphere* is the hardware and software infrastructure for the Responding to Crisis and Unexpected Events (RESCUE) NSF-funded project. The vision for *Responsphere* is to instrument selected buildings and a section of the UCI campus (approximately one third of the campus) with a number of sensing modalities. In addition to these sensing technologies, the researchers have instrumented this space with pervasive IEEE 802.11a/b/g Wi-Fi and IEEE 802.3 to selected sensors. They have termed this instrumented space the "UCI Smart-Space." The sensing modalities within the Smart-Space include audio, video, powerline networking, RFID, and *people counting* (ingress and egress) technologies. The video technology consists of a number of fixed Linksys WVC54G cameras (streaming audio as well as video) and several Canon VB-C50 tilt/pan/zoom cameras. These sensors communicate with an 8-processor (3Ghz) IBM e445 server. Data from the sensors is stored on an attached IBM EXP 400 with a 4TB RAID5EE storage array. This data is utilized to provide emergency response plan calibration and perform information technology research, as well as feeding into our Evacuation and Drill Simulator (DrillSim).

One of the goals of the researchers at the Responsphere Project is to open this infrastructure to the first-responder community. Their desire is to provide an infrastructure that can test emergency response technology and provide metrics such as evacuation time, casualty information and behavioral models. These metrics can be utilized to provide a quantitative assessment of information technology effectiveness.

For more information on the Responsphere Infrastructure, please visit our website at:
www.responsphere.org

A web site has been created (http://www.itr-rescue.org) that not only provides information about RESCUE but also links to other crisis response related information.

4.5 WITHIN OTHER ASPECTS OF PUBLIC WELFARE BEYOND SCIENCE AND ENGINEERING, SUCH AS COMMERCIAL TECHNOLOGY, THE ECONOMY, COST-EFFICIENT ENVIRONMENTAL PROTECTION, SOLUTION OF SOCIAL PROBLEMS

The fundamental goal of the RESCUE project is to transform the ability of responding organizations to collect, analyze, share and disseminate information during large disasters, resulting in real-time and accurate situational awareness. Enhanced awareness, in turn, can significantly improve the decision-making ability of first responders making crisis response more effective and timely. Furthermore, our research explores IT innovations to facilitate multi-organization virtual teams that form during a crisis. We believe that the technologies developed will significantly improve information flow between key emergency response organizations and the public.

Besides contributing to the improvement of crisis response systems, we believe that our approach to building situational awareness tools using multimodal data that includes speech, event extraction data, data on spatio-temporal events will significantly contribute to other systems that operate in a non-disaster situation, e.g., next-generation 911 emergency system.

5. BUDGET JUSTIFICATION

UC Irvine FY 2005-2006 Budget

The RESCUE project was funded at 80% of the amount requested in the original proposal for Year 3. A total of $1,877,706 was awarded to UC Irvine with $560,271 of the total budget allocated to five subcontract projects. Allocations to participating subcontractors were as follows:

Brigham Young University	$82,093
ImageCat, Inc.	$274,940
University of Colorado, Boulder	$79,685
University of Illinois, Urbana-Champaign	$79,560
University of Maryland, College Park	$43,993

University of California, Irvine FY 2005-2006 Expense Justification

A total of $1,317,437 was allocated to UC Irvine for Year 3. Some re-budgeting within categories occurred, specifically, $58,000 was moved from Supply funds, $80,000 was moved from Equipment funds, and $13,000 was moved from Travel funds into Tuition and Fees.

Salary

During Year 3 of the project there have been changes and additions to personnel. The project manager, previously appointed at 60%, reduced his appointment to 5% time. An external relations officer was hired at 10% time to cover industrial and government affairs, all other duties will be absorbed by the remaining project management staff. A full-time programmer was hired this year to replace the previous programmer which was at a 65% appointment, and additional temporary programmers were also hired during the year to augment the project's programming needs.

Travel
Travel funds for year 3 were spent on academic and staff participation in conferences and project meetings with RESCUE project partners.

Equipment & Supplies
During Year 3 of the award, $14,000 was budgeted for equipment needs. This equipment was leveraged from other sources, and these funds were re-budgeted for graduate student participation on the project. As a result of the re-budgeting, there was no change in scope of the program.

Other costs
Funds were used for materials in support of various research projects and workshops within RESCUE.

It is anticipated that the majority of funds will be spent out. Any funds remaining to be carried to Year 4 will not exceed 15%.

University of California, San Diego FY 2005-2006 Budget and Expense Justification
A total of $709,000 was awarded to UC San Diego for Year 3. Some re-budgeting within categories occurred, specifically, $50,000 was moved from Academic Salaries and $80,000 was moved from Equipment funds and into the following categories:
Staff Salaries, ($15,000 increase from original year 3 budget); Student Salaries, ($9500 increase); Benefits ($5000 increase); Supplies ($30,000 increase); Travel ($10,000 increase); GSR Salaries ($23,000 increase); GSR Tuition Remission ($17,500 increase); indirect cost re-budget ($20,000 increase)

Salary
Effective October 2005, both budgeted postdoctoral researcher positions budgeted were filled. All 3 budgeted Graduate Student Researchers were funded. A third postdoctoral researcher is being partially funded by RESCUE.

Some salary funds were used to allocate support of Calit2 development engineers to the RESCUE project. These personnel make significant contributions to RESCUE research in the areas of GIS and wireless applications. Part of their time is also spent mentoring and advising undergraduate and graduate students in engineering group design project courses sponsored by RESCUE. Some salary funds were also used to accommodate actual salaries (salary increases/changes) for staff members on the project.

Travel
Travel funds for year 3 were spent on academic and staff participation in conferences and project meetings with RESCUE project partners. In addition, UCSD received approval from the CISE-IIS program director to use travel funds to send a postdoctoral researcher to India in December 2005, where he organized and chaired the First IEEE International Workshop on Next Generation Wireless Networks 2005 (IEEE WoNGeN '05) - held in conjunction with IEEE International Conference on High Performance Computing 2005 (IEEE HiPC '05) in Goa, India.

Equipment & Supplies
Equipment and supplies funds were used to purchase laptops, desktops, and servers that were used to conduct research on RESCUE. Because of a change in the University of California policies on classifying inventoriable and non-inventoriable equipment, laptops, computers, and similar devices now appear as supplies, not equipment. We have re-budgeted to take this change into account.

Other costs
Funds were used for materials in support of various research projects and workshops within RESCUE.

It is anticipated that the majority of funds will be spent out. Any funds remaining to be carried to Year 4 will not exceed 15%.

Brigham Young University FY 2005-2006 Expense Justification
It is anticipated the Year 3 funds will be fully expended. Minor re-budgeting occurred within categories to accommodate small increases in travel, salary, tuition and fees.

ImageCat, Inc. FY 2005-2006 Expense Justification
It is anticipated the Year 3 funds will be fully expended. Minor re-budgeting occurred within categories to accommodate additional programming needs for the INLET software and changes in personnel and salaries.

University of Colorado, Boulder FY 2005-2006 Expense Justification
It is anticipated the Year 3 funds will be fully expended. Minor re-budgeting occurred within categories to accommodate increases in travel.

University of Illinois, Urbana-Champaign FY 2005-2006 Expense Justification
It is anticipated the Year 3 funds will be fully expended at the end of the Year 3 project period.

University of Maryland, College Park FY 2005-2006 Expense Justification
It is anticipated that a majority of the Year 3 funds will be expended at the end of the project year. Remaining funds will be used to support graduate student salary need for Year 4.

UC Irvine FY 2006-2007 Budget Request
There is no change to the budget request for Year 4 funds. The current budget requests a total of $1,848,175 in funds awarded to UC Irvine with $518,844 of the total budget being awarded to four subcontracts. Proposed allocations to participating site are as follows:

Brigham Young University	$82,093
ImageCat, Inc.	$275,422
University of Colorado, Boulder	$79,995
University of Illinois, Urbana-Champaign	$81,334

UC San Diego FY 2006-2007 Budget Request

The current budget requests a total of $717,000 in funds awarded to UC San Diego. No changes have been made to the budget request for Year 4 funds.