# Second Year RESCUE Progress Report

Responding to Crises and Unexpected Events

## ITR
## Collaborative Research: Responding to the Unexpected

**National Science Foundation Award Numbers:**

**IIS-0331707, University of California, Irvine**

**IIS-0331690, University of California, San Diego**

**May 26, 2005**

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# 1. PARTICIPANTS

## 1.1 PEOPLE WHO HAVE WORKED ON 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 hours*** | ***Work on project*** |
|---|---|---|---|
| Sharad Mehrotra | Principal Investigator | Yes | Data Management |
| Ramesh Rao | Principal Investigator | Yes | Wireless Applications |
| Carter Butts | Co-Principal Investigator | Yes | Social Phenomena |
| Ronald T. Eguchi | Co-Principal Investigator | Yes | Loss Estimation |
| Nalini Venkatasubramanian | Co-Principal Investigator | Yes | Middleware |
| Marianne Winslett | Co-Principal Investigator | Yes | Trust Negotiation |
| Bhaskar Rao | Co-Principal Investigator | Yes | Voice Recognition |
| Mohan Trivedi | Co-Principal Investigator | Yes | Image Processing |

### 1.1.2. Other RESCUE Senior Personnel

Additional people 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 hours*** | ***Work on Project*** |
|---|---|---|---|
| Robert Bradshaw | Undergraduate Student | No | Trust Negotiation |
| Jim Henshaw | Graduate Student | No | Trust Negotiation |
| Jason Holt | Graduate Student | Yes | Trust Negotiation |
| Travis Leithead | Graduate Student | Yes | Trust Negotiation |
| Kent Seamons | Senior Personnel | Yes | Trust Negotiation |
| Tim van der Horst | Graduate Student | Yes | Trust Negotiation |

**ImageCat, Inc.**

| ***Name*** | ***Role(s) on Project*** | ***>160 hours*** | ***Work on Project*** |
|---|---|---|---|
| Paul Amyx | Technical Staff | Yes | Software Development |
| Beverly Adams | Senior Personnel | Yes | Remote Sensing |
| Sungbin Cho | Senior Personnel | Yes | Transportation Analysis |
| Howard Chung | Senior Personnel | Yes | Image Processing |
| Shubharoop Ghosh | Senior Personnel | Yes | Urban Planning |
| Charles Huyck | Senior Personnel | Yes | GIS Applications |

| | | | |
|---|---|---|---|
| Michael Mio | Senior Personnel | Yes | Software Development |

**University of Colorado, Boulder**

| ***Name*** | ***Role(s) on Project*** | ***>160 hours*** | ***Work on Project*** |
|---|---|---|---|
| Kathleen Tierney | Senior Personnel | Yes | Organizational Networks |
| Jeannette Sutton | Post-doctoral Researcher | Yes | Organizational Networks |
| Christine Bevc | Graduate Student | Yes | Organizational Networks |

**University of Illinois, Urbana-Champaign (UIUC)**

| ***Name*** | ***Role(s) on Project*** | ***>160 hours*** | ***Work on Project*** |
|---|---|---|---|
| Mike Rosulek | Graduate Student | Yes | Trust Management |
| Lars Olson | Graduate Student | Yes | Trust Management |
| Jintae Lee | Graduate Student | Yes | Trust Management |

**University of Maryland, College Park (UMD)**

| ***Name*** | ***Role(s) on Project*** | ***>160 hours*** | ***Work on Project*** |
|---|---|---|---|
| Peter Chang | Senior Personnel | Yes | Bridge Sensor Development |
| Ms. Sujata | Graduate Student | Yes | Bridge Sensor Development |
| Ming Wang | Graduate Student | No | Bridge Sensor Development |

**University of California, Irvine (UCI)**

| ***Name*** | ***Role(s) on Project*** | ***>160 hours*** | ***Work on Project*** |
|---|---|---|---|
| Mohanned Alhazzazi | Undergraduate Student | Yes | Video Applications |
| Kemal Altıntaş | Graduate Student | Yes | Spoken Language Understanding |
| Alfred Anguino | Undergraduate Student | No | Human-as-sensor |
| Naveen Ashish | Senior Personnel | Yes | Situational Awareness |
| Vidhya Balasubramanian | Graduate Student | Yes | Spatial Representation and Navigation |
| Swagata Banergee | Graduate Student | Yes | Post-disaster Routing |
| Quent Cassen | Project Manager | Yes | Project Management |
| Earth Chandrruangphen | Graduate Student | Yes | Spatial Representation |

| | | | |
|---|---|---|---|
| Stella Zhaoqi Chen | Graduate Student | Yes | Event Extraction |
| Thomas Chen | Undergraduate Student | Yes | DrillSim/CAMAS |
| Jean Chin | Project Support | Yes | Administrative Support |
| Jonathan Cristoforetti | Undergraduate Student | Yes | Adaptive Collection |
| Remy Cross | Graduate Student | Yes | Data Analysis |
| Mahesh Datt | Graduate Student | Yes | Privacy and Data Collection |
| Chris Davison | Technology Manager | Yes | Technology Manager |
| Rina Dechter | Senior Personnel | Yes | Probabilistic Modeling and Reasoning |
| Mayur Deshpande | Graduate Student | Yes | Peer-to-Peer Dissemination |
| Maria Feng | Senior Personnel | No | Sensor Development |
| Allessandro Ghigi | Undergraduate Student | Yes | Customized Disseminaiton |
| Vibhav Gogate | Graduate Student | Yes | Activity Modeling and Bayesian Inference |
| Qi Han | Graduate Student | Yes | Data Collection |
| Ramaswamy Hariharan | Graduate Student | Yes | GIS Modeling |
| Bijit Hore | Graduate Student | Yes | Privacy and Data Collection |
| Yun Huang | Graduate Student | Yes | Resource Management |
| Jon Hutchins | Graduate Student | Yes | Data Mining/Occupancy Modeling |
| Ravi Jammalamadaka | Graduate Student | Yes | Secure Data Warehousing |
| R. Jayakrishnan | Senior Personnel | No | Transportation Modeling |
| Dmitri Kalashnikov | Post-doctoral Researcher | Yes | Data Cleaning, Event Extraction |
| Parin Kenia | Graduate Student | Yes | Privacy & Data Collection |
| Ali Khoaedi | Graduate Student | Yes | Spatial Representation and Navigation |
| Haimin Lee | Graduate Student | Yes | Data Extraction |
| Gabriel Lawson | Graduate Student | Yes | Dissemination Modeling |
| Iosif Lazaridis | Graduate Student | Yes | Quality Aware Querying |
| Fabio Leite | Graduate Student | Yes | Reliability |

| | | | |
|---|---|---|---|
| | | | Modeling |
| Chen Li | Senior Personnel | Yes | Data Integration |
| Yiming Ma | Graduate Student | Yes | Data Filtering |
| Gloria Mark | Senior Personnel | No | Technology Assessment |
| Daniel Massaguer | Graduate Student | Yes | Evacuation Simulation |
| Amnon Meyers | Programmer/Analyst | Yes | Event Extraction |
| Jeremy Miner | Undergraduate Student | No | Privacy Infrastructure Deployment |
| Suraj Nagasrinvasa | Graduate Student | Yes | Situational Awareness |
| Rabia Nuray | Graduate Student | Yes | Data Cleaning |
| Sridevi Parise | Graduate Student | Yes | Video Trajectory Modeling |
| Miruna Petrescu-Prahova | Graduate Student | Yes | Data Analysis |
| Steve Ponting | Project Support | Yes | Administrative Support |
| Will Recker | Senior Personnel | Yes | Transportation Analysis |
| Nitesh Saxena | Graduate Student | Yes | Group Admission Control |
| Dawit Seid | Graduate Student | Yes | Graph-Based Querying Language |
| Hope Seligson | Graduate Student | Yes | Post-disaster Routing |
| Masanobu Shinozuka | Senior Personnel | Yes | Post-disaster Routing |
| Michal Shmueli-Scheuer | Graduate Student | Yes | Data Dissemination Architecture |
| Padhraic Smyth | Senior Personnel | Yes | Data Mining Techniques |
| Gene Tsudik | Senior Personnel | Yes | Security |
| Jinsu Wang | Graduate Student | Yes | Distributed Data Collection |
| Jehan Wickramasuriya | Graduate Student | Yes | Access Control and Privacy |
| Yonghua Wu | Graduate Student | Yes | Security |
| Xingbo Yu | Graduate Student | Yes | Distributed Data Collection |
| Qi Zhong | Graduate Student | Yes | Data Sharing Querying |

### 1.1.3 UCSD Senior Personnel

Additional people 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 |
| Ganapathy Chockalingam | Principal Development Engineer | Yes | GIS Applications, Software Development |
| Babak Jafarian | Senior Development Engineer | Yes | Wireless Applications |
| John Zhu | Senior Development Engineer | No | Wireless Applications |
| BS Manoj | Post-doctoral Researcher | Yes | Wireless Applications |
| Sangho Park | Post-doctoral Researcher | No | Computer Vision |
| Stephen Pasco | Senior Development Engineer | Yes | Software Systems and Architecture |
| Helena Bristow | Project Support | Yes | Administrative Support |
| Alexandra Hubenko Baker | Project Manager | Yes | Project Management |
| Raheleh Dilmaghani | Graduate Student | Yes | Network optimization and modeling |
| Shankar Shivappa | Graduate Student | Yes | Speech Recognition |
| Wenyi Zhang | Graduate Student | Yes | Speech Recognition |
| Vincent Rabaud | Graduate Student | Yes | Computer Vision |
| Aaron Jow | Graduate Student | Yes | Platform Development |
| Javier Rodriguez Molina | Undergraduate Student | No | Software and Hardware Device and Applications |
| Diep Ngoc Nguyen | Undergraduate Student | Yes | Software Development |
| Ping Zhou | Graduate Student | No | Networking |

## 1.2 ORGANIZATIONS THAT HAVE BEEN INVOLVED AS PARTNERS

***Steve Carter, City Manager, City of Champaign; Fred Halenar, IT Director, City of Champaign; Stephen Clarkson, Deputy Fire Chief, City of Champaign; Mark Toalson, GIS Director, Champaign County Regional Planning Commission***

These city and county officials are the local force behind the Champaign Testbed. Marianne Winslett has met and corresponded with them many times over the past year. These officials suggested the application that forms the core of the Champaign Testbed (an interactive GIS with integrated real-time data feeds), and have supplied RESCUE with miscellaneous 911 call transcripts and with a complete transcript of all fire, police and 911 communications related to a terrorist-like incident that occurred in Champaign in March 2005.

***Jim Watkins, California Governor's Office of Emergency Services (OES)***

Member, RESCUE Community Advisory Board. OES is partnering with RESCUE to beta test and review the products of RESCUE research. These products include the integration of GIS and other spatial data in an online environment for emergency response. OES is especially interested in processed data and its integration into maps in real-time during disasters, and getting it to incident commanders and decision makers.

***Dawna Finley, Tom Hume, Eileen Salmon; City of Irvine, Emergency Management***

Members, RESCUE Community Advisory Board. Local city agency providing access to local information and facilities.

***Bob Garrott, Los Angeles County***

Member, RESCUE Community Advisory Board. Provides access to Los Angeles County facilities, data and emergency operations management strategies.

***Karen Butler, Communications Division, San Diego Police Department***

Member, RESCUE Community Advisory Board. Participant in GLQ testbed.

***William (Bill) Maheu, Asst. Chief of Police, City of San Diego***

Member, RESCUE Community Advisory Board. Participant in GLQ testbed.

***Paulette Murphy, Space and Naval Warfare Systems Command***

Member, RESCUE Community Advisory Board. Provide additional testbeds for examining 'human as sensor' as an information technology solution.

***Ellis Stanley, City of Los Angeles, General Manager, Emergency Preparedness Department***

Ellis Stanley serves as chair of the RESCUE Community Advisory Board (CAB), whose primary goal is to advise and help guide RESCUE researchers with specific applications of information technology within the first responder and emergency management community. Mr. Stanley acts as liaison between RESCUE, CAB members, and the first responder community, bringing issues of importance to the emergency management community and the IT community. Mr. Stanley hosted two RESCUE interns during the summer of 2004 to work on IT solutions for emergency management.

***Dr. Gokhan Tur and Dr. Dilek Hakkani Tur, AT&T Research***

Members of Industry Affiliates Group. Provide materials, resources and information for 'human as sensor' research.

## 1.3 OTHER COLLABORATORS AND CONTACTS

***Charles Jennings and Grant Roholt, Regional Alliances for Infrastructure and Network Security (RAINS-Net)***

RESCUE has opened up discussions with RAINS-Net and is engaged in developing a partnership with this non-profit private/public organization, working on the development of information-sharing tools for the first-responder community.

***Samuel Kang, IT Specialist and Former Firefighter***

Met with RESCUE research team to advise on issues of interoperability, field response and IT solutions for first responders.

***Professor Nikil Dutt, University of California, Irvine***

CAMAS testbed team member.

***Linda Bogue, University of California, Irvine, Emergency Management Coordinator***

Partnering with RESCUE to develop university-wide emergency drill under which RESCUE researchers can employ IT solutions to observe behaviors and to get a better understanding of how IT can assist in emergency situations.

***Partha Mitra, Lucent Technologies***

Member of Industry Affiliates Group

***Jim Basney and Von Welch, National Center for Supercomputing Applications***

Invited members of Industry Affiliates Group. Collaborated with Marianne Winslett at UIUC on developing approaches to deploying trust negotiation technology in real-world computational grids in a manner that allows legacy applications and clients to take advantage of trust negotiation facilities. The resulting prototype, called Traust, uses TrustBuilder as its trust negotiation module. Middleware such as Traust is needed to support dynamic coalitions that form during response to disasters.

***Clifford Neuman and Tatyana Ryutov, USC/ISI***

Invited member of Industry Affiliates Group. Collaborated with Kent Seamons at BYU to create an integration of the GAA-API, under development at USC, with TrustBuilder, under development at BYU. The resulting system provides more adaptive access control in open systems than TrustBuilder provided in the past. The GAA-API system provides enhanced capabilities to trust negotiation to detect malicious activity, such as application-level denial of service attacks against trust negotiation. A paper describing the results will appear in SACMAT 2005.

***DigitalGlobe***

Satellite data provider. Invited member of Industry Affiliates Group. DigitalGlobe has been providing commercial satellite imagery.

***Lt. David Rose, UCSD Campus Police***

Lt. Rose is heavily involved with wireless technologies and their applications for first responders. UCSD-Rescue team has provided GPS-enabled cell phones to use for location-tracking experiments in examples such as campus service officers (who escort pedestrians at night). Lt. Rose has also invited UCSD to participate in the wireless technology committee meetings of ARJIS (Automated Regional Justice Information System), a San Diego county organization.

***Phillip Van Saun and Tod Ferguson, UCSD EHS Department***
After observing a drill organized by UCSD EHS, the RESCUE team has engaged with EHS in the areas of communications, mobile command and control, and GIS mapping. We are gaining valuable real-world insight on what is needed among the first-responder community in terms of communications tools and information sharing.

***Dawn Martin, UCSD GIS Coordinator***
Ms. Martin is assisting researchers dealing with location-based applications to obtain layered maps of the UCSD campus.

***Lucent Technology***

Invited member of Industry Affiliates Group

***Qualcomm***

Invited member of Industry Affiliates Group

***Professor Xiaochun Yang***
Collaborator on data privacy

***Professors Amitabh Chaudhary, Dr. Amitabha Bagchi and Professor Michael T. Goodrich***
Collaborators on data gerrymandering

***Professors Wolfgang Nejdl, University of Hannover; and Piero Bonatti, University of Naples***

Collaborated with Marianne Winslett and Kent Seamons on PeerTrust, an approach to extending trust negotiation to situations that involve more than two parties. In real-world open systems, people often need to turn to helpful third parties to obtain assistance in establishing trust. For example, such a third party might act as a personal credential wallet, or be in charge of maintaining the lists of groups authorized to use a particular resource. PeerTrust offers a language for describing such relationships and reasoning about the effect of these third parties on trust establishment.

***Caltrans***

Ganz Chockalingam and ImageCat are collaborating with Caltrans in their research.

***Ericsson Research***

Rajesh Mishra is collaborating with BS Manoj on the Always Best Connected (ABC) platform.

***AT&T Research Labs***

Graduate Student Shankar Shivappa will do his 2005 summer internship at the speech group of AT&T Labs. He will work on an on-going project on large vocabulary conversational speech recognition.

***KPBS Radio***

There is a link to http://traffic.calit2.net on the San Diego local public broadcasting station's website.

***Ken Allen, Edudyne Foundation***

UCI is working with Ken Allen of Edudyne Foundation, a non-profit organization with a mission to accelerate learning through technology, with a particular focus on distance learning. NSF is encouraging community colleges to align themselves with universities to achieve a secure information technology network.

## 1.4 RESCUE PROJECT MANAGEMENT

Figure 1-1 shows the project management structure for RESCUE. The RESCUE Director is Dr. Sharad Mehrotra of the University of California, Irvine. He works with an Executive Committee in making key management decisions for the project. The project is also supported by two project managers (one for each main institution) and three other staff members. In addition, in the first year of the project, a Community Advisory Board (CAB) was formed. The purpose of this Board is to provide the RESCUE project with feedback regarding ongoing research, research priorities from the standpoint of first-responder needs, and facilitate joint projects and/or internships with government partners and organizations. The nine-member Board is chaired by Mr. Ellis Stanley, the General Manager of the Emergency Preparedness Department of the City of Los Angeles. In the upcoming year, an Industry Affiliates group will be formed to encourage partnerships with industry and other organizations.

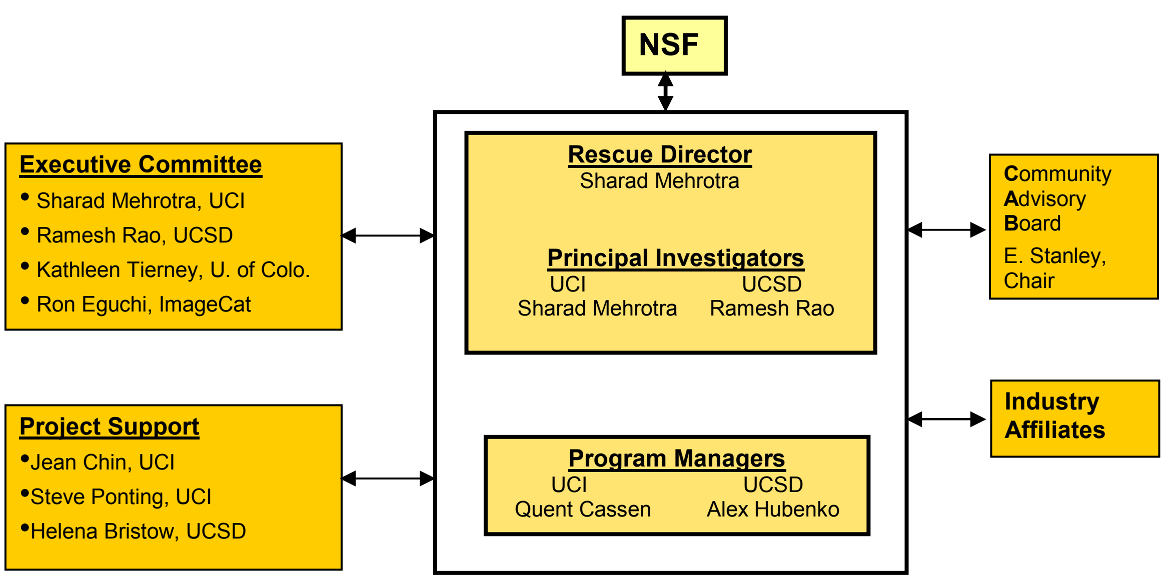


**Figure 1-1. Project Management Organization for RESCUE**

Figure 1-2 presents the research management structure for RESCUE. Research priorities are initially established by the Executive Committee of RESCUE. Input into the research program (i.e., agenda) is provided by a committee that represents the five basic research areas of RESCUE: Networks and Distributed Systems; Data Management and Analysis; Social and Organizational Science; Trust Management and Security; and Engineering and Transportation. An additional function of this committee is to ensure that innovative and ground-breaking research is achieved in each of these areas.

In addition, in order to test and evaluate research performed in RESCUE, four testbeds have been established. Each testbed will have a leader that will act as a "service provider" to ensure that his or her testbed meets the needs of the RESCUE research team. Furthermore, the testbed leaders must work jointly with government and industry partners to ensure the development of usable products or methodologies. Finally, to ensure successful development of RESCUE artifacts, a committee on Artifacts development has been established.

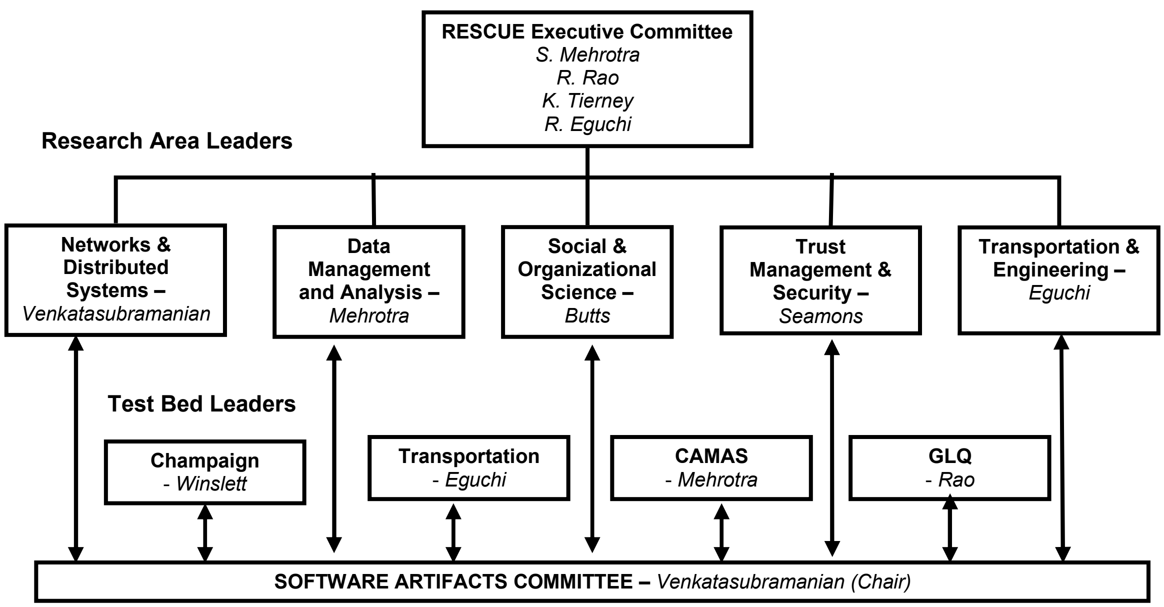


**Figure 1-2. Research Management Structure for RESCUE**

## 2. ACTIVITIES AND FINDINGS

The mission of this multidisciplinary project is to enhance the ability of emergency response organizations to mitigate crises, save lives, and prevent secondary and indirect human and economic loss by radically transforming the way in which these organizations gather, process, manage, use and disseminate information during man-made and natural catastrophes. The project is predicated on the assumption that information quality, accuracy and timeliness at all levels of emergency management profoundly affects the quality of decisions and that better information leads to improved decision-making and more effective performance of crisis-related tasks. As a result, significant improvements in crisis response capabilities can result from research on how to apply advanced information technology solutions to the crisis management field. Our goal is to show that such a fundamental transformation can be achieved by a coordinated interdisciplinary research program that synthesizes:

(a) scalable and robust IT solutions to facilitate access to the right information, by the right individuals and organizations, at the right time, and;
(b) social science research to understand the distinctive nature of dynamic virtual organizations and their information needs in the crisis and disaster context

The project has been officially organized under the title of RESCUE (RESponding to Crises and Unexpected Events), and a project center has been established on the UCI campus. Research in RESCUE encompasses numerous sub-areas within both IT and social science. In particular, our IT research covers topics within the areas of networks, mobility and location management, middleware, distributed systems, security, data management, data analysis and mining, decision-support tools, image analysis, automated speech recognition, spoken language understanding, computer vision and image interpretation. Our social science research focuses on the analysis of inter-organizational networks, emergent responses to rapidly occurring events, organizational behavior in the crisis environment, information-sharing needs, reliability modeling, and information dissemination to organizations and to the broader public.

While our research touches many different topics, our project is a tightly integrated multidisciplinary effort focused on crisis response. The fundamental basis for integration is the process of information flow through disaster networks: information collection, analysis, sharing, and dissemination. Our project seeks breakthrough innovations in computer systems, information management and social science to revolutionize the mechanisms for collecting, analyzing, sharing and disseminating information in disaster response networks.

### Major Components of RESCUE Program

In Year 2, several important organizational changes were made in order to facilitate better interaction between individual investigators, better definition of research needs and priorities, and improved interaction with end-users. Although these activities were identified as major priorities in the original proposal, it wasn't until Year 1 was completed that many of the challenges associated with multi-institutional research became clear. Because of the lessons that were learned and the experience gained in the management of the RESCUE project in the first year, the following restructuring of the RESCUE project was made.

A new conceptual diagram was developed depicting how the different elements of RESCUE fit together (Figure 2-1). The top layer contains the major research thrust areas for RESCUE. As identified in the proposal and in the NSF Cooperative Agreement, research is being conducted along the lines of Information Collection, Information Analysis, Information Sharing and Information Dissemination. Fundamentally, these four areas define the process of crisis response.

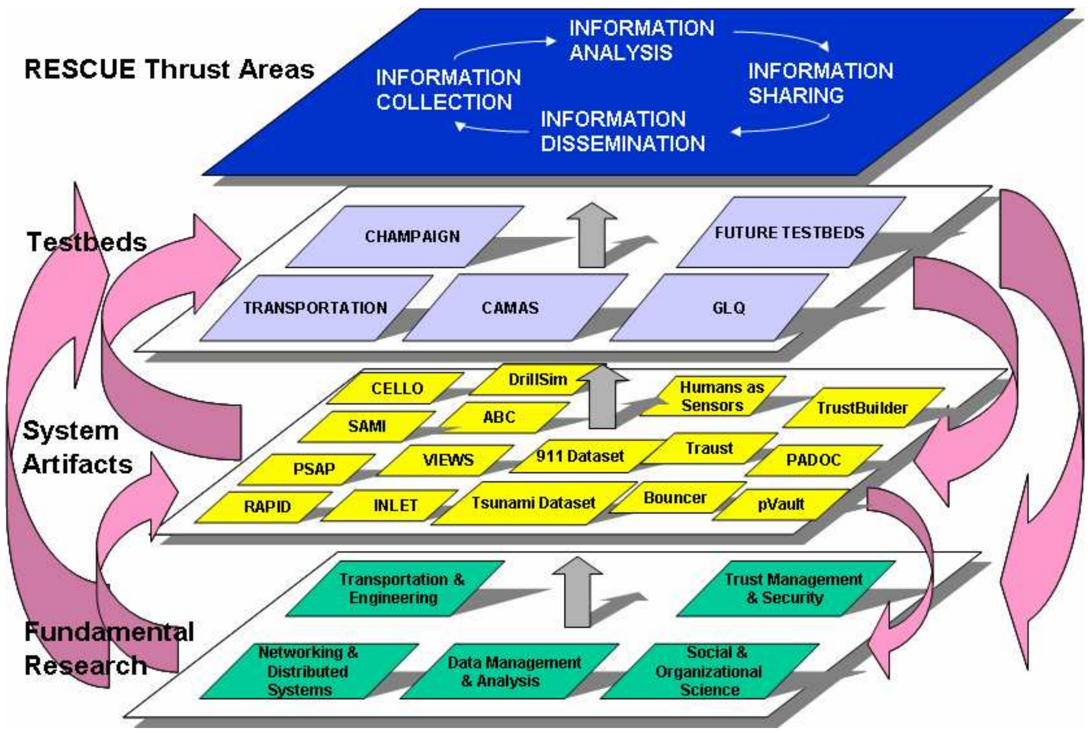


**Figure 2-1. Major Components of RESCUE Program**

The remaining three layers of Figure 2-1 represent the infrastructure that supports research in RESCUE'S four thrust areas. The concept here is that each layer is needed in order for RESCUE to achieve its ultimate mission of performing research on:

> *Enhancing the ability of emergency response organizations to mitigate crises, save lives and prevent secondary and indirect human and economic loss by radically transforming the way in which these organizations gather, process, manage, use and disseminate information during man-made and natural catastrophes.*

*Fundamental Research* forms the basis for new and innovative approaches to information collection, analysis, sharing and dissemination. The identification of these fundamental research areas is a new development in Year 2. While the information cycle provides an effective means of integrating research from different disciplines and areas, it does not allow individual researchers to highlight the significance of their work along more traditional lines of research. As a result, the Executive Committee of RESCUE decided to add an additional dimension to the research plan that called for five fundamental research areas: Networking and Distributed Systems; Data Management and Analysis; Social and Organizational Science; Transportation and Engineering; and Trust Management and Security. To ensure that research in these areas effectively "maps" into the four RESCUE thrust areas (information collection, analysis, sharing and dissemination), research area coordinators were identified and assigned specific roles. One specific role was to coordinate the presentation of research results that follow in Section 2.1.

*System Artifacts* serve two important functions. First, they provide a mechanism to focus individual research activities into a smaller set of studies. By doing so, we are able to promote coordinated research, and develop artifacts or products that are a result of more than one research institution. In this context, artifacts are essentially products that include databases, software, physical systems, etc. The second function of artifacts is to leave a legacy for RESCUE; that is, by developing products that can be transferred to first responders or other emergency personnel, RESCUE not only helps to improve the knowledge base of first-responders, but is meeting its mission statement above by actually delivering methodologies and tools that can be deployed by these groups. Figure 2-1 shows a sample of the artifacts that are currently being developed by RESCUE investigators; Section 3.4 of this annual progress report discusses the details of many of these artifacts.

*Testbeds* are a crucial element of the RESCUE plan in that they provide the means to test and validate both research and research products. Currently, RESCUE has four major testbeds: Transportation; CAMAS (A Citizen Awareness System for Crisis Mitigation); GLQ (Gas Lamp Quarter) and the Champaign Testbed. Each of these testbeds has a unique role in the RESCUE project. For the example, the Transportation Testbed is being used to evaluate IT solutions in large-scale, regional disasters. Past history has shown that emergency response systems can be stretched beyond their capacity for many reasons. However, one of the more significant challenges is responding to unexpected events (multiple) that occur in a geographically widespread area, e.g., large earthquakes. The Transportation Testbed is designed to test and evaluate IT solutions that help with initial damage assessment, communication of critical information to first-responders and the public, and effective response and recovery decision-making.

The CAMAS Testbed is unique in that it provides a testing platform for evaluating IT efficacy in localized events, e.g., World Trade Center Attack. Driven primarily by incidents that affect single-site facilities, the CAMAS Testbed is able to evaluate IT technologies that help to improve emergency response actions such as evacuation from buildings. Designed as a multi-agent simulator, CAMAS has the potential to link simulated outputs to the real actions of people. The CAMAS Testbed will be supported by physical infrastructure created by the Responsphere Project (grant #115-0331707).

The GLQ is a testbed and an example of a living laboratory. It is a hybrid wireless mesh network connected to the Internet over multiple long-haul point-to-point wireless links. It 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. The infrastructure would enable monitoring of the busy, crowded, multi-block business area in downtown San Diego by law enforcement agencies for timely responses in emergencies. Many of the current research products that are being developed as part of RESCUE, such as vision-based and location-based situational awareness, and protocols for efficient and reliable mesh networking, can be studied on this testbed. The importance of this testbed is underlined by the fact that wireless mesh networks play a very crucial role in Ground Zero communications.

Finally, the Champaign Testbed will help to evaluate and even guide research on the security requirements for information during disasters. This testbed was not initially proposed in our original proposal or agreement; however, as a result of active involvement of the user community in research being conducted by Champaign, this testbed has emerged as the fourth testbed for RESCUE. An important reason for introducing this particular testbed at this point of our research program is that it provides an opportunity to study the efficacy of IT research and solutions in a smaller-city setting. Whereas, the other three testbeds reside in large-city settings, the Champaign Testbed will expand the opportunities and challenges of implementing our research on another scale. To coordinate research within each testbed, four testbed leaders have been identified (see discussion on RESCUE management).

The interface between all four layers in Figure 2-1 is considered dynamic and fluid. That is, in many ways, what we learn out of each layer will influence what we do in the other layers. This is especially true for interactions between fundamental research and system artifacts, and between artifacts and testbeds. It is also feasible for fundamental research to feed directly into the testbeds. A complete description of all four testbeds is contained at the end of Section 2.1

## Research Methodology

Figure 2-2 describes our methodology for conducting research within the RESCUE program. The methodology has three main elements:

1. Observations, Findings and Lessons Learned
2. Problem-Focused Research
3. Transferable Artifacts and Products to End-User Community

*Observations, findings and lessons learned* are derived from research on actual events, from interviews with first-responders and domain experts, and on existing literature. For these reasons, this phase of research is significantly guided by our social science investigators. These individuals have years of experience in working with the first-responder community in identifying research needs and priorities in crisis response.

Building on the findings of the previous phase, *problem-focused research* is performed by researchers in all areas of the RESCUE project, especially in information technology. A research program driven by research needs and opportunities will ensure that a legacy remains after the RESCUE project ends after Year 5. Furthermore, developing and nurturing a research agenda that addresses empirical experience will also help to ensure that the most pressing needs are met in this project.

Finally, incorporating a strong engineering element will help to solidify the connection between end-users and researchers. Past experience supports the contention that research that can be implemented has the greatest potential for providing lasting and broad-based societal benefits. The research team has a long-history of working with end-users in adapting new and emerging technologies for crisis response. This experience will be important in ensuring that RESCUE meets its original goal of actually improving crisis response.

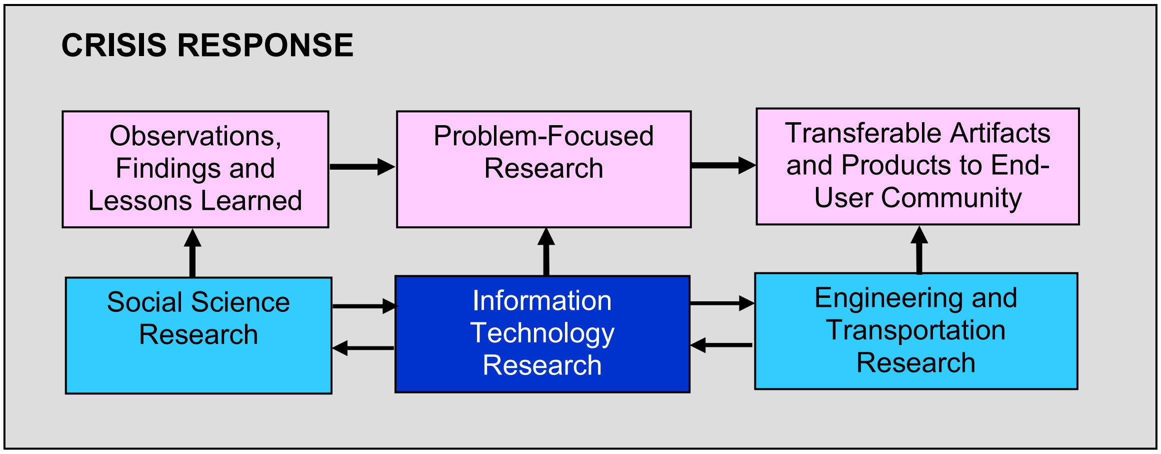


**Figure 2-2. Research Methodology – High-Level Overview**

The next section discusses the Year 2 milestones of RESCUE, as stated in our NSF Cooperative Agreement (IS-0331707).

## Year 2 Milestones

Our proposed Year 2 Milestones, as described in our *Responding to the Unexpected* Cooperative Agreement, have been met in virtually every case. Where deviations have taken place, these are described below along with an explanation for the change. In most cases where changes were made, unanticipated opportunities emerged that allowed RESCUE to expand its mission and effectiveness, e.g., the December 26, 2004 Indian Ocean earthquake and tsunami. Major milestones for Year 2, as described in the NSF Cooperative Agreement, are:

- Open, service-oriented software architecture that consisted of a prototype voice-based, event-processing network of distributed audio sensors, and a backend server infrastructure for extracting events from voice signals.
- Software architecture for a transportation performance platform, including component models for bridge fragility, damage detection and traffic congestion.
- CAMAS framework to test inferential models for unreliable reports, event extraction and adaptive information-filtering techniques.
- Hardware Infrastructure: Interlinked control rooms between UCI and UCSD.
- Software Architecture and Components – software for video analysis, and adaptive filtering and prioritization; service-based middleware that integrates additional modalities and information elements; prototype framework for quality-aware data collection; transportation system performance software.
- Education and Outreach – partnerships with local cities and state transportation agencies to implement transportation damage assessment system; partnerships with local counties to implement CAMAS system; partnerships with local law

enforcement agencies to field-test the human-as-sensor concept; agreements to work with local agencies in implementing various software products; creation of new projects and laboratory exercises, integrated into new course development; graduate course on multidisciplinary research focused on disaster response; internship programs with government partners.

**Open, Service-Oriented Software Architecture.** In Year 2, we expanded the notion of a comprehensive system with a single software architecture to a set of targeted prototype system artifacts. In doing so, we have broadened our focus to address the needs of a more diverse set of response organizations. Within RESCUE, prototype system artifacts serve the following needs:

1. Create opportunities for "Big Science" by providing context for large interdisciplinary research.
2. Create useful entities from RESCUE research which can serve as objects of technology transfer to first-responders/industry.
3. Create opportunities for collaboration and interaction among RESCUE researchers.
4. Enable easy integration and evaluation of RESCUE research into testbeds

As part of this development, we have prioritized the importance of each artifact based on 1) ethnological studies: targeted one-on-one interactions with CAB (Community Advisory Board) members and response organizations, 2) analysis of datasets obtained in the first year of RESCUE, including telephone transcripts (and police reports) from the 9/11 disaster, and news reports/alerts/blogs from the 2004 Indian Ocean Earthquake and Tsunami disaster (details in activities/findings section). Several of the artifacts in development are following an open, service-oriented software architecture and have been designed with extensibility and adaptation in mind.

In Year 2, we have also expanded to a large degree our ability to a) collect and b) use extracted information well beyond our original goal of notification. For example, advances were made in obtaining relevant information on crisis response using existing infrastructures, e.g., cellular. Advances were also made towards using multiple network-access technologies to support accurate, reliable and timely collection of information. Analytical techniques for answering queries that support awareness (people forecasting, occupancy analysis) from multimodal data were also explored in Year 2. Additionally, graph-based analytical query languages were developed that exploit the notion of relationships among entities.

One particular artifact that incorporates several facets of our research is an event-based system that models situation awareness from multimodal input. While the general architecture of this system has already been laid out and a prototype developed, the notable innovation in Year 2 has been the development of techniques to deal with the multimodal input data itself; text, video and voice input in a disaster-response context all pose significant challenges. The translation of these diverse input datasets into meaningful situational assessment information requires a slew of techniques that cater not only to the characteristics of the media (and how it is captured) but also to the interactions between the modalities as well. Some examples of innovative techniques (artifacts) for situation awareness include:

- Extraction of spatial information from text reports
- Topic detection and evolution from text reports
- Occupancy analysis from video data
- Speech processing in noisy environments
- Event disambiguation using relationships
- Graph-based query languages

Details of the projects above are discussed in Section 2 (Activities and Findings) of the annual report.

Significant progress was also achieved in Year 2 in the areas of Information Collection, Sharing and Dissemination – all driven by our enhanced understanding of the needs of the first-responders. In the area of Information Collection, we developed various techniques for quality-aware collection in failure-prone scenarios; this research also included the development of reliable and efficient information collection over multiple networks with software support for intersystem roaming. Our initial efforts led to one particularly novel research area – that of privacy preserving data collection. Techniques that enhance situation awareness rely heavily on instrumenting an environment (pervasive space) with multimodal sensing capabilities. Collection of information from pervasive spaces raises privacy concerns – often preventing the deployment of systems or activities. Our efforts in Year 2 have addressed possible solutions for privacy preserving video surveillance in pervasive spaces. As a result of this work, two prototype systems – CELLO (adaptive cellular localization system) and PADOC (a privacy protecting data collection system), have been developed. Further development is expected in the coming year.

In the area of Information Sharing, significant progress was made in Year 2 in a) organizational sharing, b) peer-based data integration, c) trust negotiation and d) authenticated trust management. Through interviews with City of Los Angeles emergency personnel, we were able to identify the information needs of inter-organizational response during crises. By analyzing actual 9/11 datasets, we learned how multi-organizational networks emerge in response to a large-scale crisis. Revolutionary approaches to trust negotiation using hidden credentials and encrypted logs, were developed in Year 2.

A significant milestone was achieved in Year 2 in the area of Information Dissemination, especially involving the public. A student internship at the City of Los Angeles' Emergency Preparedness Department (EPD) revealed an important concern in the information dissemination process; a problem that we term "flash" dissemination involves the rapid dissemination of critical information to a large number of users in an emergency. Based on insights gained from this interaction, we developed a low-cost scalable peer-based solution for flash dissemination under a variety of heterogeneous conditions. The protocols and algorithms developed have been incorporated in a software prototype that will be installed at the City of Los Angeles' EPD. Other noteworthy achievements in Information Dissemination include:

- Dissemination of customized navigation information to impaired users in disasters

- Strategies for push/pull-based information dissemination (data gerrymandering)
- Deployment of a framework for customized information dissemination to users in vehicles

Finally, we made significant progress in the deployment of the human-as-sensor concept, at a campus level (UCI) and within a metropolitan area (San Diego GLQ). Specific progress has included the deployment of multiple, wireless high-speed data networks and technologies for ABL (Always-Best-Localization). Techniques for quality-aware localization – both within an infrastructure (cellular) and using devices (using filtering techniques) – were explored by RESCUE investigators (see testbed discussions in Section 2.) Specific research activities included: mesh-networking, cross-layer strategies for supporting the notion of Always-Best-Connected (ABC) networks, adaptive localization both on-device (using multiple access interfaces) and within the infrastructure (server-based localization), and customized dissemination mechanisms that account for human behavior in reacting to key dissemination factors (source, mode, route etc.).

**Software Architecture for Transportation Performance Platform.** In Year 2, the Executive Committee of RESCUE decided to formally change the name of the transportation testbed from the ATMS (Advanced Transportation Management System) testbed to the "Transportation Testbed." This was done for several reasons, the most important of which was the need to expand the region of interest. In the ATMS example, the study area was essentially limited to a sub-area of the Caltrans ATMS system around the city of Santa Ana. Because the research team is most interested in applying information technology solutions in a large-scale disaster (i.e., one which affects many cities), it was necessary to expand the study region to include all of Southern California. Caltrans, however, remains a study partner in this testbed.

In the context of the Transportation Testbed, significant progress has been made in creating a system architecture to test and evaluate information technology research and solutions in large-scale disasters. Online software called INLET (*Internet-based Loss Estimation Tool*) has been developed that is enabling researchers to quantify the efficacy of various IT solutions by examining impacts on highway performance both with and without improved information technology. INLET currently incorporates an earthquake-generation engine that simulates the effects of large earthquake events in Southern California. INLET also has a real-time component in that it connects directly to the U.S. Geological Survey's real-time earthquake monitoring site. Currently, highway performance is measured by travel delays or evacuation times. Research that is being evaluated within the INLET platform includes: innovative origin-destination modeling techniques using Bayesian analysis; smart sensors on bridges to assess immediate post-disaster performance; occupancy modeling to better quantify exposed populations in regional incidents; vision-based recognition algorithms to distinguish different modes of traffic (e.g., passenger vs. commercial); mobile-based applications for customized messaging during disasters; and decision-support technologies for optimized routing of emergency acute care vehicles. During the remaining part of Year 2, the research team will be incorporating an optimal-routing algorithm that will help to define effective evacuation strategies given single or multiple-incident events within the region.

A major research thrust in the transportation and engineering area was the development of improved seismic fragility functions for bridges and the adaptation of technologies or methods to assess post-disaster bridge performance. Both of these objectives have been met in Year 2; fragility models were developed based on empirical data from the 1994 Northridge earthquake in Southern California, and in-situ sensors for strain measurement of key bridge components have been investigated. Additional research has been completed on the use of terrestrial and satellite/airborne sensors for post-disaster damage assessment. An important development that has helped accelerate progress in this last area has been the availability of high-resolution, optical satellite imagery. A discussion of its use in the recent 2004 Indian Ocean tsunami is provided in discussion of research activities.

**CAMAS Framework.** In Year 2, our plans for CAMAS expanded significantly, both in terms of scope and resources. First, we were awarded an infrastructure grant by NSF to create the *Responsphere* infrastructure -- a campus-level Information Technology infrastructure to test and validate research on crisis response (grant # 115-0331707). Responsphere consists of two parts: 1) instrumented smart spaces at the UCI campus that are connected to a data laboratory that houses high-performance storage and computing infrastructure, and 2) a mobile command-and-control infrastructure at UCSD. The UCI-fixed infrastructure creates a pervasive environment that covers a few selected buildings and a section of the UCI campus with a variety of sensing technologies including video, audio, motion detectors, RFID technologies, and people-counting (ingress and egress) technologies. These technologies are integrated into the campus backbone system using a variety of wireless technologies. Data from these sensors flow over the wireless and wireline networks directly to the storage and computational infrastructure housed in the RESCUE data laboratory. Agreements with university authorities (including NACS, which is the campus network and computing service, as well as authorities at the participating buildings) has enabled the *Responsphere* infrastructure to be used as an experimental platform for developing, testing and validating many of the RESCUE artifacts.

With the deployment of *Responsphere* at UCI, the scope of the CAMAS testbed (originally intended to test and validate information technologies for situational awareness) has significantly increased. Specifically, Responsphere has made it possible to instrument and monitor campus-level emergency drills in order to study the impact of IT solutions on information collection, analysis, sharing, and dissemination. Such drills are organized on a regular basis at UCI by the Department of Environmental Health and Services (EH&S); we have developed a strong relationship with EH&S and have participated in these drills in various capacities, e.g., as observers, participants and technology implementers. Furthermore, as part of the CAMAS testbed, we are implementing a multi-agent crisis simulator for campus evacuation, which we refer to as DrillSim. DrillSim is a mixed-reality simulator in which actors in the physical world are seamlessly integrated with a simulated world to react to various crisis incidents, e.g., evacuation (see Section 2, Testbeds and Section 3.4, Specific Products Developed, for more details on DrillSim).

Another significant and new effort in the CAMAS testbed is the creation of large crisis-related datasets and models. These include datasets from various natural and manmade disasters (2004 Indian Ocean earthquake and tsunami, and the September 11$^{th}$ attacks on the World Trade Center), reports/transcripts from various 911 call centers, voice reports of radio exchanges among responders, problem or incident reports on UCI facilities. A variety of GIS datasets and tools are also incorporated into this infrastructure. Using these datasets, we have tested and evaluated research on event disambiguation, event extraction, adaptive filtering and inferential models, and GIS-based visualization. Initial work on inferential models for unreliable informant reporting (using early datasets) underscored the need for larger and expanded datasets.

While our research can be carried out using the CAMAS datasets described above, we strongly believe that additional data must be obtained in order to more fully assess robust solutions to crisis response. In Year 2, we are evaluating the utility of our solutions/technologies in live response scenarios, i.e., in drills and exercises conducted in cooperation with the campus emergency services (EH&S, parking, police etc.) Such live datasets are also key to understanding and developing models for unreliable informant reports. These datasets will also support more detailed testing of real-time speech recognition and disambiguation research in live crisis scenarios.

**Hardware Infrastructure.** During the past year, the UCSD Collaborative Visualization Center (CVC), a collaborative effort supported by RESCUE, Calit2 UCSD, and the Jacobs School of Engineering, was formally opened to the Calit2, UCSD and local research communities. One of its intended uses is to serve as a mock command and control center.

Hardware instrumentation at UCI focused on the initial deployment of Responsphere. An indoor/outdoor video/audio sensing and communication infrastructure for a portion of the UCI campus has been successfully deployed. Other sensing modalities that are in the testing phase (within the RESCUE labs) include RFID, motion detection, people counting and powerline sensing technologies. We are also developing industrial partnerships (e.g. IBM, Canon and Linksys) for enhanced instrumentation of this space.

In addition, the UCI data laboratory was recently augmented with additional hardware, (servers, storage) and software capabilities. Multimodal information from recent drills at UCI was captured and stored on machines in the data laboratory; this data was triaged to the mock control center set up at the RESCUE offices. An early version of the situation-awareness system was tested during one of these drills in early 2005 – a hazmat release exercise conducted in cooperation with the Orange County Fire Department. During this hazmat drill, the CVC center at UCSD was used to view the ongoing activities at UCI.

To test and validate the GLQ testbed plan before full deployment, UCSD has designed and built a wireless mesh network in the RESCUE Laboratory at UCSD. This laboratory deployment is helping the research team run experimental studies before the actual deployment in the Gas Lamp Quarter. In the first stage of this laboratory deployment, several experiments were conducted to confirm the testbed's functionality. Wireless client nodes were also configured to communicate through this gateway. In the second stage of this deployment, we will set up multi-hop relaying, routing and communication to the Internet through the gateway. Currently, we are in the process of building the laboratory testbed for the GLQ wireless mesh network. The actual GLQ testbed will be outfitted early in Year 3. At that time, the prototype of the quality-aware data collection framework will be implemented and tested within the GLQ testbed.

**Software Architecture and Components**. As mentioned earlier, a key development in Year 2 was introducing the notion of multiple system software artifacts that could play vital roles in emergency response (as opposed to just one system for multimodal information flow). We categorize software into three main classes:

1. Reusable and modular software: These are mostly tools, modules and components that encapsulate research achievements and are often developed by individual or small groups of researchers. In several cases, we are able to envision how to compose, assimilate or adapt the individual components to address larger prototype needs. We expect that some of the modules will play the role of being core services that can be reused in the chosen prototypes. The following are examples of such modules/components:

    - Video analysis software that focuses on reliable tracking and analysis of moving objects (people, cars) to enable applications such as surveillance. The software incorporates techniques for video object segmentation, multi-level representations of objects, and vision-based techniques for object and character recognition.
    - Robust speech-recognition software that utilizes microphone arrays to improve the robustness of speech recognition in noisy environments. Video-assisted speech-recognition modules merge audio and video information for context-driven speech recognition.
    - Cellphone-based localization software that adaptively obtains localization information from users to handle surge capacity needs in crisis and provide better situational information to response agencies.
    - Software for adaptive filtering and prioritization that focuses on event-filtering based on user profiles as well as push-pull technologies for event triaging to both first-responders and possibly the general public.

2. Service-oriented software: Some of the software developed follows a more service-based approach. This is especially true in cases where the service is targeted at individual subscribers (e.g. ordinary citizens) who interact with a more sophisticated engine to obtain service or some benefit. The engine (server) in this case encapsulates more complex services that may involve other service providers. The benefit of this paradigm is that the end-user interface is transparent to complex protocols and interactions that are implemented within the system, thereby promoting easier use. Examples of service-oriented software developed in Year 2 include:

    - Online software that assesses the performance of regional transportation systems (INLET). This software has been tested on several historic events; adjustments have been made in order to more accurately match actual observations in these events. Future plans include examining the use of INLET in smaller incidents that might be more characteristic of human threats.
    - Pvault, a system for secure password sharing that allows a user to securely maintain and use multiple passwords for different services from anywhere in the network – the nomadic/mobile user is freed from the burden of having to remember numerous passwords while accessing information. This work is currently being expanded to support distributed object-sharing services, where objects and data are protected not just from intruders, but from the

service provider itself. We expect to build upon our research on the concept of DAS (database-as-a-service).

3. Integrative artifacts: These artifacts address the larger goals of response organizations and incorporate both reusable modules and services as part of a larger architecture. We expect that such systems will evolve over time as our research agenda progresses. Below are larger systems/artifacts that are being targeted:

    - A Situational Awareness System for Processing Events: This incorporates modules and research in ontology-based extraction, multimodal data collection, extraction and analysis, event representation, event disambiguation, spatial and temporal analysis, and query support for basic and analytical queries.
    - A Secure Distributed Data Sharing Architecture: This incorporates work on peer-based information integration, techniques for trust negotiation and trusted authentication in organizational information exchange, secured exchange of information over unreliable channels, and secured storage of information on unreliable hosts.
    - An Adaptive Multimodal Data Collection System: This integrates work on robust, secure and timely data collection in instrumented environments, data collection in pervasive spaces (with privacy guarantees), multimodal data collection, and data collection from mobile devices (cellphones, handhelds) that may communicate using multiple access technologies.
    - A Customized Dissemination System: This system focuses on customized dissemination of crisis-related information over heterogeneous networks and diverse users. This builds upon the current Rapid system for flash dissemination of critical information to large numbers of users and incorporates human behavior to disseminate information, the ability to communicate information through various modalities and techniques for prioritization in the dissemination process.

**Education and Outreach.** As discussed above, the research team is working directly with Caltrans to implement INLET, the online damage assessment system for transportation networks. In addition to Caltrans, preliminary discussions have been conducted with the City of Los Angeles for additional deployment in its Emergency Operations Center (EOC).

We have also forged a strong relationship with the Emergency Preparedness Department of the City of Los Angeles. RESCUE investigators have worked closely with Mr. Ellis Stanley, the general manager of the EPD. As a result of this interaction, the following milestones have been achieved:

- RESCUE summer internship with the City of Los Angeles during 2004. This resulted in a new system prototype (the Rapid system for flash dissemination) currently being transferred back to the City of Los Angeles, and;
- A field study that involved interviews and discussions with Los Angeles emergency officials. This field study has served two important purposes: 1)

researchers have gained feedback on how their work could be adapted and applied effectively in the emergency management domain; and 2) our government partners have become aware of new enabling technologies and potential tools.

Through our connections with the City of Los Angeles, RESCUE team members were invited to observe and participate in a large-scale terrorism drill – Determined Promise 2004 (involving the Port of Los Angeles, City of LA, State of California, FEMA and FBI). Several important insights that were gained during this large exercise were communicated to all RESCUE members during the annual PI meeting in October 2004. We have also interacted with the State of California Governor's Office of Emergency Services to obtain information on GIS-based data-integration groups within California. An important accomplishment in Year 2 was the establishment of close ties with the Emergency Response Division of the City of Champaign, Illinois. As a result of this interaction, a fourth testbed has been established in the RESCUE project that utilizes personnel and resources in the City of Champaign. Other outreach activities can be found in Section 2.3 of this report.

Education efforts have continued to incorporate new projects and laboratory exercises that are motivated by disaster-response research. Four new courses were introduced by Professors Butts, Mehrotra and Venkatasubramanian at UCI. Both UCI and UCSD continue to work with undergraduate and graduate students in their final project courses, developing prototype technologies based on core research and academic instruction. Details of these achievements are discussed the Education Outreach part of Section 2.3.

A program for visitor exchange and student internships between institutions and with participating government partners was implemented in Year 2. Notable achievements in this program include: 1) a UCI student serving an internship at the City of Los Angeles' Emergency Preparedness Department; (2) a University of Colorado researcher conducted a series of interviews at the City of Los Angeles to determine first-responder IT needs; (3) frequent onsite interactions of UCI students with team members at UCSD; 4) UCI student and faculty visits to Boulder for interactions at the University of Colorado Natural Hazards Center; 5) Professor Seamons and his students from BYU visited and had technical interchange with the RESCUE team at UCI; and 6) Professor Kathleen Tierney and researcher Jeannette Sutton from Colorado visited and gave presentations at UCI.

In November 2004, a successful Principal Investigator's meeting was held at the Beckman Center at UCI. Approximately 70 RESCUE researchers from all institutions attended this meeting. The keynote speaker was Dr. David Banks, Director of the Center for Asymmetric Warfare. The Center for Asymmetric Warfare, along with U.S. Northern Command, has been involved in developing large-scale terrorism drills – the RESCUE team attended one such drill (Determined Promise 2004). Students and professors participated in breakout and poster sessions over two days. This year's annual all-hands meeting will take place in San Diego on November 3-4, 2005. The tentative agenda includes a research review, breakout sessions, and an open house to which our industrial and academic communities and first-responder partners will have an opportunity to learn about the research activities and progress

## Major Research Thrust Areas

Four specific research thrust areas have been defined for this project: Information Collection, Information Analysis, Information Sharing and Information Dissemination. In addition to these major thrust areas, four testbeds have been initiated: a) Transportation Testbed, b) CAMAS (A Citizen Awareness System for Crisis Response), c) GLQ – Gas Lamp Quarter, and d) Champaign Testbed. Progress in each of these areas is discussed below. In order to provide a "roadmap" for these discussions, Table 2-1 has been included. This table lists the different project areas of RESCUE. More detailed tables appear later in this report that identify Tasks/Investigators under each project area. Although tasks have been identified for each project area, some are just at the beginning stages of development. Where this is the case, we note this for the reviewer.

**Table 2-1. RESCUE Projects (Year 2)**

| THRUST AREA | PROJECT TITLE |
|---|---|
| **Information Collection (C)** | C1: Robust Distributed Speech Recognition |
| | C2: Video Analysis |
| | C3: Sensing Technologies |
| | C4: Robust Networking Systems |
| | C5: Adaptive Data Collection Mechanisms |
| | C6: Privacy Challenges in Data Collection |
| **Information Analysis (A)** | A1: Multimodal Analysis and Extraction |
| | A2: Event Awareness |
| | A3: People Awareness |
| | A4: Domain Independent Decision-Support Tools |
| | A5: Domain-Driven Decision-Support Tools |
| **Information Sharing (S)** | S1: Understanding Emergent Networks |
| | S2: Trust Management in Crisis Networks |
| | S3: Security and Privacy Concerns in Information Sharing |
| | S4: Mediation, Integration, Querying, Filtering |
| **Information Dissemination (D)** | D1: Understanding and Classifying Dissemination Scenarios, Modalities and Needs |
| | D2: Behavior Model of Social Phenomena |
| | D3: Customizable Dissemination Systems |
| | D4: Exploiting IT Infrastructure for Dissemination |
| | D5: Dissemination Systems and Optimizations |

## 2.1 MAJOR RESEARCH AND EDUCATION ACTIVITIES, INCLUDING MAJOR FINDINGS

The following sections provide a summary of major research and education activities for the RESCUE project. In addition, within these discussions, we provide our assessment of major findings as they relate to the four main thrust areas: Information Collection; Information Analysis, Information Sharing and Information Dissemination. A discussion of outreach activities (first-responder community, industry, community in general, and education) is also provided at the end of this section.

### INFORMATION COLLECTION

This thrust area encompasses both sensing and collection. In the context of sensing, we are exploring new and emerging technologies for bridge monitoring and remote sensing, both of which address near real-time damage detection after large-scale disasters. Our work on speech recognition and video analysis can be viewed as converting speech/video signals into a form that is suitable for analysis and interpretation within the context of crisis response.

Research on collection focuses on: a) developing networking infrastructure to support information collection that scales to unpredictable situations; b) protocols/mechanisms for distributed information collection from the sensor nodes; and c) privacy challenges in information collection. Table 2-2 presents a listing of active research projects and tasks in the area of Information Collection.

**Table 2-2. Information Collection - Project Areas, Tasks and Investigators**

| Project Area | Task No. | Task Description | Institution/ Investigator |
|---|---|---|---|
| C1: Robust Distributed-Speech Recognition | C1.1 | Robust Speech Recognition | UCSD/ B. Rao |
| C2: Video Analysis | C2.1 | Multi-Person Tracking | UCSD/ M. Trivedi |
| | C2.2 | Vision-Based Crowd and License Plate Recognition (LPR) Monitoring | UCSD/ S. Belongie |
| C3: Sensing Technologies | C3.1 | Remote Sensing | ImageCat/ R. Eguchi, B. Adams, C. Huyck |
| | C3.2 | Bridge Sensors | UMD, P. Chang |
| C4: Robust Networking Systems | C4.1 | Always Best Connected (ABC) | UCSD/ R. Rao |
| C5: Adaptive Data Collection Mechanisms | C5.1 | Adaptive Data Collection in Dynamic Distributed Systems | UCI/ S. Mehrotra, N. Venkatashubramanian |
| | C5.2 | Cell Phone as a Sensor | UCI/ S. Mehrotra, N. Venkatasubramanian |
| | C5.3 | Cellular Platform for Location Tracking | UCSD/ R. Rao, J. Zhu |

| Project Area | Task No. | Task Description | Institution/ Investigator |
|---|---|---|---|
| | C5.4 | High-Level Architecture Design of Two-Level Telecommunication Simulator | UCSD/ R. Rao/B. Jafarian |
| C6: Privacy Challenges in Data Collection | C6.1 | Privacy Preserving Pervasive Spaces | UCI/ S. Mehrotra, N. Venkatasubramanian |
| | C6.2 | Privacy Preserving Index for Range Queries | UCI/ S. Mehrotra, N. Venkatasubramanian |
| | C6.3 | Querying Encrypted XML Documents | UCI/ S. Mehrotra |
| | C6.4 | A Systematic Search Method for Optimal K-Anonymity | UCI/ S. Mehrotra, N. Venkatasubramanian |
| | C6.5 | Privacy Protecting Video Surveillance and Data Collection in Media Spaces | UCI/ S. Mehrotra, N. Venkatasubramanian |
| | C6.6 | Dynamic Access Control for Ubiquitous Environments | UCI/ S. Mehrotra, N. Venkatasubramanian |

## Major Activities and Findings:

## C1 ROBUST DISTRIBUTED SPEECH RECOGNITION

### C 1.1 Robust Speech Recognition *(UCSD/ B. Rao)*

Speech recognition with multiple microphones holds considerable promise in improving the robustness of automatic speech-recognition systems because in a noisy environment the multi-channel signals obtained via spatial sampling can suppress noise and interference, and enhance the desired speech signal. We studied various beamforming algorithms and identified two significant problems that limit narrowband adaptive beamforming algorithms in practice. One is robustness against steering-vector error, and the other is correlation between the desired signal and interference (most adaptive beamforming algorithms are developed using narrowband signal assumption, while speech is a broadband signal).

We compared and analyzed existing adaptive beamforming algorithms and developed some variations of them that promise more robust results. We also developed a new algorithm that utilizes the correlation between the source signals to accurately estimate the direction of arrival, and spatially notch the interference out while preserving the desired signal. We are also actively considering time-domain-based broadband adaptive beamforming algorithms, which have potential advantages in processing speech, since we don't have to turn to the frequency domain where the correlation appears more problematic.

For our robust microphone array speech-recognition project, a real environment multi-microphone database is important. Such databases are not readily available and some of our effort has been geared towards this database and experimental testbed design. We have designed a two-microphone array system for the Rescue project: a handheld two-microphone system, which has been configured and is ready for collecting data; and an in-car multi-microphone system, which currently is being assembled and deployed.

## C2 VIDEO ANALYSIS

### C2.1 Multi-Person Tracking *(UCSD/ M. Trivedi).*

Reliable tracking and analysis of moving persons and their activities are basic tasks in video camera-based applications such as surveillance and user interface in the RESCUE project. These tasks are especially challenging in outdoor environments due to changes in background clutter and temporal variation in illuminations. In Year 2 the research has focused on the basic investigations of the characteristics, constraints, and requirements of algorithms and mechanisms in outdoor tracking under varying illuminations.

Our research integrated state-of-the-art human tracking systems and gesture recognition systems, using single rectilinear camera and multiple omni-directional cameras for indoor settings, and extended its application area from indoor to outdoor environments. We developed a fully automated multi-level representation framework for the human body, where the entire body of a person was detected and divided into salient body parts such as head, upper body and lower body, based on appearance. The detailed representation of the human body with the color-based appearance model has several advantages; it is robust enough to track failure and more reliable in recovering from the track loss.

We developed algorithms for automatic learning of background models for segmentation, a constant monitoring method of a given scene, adaptive representation of pixel color distributions, and segmentation and tracking of multiple persons under varying illuminations of the same light sources. We are currently investigating tracking multiple persons under various illuminations with different light sources and tracking persons in detailed levels that involve tracking of individual body parts as well as whole bodies.

### C2.2 Vision-Based Crowd and License Plate Recognition (LPR) Monitoring *(UCSD/ Serge Belongie).*

Our computer vision research in crowd counting and LPR will be a primary source of information for the decision center of RESCUE by providing a direct interpretation of visual data during an event involving crowds, and providing information such as identifying which vehicles are present at the emergency site, enabling a search for vehicles responsible for responding to a catastrophic event in the case of a roadway or campus emergency, or aiding the distribution management of emergency vehicles.

One research area has involved researching algorithms to accurately count people in crowded situations, recognize crowd behavior (e.g. normal, running, rioting actions), and benchmark our results against human-expert labeled data. Our preliminary results have demonstrated people counting on a 10-minute video clip captured on campus during a set period. We were able to determine the count for a crowd size of approximately 40 persons with 20% accuracy.

Other research has involved development of a super resolution algorithm to find and track a license plate in a video footage, and a character-recognition algorithm to read the license plates. We have successfully implemented this algorithm, which was based on a text zone recognition process that we have trained exclusively on license plates.

## C3 SENSING TECHNOLOGIES

### C3.1 Remote Sensing *(ImageCat, R. Eguchi, B. Adams and C. Huyck)*

In Year 2, ImageCat researchers have investigated various types of satellite and airborne sensors for post-disaster damage detection, including synthetic aperture radar (SAR), low-, moderate-, and high-resolution multi-spectral optical sensors and LIDAR data (LIght Detection and Ranging). The research team has developed several change-detection techniques using procedures such as correlation of optical reflectance between moderate-resolution images, coherence of SAR reflectance, changes in LIDAR elevation and reflectance, and texture change between pre- and post-event image segments. Where possible, each change detection result is cross-referenced with observed damage to determine the level of damage detection possible. Previous disasters including the recent Indian Ocean earthquake and tsunami are being used to calibrate the ability of each sensor to produce meaningful information on post-disaster damage. In addition, the practicality of these sensors as post-disaster response tools is being investigated by evaluating image acquisition and processing time, and the consistency of algorithm performance. Since delays greater than 3 days are problematic for regional disaster response, current methods of data storage, access and formatting issues that impact image download, stitching and geo-processing are being assessed.

### C3.2 Bridge Sensors *(UMD, P. Chang).*

During Year 2, bridge damage sensors were studied as a way to collect information after a major event. The fiber sensors studied are simple, cost effective and extremely resistant to environmental damage. Different forms of fiber orientation, fiber layout and the effects of different adhesives were studied. Results indicated that the sensors have a viscoelastic property that makes them appropriate for quasi-static (rather than dynamic) strain measurements. Transfer functions were developed to convert these strain measurements to bridge deformation. Numerical verification of the method was performed and compared to theoretical predictions. These experiments indicated that the transfer function could accurately predict bridge deformation. These deformations could be used as an indicator of the health status of a bridge after a major event. Excessive deformation could be used as a damage indicator. Bridge collapse information could also be obtained by using the total strain measurement along the length of the bridge. Current and future research involves development of improved methods to attach the fiber sensor, and study of continuous tracking of strain and deformation as a metric of sudden damage.

## C4 ROBUST NETWORKING SYSTEMS

### C4.1 Always Best Connected (ABC) *(UCSD/ R. Rao)*

The *Always Best Connected* (ABC) concept refers to an environment where several different types of access networks and different devices are available to a user for communication. The user can choose at any time the access network and device that best suits his or her needs depending on the applications that he or she is currently running, and change whenever something better becomes available. In recent years, the following functionalities of ABC have been built and tested in our labs: Access Discovery and Selection; Mobility Management; Bandwidth Aggregation in Ad-Hoc networks; Measurements; and Profile-Based Access Control.

Access Discovery performs the task of determining what network accesses are currently available for the client and whether there is connectivity to a point in his home network. Access Selection allows the user to select different access networks depending on his predefined preference or based on the dynamic preference based on his profile stored in the network. Mobility Management manages the session continuity for various services. Bandwidth Aggregation handles the use of multiple interfaces simultaneously. Measurements are done for getting the throughput, delay and some other statistics for the client machine. Profile Server helps the client to store and manage its various preferences. Some of the preferences can include the network preferences, application characteristics, device characteristics, etc. With the addition of all these features, ABC has become a versatile testbed for current and future projects.

## C5 ADAPTIVE DATA COLLECTION MECHANISMS

### C5.1 Adaptive Data Collection in Dynamic Distributed Systems

*(UCI/ S. Mehrotra, N. Venkatasubramanian)*

In Year 2, the primary goal has been to develop system support for dynamic data collection in the context of highly heterogeneous environments and extreme situations. Such data collection and processing systems have numerous overlapping and conflicting concerns, including the availability of energy in wireless devices, acceptable bandwidth, resilience of the physical infrastructure during crises, competition for resources from different applications, and tension between the need for simple and robust "best-effort" solutions and more complex and semantically complete ones. The research team has developed techniques to address the collection and processing of data from heterogeneous dynamic data sources, such as sensors and cell phones, and the querying of such data when stored (imprecisely) in databases. There are 4 major areas of research where significant progress has been made over the past year: 1) Quality-Aware, Cost-Effective Basic Architecture for Dynamic Data Collection; 2) Quality-Aware Query Processing over Imprecise Data; 3) Energy Efficiency, Fault Tolerance and Timeliness in Sensor Networks; and 4) Cell Phone as a Sensor.

***Quality-Aware, Cost-Effective Basic Architecture for Dynamic Data Collection.*** In Year 2, using a target-tracking application, the research team has focused on a feasibility assessment of the basic adaptive data-collection premise. The objective was to determine the track of a moving target (at some level of approximation) by deploying a field of instrumented acoustic sensors. As part of this deployment, we developed a quality-aware information collection protocol designed for sensor networks. The protocol explores the trade-off between energy usage and application quality in order to significantly reduce energy consumption in the sensor network, thereby enhancing the lifetimes of sensor nodes. Simulation results over basic movement patterns (in a tracking application scenario) have underscored the merits of our adaptive information collection framework.

***Quality-Aware Query Processing over Imprecise Data.*** Over the past year, we have made significant progress in three areas: Selection Queries, Continuous and Aggregation Queries, and In-Network Queries.

*Selection Queries.* We have examined the problem of evaluating selection queries over imprecisely represented objects – where the object is much smaller in size when compared to precise data (e.g., compressed versions of time series) or imprecise replicas of fast-changing objects across the network (e.g., interval approximations for time-varying sensor readings). Retrieving the precise objects themselves (at additional cost) was explored to increase the quality of the reported answer. We allowed queries that were tied to specific quality requirements, and showed how the query evaluation system met these requirements with minimal work. We also considered queries with set-based answers whose aim was to minimize the combined cost of data processing and probe operations in a single framework. Based on our research, we concluded that a beneficial answer accuracy/performance tradeoff in a general setting is more realizable than previously thought.

***Continuous and Aggregation Queries**.* One important application of wireless sensor networks is aggregate monitoring, where a continuous aggregate query is posed and processed within networks; but supporting data aggregation strategies can be very energy-expensive with battery-operated sensors. Using approximate aggregation, where a certain amount of error can be tolerated by users, we developed continuous aggregate query processing that exploited error tolerance to achieve energy efficiency. We scheduled transmission and listening operations for each sensor node to achieve collision-free communication for data aggregation. We dynamically adjusted error bounds at sensor nodes to minimize power consumption and adapted the adjustment period to cater to dynamic data behavior. Adjustments were performed on network sections and on the entire network. Simulation results indicated that the adaptive techniques resulted in an energy savings with small error tolerance, about {20~60%}.

*In-Network Queries.* We developed SURCH, a decentralized algorithm that exploits the distributed nature of wireless sensor networks (no pre-established infrastructures) to efficiently process queries. With a small number of messages, the algorithm searches the region specified by a query. Partial query results are aggregated and identified before being delivered to a destination node for final processing. SURCH is a powerful tool for handling ad hoc queries generated in-network, efficient for queries that solicit data from only a small portion of relevant sensor nodes, and is power-aware and failure-resilient. In a normal network setup, SURCH saves about 60% of messages compared with other aggregation techniques.

***Energy Efficiency, Fault Tolerance, and Timeliness in Sensor Networks.*** In a crisis, information is needed rapidly and over failing infrastructures. Our research considers adaptive data collection mechanisms for sensor environments that adjust to differences in stability of sensor values, and the varying application needs that impose different quality requirements across sensor variations while optimizing sensor energy consumption. In a series of sensor models that progressively expose increasing numbers of power-saving states, we developed quality-aware data-collection mechanisms that enabled satisfactory query-quality requirements while minimizing resource (energy) consumption. Experimental results show significant energy savings compared to the naïve approach to data collection.

Small, distributed wireless sensors are fragile, have finite energy supply, and can lose packets over wireless channels; reports sent from them may not reach destination nodes and the “quality” of the information collected from them is uncertain. We have developed a data-collection protocol using re-transmission that provides expected reliability guarantees while minimizing resource consumption by adaptively adjusting the number of retransmissions based on current network fault conditions. The sensor derives optimal re-transmission times for data items based on the feedback from the server.

To provide a real-time context information-collection service that delivers the right context information to the right user at the right time, we have used Quality-of-Service (QoS) to express timeliness, Quality-of-Data (QoD) to express accuracy, and collection cost. We have created a middleware framework for real-time information collection incorporating a family of algorithms that accommodates diverse characteristics of information sources and varying requirements from information consumers. The framework contains an information mediator to coordinate and facilitate communication between information sources and consumers. We have developed distributed mediator architectures to support QoS and QoD. We also have evaluated standard sensor-server architectures, and distributed and centralized mediator architectures to study the QoS/QOD/Cost balance; we are integrating this work into AutoSEC, a prototype service composition framework being developed at UCI.

### C5.2 Cell Phone as a Sensor *(UCI/ S. Mehrotra, N. Venkatasubramanian)*

During crises, a cell phone can be used to give location-specific information to users and information about the spatial distribution of individuals to responders. We have investigated ways to collect location data and predict motion patterns of users despite likely failures in infrastructure. We have developed a prototype system called CELLO to gather location information from cell phones in real time, using BREW-based clients running on cell phones that periodically sampled a unit's location, using assisted GPS technology. Data is forwarded via data transmission (IP) to a Java-based server with a relational database back-end, where the data is stored. We anticipate the future location of each object with simple motion-prediction techniques, and create a frequency-adapting mechanism for sample acquisition. Current research considers a basic architecture with adaptive data-collection protocols, that modifies the frequency and accuracy of the incoming data stream depending on the “predictability" of the user's trajectory, the interest of applications in his trajectory, and the correlation of users' location with other spatially distributed “events," such as first-responder teams, or the distribution of hazards in the crisis region. Our architecture is part of a larger reflective cellular architecture that is resilient to disasters and fluctuations of resource availability, and can function in the most mission-effective manner.

We have derived rules supporting seamless integration of information collection, resource-provisioning mechanisms for mobile environments, and have developed a family of information-collection policies that vary in the granularity at which system state information is represented and maintained. We have evaluated the impact of these policies on the performance of diverse resource-provisioning strategies, and have observed that resource-provisioning benefits significantly from customized information-collection mechanisms that take advantage of user-mobility information. Performance results indicate that effective utilization of coarse-grained user-mobility information renders better system performance than using fine-grained user-mobility information.

### C5.3 Cellular Platform for Location Tracking *(UCSD/ R. Rao, J. Zhu)*

Mobile phones have evolved into smart computing devices that provide instantaneous information anywhere, anytime. We have built a system to monitor and track the location of UCSD campus shuttle buses, based on the latest technology developed from Qualcomm, to allow GPS fixing from mobile phones. The system combines location information with multimedia data sharing among mobiles and servers. It includes a real-time map view of buses indicating their location, speed and identity (e.g., campus loop, east parking, etc.) on both web and mobile interfaces; and a management system including mobile phone assignment to individual buses, messaging to one or more buses, and enabling or disabling the mobile-tracking feature (this feature is only available to bus dispatcher).

We have developed a set of specifications/requirements and built a client- and server-based system, where the client resides in the mobile phone and the server resides in a Java-based web server. The deployed system will demonstrate the availability of the position of a bus and multimedia data in real-time. The complete system includes the following components and related software: a mobile phone (with Assisted GPS, Camera, BREW 2.x); software at the mobile to perform GPS fixing and networking for data exchange with server (the GPS data includes the latitude, longitude, horizontal speed, heading and altitude); and a Java-based server for web-based presentation of GPS position, bus speed and bus identity. The system will be integrated with a GIS engine to display a UCSD campus map. Our continued work includes completing system integration, testing the system against the specifications/requirements, and conducting a field trial by installing the system onto campus buses at UCSD and testing.

### C5.4 High Level Architecture Design of Two Level Telecommunication Simulator *(UCSD/ Rao,Jafarian)*

In Year 2, research is being conducted at UCSD to develop a two-level telecommunication simulator that will tie into the Transportation Testbed. In natural disasters, such as earthquakes and hurricanes, the behavior of ordinary people close to the incident will be dramatically changed depending upon many different factors, including the type of incident, the perceived or actual hazard, and knowledge of the details of the incident by both the public and emergency response personnel. From the point of view of communications, additional factors that will influence the effectiveness of emergency-response capabilities will be the load on the communication system; e.g., past disasters have identified overload on the system from people wanting to contact family members regarding their safety in an event. Under abnormal situations, mobile cellular systems can be vulnerable to disruption from two major sources: a) damage to physical infrastructure, e.g., towers, or power systems supplying service to towers and other infrastructure; and b) unexpected increase in load from users. Most cellular systems are designed to handle normal traffic load conditions and will collapse during unexpected traffic loads. The research that is being conducted by UCSD is focused on understanding the vulnerabilities of cellular systems in large-scale disasters and incorporating this understanding in a complementary simulator that will connect into the Transportation Testbed. This simulator will estimate where service connections may be vulnerable based on regional analysis of disaster effects, e.g., localized damage from a large earthquake. Future areas of research include: a) incorporating a real-time element into the simulator that will provide rapid information on serviceability; and b) importing information on transportation system performance in order to help guide system operators of telecommunication systems in post-disaster response activities and repairs.

## C6 PRIVACY CHALLENGES IN DATA COLLECTION

Building pervasive spaces requires collecting and logging information about the state of the environment, its users and its resources. For pervasive environments to provide utility for their users, collected data may include personalized information, resulting in a potential violation of an individual’s privacy. In Year 2, our research has been focused on privacy concerns stemming from interactions between individuals and the environment within human-centric pervasive environments in which human subjects are embedded in pervasive spaces. Many types of privacy challenges can be identified: privacy of individuals from the environment, privacy of individuals from other users and privacy of interactions among individuals. We have aimed to design data collection strategies in such a way that services offered by pervasive environments do not come at the expense of individuals' privacy. (In a complementary research effort, Kent Seamons of BYU is looking at privacy of interactions among users immersed in pervasive spaces.) Our research has focused on the following efforts: 1) Privacy-Preserving Triggers for Pervasive Spaces; 2) A Privacy-Preserving Index for Range Queries; 3) Querying Encrypted XML documents; 4) A Systematic Search Method for Optimal K-Anonymity; 5)

Privacy Protecting Video Surveillance and Data Collection In Media Spaces; and Dynamic Access Control for Ubiquitous Environments.

**C 6.1 Privacy-Preserving Triggers for Pervasive Spaces**
*(UCI/ S. Mehrotra, N. Venkatasubramanian).*

Privacy is a concern in a trigger-based pervasive environment in which end-user services are built using triggers over events detected through. Using secret-sharing techniques from applied cryptography, we devised protocols to test such conditions in a way that the user data is not accessible or viewable until the time at which the condition (or set) is met. Our approach was useful in the implementation of access-control policies of the pervasive space. Our approach showed that the adversaries (i.e., people with access to the servers and logs of the pervasive space) did not know any additional information about individuals except what it deciphered from the knowledge of trigger execution. The triggers for which our technique is designed are limited to counting triggers, but they are powerful enough to support a variety of functionalities in the surveillance application.

**C6.2 A Privacy-Preserving Index for Range Queries**
*(UCI/ S. Mehrotra, G. Tsudik)*

Privacy is threatened when relational data is stored over untrusted servers that must provide efficient access to multiple clients. We analyzed the data-partitioning (bucketization) technique and algorithmically developed this technique to build privacy-preserving indices on sensitive attributes of a relational table. Such indices enable an untrusted server to evaluate obfuscated range queries with minimal information leakage. We analyzed the worst-case scenario of inference attacks that can potentially lead to breach of privacy (e.g., estimating the value of a data element within a small error margin) and identified statistical measures of data privacy in the context of these attacks. We also investigated precise privacy guarantees of data partitioning that form the basic building blocks of our index. We developed a model for the fundamental privacy-utility tradeoff and designed a novel algorithm for achieving the desired balance between privacy and utility (accuracy of range query evaluation) of the index.

**C6.3 Querying Encrypted XML Documents** *(UCI/ S. Mehrotra)*

When XML data is stored over untrusted servers that must support efficient access to clients, encryption offers a natural solution to preserve the privacy of the client's data, but it is challenging to execute queries over the encrypted data without decrypting them at the server side. We developed security mechanisms on the XML documents, which help the client to encrypt portions or totality of the XML documents; analyzed techniques to run SPJ (Selection-projection-join) over encrypted XML documents; and exploited a strategy where indices/ancillary information was maintained along with the encrypted XML document.

**C6.4 A Systematic Search Method for Optimal K-Anonymity**
*(UCI/ S. Mehrotra, N. Venkatasubramanian)*

The notion of K-anonymity was introduced to protect privacy concerns in organizations that collect huge amounts of information pertaining to individuals while keeping the data information rich for its subsequent use. A K-anonymized dataset has the property, where any tuple in the dataset is indistinguishable from k-1 other tuples. We conducted experiments that showed that using the tuple-generalization approach (a data centric approach which clusters similar tuples in a fashion that releases more information than was possible in attribute generalization), we explored a bigger solution space and increased the chances of finding better solutions than previous search methods did.

### C6.5 Privacy Protecting Video Surveillance and Data Collection in Media Spaces

*(UCI/ S. Mehrotra, N. Venkatasubramanian)*

In our research, we fused sensor information with traditional video surveillance streams to make decisions about how to display individuals being surveyed to create a system within a privacy-protecting framework. Our system utilized off-the-shelf sensor hardware (i.e. RFID, motion detection) for localization, and combined it with a XML-based policy framework for access control to determine violations within the space. We made enhancements to algorithms for object detection, tracking and masking, and began work on handling the fusion of multiple surveillance streams. We implemented several video-masking techniques corresponding to varying user-privacy levels and achieved results in real-time at acceptable frame rates, while meeting our requirements for privacy preservation.

### C6.6 Dynamic Access Control for Ubiquitous Environments

*(UCI/ S. Mehrotra, N. Venkatasubramanian)*

We took a domain-based approach to access control in distributed environments with mobile distributed objects and nodes, utilizing a different notion of an object's “view" by linking its context to the state information available to it for access control purposes. We investigated the problem of hiding and managing sensitive information in insecure environments by providing objects in the system with a view of their state information. We re-evaluated security considerations for mobile objects by combining access control requirements and multilevel security with mobile and contextual requirements of active objects. We developed a middleware-based architecture to provide access control in the environment and view-sensitive mechanisms for protection of resources while both objects and hosts are mobile, and examined issues with delegation of rights in these environments.

## INFORMATION ANALYSIS

The objective of this thrust area is to transform low-level sensor data about situations or incidents into meaningful information for decision making. Situations can be thought of abstractly as crisis events, people or resources. Another key factor in the analysis of information is awareness. By awareness, we refer to both awareness of a current situation, as well as awareness of a predicted situation. Awareness is crucial for effective decision-making and within this thrust area, we include decision-support tools that enhance the decision-making process. Table 2-3 presents a listing of active research projects and tasks in the area of Information Analysis.

**Table 2-3. Information Analysis - Project Areas, Tasks and Investigators**

| Project Area | Task No. | Task Description | Institution/ Investigator |
|---|---|---|---|
| A1: Multimodal Analysis and Extraction | A1.1 | Multi-Modal Speech Recognition | (UCSD/ B. Rao, M. Trivedi) |
| | A1.2 | Topic Extraction from Text | UCI/ P. Smyth |
| | A1.3 | Video Data Analysis | UCI/ P. Smyth |

| Project Area | Task No. | Task Description | Institution/ Investigator |
|---|---|---|---|
| | A1.4 | Information Extraction from Text | UCI/ A. Meyers |
| | A1.5 | Entity Disambiguation | UCI/ S. Mehrotra, D. Kalashnikov |
| | A1.6 | Ontology Driven Event Extraction from Text | UCI/ S. Mehrotra, N. Ashish |
| A2: Event Awareness | A2.1 | Event DBMS | UCI/ S. Mehrotra, N. Venkatasubramanian, D. Kalashnikov |
| | A2.2 | Event Disambiguation | UCI/ S. Mehrotra, N. Venkatasubramanian, D. Kalashnikov |
| | A2.3 | Spatial Awareness from Reports | UCI/ S. Mehrotra, N. Venkatasubramanian, D. Kalashnikov |
| | A2.4 | Knowledge-Driven Event Reasoning | UCI/ S. Mehrotra, N. Ashish |
| A3: People Awareness | A3.1 | Modeling Car Travel Activity of Individuals | UCI/ Dechter |
| | A3.2 | Inferring “Who is Where” from Sensor Data | UCI/ P. Smyth |
| A4: Domain Independent Decision-Support Tools | A4.1 | Graph Analysis Methods | UCI/ S. Mehrotra |
| | A4.2 | Hybrid Bayesian Networks | UCI/ Dechter |
| | A4.3 | Hybrid Dynamic Bayesian Networks | UCI/ Dechter |
| | A4.4 | Approximate Algorithms for Inference | UCI/ Dechter |
| A5: Domain-Driven Decision-Support Tools | A5.1 | A Centralized Web-Based Loss Estimation Methodology | ImageCat/ R. Eguchi, C. Huyck, H. Chung, M. Mio, S. Cho |
| | A5.2 | Optimal Routing of Emergency Vehicles | UCI/ M. Shinozuka |
| | A5.3 | Bayesian Analysis of Informant Reports | UCI/ C. Butts |
| | A5.4 | Vertex Disambiguation within Communication Networks | UCI/ C. Butts |

## Major Activities and Findings:

## A1 MULTIMODAL ANALYSIS AND EXTRACTION

### A1.1 Multi-modal Speech Recognition *(UCSD/ B. Rao, M. Trivedi)*

Cell phones are now equipped with cameras and microphones; in the future we could expect hand-held devices that can collect data from multiple modalities: audio and video. Audio speech recognizers, based on the acoustic waveform produced by a speaker, have been extensively investigated, while visual speech recognizers – movements of the lips, tongue and other facial muscles of a speaker – have not. The goal of our research was to improve robustness of speech-recognition systems by incorporating the information from audio and visual domains into the speech-recognition framework.

We developed effective, real-time speech recognizers in the audio and video domains, and a new framework to merge the audio and video recognizers. The video-assisted audio speech recognizer we developed is robust to background noise which drastically affects the performance of the audio speech recognizer, and does not break down in the absence of any one of these streams of information. A general merging technique will enable us to incorporate the possible inclusion of gesture and context-based speech recognition in the future.

### A1.2 Topic Extraction from Text *(UCI/ P. Smyth)*

In Year 2, topic extraction algorithms were successfully applied to news reports obtained from the Web that were related to the December 2004 tsunami disaster, and the resulting topic models were used as part of the framework for a prototype "tsunami browser."

### A1.3 Video Data Analysis *(UCI/ P. Smyth)*

We developed a general framework, including statistical models and learning algorithms that automatically extract and learn models of trajectories of individual pedestrian movement from a fixed outdoor video camera. This work was reported in a technical report by student Sridevi Parise.

### A1.4 Information Extraction from Text *(UCI/ A. Meyers)*

Natural language engineering methods were applied to extract information primarily from three data sources: (a) tsunami web data set; (b) 9/11 World Trade Center police transcripts; and (c) UCI Facilities problem reports. Extracted information supported various research projects, including topic extraction, the "tsunami browser," and a facilities report browser. In some cases, databases were automatically constructed and updated by the IE systems, and IE systems formed part of end-to-end integrated demonstration systems. Extraction products included data cleaning/normalization/conversion, categorization, bag-of-words, semantic cases (entities, actions, spatial, temporal and other features), and events.

### A1.5 Entity disambiguation

Unlike information sources that are based on sensory data, extracting information from human-generated reports in free text can be problematic. The raw datasets in this latter context are often inherently ambiguous, i.e., the descriptions of entities and relationships are not sufficient to uniquely identify or "disambiguate" entities. For example, if a particular report refers to a person named "J. Smith," the challenge is to decide which J. Smith the report is referring to. Similar challenges exist for city names. In Year 2, we have made significant progress in designing several event disambiguation methods. For example, a novel *Relationship-based entity Disambiguation* (RED) framework has been developed that is currently capable of addressing two important disambiguation challenges, that is, "reference disambiguation" and "object consolidation." While traditional methods, at the core, employ feature-based similarity to techniques to address these problems, RED enhances the basic features of these techniques by also analyzing relationships that exist between entities. Preliminary experiments using two real datasets show that the analysis of relationships is significantly improved when RED is employed.

### A1.6 Ontology Driven Event Extraction from Text

Event information needs to be extracted from reports, our initial focus being on text reports. While information extraction has been a research and technology area for decades, extracting events poses unique new challenges. We have initiated an approach to event extraction from text that is powered by semantics-based technologies such as ontologies. We are developing new, more expressive extraction methods using ontologies, and leveraging on existing information extraction work from the information retrieval (IR) and natural language processing (NLP) communities. Dr. Ashish who has recently joined RESCUE is spearheading this effort.

## A2 EVENT AWARENESS

### A2.1 Event DBMS *(UCI/ Mehrotra, Venkatasubramanian, Kalashnikov)*

Many contemporary scientific and business applications, and especially situation awareness applications, operate with collections of events, where a basic event is an occurrence of a certain type in space and time. Applications that deal with events might require the support of complex domain-specific operations that involve querying of events; in many instances, the manipulation of information on events is common across domains. Events can also be very diverse from application to application. However, despite these diversities, commonalities can be found which link these events together, e.g., type, time and location. We argue that many of such applications can benefit from an Event Database Management System (EDBMS). Such a system should provide a convenient and efficient way to represent, store and query large collections of events that often evolve over time. The EDBMS is a core element of our situation awareness toolkit. In Year 2, we have made progress in identifying the challenges that must be overcome in order to create the system and have designed a high-level representation of EDBMS, i.e., EventWeb view. The following discussions highlight progress in specific areas of situation awareness and monitoring.

### A2.2 Event Disambiguation *(UCI/ Mehrotra, Venkatasubramanian, Kalashnikov)*

Event disambiguation refers to the general problem of determining if two events extracted from raw sensor information (including textual reports) refer to the same incident. The problem of entity disambiguation described in A1.5 is a part of this event disambiguation problem. Ambiguity in event descriptions may also arise from location ambiguity, ambiguity in attribute values, ambiguity in relationships, etc. We have recently initiated our work on disambiguating events which generalizes our work described in A1.5. Our approach exploits context, knowledge of relationships and domain-knowledge for disambiguating among events. The work is preliminary and the ideas are being tested on 9/11 data sets we have collected. We hope to make significant progress on this over the next year.

### A2.3 Spatial Awareness from Reports (*UCI/ Mehrotra, Venkatasubramanian, Kalashnikov)*

Situational awareness (SA) applications monitor the real world and the entities therein to support tasks, such as rapid decision-making, reasoning and analysis. Raw input about unfolding events may arrive from a variety of sources in the form of sensor data, video streams, human observations and so on, from which events of interest are extracted. Location is one of the most important attributes of events useful for a variety of SA tasks. We are proposing an approach to model and represent (potentially uncertain) event locations described by human reporters in the form of free text. We will analyze several types of spatial queries of interest in SA applications. We plan to design techniques to store and index uncertain spatial information, to support the efficient processing of queries. Our experimental evaluation over synthetic and real datasets will demonstrate the efficiency of our approach.

### A2.4 Knowledge-Driven Event Reasoning *(UCI/ Mehrotra)*

For analyzing and reasoning with events, we have the situational event information from a particular instance. In addition, prior knowledge of the domain may prove to be useful in analyzing or reasoning with events. For instance, prior specialized knowledge about toxic chemicals may be useful in reasoning about a particular chemical attack or dispersion situation. We are working on an approach to representing and reasoning with such domain knowledge when reasoning with events. Semantics-based approaches, such as ontologies, appear as suitable tools at this point.

## A3 PEOPLE AWARENESS

### A3.1 Modeling Car-Travel Activity of Individuals *(UCI/ Dechter)*

In Year 2, the research team has developed a probabilistic model, that given a time and current GPS reading of an individual, can predict the destination of this individual and his/her route. We are using the Hybrid Dynamic Mixed Network framework for modeling this application. Some important features of the model include: a) inference of locations where a person spends a significant amount of time; b) inference of an Origin-Destination matrix for an individual that will also contain the number of times a user moves between given locations; and c) answers to queries such as where a person will be after 10 minutes or, whether a person is heading home or picking up his/her kids from a day-care center. In the future, we will be seeking to extend this model to compute aggregate Origin-Destination models for a region/town and model the behavior of individuals in situations that involve traffic jams or accidents.

### A3.2 Inferring “Who is Where” from Sensor Data

We have begun developing an archive of time-series data from the UCI campus that relates to human activity over time on campus. Commercial "people-counter" devices and software (based on IR technology for door entrances and exits) have been ordered and will be tested in Year 2. If these devices work as planned, a small number will be installed to collect data (in an anonymous manner) at the main CALIT2 building entrances. To date, the following activities have been completed: (1) we have obtained preliminary internet and intranet network traffic data from ICS support and NACS, such as sizes of outgoing email buffer queues every 5 minutes, indicating email activity on campus; (2) electricity usage data for the campus, consisting of hourly time series data, has been collected; (3) current and historical class schedule and class size information has been collected from relevant UCI Web sites; and (4) we have had detailed discussions with UCI Parking and Transportation about traffic and parking patterns over time at UCI and obtained various data sets related to parking. We have conducted preliminary exploratory analysis of the various time-series data sets, including data verification and interpretation, data visualization and detection of time-dependent patterns (e.g., daily usage patterns). We have also developed an initial probabilistic model (a Bayesian network) that integrates noisy measurements across multiple spatial scales and that can connect measurements across different times. We are currently working on how to parameterize this model and test it on simple scenarios.

## A4 DOMAIN INDEPENDENT DECISION SUPPORT TOOLS

### A4.1 Graph Analysis Methods *(UCI/ Mehrotra)*

Events in the EDBMS model form a web (or graph) that is based on linkages representing different relationships. The graph view of events, referred to as *EventWeb*, provides a powerful mechanism to query and analyze events in the context of disaster and/or situation assessment. Our goal has been to study general-purpose graph languages and graph algebra that would allow the creation of EventWeb, and facilitate analytical queries on top of it. We have developed a graph language called GAAL that provides analytical capabilities to graphical data.

### A4.2 Hybrid Bayesian Networks *(UCI/ Dechter)*

Hybrid Bayesian Networks are the most commonly used modeling framework for characterizing real-world phenomena using probabilistic information on discrete and continuous variables. However, when deterministic information is present, its representation in Hybrid Bayesian Networks can be computationally inefficient. We have addressed this problem by introducing a new modeling framework called Hybrid Mixed Networks that extends the Hybrid Bayesian Network framework to efficiently represent discrete deterministic information.

### A4.3 Hybrid Dynamic Bayesian Networks *(UCI/ Dechter)*

Most real-world phenomena like tracking an object/individual also require the ability to represent complex stochastic processes. Hybrid Dynamic Bayesian Networks (HDBNs) were recently proposed for modeling such phenomena. Fundamentally, these are factored representations of Markov processes that allow for discrete and continuous variables. Since they are designed to express uncertain information, they represent deterministic constraints as probabilistic entities which may have negative computational consequences. We have addressed this problem by introducing a new modeling framework called Hybrid Dynamic Mixed Networks that extend Hybrid Dynamic Bayesian Networks to handle discrete, deterministic information in the form of constraints. A drawback of the frameworks above is that they are not able to represent deterministic information on continuous variables or a combination of discrete and continuous variables. We are currently seeking to overcome this drawback by extending our modeling frameworks with a special emphasis on addressing these variants.

### A4.4 Approximate Algorithms for Inference *(UCI/ Dechter)*

Once a probabilistic model is constructed, a typical task is to "query" the model. In the literature, this is commonly referred to as an "inference problem." In Year 2, we have focused on the development of various inference algorithms that will support the network frameworks above. Since the general inference problem is NP-hard in Hybrid Mixed Networks, we have resorted to approximate algorithms. Two commonly used approximate algorithms for inference in probabilistic frameworks are Generalized Belief Propagation and Rao-Blackwellised Importance Sampling. We are seeking to extend these algorithms to Hybrid Mixed Networks. Extending Generalized Belief Propagation to Hybrid Mixed Networks is straight-forward, however, a straight-forward extension of Importance Sampling results in poor performance. To address this problem, we are working on a new sampling algorithm that uses Generalized Belief Propagation as a pre-processing step. Our results so far indicate that our new algorithm performs better than the straight-forward extensions of Generalized Belief Propagation and Importance Sampling, when viewed in terms of approximation error. This new algorithm also allows a balancing of time with accuracy in a systematic way. We are also adapting the algorithms above to Hybrid Dynamic Mixed Networks that model sequential stochastic processes.

## A5 DOMAIN-DRIVEN DECISION SUPPORT TOOLS

### A5.1 A Centralized Web-Based Loss Estimation Methodology

*(ImageCat/ Eguchi, Huyck, Chung, Mio, Cho)*

In Year 2, significant progress has been made in creating a centralized web-based loss estimation and transportation modeling platform that will be used to test and evaluate the efficacy of Information Technology (IT) solutions in reducing the impacts of natural and manmade hazards on transportation systems. The web-based simulation platform (INLET for Internet-based Loss Estimation Tool) incorporates a Geographic Information System (GIS) component, a risk-estimation engine, and a sophisticated transportation-simulation engine. When combined, these elements provide a robust online calculation capability that can estimate damage and losses to buildings and critical transportation infrastructure in real time during manmade or natural disasters. A Beta version of this internet web-based program has been developed using Active Server Pages (ASP) and Java Script to dynamically generate web pages, Manifold IMS as a spatial engine, and Access as the underlying database. The basic components of this system have been tested and validated in the calculation of building losses and casualties for a series of historic earthquake events in Southern California. Preliminary system models have been created that are based on two major components: disaster simulation and transportation simulation. These two components interact with an information-acquisition unit which is where the disaster event is detected and where disaster information is distributed. The information-acquisition unit also represents where the IT solutions will emerge in the Transportation Testbed. The *Transportation Simulation* component represents where detailed modeling takes place and where transportation system performance is assessed based on data and information collected on the extent and severity of the disaster. In the *Disaster Simulation* component, the impact of the disaster in terms of economic losses and other impacts (such as casualty levels) is calculated. In this scheme, the results of the disaster simulation will also feed directly into the transportation simulation engine to identify damage to key transportation components and to assess probable impacts (such as traffic delays or disruption) to the transportation system.

***Loss Estimation.*** Immediately following a significant disaster, it is difficult to obtain a clear vision of the magnitude and spatial distribution of damage. In the years following the 1994 earthquake, many earthquake researchers focused on the development of loss estimation tools to address this deficiency. INLET serves not only as a tool for simulating events to test the integration of technology into emergency response; it will become the first online real-time loss estimation system available to the emergency-management and response community. The loss-estimation utility uses simplified damage functions from freely-available models and restructures publicly-available GIS databases to harness SQL for all calculations. The result is an online loss-estimation tool optimized for speed. Additionally, INLET will use scripts triggered by an actual earthquake to estimate losses from USGS ShakeMap ground motion estimates.

***Transportation.*** INLET incorporates the functionality of a full stochastic dynamic network assignment model with destination choice, and incorporates additional research addressing traffic disruption following manmade and natural disasters. For example, the model currently illustrates how awareness of a disaster scenario and familiarity with routing alternatives can impact traffic congestion and evacuation time. Additionally, the model will also estimate bridge damage and the economic impacts associated with disruption of transportation systems.

### A5.2 Optimal Routing of Emergency Vehicles *(UCI/ Shinozuka)*

In Year 2, relevant data on search and rescue activities, ambulance availability, highway/street conditions, hospital conditions and capacities has been collected and is being analyzed. This research is directed at defining research priorities and issues associated with post-disaster transportation. In one context, the movement of emergency vehicles (ambulances) is considered for a particular area in Orange County. In order to demonstrate the efficacy of these models, a large earthquake on the San Joaquin fault has been modeled. Earthquake was selected because it represents an event that can damage and cause disruption to many parts of a transportation network.

To support this platform, researchers are working on simulation techniques for routing injured people to acute hospital facilities using optimized linear programming techniques. A prototype of this simulator will be integrated into the Transportation Testbed as module in INLET. In addition to these routing algorithms, UCI researchers are developing improved damage or fragility models for highway bridges. So far, we have quantified the ductility capacity of various bridge damage states using data and information from the 1994 Northridge earthquake. These models will eventually be incorporated into INLET as part of the network-simulation model.

### A5.3 Bayesian Analysis of Informant Reports *(UCI/ Butts)*

Building on the informant-reporting model developed in Year 1, UCI has worked to collect a data set for model testing and validation in the disaster context. In particular, a systematic data-collection framework was created for monitoring news items posted to English-language weblogs, based on a total sample of approximately 1800 blogs monitored four times per day. This framework was in place at the time of the Boxing Day Tsunami, and as such was able to collect initial reports of the disaster (as well as baseline data from the pre-disaster period). Monitoring of the sample was continued for the next several months, yielding a rich data set with extensive intertemporal information (approximately 650,000 documents at more than 350 time points). In Year 3, this data set will be used to calibrate and validate the intertemporal informant-reporting model for crisis-related events.

### A5.4 Vertex Disambiguation within Communication Networks *(UCI/ Butts)*

In Year 2, work has begun on statistical models for vertex disambiguation in the context of data derived from communication transcripts. Transcripts of responder radio communications at the World Trade Center (WTC) are being utilized as the test case for this analysis. Based on heuristics developed by a human coding of the radio transcripts, a discrete exponential family model has been developed for maximum likelihood estimation of a latent multigraph with an unknown vertex set. This model utilizes contextual features of the transcript (e.g., order of address, embedded name or gender information, etc.) to place a probability distribution on the set of potential underlying structures; the maximum probability multigraph is then obtained via simulated annealing. This model has been applied to the WTC test data, where results appear to be roughly comparable to human coding. Further refinement of the model in Year 3 is expected to enhance performance vis-à-vis the human baseline.

## INFORMATION SHARING

This thrust area addresses related research activities that facilitate seamless sharing of information among decision-makers across organizational boundaries. Special emphasis is placed on seamless information-sharing and collective decision-making across highly-dynamic emergent virtual organizations. The research can be classified into two parts: social science research (S1) provides context; and S2-S4 relate to IT research. Table 2-4 presents a listing of active research projects and tasks in the area of Information Sharing.

**Table 2-4 Information Sharing - Project Areas, Tasks and Investigators**

| Project Area | Task No. | Task Description | Institution/ Investigator |
|---|---|---|---|
| S1: Understanding Emergent Networks | S1.1 | Emergent Multi-Organizational Networks | CU/ K. Tierney, J. Sutton |
| | S1.2 | Interviews with City of Los Angeles | CU/ K. Tierney, J. Sutton |
| | S1.3 | Network Analysis of the Incident Command System (ICS) | UCI/ C. Butts |
| S2: Trust Management in Crisis Networks | S2.1 | TrustBuilder | BYU/ K. Seamons & UIUC/ M. Winslett |
| | S2.2 | Hidden Credentials | BYU/ K. Seamons |
| | S2.3 | Trust Credentials | BYU/ K. Seamons |
| | S2.4 | Trust Negotiation Facilities for Legacy Clients and Services | UIUC/ M. Winslett |
| | S2.5 | Support for Friendly Third Parties during Trust Negotiation | UIUC/ M. Winslett |
| S3: Security and Privacy Concerns in Information Sharing | S3.1 | Secure XML Publishing | UCI/ C. Li |
| | S3.2 | Authentication and Access Control | UCI/ G. Tsudik |
| | S3.3 | LogCrypt | BYU/ K. Seamons |
| | S3.4 | Phishing Warden | BYU/ K. Seamons |
| | S3.5 | Secure Object Store | UCI/ S. Mehrotra |
| S4: Mediation, Integration, Querying, Filtering | S4.1 | Peer-Based Information Sharing | UCI/ C. Li |
| | S4.2 | Similarity Search on Peer-Based Sharing Systems | UCI/ C. Li |
| | S4.3 | GIS-Based Search | UCI/ C. LI |

### Major Activities and Findings:

### S1 Understanding Emergent Networks

**S1.1 Emergent Multi-Organizational Networks (EMONs)** *(CU/ K. Tierney, J. Sutton)*
Research has focused on developing and preparing a large data set regarding EMONs in the WTC disaster for RESCUE use. UCI (Butts) has been collaborating on data-

representation issues, and will be working with UCB on subsequent analysis. UCI (Butts) has also initiated work on a network analysis of the Incident Command System, using the MetaMatrix framework for organizational analysis; this work also includes the analysis of EMONs drawn from search and rescue activities associated with six crisis events. These data and associated analyses contribute to the RESCUE project's ongoing objective of assessing (and ultimately improving) DEVO structure within crisis response.

### S1.2 Interviews with City of Los Angeles *(CU/ K. Tierney, J. Sutton)*

We completed 37 interviews with personnel from six departments in the City of Los Angeles whose general managers are representatives on the Emergency Operations Board. These departments included the Emergency Preparedness Department, Information Technology Agency, Los Angeles Police Department, Los Angeles Fire Department, Recreation and Parks, and the Board of Public Works – Bureau of Engineers. Additional interviews are being scheduled with personnel from the Department of Transportation, Department of Water and Power, General Services, Airport, and Harbor. UCSD (Pasco) collaborated with UCB on interviews with LAPD, focusing on issues relating to interoperability and intra-departmental communication systems. These interviews have lead to preliminary findings regarding current technology use within the city of Los Angeles for information/data gathering, sharing, analysis and dissemination to the public, as well as security concerns and protocols for data sharing between agencies.

### S1.3 Network Analysis of the Incident Command System (ICS) *(UCI/ Butts)*

Practitioner documentation on the ICS was obtained from FEMA training manuals and other sources during Year 2. This documentation was hand-coded to obtain a census of standard vertex classes (positions, tasks, resources, etc.) for a typical ICS structure. Some difficulty was encountered during this process due to the presence of considerable disagreement among primary sources. For this reason, it was decided to proceed with a relatively basic list of organizational elements for an initial analysis. Based on this list, adjacency matrices were constructed based on practitioner accounts (e.g., task assignment, authority/reporting relations, task/resource dependence). We accomplished all of our research objectives, which were identification of relevant documentation, identification of Metamatrix vertex sets, and construction of adjacency matrices. Further validation of these relationships by domain experts will be conducted in Year 3, prior to analysis of the system as a whole.

## S2 TRUST MANAGEMENT IN CRISIS NETWORKS

### S2.1 TrustBuilder *(BYU/ K. Seamons and UIUC/ M. Winslett)*

These researchers have continued work on the development of TrustBuilder, a prototype system supporting trust negotiation. There are two aspects of the current work in TrustBuilder at BYU that has relevance to helpful third parties. The first is the design and implementation of surrogate trust negotiation as one approach for someone to store her credentials on her home computer and have a service negotiate for access to her credentials at run-time. The second is based on an examination of existing approaches to storing credentials in local or remote repositories. BYU identified the advantages and disadvantages of each approach, and then proposed a hybrid model that leverages the best of both worlds. The result is Thor, a hybrid online repository for storing and managing credentials in a mobile environment. The system incorporates the IETF SACRED standard. As part of this effort, BYU collaborated with NCSA to implement the first freely available SACRED server. The long-term goal of this work is an architecture that emergency personnel will find easy to use to securely access sensitive data during a crisis.

### S2.2 Hidden Credentials *(BYU/ K. Seamons)*

We introduced hidden credentials as a revolutionary approach to trust negotiation where sensitive information is encrypted in such a way that a recipient could only access it with the proper credentials. Hidden credentials were built using identity-based encryption (IBE). They permitted traditional trust negotiations that required several rounds of communication to be accomplished in a single message. A server could send a resource to an unknown client encrypted according to a complex policy, requiring the user to have a certain set of credentials in order to access the resource. In addition to reducing the cost of a negotiation, hidden credentials also provide greater privacy protection because a credential owner can now access sensitive resources without ever revealing an ultra-sensitive credential. More recently, BYU has enhanced hidden credentials to offer significantly improved performance when using Boneh/Franklin Identity Based Encryption and to offer improved concealment of policies from unsatisfied recipients. We accomplished policy concealment by using a secret-splitting scheme that only leaks those parts of a policy that the recipient satisfies.

### S2.3 Trust Credentials *(BYU/ K. Seamons)*

Our research explored ways to incorporate more contextual knowledge in a trust negotiation so that an agent can make better decisions about what credentials are needed to establish trust. The goal was to support improved privacy and performance to trust negotiation. With this extra knowledge, phishing attacks can be detected and thwarted. Also, trust negotiation could be streamlined if the participants can eagerly push credentials that they anticipate will be highly likely to establish trust. We utilize ontologies during trust negotiation as a mechanism to describe credentials that are relevant to a certain context. The importance to emergency response is that a priori knowledge about crises can be captured in ontologies and automatically incorporated into a system at runtime to modify behavior during an emergency.

### S2.4 Trust Negotiation Facilities for Legacy Clients and Services *(UIUC/ Winslett)*

We have been experimenting with the use of trust negotiation technology in real-world situations by cooperating with Jim Basney and Von Welch at NCSA, who are responsible for certain aspects of the Grid Security Infrastructure. We have developed an approach to making trust negotiation facilities available to applications on the Grid or elsewhere, and embodied it in the Traust prototype. Traust provides clients with the ability to acquire access tokens for networked resources dynamically at run-time. Traust uses automated trust negotiation to support bilateral trust establishment, the discovery of resource access control policies, and the protection of client and server privacy. The Traust service has been designed in such a way as to support both loose integration with existing "legacy" services and tighter integration with newer trust-aware resources.

A session between a client and a Traust server consists of five distinct stages. First, the client generates a resource request and classifies its sensitivity level using a local resource classifier. Next, the client carries out a trust negotiation with the Traust server to ensure that the server can satisfy the disclosure policies the client has placed on her sensitive resource request. This prevents inadvertent disclosure of sensitive resource requests to untrusted servers. If this negotiation succeeds, the client discloses her resource request. The server now uses trust negotiation to determine whether the client is authorized to access the requested resource. The final stage of the Traust interaction involves the server generating the access credentials needed for the client to access the resource and disclosing these credentials to the client. The credential generation could be as simple as a static credential lookup or as complicated as dynamic account creation or interaction with MyProxy, Community Authorization Service, or Kerberos servers. All communications between clients and the Traust server occur inside of a TLS tunnel used to provide confidentiality and integrity for the session. It is important to note that this tunnel does not provide any notion of authentication or authorization control; the trust negotiation sessions serve this purpose.

### S2.5 Support for Friendly Third Parties during Trust Negotiation *(UIUC/ WInslett).*

With current trust negotiation software, manual intervention is required to carry out interactions with these third parties. During the past year, we have examined ways of automating these interactions and of reasoning about the properties of the resulting system. For example, an emergency analyst may want to ask, in advance, "During a code 3 disaster, will all rescue dog handlers be able to access the same one person's information service? During a code 3 disaster, who from outside a hospital (not ordinarily authorized to) look at medical records may do so?"

To help automate the inclusion of third parties and provide a framework for answering analysis questions, we developed PeerTrust2, a language based on distributed logic and designed to solve distributed authorization problems. PeerTrust2 policies support delegation, purpose, exposure control, proof hints and sticky policies. We worked with European colleagues W. Nejdl and P. Bonatti to revamp and extend PeerTrust semantics, resulting in PeerTrust2, and have shown how to use PeerTrust2 to write simple yet expressive access control policies that involve helpful third parties. PeerTrust2 can serve as a trust negotiation language, but our long-term intent is to use the powerful new features in PeerTrust2 and add them to other policy languages such as XACML so users of those languages can also take advantage of helpful third parties.

There are two aspects of our current work in TrustBuilder that has relevance to helpful third parties. We have designed and implemented surrogate trust negotiation as one approach for someone to store her credentials on her home computer and have a service negotiate for access to her credentials at run-time. Next, we examined existing approaches to storing credentials in local or remote repositories. We identified the advantages and disadvantages of each approach, and then proposed a hybrid model that leverages the best of both worlds. We designed Thor, the hybrid online repository for storing and managing credentials in a mobile environment. Our long-term goal is an architecture that emergency personnel will find easy to use to securely access sensitive data during a crisis.

## S3 SECURITY AND PRIVACY CONCERNS IN INFORMATION SHARING

### S3.1 Secure XML Publishing *(UCI/ C. Li)*

This research involves protecting sensitive information when XML data is exchanged between two business partners in order to meet precise security requirements. The focus is on data-sharing applications where the owner specifies what information is sensitive and should be protected. If a partial document is shared carelessly, users of the other company can use common knowledge (e.g., "all patients in the same ward have the same disease") to infer additional data, which can cause leakage of sensitive information. Our goal is to protect such information in the presence of data inference with common knowledge. Common knowledge is represented as semantic XML constraints. We formulated the process for how users can infer data using three types of well-known XML constraints. Interestingly, no matter what sequences users follow to infer data, there is a unique, maximal document that contains all possible inferred documents, even if different inference sequences could produce documents that may look different. We developed algorithms to find a partial document of a given XML document without causing information leakage, while publishing as much data as possible. We experimented with real data sets to show the effect of inference on data security, and demonstrated that the proposed techniques can prevent such leakage from happening.

### S3.2 Authentication and Access Control *(UCI/ Tsudik)*

This research group developed novel techniques for secure and efficient processing of authenticated query replies for queries against outsourced data. The work specifically included the investigation of several new signature aggregation methods that greatly speed up digital signature verification without sacrificing security.

We made several novel advancements in authentication and access-control techniques. First, several new anonymous authentication protocols (secret handshake) were constructed. These protocols are provably secure, based on well-known cryptographic assumptions and offer efficiency superior to that of prior art. Second, techniques for anonymous role-based communication are under development. Known also under the name OSBE (Oblivious Signature-Based Envelopes), such techniques allow anyone to anonymously communicate information to an entity who claims a certain role (e.g., an FBI agent) without finding out whether the recipient is indeed in that role. Prior work is limited to the RSA- and ID-based OSBEs. Third, we constructed (and proved security of) two new secure group admission protocols: one based on ID-based cryptography and one on threshold Schnorr signatures. We developed a full-blown prototype of Bouncer – the group admission control toolkit. Bouncer allows fully distributed secure admission based on thresholds. It includes 5 different cryptographic protocols varying in the level of security, efficiency and state requirements.

### S3.3 Logcrypt *(BYU/ Seamons)*

Seamons has developed LogCrypt, support for 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 log. 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, meaning 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.

### S3.4 Phishing Warden *(BYU/ Seamons)*

Research in this group involves development of technology that employs trust negotiation to prevent phishing attacks. One approach was to use a client-side filter to dynamically detect when sensitive information is disclosed to a server and demand suitable credentials from the server to authorize the disclosure. We developed a browser extension that identifies personal information being disclosed to a stranger before any downloaded code in a Java applet can obfuscate the data to bypass the filtering software. Prior approaches to solving this problem have been vulnerable to this threat. Phishing Warden is designed to establish trust in a web server before disclosing sensitive information. A second approach was to redirect a server that wants personal information to a broker that negotiates on behalf of the user to disclose the client's personal information.

### S3.5 Secure Object Store *(UCI/ Mehrotra)*

Today's applications are generating gargantuan amounts of information and data. Data intensive applications such as radio telescopes and sensor applications in pervasive environments produce constant streams of data. Even though storage costs have dropped exponentially, the cost of managing stored data in a safe and fault-tolerant manner has not dropped. A solution to the above challenge is storage outsourcing via a service-oriented interface. Such a storage solution can significantly reduce operation due to cost amortization of managing storage, including human cost. Other advantages include mobile access to data and facilitation of data-sharing across organizational boundaries.

There are many security challenges that need to be addressed for a service of this kind. Since data is the most valuable asset for organizations/individuals, the data owners would like to protect themselves from both insider/outsider attacks before outsourcing their data. Encryption offers a natural solution that offers security against the above attacks. Our research focuses on developing techniques that will allow the service provider to cater query-management and data-sharing services on encrypted data.

The secure sharing enables multiple interesting applications. One such application is password sharing. Today, users use the same passwords across different sites, including secure and insecure sites which cannot be trusted. Pfishing attacks are common as a result. Now imagine that secure sharing is available. In this case, one can build a service in which passwords can be stored at the server. Since the service remembers the passwords, users can use extremely complex passwords which they do not need to remember. We have built such a service and it has been operational for some time now. The service allows password generation, storage on server, retrieval of passwords, and also filling out passwords on the web.

## S4 MEDIATION, INTEGRATION, QUERYING, FILTERING

### S4.1 Peer-Based Information Sharing (*UCI/ C. Li)*

In a crisis-response situation, many participating organizations collaborate in the context of a variety of tasks related to disaster mitigation (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 different organizations 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.

To study how to support distributed data-sharing in crisis-response organizations, we have developed a system called "RACCOON," in which different sources can publish and share their data. In the system, peers (data owners) are connected in an overlay network, in which semantic mappings can be created between peers. Existing peers can leave the system, and new peers can join the network. A user can search for relations that are similar to a given relation. For such a search query, the system adopts schema-mapping techniques to locate relevant sources, and creates source mappings on the fly. The system provides a visualization tool to show the neighbors of each peer, which makes it easier for users to browse peer contents and issue queries. The system supports queries that request information from multiple peers. The system also allows a query to be “expanded” by accessing other peers that have schema mappings with the peers used in the query. In this way a user can retrieve as much information as possible to answer a query.

### S4.2 Similarity Search on Peer-Based Sharing Systems *(UCI/ C. Li)*

Data sharing in crisis situations can be supported using a peer-to-peer (P2P) architecture, in which each data owner publishes its data and shares it with other owners. The research studied how to support similarity queries in such a system. Similarity queries ask for the most relevant objects in a P2P network, where relevance is based on a predefined similarity function, and the user is interested in obtaining objects with the highest relevance. Because retrieving all objects and computing the exact answer over a large-scale network is impractical, we created a novel approximate answering framework that computed an answer by visiting only a subset of network peers. Users were presented with progressively refined answers consisting of the best objects seen so far with continuously improving quality guarantees providing feedback about the search’s progress. We developed statistical techniques to determine quality guarantees in this framework and mechanisms to incorporate quality estimators into the search process. We developed a framework to support progressive query-answering in P2P systems and techniques to estimate answer qualities based on objects retrieved in a search process. We conducted experiments to evaluate these techniques, and concluded that similarity queries are very important in P2P systems. By accessing a small number of peers, a similarity query can be approximately answered with a certain quality guarantee.

### S4.3 GIS-based Search *(UCI/ C. Li)*

In crisis situations there are various kinds of GIS information stored at different places, such as map information about pipes, gas stations, hospitals, etc. Since first-responders need fast access to important, relevant information, it becomes important to provide an easy-to-use interface to support keyword search on GIS data. The goal of this project is to provide such a system, which crawls and/or archives GIS data files from different places, and builds index structures. It provides a user-friendly interface, that allows a user to type in a few keywords, and the system can return all the relevant objects (in a ranked order) stored in the files. For instance, if a user types in “Irvine school,” the system will return schools in Irvine stored in the GIS files, the corresponding GIS files, possibly displayed on a map. This feature is similar to online services such as Google Local, with more emphasis on information stored in GIS data files.

Our goal is to implement such a system prototype and study related research challenges. Last November, we started the project of “keyword queries on GIS data,” since it is very relevant to the RESCUE project. We are still in the early stage, and we already have built a very simple prototype. We are currently working on technical problems.

## INFORMATION DISSEMINATION

This final thrust area focuses on research activities that study how information can be dispersed quickly and efficiently to various entities and organizations. The research explores how various forms of social behaviors emerge during disasters and how knowledge of these behaviors can help customize and personalize information delivery to save lives and property. Table 2-5 presents a listing of active research projects and tasks in the area of Information Dissemination.

**Table 2-5 Information Dissemination - Project Areas, Tasks and Investigators**

| Project Area | Task No. | Task Description | Institution/ Investigator |
|---|---|---|---|
| D1: Understanding and Classifying Dissemination Scenarios, Modalities and Needs | D1.1 | Network Data Sets | UCI/ C. Butts |
| | D1.2 | Responder Networks in the WTC Disaster | UCI/ C. Butts |
| D2: Behavior Model of Social Phenomena | D2.1 | Modeling Information Flow Through Networks | UCI/ C. Butts |
| D3: Customizable Dissemination Systems | D3.1 | Customizable Dissemination in Pervasive Spaces | UCI/ S. Mehrotra, N. Venkatasubramanian |
| | D3.2 | Navigation Support for Users with Disabilities | UCI/ S. Mehrotra, N. Venkatasubramanian |
| | D3.3 | Targeted Dissemination | UCSD/ R. Rao, G. Chockalingam |
| D4: Exploiting IT Infrastructure for Dissemination | D4.1 | Flash Dissemination in Heterogeneous Networks | UCI/ S. Mehrotra, N. Venkatasubramanian |
| | D4.2 | Rapid Middleware Framework | UCI/ S. Mehrotra, N. Venkatasubramanian |
| D5: Dissemination Systems and Optimizations | D5.1 | Gerrymandering: Efficient Data Dissemination in Client-Server Environments | UCI/ C. Li |
| | D5.2 | Route Preview Software with Audio Cues for First Responders | UCSD/ R. Rao, J. Miller |
| | D5.3 | VIEWS | ImageCat/ R. Eguchi, C. Huyck, M. Mio, S. Ghosh |

### Major Activities and Findings:

## D1 UNDERSTANDING AND CLASSIFYING DISSEMINATION SCENARIOS, MODALITIES AND NEEDS

### D1.1 Network Data Sets *(UCI/ C. Butts)*

Our research utilized data from the World Trade Center disaster (obtained from the Port Authority of New York and New Jersey) to construct two large network data sets for emergency phase responder interaction. The first of these data sets involved 17 networks (ranging in size from approximately 50-250 responders) describing interpersonal radio communications among various responder groups (including both specialist (e.g., security, police) and non-specialist (e.g., WTC maintenance workers) responders. The second data set consisted of approximately 160 networks of reported communication and interaction, based on police reports filed by the Port Authority Police Department. Initial analyses of this data have already yielded a number of useful findings regarding the use of radio communication systems during the early hours of the WTC disaster. Individual system usage was found to vary greatly in terms of communication volume, number of partners and system role; surprisingly, however, few significant differences were observed between specialist and non-specialist communication patterns. While responders whose formal roles entailed coordinative activity were found to be more likely to occupy central positions than those without such roles, the overwhelming majority of central actors appear to have been "emergent" coordinators. These and other results suggest that responder communication systems must support heterogeneous usage patterns, and that any usage constraints (e.g., bandwidth caps) must be sufficiently flexible to allow on-the-fly reconfiguration by responders in the field. Problems with unit separation further suggested that automated location dissemination systems might have reduced the communicative load for many responders, and allowed for the more rapid evacuation of the WTC facility.

### D1.2 Responder Networks in the WTC Disaster *(UCI/ C. Butts)*

Our research set the context for dissemination overlay networks similar to the ones used in the RapID system described above. Examining responder radio communication networks at the WTC disaster showed that emergency-phase communications were dominated by a relatively small group of "hubs" working with a larger number of "pendants" (responders with a single communication partner). Very little clustering was observed, strongly differentiating these networks from most communication structures observed in non-emergency settings. More surprising was finding that communication structures among specialist responders (police, security, etc.) did not differ significantly from those of non-specialist responders (maintenance or airport personnel) on most structural properties. This seems to suggest that emergency radio communication in WTC-like settings is not a function of training or organizational context, and that similar considerations should enter into the design of communication systems for both types of entities.

While communication structure at the WTC showed surprising homogeneity across responder type, substantial differences were observed across individual responders. Most responders communicated a small number of times with very few partners (often only one), but some had many partners (in some cases covering 30-50% of the whole network). Those with many partners tended to act as coordinators, bridging many responders who did not otherwise have contact with one another. Strong heterogeneity between positions suggested that effective communication systems for first responders must be able to cope with substantial interpersonal differences in usage. More significantly, subsequent analysis of coordinators at the WTC found approximately 85% to be "emergent," or lacking an official coordinative role in their respective organizations. We found that not only must effective responder communication systems deal with heterogeneous usage patterns, but system designers cannot assume that intensive users will be identifiable ex ante. A lack of significant differences between specialist and non-specialist responders indicates that this concern is relevant for established crisis response organizations and those not conventionally involved in crisis response.

Two major findings have already emerged from preliminary analyses of the WTC police response. The network of interaction among Port Authority police at the WTC site appears to be quite well-connected. Individual reports suggest that the response fragmented into small, isolated groups, but the interactions of these groups over the course of the response appears to have led to a fairly well-integrated whole; the scale of the integration was likely not easily understood by individuals in the field. Despite this overall connectivity, police reports suggested that effective localization technology might have aided the WTC response, particularly during the period following the collapse of the first tower (when many units lost visual contact due to the resulting dust clouds). The extensive effort devoted to finding and tracking personnel seen in the WTC radio communications seems to indicate that localization could permit faster evacuation during events of this kind.

## D2 BEHAVORIAL MODEL OF SOCIAL PHENOMENA

**D2.1 Modeling Information Flows Through Networks.** Work on this task has been inactive this year and is expected to resume in Year 3.

## D3 CUSTOMIZABLE DISSEMINATION SYSTEMS

### D3.1 Customized Dissemination in Pervasive Spaces
*(UCI/ S. Mehrotra, N. Venkatasubramanian)*

Using an evacuation application as an example of a crisis-related activity, this work explored dissemination where users in a pervasive space have varying communication channels at different levels of reliability. The work formulated the customized dissemination problem for pervasive spaces, showed the complexity and developed a linear programming solution to the problem.

### D3.2 Navigation Support for Users with Disabilities
*(UCI/ S. Mehrotra, N. Venkatasubramanian)*

Crisis scenarios can cause temporary impairments for users, so evacuation procedures cannot be generalized for normal populations. Technologies to aid in evacuation of users with disabilities and those impaired due to the crisis are important in crisis response. We developed a system called SAFE – Systems-based Accessibility For Evacuation – to support evacuation of users with disabilities from a region that has been affected by a disaster or get first responders to the users in need.

### D3.3 Targeted Dissemination *(UCSD/ R. Rao, G. Chockalingam)*

Research goals of this group were to develop a fully automated system building on the concept of "humans as sensors" to 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 confusing to the public. 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.

Using San Diego as a testbed, we will develop, deploy and test a targeted dissemination system that will empower the general public (in particular, commuters) 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 speech-recognition-based system can be accessed simply by making a phone call to the system. Because past experience (the San Diego wildfires of 2003) has shown that that the general public will not adopt such a system if you inject a new phone number during the time of a disaster, the system should be available on a regular basis, disseminating information that is valuable to the public on an everyday basis.

We will address these problems by using a traffic notification system that has been operational for the past two years and used by thousands of San Diego commuters every day as the basis for prototype. The system currently provides personalized real-time traffic information to commuters via cell phones (http://traffic.calit2.net). We are modifying this system to enable commuters to report incidents 24x7, including time, location, severity and the urgency of the event.

## D4 EXPLOITING IT INFRASTRUCTURE FOR DISSEMINATION

### D4.1 Flash Dissemination in Heterogeneous Networks

*(UCI/ S. Mehrotra, N. Venkatasubramanian)*

Flash dissemination is a new form of dissemination that arises in mission-critical applications where critical information is disseminated to a large number of recipients in a very short period of time. Any solution must address the unpredictable nature of information dissemination in a crisis. Since dissemination events (e.g. major disasters) are unpredictable and may be rare, deployed solutions for flash dissemination may be idle for a majority of the time. Upon invocation of the flash dissemination, large amounts of resources must be (almost) instantaneously available to deliver the information in the shortest possible time. Heterogeneity of receivers and communication networks poses challenges in determining efficient policies for rapid dissemination of information to a large population of receivers. We explored this problem from theoretical and pragmatic perspectives, developed optimized protocols and algorithms to support flash dissemination and aimed to incorporate our solutions in a prototype system. During periods of non-use the *idling-cost* (e.g. dedicated servers, background network traffic) of the system must be minimum (ideally zero), while during times of need, maximum server and network resources must be available.

Flash dissemination may need to reach a very large number of recipients, leading to *scalability* issues. For example, populations affected by an earthquake must know within minutes about protective actions that must be taken to deal with aftershocks or secondary hazards (hazardous materials release) after the main shock. Given the potentially large number of recipients who connect through a variety of channels and devices, heterogeneity is a key aspect of a solution. In the earthquake example, customized information on care, shelter and first-aid must be delivered to tens of thousands of people with varying network capabilities (dial-up, DSL, cable, cellular, T1). Flash dissemination in the presence of various forms of heterogeneity is a significant challenge. The heterogeneity is manifested in the data (varying sizes, modalities) and in the underlying systems (sources, recipients and network channels). Varying network topologies induce heterogeneous connectivity conditions – organizational structures dictate overlay topologies, and geographic distances between nodes in the physical layer influence end-to-end transfer latencies.

We investigated a peer-based approach transferring the dissemination load to information receivers. Using theoretical foundations from broadcast-theory, random graphs and gossip-theory, we developed protocols for flash dissemination that work under a variety of situations. DIM-RANK is a centralized, greedy, heuristic-based approach; CREW (Concurrent Random Expanding Walkers) is an extremely fast, decentralized, fault-tolerant protocol that incurs minimal (to zero) idling overhead.

**D4.2 *Rapid Middleware Framework*** *(UCI/ S. Mehrotra, N. Venkatasubramanian)*
RapID is a P2P prototype flash-dissemination system to support fast, distributed dissemination of critical information. A network of machines forms the overlay network. Because RapID is content agnostic, it can be used to distribute any file. A sender machine can send data/content to all the other machines in a fast, scalable fashion. The file to be disseminated is input at a command line, broken into chunks and 'swarmed' into the overlay. On the receiving end, chunks are collected in the 'right-order' (using a 'sliding window'), and the output can be piped into another program or redirected into a file (to be stored). We have prototyped a family of flash-dissemination protocols in Rapid including DIM, DIM-RANK, Distributed DIM and CREW.

## D5 DISSEMINATION SYSTEMS AND OPTIMIZATION TECHNIQUES

### D5.1 Gerrymandering: Efficient Data Dissemination in Client-Server Environments *(UCI/ C. Li)*

In our research, we considered a client-server environment where dynamically changing data resides on the server, and queries on the client need to be answered using the latest server data. Since the queries and data updates have different “hot spots” and “cold spots,” to reduce communication costs, the PUSH and PULL paradigms need to be combined. Data gerrymandering involves finding the minimum possible communication cost by partitioning the data space into PUSH/PULL regions for a given workload. This problem is relevant to applications such as traffic report and mediation systems. In the PUSH regions, the server notifies the client about updates; in the PULL regions the client sends queries to the server. We presented solutions under different communication cost models for range queries and point updates. We gave a provably optimal-cost dynamic programming algorithm for gerrymandering on a single range query attribute, proposed a family of heuristics for gerrymandering on multiple range query attributes, handled the dynamic case in which the workload evolved over time, and validated our methods through extensive experiments on real and synthetic data sets.

Our research also considered other related variations on gerrymandering, including a “passive” server (no PUSH); and having a client allow answers using stale data. We studied how to answer client queries using server data to minimize the communication cost while maximizing a certain goodness function. We completed a systematic study on different algorithms for push/pull-based data dissemination, developed a family of gerrymandering algorithms, and conducted extensive experiments to compare these algorithms.

### D5.2 Route Preview Software with Audio Cues for First Responders *(UCSD/ R. Rao, J. Miller)*

The goal of this research was to investigate how to present audio cues to a first-responder using a GIS database and a location-based application so that the first-responder may follow a pre-defined path. We also investigated how audio cues can allow a first-responder to become oriented in an unfamiliar environment. Assuming a first-responder relies on his own senses for collision avoidance and personal safety, we created a location-based application that will enable a first-responder to either maintain orientation or follow a pre-defined route.

Our software application includes several features; it allows marking favorite waypoints and paths, and supports presenting waypoints via an audio description in a meaningful way. It marks waypoints as visited or unvisited, displays a list of neighboring waypoints to the user's current waypoint, identifies the last waypoint visited using the software's "back" feature, and allows a user to traverse a series of waypoints from the current position back to the starting position. The software also presents neighboring waypoints at an intersection in clockwise order, starting with the northern-most waypoint and listing the remaining neighboring waypoints in the order of East, South and West. The user interface (UI) models the UI of a cell phone application, enabling a user to select information from a menu by entering numerical digits 0 through 9, and get information as with a standard phone menu.

The software can guide a rescue worker through any defined path. From the beginning of this path, the software will mark waypoints at an intersection that will lead him to the end of this path. This feature will allow a rescue team to examine a hazardous situation and guide a first responder along a pre-defined path. The software allows the user to create a new path so that a first responder can mark a route to a desired waypoint.
Our research found that presenting neighboring waypoints in clockwise order efficiently oriented the user with audio cues.

**D5.3 VIEWS** *(ImageCat/ R. Eguchi, Huyck, Mio, and Ghosh)*
The research team at ImageCat has been able to test and validate the application of the VIEWS (Visualizing the Impacts of Earthquakes with Satellite) after the December 26, 2004 Indian Ocean earthquake and tsunami. VIEWS spatially catalogs video feed with GPS. Observations made from video stills can be cross-referenced with any spatial data set, yielding data such as damage level, distance-to-coast, or wave height from very rapid data collection. VIEWS was initially developed with funding from the Multidisciplinary Center for Earthquake Engineering Research (MCEER); its application during the Indian Ocean earthquake and tsunami was a RESCUE research activity where data and information collected by other RESCUE investigators (Mehrotra, Venkatasubramanian) was integrated with moderate- and high-resolution satellite imagery served from within the VIEWS system.

## TESTBEDS

In order to exploit the many opportunities for testing and evaluating the research and research products that result from the RESCUE program, the research plan (as documented in the NSF Cooperative Agreement) calls for three testbeds: 1) transportation; 2) CAMAS (Citizens Awareness …); and 3) GLQ (Gas Lamp Quarter). The Transportation Testbed has been designed to test and evaluate IT solutions in large, regional disasters. These would include earthquakes, hurricanes and human threats that involve multiple incidents occurring at the same time. The CAMAS testbed provides an environment where IT solutions in a contained setting can be tested and evaluated within the context of localized response. In order to establish an effective interface between real response and modeled response, the CAMAS testbed has been set up as a multi-agent simulator. Finally, the GLQ (Gas Lamp Quarter) testbed provides a testing and evaluation environment that fits between the Transportation and CAMAS testbeds. Set in one of the most popular tourist areas of San Diego, the GLQ

Testbed will allow the testing and evaluation of rapidly deployable mobile networking, computing, and geo-localization infrastructure in the context of incident-level response. These three original testbeds therefore allow a broad assessment of IT technologies and solutions at different geographical scales.

At the end of Year 1, however, an opportunity to develop a fourth testbed emerged, largely as a result of excellent relationships that were developed between the city of Champaign, Ill. and the research team leading the security and trust research in the RESCUE project. What was discovered in these discussions was the fact that emergency response in the city of Champaign was quite different from that employed by Los Angeles and San Diego. Furthermore, it became clear that implementing a testbed much closer to the core of the security and trust research efforts would have other significant benefits. Therefore, a fourth testbed was established in Year 2. This fourth testbed will also ensure that the research being conducted in RESCUE will have applicability to smaller and more moderate-sized cities and communities.

The details of each testbed are discussed below. The emphasis is on current progress and on deployable system platforms. Ultimately, these platforms will be artifacts of RESCUE which will be handed over to end-user partners.

## Transportation Testbed

To provide a platform for testing and evaluating the efficacy of information technology and social science research within the context of regional crisis response, the RESCUE project is utilizing a multi-dimensional testbed that simulates the performance of large transportation networks during catastrophic events. The reasons for selecting transportation networks are three-fold: 1) transportation networks are geographically very large, and therefore, are susceptible to a broad range of hazards or events; 2) because they are interconnected systems, effective performance is often based on the proper performance of its components, i.e., a damaged component such as a bridge can disrupt the entire system; and 3) information technology can play a key role in improving the performance of transportation networks during disasters by identifying problem areas and implementing more efficient solutions to overcome these problems.

In setting up this testbed, certain criteria were established to ensure that it could effectively be used as a platform for testing and evaluating the value of information technologies. These criteria included:

- The testbed must allow a real-world evaluation of the efficacy of information technologies for crisis response;
- The testbed should include two major components: an information technology and social science (IT-SS) component, and a simulation component;
- The testbed must be easily accessible to all users, i.e., an internet-based platform;
- The testbed must be set up to allow users to define the scope of their test or evaluation;
- The testbed must provide quantitative results or feedback quickly.

The two components defined above (information technology/social science component and simulation component) have specific objectives. The purpose of the IT-SS component is to develop methodologies and solutions that allow for more rapid evaluation of damage or impacts in large disasters, for better communication and dissemination of data and information between critical response organizations and the public, and for better decision-making capabilities. An important overall goal of these technologies is to mitigate the potential for secondary impacts or events, i.e., cascading failures or incidents.

The purpose of the simulation component is to serve as a surrogate for real-world conditions in a disaster. This component must be able to simulate results with and without the use of improved information technologies in order to quantify their value.

Information technology and social science research being performed in the RESCUE project includes:

- Dynamic data collection
- Rendering multimodal data
- Reliable knowledge from unreliable informants
- Event extraction from multimodal data streams
- Adaptive filtering of event streams
- Damage and impact assessment
- Optimizing organizational structure in dynamic and evolving virtual organizations (DEVO)
- Open distributed computing support for DEVOs
- Trust management in DEVOs
- Structured approach to disseminating information
- Emergent social behavior within the context of a disaster
- System for customized information delivery

The simulation model will be used to approximate the following conditions:

- Damaged transportation elements, e.g., bridges
- Disrupted highway links,
- Release and spread of gaseous hazardous materials,
- Travel times (and delays) between destinations with and without technology solutions
- Evacuation times with and without technology solutions

The following sections describe the basic framework for the Transportation Testbed, the simulation scheme for evaluating the value of information technologies during crises, integration of the transportation testbed with communication networks (cellular), and key milestones over the next several years.

***Framework.*** The basic framework for the model that is used in the Transportation Testbed is described in a paper in the Year 2 Research Highlights (A Centralized Web-based Loss Estimation and Transportation Modeling Platform for Disaster Response by H. C. Chung, et al., 2005), which is being provided under separate cover. The Chung (2005) paper introduces the computational platform that is used to "operationalize" the Transportation Testbed. The platform is called INLET for Internet-based Loss Estimation Tool.

INLET has been designed as a web-based solution to test the efficacy of information technologies within the context of crisis response. The platform offers a centralized, web-based modeling environment, where the level of effectiveness (as measured by reduction in expected losses, evacuation times and other impacts) can be determined for each technology tested. Centralized and wireless dissemination of loss results can improve response efforts by ensuring 1) that the same information reaches all parties, thus minimizing the potential for conflicting response, and 2) that critical information be readily accessible.

The simulation platform consists of seven major blocks, as illustrated in Figure 1. The first block is the *Disaster Simulation* module. This module simulates the initial conditions of the disaster. In the case of earthquake, information on the location and size of the event, the expected ground motion patterns, an assessment of the number of damaged buildings and resulting economic loss, the number and locations of damaged highway bridges, and other impacts such as number of casualties are calculated. The next module is the *Network Configuration* module. This module updates the physical composition of the system by identifying and closing down those highway bridges that have been impacted by the disaster. In order to perform this assessment, damage functions and structural fragility models are employed that correlate different performance states (e.g., operating or not operating) with different levels of damage. The next module is the *Evacuation Demand* module. This module is used to quantify population exposures throughout the study region. In general, this information is needed in order to determine how many people need to be evacuated from an area. The fourth module is the *Origin-Destination* module. In this module, travel patterns are documented between different transportation analysis zones. This information is critical in establishing 1) what the likely loads will be on the transportation system during a crisis, and 2) which areas will be affected by an incident. The *Driver's Behavior* module describes, in a quantitative sense, how drivers' will respond in different crisis situations and more importantly, to different messaging. Accurate and complete information can effectively reduce travel times when viewed in the context of evacuation (see example in Chung, 2005a) The *Dynamic Network Rerouting* module is key in characterizing traffic movement when bridge or highway closures are introduced. An optimized algorithm can also be useful in identifying efficient strategies to overcome these obstacles. Finally, the last block provides the end result of the analysis. That is, measuring the performance of the system under crisis conditions, and more importantly, the performance of the system when IT solutions are introduced. Initially, we are planning to quantify system performance using the following measures: a) total time to evacuate; b) total travel time delays; and c) total casualties resulting from exposure to gaseous toxic materials.

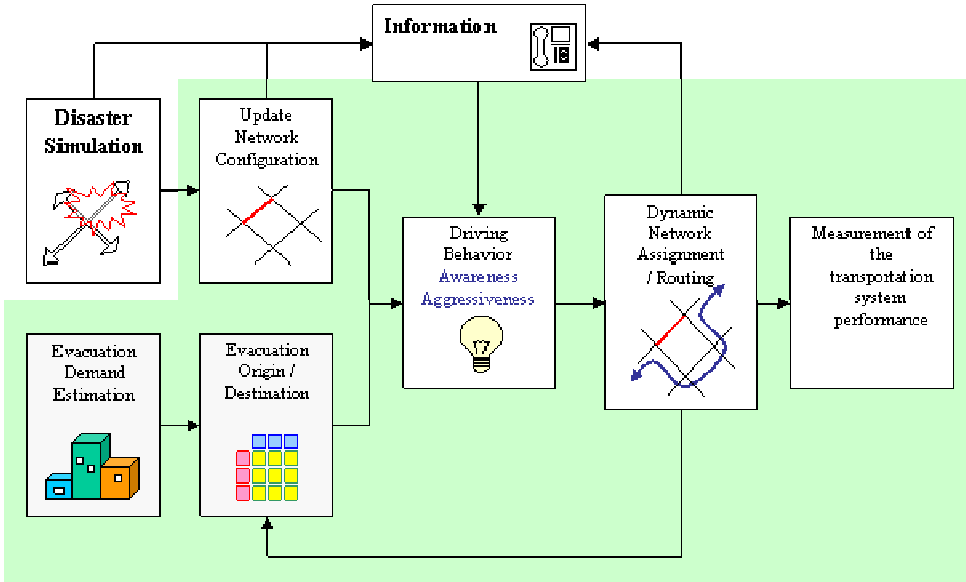


**Figure 1. Transportation Simulation Model**

***Simulation Scheme.*** The simulation scheme is based on modeling the movement of people in cars both before and after information technologies are applied. For example, one of the information technology solutions that will be tested is the use of customized messaging for cell phone users based on where the users are located. Since most cell phones are geo-locatable, it is possible that custom messages could be sent to cell phone users based on their current locations. So, in the case of a serious incident (such as a hazardous materials release), drivers could be instructed to stay away from the incident or be given directions that will help them evacuate safely away from the incident. This technology solution (i.e., customized messaging) would be evaluated in the INLET platform by modifying the parameters of the dynamic network assignment or routing module in Figure 1, i.e., re-routing drivers based on different levels of information (see example in Chung 2005). The measure of effectiveness might be the number of people avoiding the effects of the incident, or the time required to evacuate vehicles from the affected area.

Another example would be the use of in-situ sensors on bridges or other key transportation elements in quickly identifying the damage states of these elements after a large disaster (see Chang et al., 2005 in the Year 2 Research Highlights Volume). One of the more difficult tasks that structural engineers face after a major earthquake is assessing the amount of damage caused by the disaster. This task often requires field inspections that can be time-consuming and limited because of the large demand on resources. With sensors on key bridges, it is possible that the performance state of these bridges could be determined in near real-time and relayed back to some central site for evaluation. The benefits of these rapid evaluations are 1) better information to prioritize response, 2) more reliable data on “troubled” spots that can be passed on to drivers in the area, and 3) a more informed basis for assessing the structural safety of key bridges. The value of this information technology solution could be tested by modifying the parameters of the *Update Network Configuration* module.

Other information technologies that can be evaluated include:

- Remote sensing to more rapidly quantify the scope and magnitude of the disaster, especially on a large regional scale;
- Use of loop sensors to estimate daytime populations in densely-populated areas;
- Use of cell phones to estimate daytime populations in all areas;
- Smart transportation traffic systems to more effectively implement traffic movement after a disaster.

INLET has been designed to ensure user-friendly access to the Transportation Testbed. The implementation plan calls for a user interface that allows the user to adjust key parameters within INLET to simulate the conditions that would result if the technology solution is implemented. For example, in the case of the customized messaging, the user will be able to adjust the level of information reaching a driver, the percentage of drivers receiving these customized messages, and the reliability of these messages.

By using the INLET model, researchers will be able to achieve the following: 1) evaluate the system performance benefits of their research; and/or 2) determine the performance objectives or criteria for their research in order to achieve measurable benefits.

***Integration with Cellular Networks.*** A future expansion of the Transportation Testbed could include the addition of cellular networks. Since some of the technology solutions that will be tested in the Transportation Testbed involve the use of cellular networks, the research team is considering merging the cellular network models being developed by both UCSD and UCI with the transportation simulation model.

Figure 2 shows a possible configuration for this integration. Both networks would be connected to a *crisis simulator*. The purpose of this simulator would be to lay out the initial conditions of the disaster. In the case of earthquake, this could mean the identification of damaged bridges, the detection of damaged cell towers or other cellular infrastructure, and conditions where the performance of one network may affect the performance of the other. For example, if the cellular network is damaged and not functional in some event, this will directly impact the ability of emergency personnel to provide custom messages to drivers in these affected areas. Similarly, if the transportation system is disrupted, this will hamper the ability of cellular companies to get to affected areas to make repairs.

The simulation engines for both networks can also be merged in such a way as to provide real support during actual emergencies. For example, if the state of each system can be determined quickly and reliably in an actual event (based on the use of the information technology solutions mentioned above), the simulation engines could provide the basis for coordinating post-event repairs or response activities for both systems. That is, the simulation engines for both networks become interactive and provide “system-level” information that can be used to evaluate different response and recovery strategies.

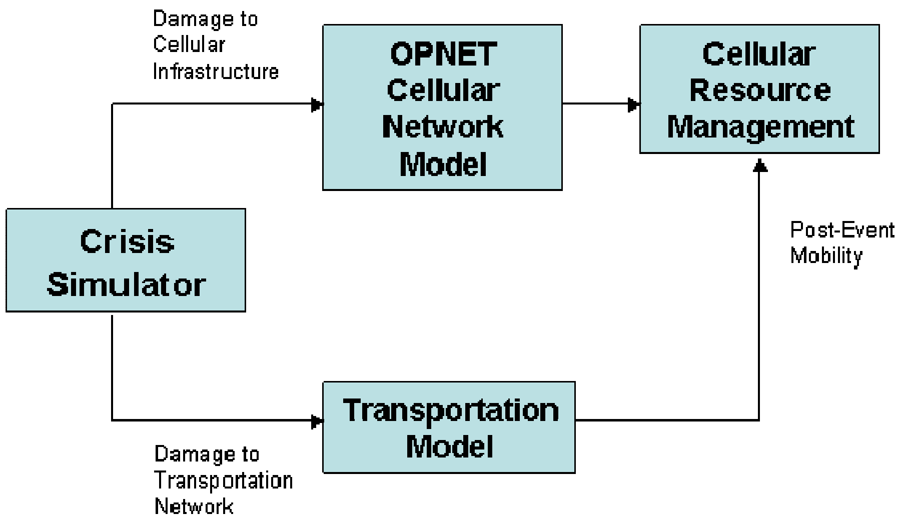


**Figure 2. Multi-network Integration Scheme**

***Transportation Testbed Milestones.*** The following milestones are presented for the next several years:

- Loss estimation modules completed in 2004;
- Beta-version of INLET online at UCI in early 2005;
- Transportation module completed by Fall 2005;
- User-interface protocols finalized by Summer 2005;
- First tests initiated in Fall 2005 or Spring 2006;
- Beta-testing of INLET at government partner's site, Spring 2006;
- INLET ready as operational testbed in Summer 2006;
- Final version of INLET delivered to government partner(s) in Fall 2006.

## CAMAS Testbed

***Testbed Overview.*** 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 for crisis-activity monitoring. The objective is to be able to play out a variety of crisis-response activities (evacuation, medical triaging, firefighting, reconnaissance) for multiple purposes – IT solution integration, training, testing, decision analysis, impact analysis, etc.

***Rationale of Research:*** The response effectiveness in a crisis depends heavily on information about the situation (e.g., state of civil, transportation and information infrastructure) and on information about available resources. While crisis response is comprised of many different activities, our view is that it can be modeled (in part) by the flow of information between individuals and organizations. In general, this process involves four main information-related activities: collection, analysis, sharing, and dissemination. The simulator in this testbed plays out specific response activities that are usually under the control of an on-site, incident commander who reports to a central Emergency Operations Center (EOC). These activities include evacuation, traffic management, triage and provision of medical services, and damage assessment. The proposed simulator models these different activities (at both a macro and micro level) and the information flow between different entities. The simulator allows plugging and unplugging different IT solutions, at interface points between these activities or at specific junctures in the information flow cycle, to study the effectiveness of IT solutions in the response process.

Such an activity-based simulator consists of (a) different models that drive the activity, (b) entities that drive the simulation and (c) information that flows between different components. Models characterize the scenario and represent spatial information (e.g., location of entities, movement) about the crisis and its effects, and the activity of different agents. In the current context, agents simulate the activities of people. In this role, agents also take on different roles during an evacuation (e.g., the public, response personnel). Moreover, the simulator can be deployed in an actual drill. In this case, some agents simulate people while other agents reflect (and learn from) the actions of real people in the real drill. Agents have access to information based on the sensors available to them. These sensors include the agent's own sensors (e.g., eyes, ears), the devices the agent carries (e.g., cellphone, PDA), and sensors deployed on facilities (e.g., video cameras). Using this information, agents are in the position to make key decisions about a specific response activity. Human models will drive the decision-making process of agents. Moreover, based on the agent's role, the agent's activities and the access to privileged information may vary. The activity model characterizes the types of activities captured in the simulator (this can be done on a per-agent basis or at a more coarse level).

To add further realism to this testbed, the simulation platform has been integrated into a real-world instrumented framework (the UCI Responsphere Infrastructure) that captures physical reality during an activity as it occurs. Responsphere is an IT infrastructure that is designed to support the overall objectives of RESCUE. Responsphere incorporates a multidisciplinary approach to emergency management and draws upon support from academia, government and private enterprise. The instrumented space in Responsphere will be used to conduct and monitor emergency drills within UCI. Sensed information of the physical world will be fed into the simulator to update the simulation and hence calibrate the activities at different stages of an exercise. Such integration will also allow real people to assume specific roles in the multi-agent simulator (e.g., a floor warden in an evacuation process, the public) and to monitor (for calibration or training purposes) the decisions made by agents as they actively engaged in the exercise. The integration will help to extend the scope of the simulation framework to capture both the virtual and physical worlds and merge them into an implementable framework.

***Challenges in Designing CAMAS.*** Creating a testbed that can test and evaluate IT solutions for disaster management poses different challenges:

- **IT Integration.** The simulator must be modular so that IT solutions (hardware and software) are easily plugged in. Moreover, to adequately test IT solutions, it is necessary to translate IT metrics into disaster metrics.

- **Representing Spatial-Temporal Data.** Data representation techniques must be developed to capture key data on geography (i.e., location), evolving crisis events, scenario attributes and the state of the different entities (e.g., responding organizations) in the response event. The challenge here is modeling spatial and temporal data given the following: the large amount of data collected; the need for different navigation algorithms for different spatial information; employing real-time constraints in order to synchronize the simulated scenario with the real-world scenario; and ensuring that enough information is saved so that the simulation can be replayed a posteriori.

- **Modeling Human Behavior**. Response is a decision-based event – hence human decisions must be accurately captured in order to replicate realism.

- **Virtual Reality, Augmented Reality Integration**. The testbed must be designed to simulate the event, as well as consider ongoing drills as they evolve. Real-time constraints must be implemented in order to synchronize the simulated event (e.g., evacuation) and an ongoing drill. Furthermore, both worlds (simulated and real) must be integrated in such a way that events and actions in one world influence the other world.

Our research (over multiple years) will address each of these challenges.

***Year 2 Research Objectives and Progress.*** In Year 2, our objectives have been to:

1. Design the architecture for CAMAS testbed;
2. Instrument Calit2 Building as part of the testbed;
3. Model spatial information and design navigation algorithms;
4. Integrate information dissemination and collection techniques into the testbed.

Much of this work is a result of the refinement of the vision/goals/objectives set forth in the original proposal. The research tasks associated with this testbed were not explicitly identified in the proposal or NSF Cooperative Agreement. As a result, most of the tasks identified above are new; significant progress, however, has been made in all areas.

1. **Design and Architecture of CAMAS:** We are developing a multi-agent discrete event simulator within the context of crisis response. Different types of events are modeled in this simulator with the emphasis on information exchange and flow. In order to realistically play out the response event, we have designed agents that take on the roles of the public and/or response personnel. Human models are used to model the agents and in some aspects, their decision-making abilities. Furthermore, agent behavior is calibrated based on the actions of their human counterparts.
   The architecture of the system is shown in Figure 3. The simulator captures both the simulated world as well as the physical world. The simulated world consists of the simulated geographic space, the crisis event as it unfolds, and the current scenario, which represents where people are at a given time and what they are doing. The

current crisis represents both the disaster and the changes that result (modeled as an effect of the disaster). These changes are reflected in both geographical space and in the scenario. As the event evolves, changes are also reflected in the simulated world. The physical world is the real world which is captured using the sensing capabilities of the instrumented environment; in this case, the infrastructure is *Responsphere*.

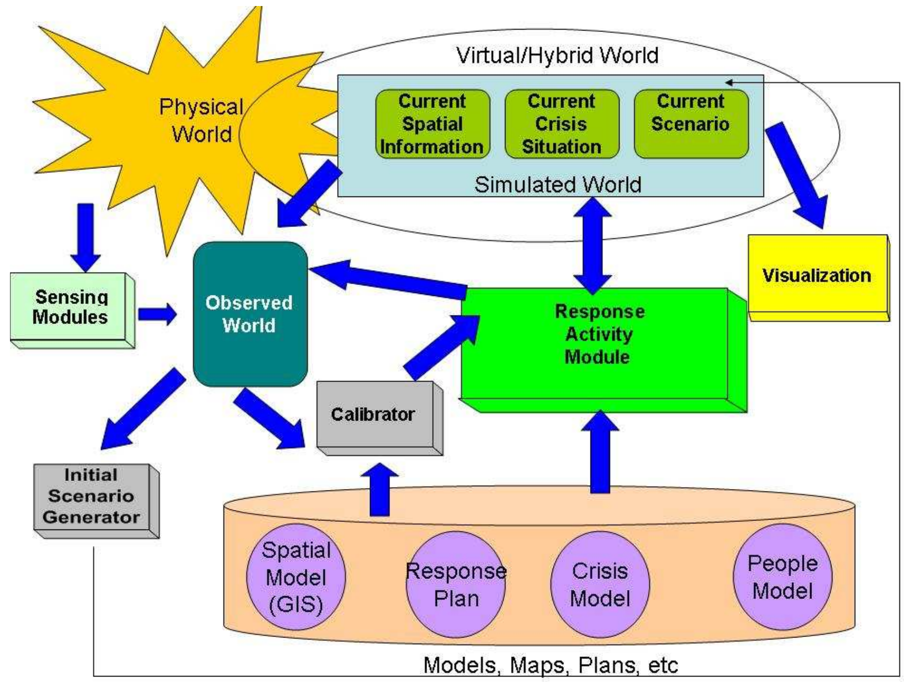


**Figure 3. Simulator Architecture**

2. **Instrumented Framework for CAMAS.** The CAMAS testbed consists of a pervasive infrastructure with various sensing (including video, audio), communication, computational and storage capabilities. While the testbed is designed to support crisis-related activities including simulations and drills, the testbed will also support a variety of other applications and uses during normal use time. An example is the monitoring of equipment and people-related activities within the Calit2 space.

3. **Modeling Spatial Information.** There is a substantial amount of spatial information that must be processed by the simulator, including information on the geo-location of agents. In the context of the simulator, geographical space includes both indoor and outdoor areas. Representation of spatial information will be accomplished through the use of databases and there will be an interface that agents will use to access this spatial information as part of the decision-making process. As part of this development, we are designing navigation algorithms to simulate the evacuation of people. In this context, different representations (of navigation) are superimposed on the basic database, acknowledging the individual requirements of agent and the algorithm. The navigation scheme includes hierarchical path planning and obstacle avoidance.

4. **Prototype System Implementation.** A prototype (DrillSim v1.0) of the CAMAS testbed that simulates the evacuation of people within a building has been developed in Year 2.

**Integration of Dissemination and Collection Techniques in the Testbed.** Specific IT solutions for improving information collection and dissemination have been developed by the research team in other tasks. The plan is to test these solutions within the CAMAS Testbed. An example of an information-collection solution is the development of a multimodal collection algorithm that focuses on localization information from a crisis. A dissemination IT solution targets the distribution of information in a multi-agent context, where agents have access to different communication devices.

## Gas Lamp Quarter (GLQ) Testbed

The Gas Lamp Quarter (GLQ) Testbed consists of a rapidly deployable mobile networking, computing, and geo-localization infrastructure in the context of incident-level response to spatially-localized disasters, such as the World Trade Center attack. The testbed focuses on situations where the crisis site either does not have an existing infrastructure, or alternatively, the infrastructure is severely damaged. This testbed focuses on supporting basic services essential to the first responders that can be brought over to crisis sites for rapid deployment. Such services include communication among the first-responders, accurate geo-localization both inside and outside of buildings, in urban as well as rural areas, computation infrastructure, incidence level command center, and technology to support information flow from/to crisis sites to/from regional emergency centers.

This testbed will be deployed in the Gas Lamp Quarter district in downtown San Diego. The testbed will provide a seamless Wi-Fi (802.11b) connectivity for first-responders in this area. GLQ is currently divided into three zones, where each zone has its central post in direct line of site to the top of the NBC building. The transmitter on top of NBC building provides the broadband access to these three lampposts via a 5.2 – 5.7 GHz backhaul. By using Tropos Networks 5110 outdoor units, the coverage of these three zones will be expanded and we are able to provide the support for standard 802.11b users.

Tropos units will find each other and mesh together using a standard ISM band which will also act as an 802.11b access point for end users. By connecting these three locations to the network, the testbed will cover a large area. Also by having three entry points, the reliability of the system will be enhanced. The three lampposts with backhaul connectivity (5th and Market, 5th and E, 4th and G) will have a Motorola Canopy receiver and a Tropos 5110 unit installed. The others will just have a Tropos 5110 unit installation. The 802.11b cells communicate with each other wirelessly through a mesh routing algorithm implemented within the access points. The control protocol is part of the Tropos Sphere operating and management tool. The following discussion highlights lessons learned during design and lab trials prior to network deployment.

***Network Design.*** For this testbed, there is a need for a reliable and controlled wireless network that covers the entire GLQ area in downtown San Diego. Although there are several wireless ISPs in this area, most of have patchy coverage and are not reliable.

RESCUE is in a good position to design and deploy its own network to cover this area. This will provide an opportunity for researchers to have a more reliable network and to maintain control of the system. In deploying this system, the following issues are being addressed.

*Frequency Band*. The system can deploy in an unlicensed band and use standard off-the-shelf equipment. This will reduce the cost of deployment significantly. Our approach is to have a *hybrid network* design. While using the standard 802.11b for reaching the end-users, 5.2 GHZ and 5.7 GHz will be used for backhauls to increase the capacity of the system. The other option is using Ensemble (a San Diego-based company)/XO partnership. Recently, Ensemble and XO announced that they are able to provide equipment and spectrum to support any wireless deployment in the downtown San Diego area. This will certainly increase the reliability of the system since that system will operate in a licensed band.

*Site Acquisition*. Sentre Partners, one of the leading real estate companies in San Diego, has already committed itself to several projects in order to promote the city of San Diego. They own three of the tallest buildings in the downtown area. By using their rooftops, it will be easy to have a large footprint and cover the downtown area.

*Backhauls*. The cost of the backhaul is the most critical factor affecting long-term deployment. One possible solution for meeting this need is to involve some of the local telephone companies, e.g., Verizon or SBC, in providing the backhaul. Another solution is to use the under-utilized bandwidth in the buildings to connect our base stations to the network. Sentre Partners, the owner of NBC building, is committed to provide this access and enough bandwidth for the project; therefore, this is the solution we have chosen.

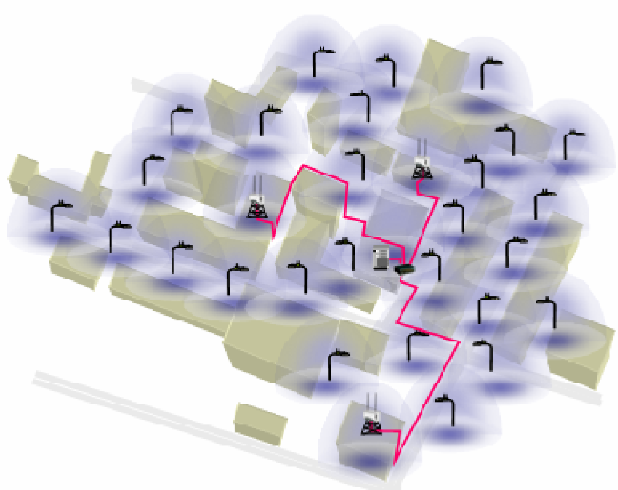

**Figure 4. A Metro-Scale Cellular Wi-Fi Deployment**

*Throughput Analysis in Large Networks.* Maximizing throughput in large networks requires minimal network bandwidth for protocol traffic control and optimal data paths for users in the face of highly variable RF conditions. Wireless link bandwidth is a finite resource and any traffic for control signals will reduce the capacity for user traffic. Traditional mesh nodes maintain routes between all nodes in the network, using either link-state or distance-vector protocols. As a result, the routing tables and information exchanged between nodes grows proportionally to the size of network. After the network reaches a certain size, the routing overhead will exceed the data traffic. In the present GLQ testbed architecture, the nodes and their routing mechanism maintain constant routing overhead as network elements grow in number.

Wireless links are prone to multi-path fading and interference. These effects are dynamic, asymmetric and vary over time, particularly in a mobile environment. Ultimately, these effects manifest themselves as 802.11 packet reception errors, making them the major source of throughput loss on the wireless data link. In sharp contrast to wired networks where link-status is binary, throughput measured across one or more wireless hops can fluctuate anywhere between 0 and 100% of its theoretical maximum due to packet errors. Recent research has shown that routing algorithms that minimize hop-count or rely solely on RF signal strength to make routing decisions will fail to converge on a useful network topology, and offer poor throughput. Since these routing decisions are uncorrelated with throughput, they achieve far less throughput over time. This would include the vast majority of wired-routing protocols as well as the wireless-routing algorithms employed by interconnected-based client mesh networks.

In contrast, the Predictive Wireless Routing Protocol (PWRP), used in GLQ deployment, is sensitive to these variations in throughput, i.e., by taking bi-directional measurement samples multiple times a second across wireless links. Based on a history of these measurements, predictive algorithms dynamically tune the selection of the multi-hop paths from the available paths in the mesh network. By estimating the throughput of each alternative path using advanced multi-hop metrics, PWRP ensures that it consistently selects paths in the top few percentiles of all available paths. On average, this achieves more than twice the throughput of competing routing approaches which are, in effect, choosing their paths at random with respect to throughput. In fact, PRWP consistently ensures a stable and high level throughput for Wi-Fi clients.

*Network Layer Resiliency.* In the initial development of this testbed for RESCUE, resiliency to unexpected failure was the main assumption in design and deployment. Cellular networks are prone to service interruption due to loss of network components (BSS and MSC). Wi-Fi networks, on the other hand, are vulnerable to severe interferences. PWRP incorporates network layer resiliency and self-healing features that enable network deployment with the desired reliability. PWRP is fully distributed and eliminates all single points of failure allowing for geographic distribution and rapid restoration. The GLQ testbed quickly detects backhaul failures and degradation, and re-routes the traffic through other nodes to other available backhaul links. The routing protocol typically relies on a small number of “hello” packets to detect the state of a link. It is important to discriminate between temporary wireless fades and an actual loss of link. During all these processes, the application and all active sessiones must be maintained without interruption.

***Current Progress.*** In order to execute the original San Diego Gas Lamp Quarter (GLQ) plan of deploying a highly resilient wireless mesh network in downtown San Diego, we have analyzed real behavior of mesh networks in a lab environment to ensure flawless design and deployment of the testbed. We have designed and built the wireless mesh network testbed to run most of the experimental studies before actual network deployment in the GLQ. This laboratory deployment has involved four stages of implementation and evaluation; the first two stages have been completed so far. The four stages are:

1. *Wireless Mesh Network Gateway*. We have set up the wireless mesh network gateway which acts as a bridge for both wired and wireless parts of the mesh network, and conducted studies on bridging, routing, name resolution and Internet access across wireless and wired networks;
2. *Multiple Relay Nodes and Wireless Clients*. Using a linear-string topology, we have set up a wireless mesh gateway with multiple relay nodes and wireless clients, and conducted studies on relaying, detection, association, and disassociation;
3. *Mesh Topologies*. Current work includes setup of planned mesh topologies with as many relay nodes and clients as possible. Planned studies include path selection, load balancing, hand-off, seamless roaming, video delivery, and quality of service measurements for data and video traffic. For the video delivery performance and associated studies, we partnered with Ortiva Wireless, Inc. in order to provide performance evaluation studies of their video conditioning product – Ostreamer – on our testbed. A multistage evaluation sequence, including quantitative and qualitative studies in both networking parameters and multimedia parameters, will help understand delivering efficient multimedia streams to the first-responders while considering device limitations (cell phone, PDA, etc);
4. *Long-haul Wireless Link.* The laboratory GLQ testbed will be completed using the long-haul Canopy wireless link to finalizing the configuration and prepare it for deployment in the GLQ. We will use multiple gateways that are connected to the Canopy client transceivers and Canopy clients communicate with a Canopy server that has a wired network connection;

In the first stage of this laboratory deployment, several experiments were conducted to confirm the testbed's functionality and wireless client nodes were also configured to communicate through this gateway. In the second stage of this deployment, we will set up multi-hop relaying, routing and communication to the Internet through the gateway. Currently, we are in the process of proceeding with the stages (3) and (4) to build the laboratory testbed for the GLQ wireless mesh network.

## Champaign Testbed

In the past year, members of the RESCUE research team have formed a new partnership with the City of Champaign, Ill. In establishing this relationship, they have had several goals, relating to requirements-gathering and data-gathering, deployment of research ideas and outreach. These include:

- To guide their research, they need information about security requirements for information sharing during disasters. This process has required many face-to-face meetings. Most of the security researchers in the RESCUE project do not live in Southern California, which makes it hard for to gather requirements from the RESCUE first-responder partners. Requirements-gathering in Champaign has been much easier for Winslett who lives in Champaign;

- For some of the ideas emerging from the RESCUE project, it is easier to try them out in a medium-size (160,000) metropolitan area than in Los Angeles/San Diego, which is a large area;
- Certain security research ideas in RESCUE do not fit into the three RESCUE testbeds described above. Champaign offers testbed opportunities for these security ideas;
- From their interactions with local officials, they have learned that disaster response in Champaign is very different from Southern California. There are many U.S. cities the size of Champaign, so what they learn locally can broaden the impact of the RESCUE project. Similarly, the RESCUE sociologists can learn about the differences between disaster response in large and medium cities by comparing data they obtain in L.A. and in Champaign;
- Certain types of useful data for RESCUE are more easily obtainable from Champaign than from the LA/San Diego area;
- Because Champaign is so much smaller than Los Angeles, there are fewer people who are responsible for disaster management in Champaign, which greatly simplifies requirements-gathering and data-gathering.

In partnering with the RESCUE project, there are a number of possible benefits for the City of Champaign:

- Champaign is interested in learning about the various ideas from RESCUE, and in experimenting with those ideas that might help with response to local disasters. This is especially true for the testbed described below;
- Champaign is very interested in participating in disaster-response roundtables organized by the University of Colorado team. They think that the lessons learned from those roundtables might possibly help them in responding to future crises;
- The ties developed with researchers in the context of the RESCUE project may be helpful to the city in the long run, e.g., by eventually leading to development of new software products that will be useful during disaster response in Champaign.

To understand the Champaign Testbed, it is helpful to know about the most likely kinds of disasters in Champaign, for each of the three main kinds of disasters: natural, technological and human. The most common natural disaster in Champaign by far is high winds, both straight-line and tornadoes; the most recent EOC activation in Champaign was in July 2004 for high wind. The potential technological disaster of most concern is a derailment with an associated chemical spill. Heavily used rail lines run through the center of the city. For a human-caused disaster, anything is possible; for example, the local mall is on the State of Illinois list of top soft targets for terrorists. In understanding the testbed, it is also important to know that in Champaign, all the main players in disaster response know one another and communicate frequently. This leads to levels of trust that are not as likely to be present in disaster response in a big city.

The Champaign Testbed contains the following components:

- GIS products developed by the CCRPC, with the following functionality
  - High-resolution aerial photographs of Champaign city and county
  - Geo-referenced road overlays for the City of Champaign
  - Parcel data for Champaign County;
- 911 call feeds
  - Call location
  - Nature of call;
- Sensor feeds
  - Road sensors in and around town, owned by a variety of authorities (These sense road temperature and other variables.)
  - Wind sensors
  - Chemical sensors in storm sewers and on lamp posts
  - Sensors at the local mall, high schools, etc.;
- Camera feeds
  - Cameras at intersections in town, owned by the City of Champaign
  - Webcams, scattered around town and owned by a variety of authorities
  - A TV camera mounted high above the city that swivels to point any direction, owned by a TV station
  - Cameras inside the local mall, high schools, etc.

The idea is for the GIS to be shown on a large screen in the city's Emergency Operations Center, with the 911 and sensor feeds to be shown as overlays. From the pattern of sensor/911 call information on the map, it will be easy for the people in the EOC to see where to deploy their resources. Camera feeds can be popped up as callouts, where desired. Further, in the long run, the GIS and its overlays should be fed into fire/police mobile command vans, so that the people in the mobile units have access to the same information as those in the EOC.

All of the input data sources mentioned above exist today, except for (some or all of) the wind and chemical sensors. The city is interested in purchasing wind and chemical sensors if it can make use of them in the manner illustrated by the testbed. The input data sources are owned by a wide variety of public and private organizations. Thus they present an excellent opportunity for trying out the RESCUE projects ideas about security for information sharing across organizational boundaries during disasters.

The current status of the testbed is as follows:

1. Researchers have obtained the GIS software mentioned above, and are studying its functionality and internal operation;
2. They have developed an overall plan for how to model the sensor input data streams. (In other words, they do not plan to use actual live data feeds from private sources. They may use live public data feeds, such as public webcams.);
3. They have spoken to one of the potential sensor/camera owners, the principal of a local high school, to learn what policies he would have on sharing his data with the

EOC during a declared emergency. They plan to speak to many more of these data source owners, to learn what their information sharing policies would be;

4. They have a student who is in charge of building the testbed.

They have not yet determined what query capabilities users will have (e.g., "show me all schools and nursing homes with 100 yards of this derailment point"). They will determine the query capabilities once they fully understand the GIS capabilities.

Their goal is to have the testbed up and running in the summer of 2005. The first research ideas to be deployed in the testbed will be from the trust management portion of RESCUE, under investigators Winslett and Seamons. The trust management middleware will control the sharing of data across organizational boundaries during declared crises.

In the longer term, they hope that Kathleen Tierney's (CU) team will be able to do sociological studies of disaster management in Champaign. The city is enthusiastic about the opportunity, so *if time and funds permit*, it will be a nice opportunity for RESCUE and for the city. Ideally, they would like to have three roundtable discussions, focusing on the response to a hypothetical technological, man-made, and natural disaster (a derailment with chemical spill, a school shooting and a wind storm). The Champaign city manager is very enthusiastic about these, and other key city people are interested in participating.

## 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

A summer exchange program involving RESCUE organizations was initiated in the summer of 2004. The following activities have taken place:

- A summer internship program was initiated with organizations that comprise our Community Advisory Board (CAB). Specifically, one graduate student from UCI, Mayur Deshpande, and one post-doctoral researcher from the U. of Colorado, worked at the City of Los Angeles to help understand how emerging information technologies can help to improve crisis response and what approaches are effective in improving dissemination of emergency-planning information using the Internet. Mayur's work was invaluable for paving the way to successful interviews of L.A. first-responders that were carried out by Jeannette Sutton of CU Boulder. Mayur also learned that Information Technology is being increasingly used in dissemination by emergency response organizations. For example, the Update-LA web site (http://www.updatela.com) of the Los Angeles Emergency Preparedness Department (LA-EPD) is specifically set up to provide information over the Internet to the public. However, during crisis times it is quite foreseeable that this web site can experience a huge spike in traffic, leading to unavailability of information from it. This can severely limit the usefulness of such a web site. The general problem can be described to be that of provisioning for scalability of any information source. Provisioning for spike-load in turn can be quite costly, thereby limiting the adoption of this technology. Adding to this requirement, and also closely tied to it, is the issue of timely delivery of information. For example, LA-EPD routinely experiences delays in the receipt of earthquake information from ANSS (Advanced National Seismic System). Again, the issue is that of scalable and timely delivery of information to multiple recipients. Having identified this fundamental problem during his internship at LA-EPD, RESCUE graduate student Mayur Deshpande and his team are now developing radically new technologies based on the Peer-to-Peer approach. The guiding philosophy is to "shift the load to those causing it." RapID is a prototype artifact that we are developing in this regard. The availability of this software will help emergency organizations provide timely, scalable information to tens of thousands of recipients without the need for high-end servers or high-bandwidth links. This will dramatically impact, and usher in wholly new ways of the use of information technology in the emergency response organizations.
- UCI students Iosif Lazaridis and Xingbo Yu worked on the UCSD campus during the summer quarter of 2004. Their research involved implementing a prototype system for localizing cell phones using assisted GPS technology and collecting this location data adaptively at a central server. The captured motion trajectories are then able to be used by location-aware applications for situational awareness and customized information dissemination. The work of these students led to a new project on Reflective Cellular Architecture which aims to scale cellular technology to surge demands during crisis events. This technology being developed collaboratively by UCI and UCSD researchers will also provide mechanisms for awareness useful during responses using the cellular infrastructure. (See http://www-db.ics.uci.edu/pages/research/cello/index.shtml for details.)
- Ramaswamy Hariharan worked at Microsoft Research Labs as an intern researcher during the summers of 2003 and 2004. In 2003, he worked on a project named "Modeling Location Histories of People," where he developed algorithms for extracting higher level semantics, such as stays and destinations, from location information of individuals, e.g., persons carrying a GPS receiver. The extracted semantics was later incorporated for developing models that can predict the movements of people. In 2004, he worked on a research project named "Context-enhanced GPS." In this project, where GPS information is lost, context information such as temperature, WWW, nearby locations, and mobility measured from various

sensors can be used to predict the location of individuals. Both projects will help in dissemination of disaster-related information to people who are subscribed to such services.

- Undergraduate student Mohanned Alhanazzi (UCI) has been heavily involved in the core development of the Privacy Preserving Pervasive Spaces system.
- Shankar Shivappa (UCSD) will intern at AT&T Bell Labs during the summer of 2005. He will work on a project on large vocabulary conversational speech recognition.
- Undergraduate student Alfred Anguiano (UCI), participating in the California Alliance for Minority Participation (CAMP) program in Science, Engineering and Mathematics, worked on speech processing of 911 live radio transcripts between dispatchers and city law enforcement officials from the city of Irvine. CAMP is a statewide initiative to increase the quantity and quality of underrepresented undergraduate students.
- Wenyi Zhang (UCSD) worked during the summer of 2004 on an internship with AT&T Research Labs. His work there focused on speech separation, which can be used for speech enhancement and noise cancellation, helping to improve the performance of a speech recognition system. Independent Component Analysis (ICA) has gained attention in the area of linear signal processing. ICA is a recently developed blind-source separation technique that extracts separate sources from mixtures based on statistical dependence analysis. The project involved a survey of the theory and different algorithms for ICA and applied it to speech-mixture signal separation. Zhang studied and compared different principles of ICA and derived different algorithms – time domain algorithms and frequency domain algorithms – based on these principles. He experimented with various algorithms with the AT&T name databases and found that the ICA algorithms work well with instantaneous mixtures but not so well with convolutive mixtures. He experimented with speech recognition testing and performed spectral analysis of the speech signals, finding the root cause of why frequency domain ICA algorithms do not perform as well.

## Interactions with Government and RESCUE Partners

Interactions with the government and RESCUE partners have provided an opportunity for our students to learn about domain, showcase their research and its relevance to the crisis response, and get practice demonstrating and talking about their research. Specific interactions between our group and the government and RESCUE partners have been in multiple forms. Several examples are listed below:

- Regular Environmental Health & Safety (EH&S) drills on the UCI campus have allowed 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;
- CAMAS (Crisis Assessment, Mitigation and Analysis) focuses on the design and development of a multi-agent crisis simulator for crisis activity monitoring. The objective is to be able to play out a variety of crisis response activities (evacuation, medical triaging, firefighting, reconnaissance) for multiple purposes: IT solution

integration, training, testing, decision analysis, impact analysis, etc. Simulating such an environment, we have begun to instrument a significant portion of the UCI campus with wireless access points and video equipment to create smart corridors and open spaces Linda Bogue of UCI's Environmental Health and Safety Dept. (EH&S), as well as the UCI Campus Search and Rescue (CSAR) organization, are working with us to design drills as well as the simulator.

## Visits by Senior Officials

- Peter Freeman, senior staff member and asst. director of computer and information science and engineering at the National Science Foundation. Dr. Freeman visited RESCUE on Jan. 21, 2005. Highlights of his visit are summarized in an article at http://www.calit2.net/technology/features/1-24-05_freeman.html. The visit provided an opportunity for our students to demonstrate and describe their research.
- Ellis Stanley, general manager for the City of Los Angeles Emergency Preparedness Department. Mr. Stanley also serves as the chair of the RESCUE Community Advisory Board. Mr. Stanley visited RESCUE on Feb. 18, 2005, to meet student researchers and to view student posters and demonstrations.
- David Banks, director of the Center for Asymmetric Warfare. Dr. Banks gave the keynote address at the annual RESCUE Principal Investigators meeting on Nov. 14, 2004. Dr. Banks is an expert in drills. He provided the RESCUE students with insight about how emergency drills are realized and IT considerations during drills.

## 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. Each meeting includes a presentation by either a graduate student or researcher whose field is related to ongoing RESCUE research. In addition to sharing information, these presentations give graduate students public speaking experience. The weekly meetings at both UCI and UCSD have participation from various RESCUE sites. Researchers from UCSD and ImageCat frequently attend weekly UCI meetings; UCI researchers attend UCSD meetings. Meetings held during the past year include presentations from:
    - RESCUE students and professors demonstrating their research;
    - University departments engaged in research of interest to RESCUE;
    - City emergency manager workers;
    - Industry partners.

  These meetings are very useful in educating our students and researchers about the field level reality from the emergency response perspective. Documentation from weekly meetings, including presentation slides and streaming audio and video, can be accessed at http://www.ucrec.org/meetings/weekly/index.php.

- **Monthly meetings.** Once a month, the RESCUE team gathers for a meeting at UCI (researchers located away from UCI participate via video or teleconference). The main purpose of these monthly meetings is to share current research and to uncover opportunities for cross-disciplinary and cross-university collaborations. A keynote speaker presents his or her research in the context of RESCUE, followed by a question-and-answer session and discussion. Documentation from monthly meetings, including presentation slides and streaming audio and video, can be accessed at http://www.ucrec.org/meetings/monthly/index.php.
- **Workshops.** To ensure that cross-disciplinary goals are met, we are convening special workshops, seminars, demonstrations and field trips to bring researchers and public safety personnel together. 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.

## Infrastructural Support to Educational and Training

**Creation of a Common Multidisciplinary Research Facility**. We have created a multidisciplinary laboratory (RESCUE Center) that collocates students and faculty from a variety of disciplines – social science, engineering and computer science – to facilitate meaningful interactions. We have developed three required courses for all students associated with the RESCUE project. The first focuses on the social science issues related to crisis response. The second is an IT course that introduces possible roles of IT in emergency planning and response. The third focuses on IT systems for crisis response. In addition, RESCUE projects have been incorporated as special topics for related courses such as sensor networks.

At UCI, RESCUE occupies 4900 square feet in the new Calit2 building. The facility houses about 30 students from various disciplines. Our instructional approach provides an enriched environment of broad-based training that goes well beyond the usual one-mentor, one-lab, one-topic arrangement. Thus, for example, computer science students associated with the project have the opportunity to work on problems relating to social network analysis, information diffusion through human populations and organizational design – problems to which they would not otherwise be exposed. Similarly, social science students working on grant-related projects are being challenged to consider issues involving the interaction of information technology with large-scale social systems, and the design of data-collection and decision-support systems. Both groups are interacting with faculty whose interests run the gamut from data analysis and storage systems, to software engineering, to social science, thereby facilitating further cross-disciplinary collaboration.

**Creation of a Digital Library of Talks and Presentations**. At RESCUE, the audio and video of meetings, visits, talks and emergency drills in which we participate are captured and uploaded to the RESCUE intranet where they are accessible at any time by streaming. This provides a continuing source of education to our students. This media not only provides a source for education, it also helps in research. For instance, drill capture is studied by our social science students, as well as students who are building a simulator. This helps them learn about the practice and calibrate the simulation.

To ensure that cross-disciplinary goals are met, we are convening special workshops, seminars, demonstrations and field trips to bring researchers and public safety personnel together. 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:

- 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;
- The above examples and several others are explained in the Outreach section of this report.

## 2.3 OUTREACH ACTIVITIES THE PROJECT HAS UNDERTAKEN

### Outreach to the First-Responder Community

- Rescue researchers from UCI, UCSD and ImageCat met with Ellis Stanley, RESCUE Community Advisory Board (CAB) chair, on Feb.18, 2005, to discuss the status of the project and to determine how to better interact with the community. Mr. Stanley suggested a regular newsletter to communicate brief updates to CAB and to other community members with whom we have partnered.
- A monthly RESCUE E-newsletter was created to inform the RESCUE CAB of project activities of interest to the first-responder community. It features short descriptions of research and industrial developments of interest to the first responder communities. The first edition was published in April 2005.
- During the past year, we selected the UCI Responsphere infrastructure as the test platform for the CAMAS testbed. In Year 1, we had developed an initial prototype for CAMAS in cooperation with UCI facilities to allow dynamic assessment of facility problems using multimodal user input. Given our enhanced experience in the crisis-response domain through drills, interactions etc. we chose to implement the CAMAS testbed for domains which are more in line with crisis response. For this, we started out by establishing a close connection with the UCI campus EH&S. We worked with them to not only observe their drills but rather to participate with them and to instrument their exercises. Technologies incorporated with the CAMAS testbed and Responsphere infrastructure, such as dynamic data capture via video, audio and text streams, were tested in drills. First responders were outfitted with GPS and localization technologies allowing dynamic monitoring of drill activities. RESCUE team members were embedded in campus drills to provide dynamic input to our prototype situational awareness system. We set up a mock EOC within the RESCUE research space with the help of the people from Response organizations (City of Santa Ana). We continue to work closely with EH&S in designing drills with which the technologies can be tested. Our team will also consist of UCI's Parking & Transportation – their participation will enhance our ability to evaluate our technology in the context of campus evacuation drills involving cars, vehicles and parking

structures. These drills offer opportunity for real-time data capture, including voice, and to test human sensors. CAMAS, as mentioned earlier, has gathered several datasets; organizations have expressed interest in the datasets and tools collected, specifically in the context of the tsunami disaster. The data collected so far (including data from drills) was shared using the Web sites with our emergency partners and researchers. These results were also shared with the CAB partners using our newsletter (eNEWS) and 1:1 meetings. Photos and video from the campus drills can be seen at http://www.responsphere.org/drills.

- During the past year, we demonstrated a Mobile Command-and-Control Center application, an end-to-end architecture allowing first-responders to efficiently collect, manage and disseminate information within emergency response networks and to the general public. The system allows responders to collect information in the form of pictures, videos and audio clips, automatically time- and location-stamp them, and populate a GIS database without user intervention. We also demonstrated a "511" system that allows for dynamic routing and dispatch of first-responders based on current traffic conditions. The 511 system, initially deployed by Calit2 during Super Bowl 2003 at the request of the San Diego Police Department, has been operational for almost two years. It is available to the general public and receives about 50,000 calls each month.
- The RESCUE team at UCSD has been heavily engaged with the UCSD campus police, getting important feedback on technology development, use and applications, as well as using the campus as a testbed for location-based and notification technologies that are being developed. Specifically, Lt. David Rose is heavily involved with wireless technologies and their applications for first-responders. The UCSD-RESCUE team has provided GPS-enabled cell phones to use for location tracking experiments. These phones have been used by campus service officers who escort pedestrians at night. Lt. Rose has also invited UCSD to participate in the wireless technology committee meetings of ARJIS (Automated Regional Justice Information System), a San Diego county organization of multiple justice and first-responder agencies.
- The RESCUE team at UCSD has been interacting with campus police, facilities and hazmat units to determine usability of technologies being developed and to lay technological foundations so that more advanced, robust prototypes can be deployed with San Diego City police. Early prototypes of humans-as-sensors technology have been deployed with campus police and CSO (Community Service Officer) units. The outfitting of the GLQ will be completed early in Year 3, creating an opportunity to expand these prototypes and add to the sensor network, giving more accurate situational awareness in the testbed.
- In collaboration with the *Wireless Internet Information System for Medical Response in Disasters* (WIISARD) project, Ramesh Rao and Helena Bristow participated in a small-scale drill/presentation of the San Diego Metropolitan Medical Strike Team (MMST) on Nov. 17, 2004.
- On March 22, 2005, Alexandra Hubenko, B.S. Manoj and Raheleh Dilmaghani (UCSD) observed a Hazardous materials drill sponsored by EH&S. The purpose was to learn about first-responder communication patterns and understand gaps that may be filled with the help of collaborative tools. After observing a drill organized by UCSD EH&S, the Rescue team has engaged with EH&S in the areas of communications, mobile command and control and GIS mapping. We are working

with Phillip Van Saun and Tod Ferguson of UCSD EHS and Dawn Martin, UCSD campus GIS coordinator, and are gaining valuable real-world insight on what is needed among the first-response community in terms of communications tools and information sharing.

- RESCUE researchers were observers in Aug. 2004 at *Determined Promise 2004*, a tri-coastal, domestic anti-terrorism exercise sponsored by the U. S. Northern Command. The Los Angeles-Long Beach-area scenario focused on a weapon of mass destruction in the form of a "dirty" bomb with radioactive elements being detonated in the port complex. The exercise involved more than 1800 participating organizations, agencies and entities.
- On Feb. 27, 2005, Stephen Pasco of UCSD participated in a command-post exercise with the LAPD, LAFD, Los Angeles Department of Transportation and the FBI during the 77th annual Academy Awards. RESCUE was on location, observing how these different departments collaborate during an event.
- During the past year, RESCUE researcher Jeannette Sutton (U. of Colorado) participated in a series of interviews with the LAPD. On March 22, 2005, RESCUE participated in a second series of interviews, this time with the LAFD.
- Dr Serge Belongie and Vincent Rabaud of the UCSD computer vision group are using data and training videos provided by the UCSD campus police department. Working closely with the UCSD campus police community, the group is developing algorithms and researching potential applications that will assist first-responders in detecting anomalous behavior in crowded public areas.
- RESCUE researchers at UIUC, under the direction of Dr Marianne Winslett, have developed a testbed for the city of Champaign, Ill. The Champaign Testbed and partnership serve multiple purposes. If demos of the testbed receive a positive response, the City of Champaign will seek further funding to productize the demo for use in its Emergency Operations Center. Presumably a similar product would be of interest to many other medium-size cities.
- Ramesh Rao was the keynote speaker at the Space and Naval Warfare Systems Center Technical Review Board on March 9, 2005. SPAWAR and Calit2 provided overviews of technology visions and goals, and identified similar communications and software architecture challenges in military and civilian applications.
- On Feb.10, 2005, Ramesh Rao met with Gary Wang, director of Science, Technology, and Engineering at SPAWAR, to discuss shared interests in command-and-control-center applications, and in sensor-and-information management issues.
- On April 18, 2005, Ramesh Rao and other UCSD faculty RESCUE researchers met with Paulette Murphy, coordinator for Homeland Security at SPAWAR to discuss the structure of SPAWAR and Navy emergency information management.
- RESCUE graduate student Mayur Deshpande worked at the City of Los Angeles Emergency Preparedness Department to learn how emerging information technologies can help to improve crisis response and to learn what approaches are effective in improving dissemination of emergency planning information using the Internet. Mayur's team is now developing software that will help emergency organizations provide timely information, scalably, to tens of thousands of recipients without the need for high-end servers or high-bandwidth links. This will dramatically

impact and usher in wholly new ways to use information technology in emergency response organizations.

- RESCUE (Marianne Winslett, UIUC) has partnered with the emergency-responder community in Champaign, Ill. The City of Champaign has supplied RESCUE with 911 information from police and fire conversations in the immediate aftermath of what appeared to be a suicide truck bombing in Champaign. The City's IT director, deputy fire chief, and Emergency Operations Center coordinator suggested an information-sharing application that they would like to have in their own EOC, and this application has become the core of the RESCUE Champaign Testbed.
- On Feb. 4, 2005, Jacob Green, a graduating senior at UC Irvine who is a student of Prof. Butts, spoke to the UC Irvine RESCUE team on "Bridging Academia and the Emergency Management Industry." Jacob has served as an emergency management professional, intern, volunteer and researcher in Orange and Los Angeles counties. In his talk Jacob told us how local, state and federal emergency management entities can benefit from the information technology research being developed by our RESCUE team by explaining the gap between academic research and real world implementation. The audio and video from Jacob's presentation can be accessed at http://www.itr-rescue.org/meetings/weekly/Agendas/2005/02_04_05/agenda_feb04_05.htm. Jacob currently serves as the asst. emergency manager of the Santa Ana, Calif. Fire Dept.
- On March 4, 2005, Stacey Murren and Sean Brummel from the UC Irvine Parking and Transportation Dept. spoke to the UC Irvine RESCUE team on "Data Collection from UCI Parking and Transportation." Many of the pursuits and plans of Parking and Transportation at UCI parallel those of the RESCUE project. This team is implementing novel data-collection ideas, such as license plate recognition systems for real-time car detection that predict the population flow for UCI's campus. Audio and video from the presentation can be accessed at http://www.itr-rescue.org/meetings/weekly/Agendas/2005/03_04_05/agenda_mar04_05.htm.

## Outreach to Industrial Partners

- As part of ongoing collaboration that RESCUE has established between *AT&T* and Calit2 in the area of spoken language understanding, Shankar Shivappa (UCSD) will do his summer internship at the speech group of *AT&T Labs*. He will work on a project on large vocabulary conversational speech recognition.
- Dr. B.S. Manoj, a postdoctoral researcher at UCSD, is collaborating with Rajesh Mishra of *Ericsson* on research related to the Always Best Connected (ABC). They are also planning to provide 1-2 summer internship positions for training.
- A series of meetings were held between RESCUE staff at UCSD and Magnus Wallmark and Martin Sjoblom of the National Security Networks team from *Ericsson's* Stockholm offices. Ericsson is pursuing collaboration with the RESCUE project to develop integrated notification systems for crisis response. Ramesh Rao and Ganz Chockalingam visited Ericsson in Sweden in September 2004 and plan to make a second visit in June 2005 to continue discussions.
- A collaborative meeting between the RESCUE, WhyNet, and Adaptive Systems projects was held at UCSD on April 6, 2005. The meeting was a discussion of

cellular network measuring tools and sharing project infrastructure; and included a demonstration of *Ericsson's* TEMS cellular network optimization product.

- RESCUE researchers Ganz Chockalingam and John Zhu of UCSD are collaborating with *Qualcomm* and *Caltrans* to assist with location-based technologies and traffic monitoring data.
- UCSD Rescue researchers Ramesh Rao, B.S. Manoj, Babak Jafarian, and Raheleh Dilmaghani have engaged with *Ortiva Wireless*, a startup company based in San Diego. Ortiva has a technology that can enable first-responders to reliably access high-quality video information on-demand while using potentially unreliable wireless networks as the communication medium. Ortiva will provide to RESCUE a wireless video delivery service to effectively disseminate video information to emergency responders. This service is planned to be tested in drills and integrated into the GLQ testbed.
- In Feb. 2005, the Irvine Division of Calit2 and six engineers from *Microsemi* Corp. participated in "Blue Sky Day," an opportunity for collaborative discussions between academia and industry. The information exchange included a demonstration from the RESCUE project that highlighted video surveillance and privacy-protecting data collection systems. See http://www.calit2.net/articles/article.php?id=208
- Ramesh Rao was invited to give an overview talk on RESCUE and related research activities at the 2005 *Motorola* Scientific Advisory Board Associate Meeting on Seamless Mobility, April 18, 2005.
- Ramesh Rao met with Al Zollar of *Tivoli/IBM* to explore potential collaboration. This was one in a series of meetings with *IBM* to discuss shared interest in incident management database software.
- John Zhu (UCSD) and a team of students will demonstrate the Campus Bus Monitoring System in a booth sponsored by Calit2 UCSD Division at *Qualcomm's* BREW 2005 Conference in San Diego, CA, June 1-3, 2005. BREW 2005 is an educational and networking forum for BREW publishers, developers, content providers, operators, device manufacturers and technology providers.

## Outreach to Community

- Dr. Peter Freeman, assistant director of computer and iInformation science and engineering (CISE) at the National Science Foundation, visited researchers from UCSD and UCI at ResCUE project headquarters at UCI on Jan. 21, 2005. Dr. Freeman spent the day visiting with ResCUE investigators, viewing posters and demos and discussing project details with investigators and graduate student researchers. See article at http://www.calit2.net/articles/article.php?id=131.
- RESCUE PIs and personnel at UCSD and UCI have been integrally involved in BioNet, an initiative sponsored by the DHS and DTRA, and in collaboration with NHRC, SPAWAR, LLNL, LANL, Sandia National Lab, JHU APL, and SDSU. Bionet seeks to effectively manage the consequences of a biological attack. It has three objectives: develop interoperable military and civilian concepts of operation; integrate military and civilian capabilities to detect and characterize a biological event; and provide common situational awareness to ensure timely, effective and consistent response.

- Ramesh Rao has participated in a series of meetings with Michael Kleeman on behalf of the American Red Cross to frame new opportunities for exploring the role of non-governmental organizations in homeland security and crisis response.
- "Wireless Technology to the Rescue," an OpEd piece written by Ramesh Rao (UCSD) discussed how a project such as RESCUE can help personalize emergency warning systems to avoid tragedies such as the December 2004 Indian Ocean tsunami. See http://www.signonsandiego.com/uniontrib/20050217/news_lz4e17rao.html.
- The San Diego traffic information website (http://traffic.calit2.net) continues to be available to San Diego commuters. There is a link to the site on the webpage of the local public broadcasting station (KPBS).
- The RESCUE GLQ testbed, which will provide Wi-Fi Internet connectivity to local law enforcement and to the general community, will be very useful for those living and working in downtown San Diego. The testbed will also provide an opportunity for other groups (other research projects, academics, local industry) to deploy their applications in a living lab environment.
- The UCSD Collaborative Visualization Center (CVC), a collaborative effort supported by RESCUE, Calit2 UCSD, and the Jacobs School of Engineering, is a facility designed to serve as a mock command-and-control center and to be used for various kinds of visualization research. The CVC was formally opened to the Calit2, UCSD, and local research communities on Sept. 22, 2004. In early 2005, Helena Bristow held a series of short courses aimed to introduce the Calit2 and UCSD research communities to the facility, inviting them to use and explore it. This facility acts as a space for collaborative interdisciplinary interaction, drawing participants working in visual arts, bioengineering, engineering visualization and many other disciplines. The email address cvc@calit2.net was created to enable communication of inquiries regarding the facility.
- ImageCat
    - ImageCat co-sponsored the 2nd International Workshop on the Use of Remote Sensing for Post-disaster Response, Newport Beach, CA, Oct. 2004. See http://www.imagecatinc.com/newsevents/EERI.html
    - ImageCat, Inc. deployed VIEWS (Visualizing Impacts of Earthquakes with Satellites) system in Parkfield, CA to test out rapid field reconnaissance. See http://www.imagecatinc.com/newsevents/parkfield.html
    - ImageCat joined EERI reconnaissance team to deploy VIEWS for the Niigata Chuetsu earthquake in Japan http://www.imagecatinc.com/article_2004_11.html
    - ImageCat used remote-sensing technology to identify impacted areas in South Asian tsunami http://www.imagecatinc.com/article_2005_01_a.html
    - ImageCat joined Multi-Lateral Reconnaissance Team to investigate the effects of the tsunami/earthquake disaster in South Asia http://www.imagecatinc.com/article_2005_01_b.html
    - ImageCat investigates tsunami damage using DigitalGlobe Satellite Imagery http://www.imagecatinc.com/pr_2005_02_07.html
    - MCEER Reconnaissance Team investigates effects of South Asia tsunami / earthquake tragedy http://www.imagecatinc.com/pr_2005_04.html

- “Remote Sensing Technology – A Coming of Age,“ Natural Hazards Observer, March 2005, see http://www.imagecatinc.com/reports/nat_haz_obs_mar05.pdf
- ImageCat presents remote sensing research to White House Homeland Security Council. See http://www.imagecatinc.com/newsevents/white_house.html

- The following workshops, keynote addresses, panels and invited talks have been organized/delivered as part of the RESCUE outreach effort:
  - Adams, Beverley, “The Application of Remote Sensing Technology for Disaster Management & Response,” Cambridge University, 4/27/05;
  - Adams, Beverley, and Tierney, Kathleen, “Remote Sensing Technologies for Post-disaster Response & Recovery,” White House Homeland Security Council, 09/04;
  - Adams, Beverley, “Streamlining Post-Disaster Data Collection and Damage Assessment, Using VIEWS and VRS,” *2nd International Workshop on the Use of Remote Sensing for Disaster Response,* 10/04;
  - Butts, Carter T. “Building Inferentially Tractable Models for Complex Social Systems: a Generalized Location Framework." (08/05). *ASA Section on Mathematical Sociology Invited Paper Session, “Mathematical Sociology Today: Current State and Prospects," ASA Meeting*, Philadelphia, PA.;
  - Butts, Carter T. “Beyond QAP: Parametric Permutation Models for Relational Data.” (10/04). *Quantitative Methods for Social Science Colloquium,* University of California at Santa Barbara, Santa Barbara, Calif.;
  - Butts, Carter T. and Petrescu-Prahova, Miruna. “Radio Communication Networks in the World Trade Center Disaster." (08/05). ASA Meeting, Philadelphia, PA.;
  - Butts, Carter T.; Petrescu-Prahova, Miruna; and Cross, Remy. “Emergency Phase Networks During the World Trade Center Disaster." (06/05). *Third Joint US-Japan Conference on Mathematical Sociology,* Sapporo, Japan.;
  - Butts, Carter T.; Petrescu-Prahova, Miruna; and Cross, Remy. “Responder Communication Networks During the World Trade Center Disaster." (02/05). 25th Sunbelt Network Conference (INSNA), Redondo Beach, Calif.;
  - Chung, Howard, Remote Sensing for Building Inventory Update and Improved Loss Estimation in HAZUS”, *2nd International Workshop on the Use of Remote Sensing for Disaster Response,* 10/04;
  - Eguchi, Ronald T., “Remote Sensing and GIS in Disaster Management, *1st International Conference on Urban Disaster Reduction,* Kobe, Japan, 01/18-20/05;
  - Huyck, Charles., “Reconnaissance Technologies: Lessons from the Niigata Ken Chuetsu Earthquake and Southeast Asian Boxing Day Tsunami”, *EERI Annual Meeting,* Mexico, 02/05;
  - Huyck, Charles, “Damage Detection Using Neighborhood Edge Dissimilarity in Very High Resolution Optical Data 2003 Bam Iran Earthquake”, *2nd International Workshop on the Use of remote Sensing for Disaster Response,* 10/04;

- Huyck, C. "Use of Integrated GPS, Imagery, and Remote Sensing in Post Earthquake Reconnaissance," *EERI Public Briefings*, 12/04;
- Mehrotra, Sharad and Venkatasubramanian, Nalini, “System Support for Sensor based Applications,” (12/03). *International Conference on High Performance Computing, Hyderabad, India.*
- Tierney, K. J. 2005. “Interorgnizational and Intergovernmental Coordination: Issues and Challenges.” Presentation at *“Crossings” Workshop on Cross-Border Collaboration,* Wayne State University, Detroit, MI, 03/15/05;
- Tierney, K. J. 2005. “Social Science, Disasters, and Homeland Security.” Invited presentation at the *Office of Science and Technology Policy*, Washington, D.C., 02/08/05;
- Sutton, J. 2004. “Determined Promise: Information Technology and Organizational Dynamics.” Invited presentation at the *RESCUE Annual Investigator’s Meeting,* Irvine, CA, 11/14/04;
- Sutton, J. 2004. “The RESCUE Project: IT and Communications in Emergency Management.” Invited presentation at the *Institute of Behavioral Science, University of Colorado, Boulder, CO*, 11/01/04;
- Tierney, K. J. 2004. “What Goes Right When Things Go Wrong: Resilience in the World Trade Center Disaster.” Invited lecture, *Department of Sociology, University of California, Davis.* Speaker series on “When Things Break Down: Social Systems in Crisis,” 10/15/04;
- Interviewees from the City of Los Angeles as well as RESCUE collaborators will be invited to attend the Hazards Workshop in Boulder, Colorado, held annually by the Natural Hazards Research and Applications Information Center.
- M. Winslett. “An Introduction to Trust Negotiation,” Brown University (10/04), University of Pittsburgh (03/04), University of Illinois at Chicago (04/04), North Carolina State University (05/04), Purdue University (’04);
- M. Winslett, Trust Negotiation, a one-week course at the University of Trento, Italy, 02/04;
- K. Seamons. TrustBuilder: Automated Trust Negotiation in Open Systems. *CERIAS Security Seminar*, Purdue University, 02/11/04;
- John Miller’s (UCSD) research in route preview software with audio cues for first responders also has an application for the blind community, as the blind can follow audio cues in the same way as first responders. He presented this technology to the Research and Development committee for the National Federation of the Blind 02/01/05. He will also present this technology to the blind community at large at the national convention for NFB in Louisville, KY, 07/05 (expected attendance of 2000);
- On 04/05/05 Alexandra Hubenko and Stephen Pasco of UCSD presented details of disaster response project work, including RESCUE, being carried out at the UCSD division of Calit2, to the wireless technology subcommittee of ARJIS (Association of Regional Justice Information Systems). This is an association of San Diego County agency first responders whose goal is to establish a web-based “single point of entry” to query all regional justice data.

- John Zhu (UCSD) gave a presentation of the system architecture of the UCSD campus bus monitoring system he is developing at *San Diego State University,* titled “A framework for location based services” on 11/16/04. This system can be implemented throughout the UCSD community to enable commuters to track shuttle location and anticipate their commute time;
- Chen Li of UCI gave a invited talk on gerrymandering to the database group at *UCSD* on 05/04/04;
- Graduate Student Michal Schmueli-Scheuer gave a seminar on “Achieving Communication Efficiency through Push-Pull Partitioning of Semantic Spaces in Client-Server Architectures,” at *Technion University, Haifa, Israel*, 12/14/04;
- Sharad Mehrotra (RESCUE PI), Marianne Winslett (RESCUE co-PI) and Ramesh Jain co-chaired a DEVO workshop organized at *ACM SIGMOD 2004*. The paper discussed IT challenges focusing on data management issues in dynamically evolving virtual organizations. The workshop resulted in a report which was published in the SIGMOD Record journal.
- Sharad Mehrotra spoke at several industry and government venues on RESCUE IT for homeland security, including talks at (1) Mitsui & Co., New York City, (2) FDA, (3) Technology Forum of Southern California and (4) ICS TekTalk 2004 Series.
- Marianne Winslett, Sharad Mehrotra, and Ramesh Jain co-organized the “*Databases in Virtual Organizations Workshop*” in Paris, France, 05/04. A report of the workshop appeared in SIGMOD Record, 03/05;
- Marianne Winslett, Wolfgang Nejdl, Piero Bonatti, and Jennifer Golbeck organized the *“Trust, Security, and Reputation on the Semantic Web”* workshop, Hiroshima, Japan, 11/04;
- B.S. Manoj (UCSD) presented the paper “On Using Multihop Relaying in Next Generation Wireless Networks and Emergency Response,” at *IBM India Research Labs (IRL)*, New Delhi, 03/05. This talk discussed the objectives of using multihop wireless networks in projects such as ResCUE, WIISARD, and Responsphere. It discussed the GLQ testbed which is a part of RESCUE and Responsphere.
- Dr B.S. Manoj presented the paper ”Hybrid Wireless Networks: A Radical Next Generation Wireless Networking Paradigm,” at the *Indian National Science Academy* (INSA), New Delhi, 03/05. This talk focused on using wireless relaying in wireless local loop networks to enhance network capacity.
- Prof. Ramesh Rao and post-doctoral researcher B.S. Manoj (UCSD) conducted a survey of other research groups working in areas similar to the RESCUE project. They learned that about 15 universities with more than 50 professors and an even greater number of researchers are working in this area. Manoj prepared a plan of action to explore the possibility of bringing out archival publications and other knowledge dissemination methods in the focus area of the ResCUE project; active effort is underway in this direction.
- Ramesh Rao was keynote speaker at the *Wireless World Initiative* (WWI) Symposium in Brussels, Belgium, on 12/09/04, where he gave a presentation on wireless applications in crisis response.

- Ramesh Rao was an invited speaker at the *First Workshop on Internet Signal Processing* (WISP) at UCSD, where he gave a talk on Signal Processing Perspectives on Resource Allocation, 11/11/04;
- Ramesh Rao served as Distinguished Judge for the *UCSD Connect 2004 Most Innovative New Product* "MIP" Awards, fall 2004.
- Ramesh Rao served on the Technical Program Committees for *Infocom and Mobicom 2005*.
- The UCSD Division of Calit2 is sponsoring MobiQuitous *2005: The Second Annual Conference on Mobile and Ubiquitous Systems: Networking and Services,* 07/17-21/05, at which RESCUE expects to have a presence.
- Alexandra Hubenko remotely presented a paper, "Disaster Recovery & Management – the Calit2 Experience," at the Workshop *on Wireless and Pervasive Computing Technologies for Healthcare and Disaster Recovery*, National University of Singapore, 03/11/05;
- John Zhu will be demonstrating the UCSD Campus Bus Monitoring System at the Calit2 booth, *Qualcomm BREW conference*, 06/1-3/05, San Diego.
- The UCSD Division of Calit2 showcased RESCUE research at the *Calit2 Student Spectrum* on 10/25/04. Projects exhibited included work performed by and in collaboration with John Miller, Diep Nguyen, Anh Nguyen, John Zhu, Ganz Chockalingam, Nick Hill, et al.
- In Ramesh Rao's stead, Jerry Sheehan gave an overview of UCSD RESCUE activities to the *NSF House Science Committee* on 12/15/04;
- The UCSD Division of Calit2 showcased RESCUE research at the *Jacobs School of Engineering Research Expo* on 02/25/05. Projects highlighted include the GLQ and CAMAS testbeds, computer vision research done by Vincent Rabaud et al, social science research done by Remy Cross et al, network simulation research done by B.S. Manoj, Raheleh Dilmaghani et al, and applications development by John Zhu, Ganz Chockalingam, Nick Hill, et al. http://www.calit2.net/articles/article.php?id=264
- Professor Mohan Trivedi (UCSD) participated in a *Constitution Project Panel: "Video Surveillance: Legal and Technological Challenges*," 03/23/04, at the Georgetown University Law Center in Washington D.C. See http://ucsdnews.ucsd.edu/newsrel/science/TrivediConstitution.asp.. Professor Trivedi's presentation can be streamed from http://media.law.georgetown.edu:8080/ramgen/archive/video0304.rm?start=58:20.
- Professor Mohan Trivedi (UCSD) participated in a panel, "*Regional University Collaboration for Homeland Security,*" moderated by Chancellor Marye Ann Fox (UCSD) and President Stephen Weber (San Diego State University) at the National Association of State Universities and Land Grant Colleges (NASULGC) 117th Annual Conference, San Diego, 11/14/04;
- Professor Mohan Trivedi (UCSD) participated in the "*Intelligent Video Surveillance*" panel discussion (Plenary Session), "*Computers Freedom, and Privacy CFP 2005 Annual Conference,*" Seattle, Washington, 04/12-15/05. See http://www.cfp2005.org/Program.html;

- Professor Mohan Trivedi (UCSD) presented an invited talk, "Tracking and Face Capture Using Video and Infrared Arrays" at the *Department of Homeland Security (DHS) Threat and Vulnerability Testing and Assessment* (TVTA) *Meeting*, Las Vegas, 04/05;
- Professor Mohan Trivedi (UCSD) will give the keynote talk, "Computer Vision for Homeland Security: Promise and Challenges," at the *IEEE International Conference on Advanced Video and Signal Based Surveillance*, Como. Italy, 09/05;
- Professor Mohan Trivedi (UCSD) gave a Computer Vision and Robotics Research (CVRR) Laboratory Tour and Technical Presentations to the Scientific Program Managers of *DHS Homeland Security Advanced Research Projects Agency* (HSARPA), Summer 2004.

- The home page of Calit2 regularly publishes articles about the researchers of RESCUE and their projects. Recent highlights include:
  - "Babak Jafarian: Enabling Mobile Internet Access for Security and Popular Applications," 10/29/04. The article discusses Jafarian's RESCUE-related work on the San Diego Gaslamp Quarter testbed. See http://www.calit2.net/technology/features/10-29-04_jafarian.html;
  - "UCI's Gloria Mark Studies How Technology Impacts Behavior," 09/01/04. See http://www.calit2.net/technology/features/8-31-04_mark.html;
  - "UCSD Division's Cahit Akin Mixes Technology and Business," 09/29/04. Akin works on the Always Best Connected (ABC) technology platform. See http://www.calit2.net/culture/features/2004/2004-09-29_akin.html;
  - "Wireless to the RESCUE: Q&A with Ramesh Rao," 02/15/05. http://www.calit2.net/articles/article.php?id=182 (Q&A with Ramesh Rao).

## Educational Outreach

- The UCSD Division of Calit2 has continued to participate in the UCSD TIES (Teams in Engineering Service) program, in which it collaborates with the AT&T Foundation, the Jacobs School of Engineering, and the San Diego Supercomputer Center. TIES puts UCSD undergraduates to work for San Diego non-profit organizations. In conjunction with rigorous academic coursework and training, multidisciplinary teams of UCSD students will design, build, and deploy projects that solve technology-based problems for community partners. http://www.jacobsschool.ucsd.edu/TIES/
- The UCSD RESCUE team has been in collaboration with Bob Welty of SDSU to discuss opportunities for RESCUE involvement in the new Homeland Security Master's program. See http://www.sdsuniverse.info/story.asp?id=12712
- The UCI division of Calit2 and the Donald Bren School of Information and Computer Sciences initiated a RESCUE seminar series in 2005. As of May 15, 2005, two seminars have been given: March 21, 2005, "Asynchronous Multimedia Annotations for Web-Based Collaboration in Biology Education," Dr. Dragutin Petkovic professor and chair of Department of Computer Science, San Francisco State University, and April 1, 2005, "Multi-Channel Hierarchical Modeling with Applications in Speech and

Multimodal Processing," Dr. Herve Bourlard Director, IDIAP Research Institute and Professor, Swiss Federal Institute of Technology at Lausanne.

- UCI RESCUE researchers have met on several occasions with Mr. Ken Allen of EduDyne Foundation, a non-profit Orange County organization that is engaged with DHS and NSF on various proposals, the goals of which are to enhance local community college advanced technology education. EduDyne is heavily involved with the new Advanced Technology Education Park (ATEP) located near UC Irvine at the former Tustin Air Base. Active participants include the South Orange County Community College District (http://www.socccd.org/). In the coming year RESCUE expects to continue its outreach in this area to assist in defining a program that will train community college students in specific advanced technology fields.

- The following courses with topics related to disaster and crisis response have been developed at UCI:

    - ICS 280 System Artifacts for Crisis Response applications – 20 students registered, Spring 2005, http://www-db.ics.uci.edu/ics280 Instructor: Prof. Sharad Mehrotra (UCI);
    - ICS 280 Systems Support for Sensor Networks – 13 students registered, Winter 2005, http://www.ics.uci.edu/~dsm/ics280sensor Instructor: Prof. Nalini Venkatasubramanian (UCI);
    - ICS 280 Database Systems Challenges in Crisis Response Applications – approx. 18 students, 2004, http://www-db.ics.uci.edu/ics280db Instructor: Prof. Sharad Mehrotra ((UCI);
    - ICS 243F Middleware Systems and Applications – approx 25 students, 2004. In this existing graduate course, several RESCUE-related projects were incorporated. http://www.ics.uci.edu/~ics243f Instructor: Prof. Nalini Venkatasubramanian (UCI);
    - Prof. Gene Tsudik is teaching a graduate course (ICS 280) on Secure Group Communication in Spring 2005 (UCI). The topic of this graduate course is relevant to RESCUE, especially, with regard to the data dissemination area;

- The following course with topics related to disaster and crisis response have been developed at BYU:

    - Kent Seamons (BYU) taught a graduate security course during Winter Semester 2004 and 2005 on access control in open systems.

- The following courses with topics related to disaster and crisis response have been developed at UCSD:

    - UCSD's Electrical and Computer Engineering department (ECE) teaches several project-based courses, among them ECE199 (undergraduate), ECE191 (undergraduate), and ECE 291 (graduate). Projects in these courses that have been directly related to the RESCUE research efforts include:

    - ECE 191, Winter 2005: UCSD Campus Bus Monitoring System (John Zhu, UCSD). Two students participated in the project. The system is built with latest Assisted GPS (AGPS) technology. Based on AGPS, a mobile phone is used to track the position and speed of campus bus. A real-time map is provided to view location, speed and identity of buses. The system combines the location information and multimedia data-sharing among mobile phones and servers. The objective of this project is to build a client- and server-based system, where the client resides in the mobile phone and the server resides in Java-based web server. The system will be deployed in a field setting, demonstrating the availability of position and multimedia data in real-time;

- ECE 199, Spring 2005. Mobile Platform for Vision Applications: License Plate Recognition (Prof Serge Belongie, UCSD). Students are to design and build a simple mobile base for implementation of computer vision algorithms specifically for license plate recognition using readily available components. The goal is to create a generic, cheap, mobile platform for implementation of vision algorithms;
- ECE 191, Winter 2005. Route Preview software with Audio Cues for first responders (John Miller, UCSD). The research team worked to develop a suite of hardware and software location-based solutions to help first-responders. The teams built two devices: 1) sense-of-touch evaluation module; and 2) basic stamp computer control, which uses digital input for the sense-of-touch guidance system. These devices will eventually incorporate the Route-Preview software to help a first-responder to orient himself during disaster situations;
- ECE 191, Spring 2005. Warehouse Assistant for First Responders (John Miller, UCSD). Follow-on project to ECE191, winter 2005. This project investigates how software, a barcode reader, and a web cam can help efficient and accurate inventory collection in, for example, a disaster scenario in which a non-medical person has been given a list of medical supplies from a medical warehouse, at which they are not familiar with the layout. The software will help the first responder collect needed supplies efficiently without assistance of warehouse personnel;
- ECE 291, Spring 2005. ZIGZAG Sense-of-Touch Guiding System with Computer Control and Remote Video (John Miller, UCSD). Follow-on project to ECE191, winter 2005. The team's responsibility was to design a computer interface to connect a prototype device to a digitally-controlled sense of touch servo system. The prototype device was designed to assist a blind person in navigating a path, or direct first-responders, whose senses of vision and hearing are saturated with real-time information or are reduced in a smoky or loud environment, to use sense-of-touch to follow a route in a disaster situation. This opens the possibilities of GPS navigation with a sense-of-touch user interface. An initial emphasis of the design will be on computer control of a servo and a computer collecting GPS information. Additional work will complement the student's interest, be it hardware design, hardware integration, or software design. A related article showcasing the ECE 191 projects from Winter 2005 can be found at the following link: http://www.calit2.net/articles/article.php?id=365;

As a follow-on to the ZIGZAG project, and under the direction of RESCUE researcher Dr John Miller, UCSD undergraduate Javier Rodriguez Molina was hired to build 10 prototype ZIGZAG devices for field testing. He received a Calit2 Research Scholarship for summer 2005 to continue his work developing software and hardware to meet the needs of first responders, including location-based services and a tactile guiding system to direct the user to a specific location along a specific route (ref. article at http://www.calit2.net/articles/article.php?id=500). In addition, undergraduate Diep Nguyen spent the academic year 2004-05 working on developing the Route-preview software for a sense of touch guidance system;

- The following Short courses and tutorials with topics related to disaster and crisis response have been developed at UIUC:
  - Marianne Winslett gave a one week short course on Trust Negotiation, presented at the University of Trento, Italy, February 2004;
  - Marianne Winslett and Arnie Rosenthal gave a tutorial on Security of Shared Data in Large Systems (including a section on trust negotiation) at the SIGMOD 2004 conference, Paris, June 2004;
  - Marianne Winslett and Arnie Rosenthal gave a tutorial on Security of Shared Data in Large Systems (including a section on trust negotiation) at the Very Large Databases (VLDB) conference, Toronto, September 2004.
- Additional educational outreach:
  - The UCI Honors Experience and ICS High School Scholars Day event, held at UCI on March 12, 2005, was presented to 200 potential students. Demos conducted by several researchers complemented the talk from ICS Dean Debra J. Richardson on the different majors (ICS, CS/E, Informatics, and CS) ICS offers. Each demo was representative of what a student with a particular major would be able to do after she graduates. RESCUE researchers Vidhya Balasubramanian and Daniel Massaguer, under the supervision of Prof. Nalini Venkatasubramian and Prof. Sharad Mehrotra, represented the CS major with a demo on adapting distance-learning content to people with disabilities. The demo also illustrated how contextualized information can be sent to users who are impaired in disaster scenarios.
  - The Sally Ride Science festival was held at UCI Nov. 20, 2004 for girls in grades five through eight. RESCUE presented “Technologies for Emergency Response” for the girls as part of this festival. Dr. Nalini Venkatasubramanian made a presentation to students about emergency response and how information technology can assist. Dr. Magda El Zarki gave a short presentation on multimedia technology. RESCUE students demonstrated their work to illustrate IT solutions in emergency response management. Vidhya Balasubramanian, Shivajit Mohapatra, Jehan Wickramasurya and Sridevi Parise presented their demonstrations to the students.

## 3. Publications and Products

### 3.1 Journal publications and conference proceedings

**Year 2 Journal Publications and Conference Proceedings:**

**Information Collection:**


1. Banerjee, S. and Shinozuka, M. "Dynamic Progressive Failure of Bridges." *Proceeding of ASCE Joint Specialty Conference on Probabilistic Mechanics and Structural Reliability*, Albuquerque, New Mexico, P65-86, 07/26-28/04;

2. Castellucia, C., Saxena, N. and J. H. Yi. "Self-Configurable Key Pre-distribution in Mobile Ad Hoc Networks". *IFIP Networking Conference*, to appear, 05/05;

3. Chang, P. C. "Geopolymer based Sensing". *NSF Workshop for Earthquake Mitigation*, Ankara, Turkey, 09/21-23/05;

4. Chang, P. C. "Passive Wireless Sensor." *Third European Conference on Structural Control*, Vienna, Austria, 07/12-15/04, Vienna University of Technology;

5. Chang, P. C. "Sensor for Infrastructure Application." *NSF-ESF Workshop for Sensing*, Strasbourg, France, 10/2-4/03;

6. Chebrolu, K., Raman, B. and R. Rao. "A Network Layer Approach to Enable TCP over Multiple Interfaces". To appear in *ACM/Kluwer Journal of Wireless Networks* (WINET), 2005;

7. Cristoforetti, J., "Multimodal Systems in the Management of Emergency Situations". MS Thesis, University of California, Irvine, 2005;

8. Cucchiara, R., Lovell, D., Prati, A. and M. M. Trivedi. "Introduction to the Special Section on In-Vehicle Computer Vision Systems". *IEEE Trans. on Vehicular Technology*, Volume: 53, Issue 6, Pages: 1633-1712, 11/04;

9. Fang, J. and R. Rao. "Optimal flow control for end-to-end delay and power constrained wireless multihop networks." *Proceedings of IEEE Military Communication Conference* (Milcom), Monterey, Calif., 10/04;

10. Han, Q. and N. Venkatasubramanian. "Real-time Collection of Dynamic Data with Quality Guarantees." *IEEE Tran. Parallel and Distributed Systems*, in revision, 2005.

11. Han, Q. and N.Venkatasubramanian. "Information Collection Services for QoS-aware Mobile Applications." *IEEE Transactions on Mobile Computing*, to appear, 2005.

12. Han, Q., Lazaridis, I., Mehrotra, S., and N. Venkatasubramanian. "Sensor Data Collection with Expected Reliability Guarantee." *The First International Workshop on Sensor Networks and Systems for Pervasive Computing* (PerSeNS), (in conjunction with PerCom), Kauai Island, Hawaii, 03/08/05;

13. Holt, J. “Logcrypt: Forward Security and Public Verification for Secure Audit Logs.” M. S. Thesis, Brigham Young University, 02/05;

14. Hore, B., R. Jamalla, and S. Mehrotra. “A Systematic Search Method for Optimal K-anonymity” Technical Report, 2005.

15. Krotosky, S. J., Cheng, S. Y. and M. M. Trivedi. "Face Detection and Head Tracking using Stereo and Thermal Infrared Cameras for 'Smart' Airbags: A Comparative Analysis.” *7th IEEE Conf. on Intelligent Transportation Systems*, 10/04;

16. Liu, M., Rao, R, Milstein, L. “On the Existence of Fair Wireless Scheduling Protocols.” Submitted to *IEEE Transactions on Wireless Communications*, 2004.

17. Trivedi, M. M., Huang, K. S., I. Mikic. "Dynamic Context Capture and Distributed *Video Arrays for Intelligent Spaces.” IEEE* Trans. on Systems, Man and Cybernetics, Part A, Volume: 35, Issue: 1, Pages: 145-163, 01/05;

18. Wang, K., Chiasserini, C. F., Proakis, J. G. and R. R. Rao. “Joint Scheduling and Power Control Supporting Multicasting in Wireless Ad Hoc Networks.” Submitted to Ad Hoc Networks Journal, 2005.

19. Wang, K., Chiasserini, C. F., Proakis, J. G. and R. R. Rao. “Distributed Fair Scheduling and Power Control in Wireless Ad Hoc Networks.” *GLOBECOM '04. IEEE Global Telecommunications Conference* (IEEE Cat. No.04CH37615), Dallas, TX. IEEE. Part Vol.6, pp.3556-62 Vol.6. Piscataway, NJ, 11/04;

20. Wang, K., Chiasserini, C. F., Proakis, J. G. and R. Rao. “A Distributed Joint Scheduling and Power Control Algorithm for Multicasting in Wireless Ad Hoc Networks.” *EURASIP Journal on Applied Signal Processing, Special Issue on Cross Layer Design for Communications and Signal Processing Systems*, 2004;

21. Wickramasuriya, J. and N. Venkatasubramanian. “Dynamic Access Control for Ubiqitous Environments.” *International Symposium on Distributed Objects and Applications* (DOA 2004), Agia Napa, Cyprus, 10/04;

22. Wickramasuriya, J., Alhazzazi, M., Datt, M., Mehrotra, S. and N. Venkatasubramanian. “Privacy-protecting Video Surveillance.” *SPIE International Symposium on Electronic Imaging* (Real-Time Imaging IX), San Jose, CA, 01/05;

23. Wickramasuriya, J., Datt, M., Hore, B., Jarecki, S., Mehrotra, S. and N. Venkatasubramanian. “Privacy-Preserving Triggers for Pervasive Spaces.” Technical Report, 2005 (Submitted for publication)

24. Wickramasuriya, J., Datt, M., Mehrotra, S. and N. Venkatasubramanian. “Privacy Protecting Data Collection in Media Spaces.” *ACM International Conference on Multimedia* (ACM Multimedia 2004) New York, NY, 10/04;

25. Wu, J. and M. M. Trivedi. "Enhancement for Face Video from Omni-Directional Video Camera.” *CVRR Technical Report*, 11/04;

26. Yu, X., Mehrotra, S. and N. Venkatasubramanian. “SURCH*: Distributed Query Processing over Wireless Sensor Networks*.” Submitted for publication, 2005.

27. Zhou, P., Wang, X. and R. Rao. “Throughout Capacity of Wireless Mesh Networks.” Submitted to *IEEE Wireless Communications*, 04/05;

28. Zorzi, M. and R. Rao. “Coding tradeoffs for reduced energy consumption in sensor networks.” *IEEE 15th International Symposium on Personal, Indoor and Mobile Radio Communications*, Barcelona, Spain (IEEE Cat. No.04TH8754). IEEE. Part Vol.1, pp.206-10 Vol.1. Piscataway, NJ, 09/04;

29. Zorzi, M. and R. Rao. “Energy-Efficient forwarding for ad hoc and sensor networks in the presence of fading.” *IEEE International Conference on Communications*, Paris, France (IEEE Cat. No.04CH37577). IEEE. Part Vol.7, pp.3784-9 Vol.7. Piscataway, NJ, 06/04.

**Information Analysis:**

30. Burke, J. P., Zeidler, J. R., and B. D. Rao. “CINR Difference Analysis of Optimal Combining vs Maximal Ratio Combining'”. *IEEE Transactions on Wireless Communications*, 01/05;

31. Butts, C.T. and M. Petrescu-Prahova. “Emergent Coordination in the World Trade Center Disaster.” *IMBS Technical Report MBS* 05-03, University of California, Irvine, 2005.

32. Butts, C.T.. “Exact Bounds for Degree Centralization”. *Social Networks*, forthcoming, 2005.

33. Butts, C.T.. “Permutation Models for Relational Data.” *IMBS Technical Report MBS* 05-02, University of California, Irvine, 2005.

34. Chang, R., Gandhi, T. and M. M. Trivedi. "Computer Vision for Multi-Sensory Structural Health Monitoring System.” *7th IEEE Conf. on Intelligent Transportation Systems*, 10/04;

35. Chen, Z., Kalashnikov, D.V. and S. Mehrotra. “Exploiting relationships for object consolidation.” Submitted to *ACM SIGMOD IQIS Workshop*, available as TR-RESCUE-05-01, 01/07/05;

36. Cheng, S. Y. and M. M. Trivedi. "Hand Pose Estimation Using Expectation-Constrained-Maximization From Voxel Data.” *CVRR Technical Report*, 11/04;

37. Cheng, S. Y., Park, S. and M. M. Trivedi. "Multiperspective Thermal IR and Video Arrays for 3D Body Tracking and Driver Activity Analysis.” *IEEE International Workshop on Object Tracking and Classification in and Beyond the Visible Spectrum*, 06/05;

38. Chung, H., Adams, B.J., Huyck, C.K., Ghosh, S. and R.T. Eguchi. “Remote Sensing for Building Inventory Update and Improved Loss Estimation in HAZUS-99.” *Proceedings of the 2nd International Workshop on Remote Sensing for Post-Disaster Response*, Newport Beach, CA., 10/7-8/04;

39. Chung, H., Enomoto, T. and M. Shinozuka. “Real-time Visualization of Structural Response with Wireless MEMS Sensors.” Proceedings *of the 9th International Symposium on NDE for Health Monitoring and Diagnostics*, San Diego, CA., 03/14-18/04;

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41. Eguchi, R.T., Huyck, C.K. and B.J. Adams. “An Urban Damage Scale based on Satellite and Airborne Imagery.” *Proceedings of the 1st International Conference on Urban Disaster Reduction*, Kobe, Japan, 01/18-20/05;

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43. Gandhi, T. and M. M. Trivedi. "Parametric Ego-Motion Estimation for Vehicle Surround Analysis Using Omni-Directional Camera.” *Machine Vision and Applications*, 2004.

44. Gogate, V. and R. Dechter. “Approximate Inference Algorithms for Hybrid Bayesian Networks in Presence of Constraints.” Submitted to *Uncertainty in Artificial Intelligence* (UAI), 2005;

45. Gogate, V., Dechter, R., Marca, J. and C. Rindt. “Modeling Transportation Routines using Hybrid Dynamic Mixed Networks.” Submitted to *Uncertainty in Artificial Intelligence* (UAI), 2005.

46. Huang, K. and M. M. Trivedi. "Voxelized Shape Context Based Gesture Analysis Using Networked Omni Video Array.” *CVRR Technical Report*, 11/04;

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51. Jagannatham, A.K. and B.D. Rao. “Complex Constrained CRB and Its Application To Semi-Blind MIMO and OFDM Channel Estimation.” *Sitges*, Barcelona, 07/04;

52. Kalashnikov, D. V., Ma, Y., Hariharan, R. and S. Mehrotra, “Spatial queries over (imprecise) event descriptions.” Submitted to *Conference on Very Large Data Bases* (VLDB), 2005.

53. Kalashnikov, D.V. and S. Mehrotra. “Computing connection strength in probabilistic graphs.” *TR-RESCUE-04-22*, 12/08/04;

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59. Ma, Y., Hariharan, R., Meyers, A., Wu, Y., Mio, M., Chemudugunta, C., Mehrotra, S., Venkatasubramanian, N. and P. Smyth. “PSAP: Personalized Situation Awareness Portal for Large Scale Disasters.” Submitted to *Conference on Very Large Data Bases* (VLDB), 2005 (demo publication)

60. Ma, Y., Seid, D., Zhong, Q and S. Mehrotra. “A Framework for Refining Structured Similarity Queries Using Learning Techniques.” In Proc of *CIKM Conf*, 2004 (poster publication)

61. Mansouri, B., Shinozuka, M., Huyck, C.K. and B. Houshmand. “Earthquake-induced Change Detection in BAM by Complex Analysis using Envisat ASAR Data.” *Earthquake Spectra*, In press;

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Data." Proceedings of the 2nd *International Workshop on Remote Sensing for Post-Disaster Response*, Newport Beach, CA., 10/7-8/04;

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81. Subramaniam, A. D., Rao, B. D., and W. R. Gardner. “Low-Complexity Source Coding using Gaussian Mixture Models, Lattice Vector Quantization and Recursive Coding with Application to Speech Spectrum Quantization.” To appear in *IEEE Transactions on Speech and Audio Processing.*

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83. Svantesson, T. and B. D. Rao. “Capacity of Spatio-Temporally Structured MIMO Channels with Estimation Errors.” *2005 IEEE International Conference on Acoustics, Speech, and Signal Processing*, Philadelphia, PA, 03/19-23/05;

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85. Tokgoz, Y. and B. D. Rao. "Outage Capacity Improvements in Multi-Cellular CDMA Systems Using Receive Antenna Diversity and Fast Power Control.” To appear in *IEEE Transactions on Wireless Communications*.

86. Tokgoz, Y. and B. D. Rao. "Outage Capacity of Maximum Ratio Transmission Based Multi-Cellular MIMO Systems with Power Control'". *Fifth IEEE Workshop on Signal Processing Advances in Wireless Communications*, Lisbon, 07/04;

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**Information Sharing:**

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106. Mykletun, E. and G. Tsudik. "On using Secure Hardware in Outsourced Databases." *International Workshop on Innovative Architecture for Future Generation High-Performance Processors and Systems,* 01/05;

107. Mykletun, E., Narasimha, M.  and G. Tsudik. "Signature "Bouquets: Immutability of Aggregated Signatures." *European Symposium on Research in Computer Security* (ESORICS'04), 09/04;

108. Nejdl, W., Olmedilla, D. and M. Winslett.  "PeerTrust: Automated Trust Negotiation for Peers on the Semantic Web." *Proc. of the Workshop on Secure Data Management in a Connected World* (SDM'04) in conjunction with 30th International Conference on Very Large Data Bases, Toronto, Canada, 08-09/04;

109. Ryutov, T., Zhou, L., Neuman, C., Leithead, T. and K. E. Seamons. "Adaptive Trust Negotiation and Access Contro." To appear in *10th ACM Symposium on Access Control Models and Technologies*, Stockholm, Sweden, 06/05;

110. Saxena, N., Tsudik, G.  and J. Yi. "Access Control Mechanisms for Ad Hoc Networks." *IEEE Workshop on Hot Topics in Peer-to-Peer* (HOT-P2P'04), 10/04;

111. Srinivasan, V., Nuggehalli, P., Chiasserini, C.-F. and R.\,R. Rao, “An Analytical Approach to the Study of Cooperation in Wireless Ad Hoc Networks,” *IEEE Transactions on Wireless Communications*, vol.4, no.2, pp.722-33. Publisher: IEEE, USA, 03/05;

112. Staab, S., Bhargava, B. K., Lilien, L., Rosenthal, A., Winslett, M., Sloman, M., Dillon, T. S., Chang, E., Hussain, F. K., Nejdl, W., Olmedilla, D. and V. Kashyap. “The Pudding of Trust.” *IEEE Intelligent Systems* 19(5): 74-88, 2004.

113. van der Horst, T. ”Thor: The Hybrid Online Repository.” *M. S. Thesis, Brigham Young University*, 02/05;

114. Yu, T. and M. Winslett. “Policy Migration for Sensitive Credentials in Trust Negotiation.” *Workshop on Privacy in the Electronic Society*, Washington, DC, 10/03;

**Information Dissemination:**

115. Butts, C.T. and M. Petrescu-Prahova. “Radio Communication Networks in the World Trade Center Disaster.” *IMBS Technical Report MBS 05-04*, University of California, Irvine, 2005.

116. Chebrolu, K. and R. Rao. “Bandwidth Aggregation for Real –Time Applications in Heterogenerous Wireless Networks.” *IEEE Transactions on Wireless Communications*, Accepted, 2005.

117. Deshpande, M., Venkatasubramanian, N. and S. Mehrotra. “Scalable, Flash Dissemination of Information in a Heterogeneous Network.” Submitted for publication, 2005.

118. Deshpande, M., Venkatasubramanian, N. and S. Mehrotra. “I.T. Support for Information Dissemination During Crisis.” UCI Technical Report, 2005.

119. Dhamdhere, A. and R. Rao. "Scheduling on a Channel with Time-Varying Capacity.” *Workshop on Cross-Layer Issues in the Design of Tactical Mobile Ad Hoc Wireless Networks: Integration of Communication and Networking Functions to Support Optimal Information Management*, Washington, D.C., 06/04;

120. Gandhi, T. and M. M. Trivedi. "Dynamic Panoramic Surround Map: Motivation and Omni Video Based Approach.” To Appear: *IEEE International Workshop on Machine Vision for Intelligent Vehicles in Conjunction with IEEE International Conference on Computer Vision and Pattern Recognition*, 06/21/05;

121. Ghighi, A. “Dissemination of Evacuation Information in Crisis.” *RESCUE Tech Report, Also M.S. Thesis, U of Bologna,* (thesis work was done while the author was an exchange student at ITR-RESCUE), 2005

122. Ghigi, A.. “Customized Dissemination in the context of emergencies.” *MS Thesis, University of California, Irvine,* 2005

123. Nuggehalli, P., Srinivasan, V. and R. Rao. “Energy Efficient Transmission Scheduling for Delay Constrained Wireless Networks.” Accepted for publication in *IEEE Transactions on Wireless Communications*, 2005.

**Testbeds:**

124. Chung, C., Huyck, C.K., Cho, S., Mio, M.Z., Eguchi, R.T., Shinozuka, M. and S. Mehrotra. “A Centralized Web-based Loss Estimation and Transportation Modeling Platform for Disaster Response.” Proceedings of the *9th International Conference on Structural Safety and Reliability*, Rome, Italy, 06/19-23/05;

125. Shinozuka, M. and Banerjee, S. "Dynamic Progressive Damage model for Bridges under Seismic Excitation.” Proceeding of *International Conference in Commemoration of 5th Anniversary of the 1999 Chi-Chi Earthquake*, Taiwan, Taipei, 09/8-9/04;

126. Shinozuka, M., Zhou, Y.W. and S. Banerjee. "Recent Studies in Fragility Information on Highway Bridges.” *3rd US-PRC Workshop on Seismic Behavior and Design of Special Highway Bridges*, Shanghai, China, 10/21-22/04;

127. Cho, S., Murachi, Y., Fan, Y., and Shinozuka, M. "Transportation Network Simulation for Dynamic Origin-Destination Matrix under Earthquake Damage.” *Proceeding of 13th World Conference on Earthquake Engineering*, Vancouver, B.C., Canada, Paper No. 1697, 08/1-6/04;

128. Shinozuka, M. "Civil Infrastructure Systems Safety and Security.” Presented at *International Conference on Future Vision and Challenges For Urban Development*, Cairo, Egypt, 12/20-22/04;

**Year 1 Journal Publications and Conference Proceedings:**

**General RESCUE papers:**

1. Mehrotra, S., Butts, C.T., Kalashnikov, D.V., Venkatasubramanian, N., Altintas, K., Hariharan, R., Lee, H., Ma, Y., Myers, A., Wickramasuriya, J., Eguchi, R., Huyck, C. "CAMAS: A Citizen Awareness System for Crisis Mitigation." *SIGMOD 2004*, 06/13-18/04. Paris, France;

2. Mehrotra, Sharad, Butts, C.T., Kalashnikov, Dmitri V., Venkatasubramanian, Nalini, Rao, Ramesh, Chockalingam, G., Eguchi, R., Adams, B., and Huyck, C. 2003. "Project RESCUE: Challenges in Responding to the Unexpected." *SPIE Journal of Electronic Imaging, Displays, and Medical Imaging*, 5304, 179-192. December, 2003. Invited paper, IS&T/SPIE 16th Annual Symposium. San Jose, CA, 01/18-22/04;

3. Tierney, K. 2004. "Collective Behavior in Times of Crisis." Invited paper presented at the *National Research Council Roundtable on Social and Behavioral Sciences and Terrorism*, Meeting 4, "Risk Communication for Terrorism." Washington, DC, National Academies, 01/30/04;

4. Tierney, K. "Responding Effectively to Extreme Events: Reality Versus Assumptions." Invited presentation at the *Biosecurity 2003* conference, sponsored by the Harvard School of Public Health and the Harvard Medical School, Washington, DC, 10/22/03;

**Information Collection:**

5. Achler, O. and M. M. Trivedi, "Vehicle Wheel Detector using 2D Filter Banks," *Proc. IEEE Intelligent Vehicles Symposium,* Accepted 06/04.

6. Elgamal, A., J. P. Conte, M. Fraser, S. Masri, T. Fountain, A. Gupta, M. M. Trivedi, M. El Zarki, "Health Monitoring for Civil Infrastructure," *9th Arab Structural Engineering Conference (9ASEC). Abu Dhabi, United Arab Emirates,* 11/29- 12/1/03;

7. Han, Qi, Sebastian Gutierrez-Nolasco and Nalini Venkatasubramanian. Reflective Middleware for Integrating Network Monitoring with Adaptive Object Messaging. *IEEE Network, Special issue on Middleware Technologies for Future Communications Networks*, 01-02/04;

8. Han, Qi, Sharad Mehrotra and Nalini Venkatasubramanian. "Energy Efficient Data Collection for Distributed Sensor Environments." *The 24th IEEE International Conference on Distributed Computing Systems* (ICDCS), Tokyo, Japan, 03/23-26/04;

9. Han, Qi, Matthew Ba Nguyen, Sandy Irani and Nalini Venkatasubramanian, "Time-sensitive Computation of Aggregate Functions over Distributed Imprecise Data." The *12th IEEE International Workshop on Parallel and Distributed Real-time Systems* (WPDRTS) (In conjunction with IPDPS 2004), Santa Fe, New Mexico, 04/26-27/04;

10. Han, Qi, and Nalini Venkatasubramanian. "Addressing Timeliness/Accuracy/Cost Tradeoffs in Information Collection for Dynamic Environments." *The 24th IEEE International Real-time Systems Symposium* (RTSS), Cancun, Mexico, 12/3-5/03;

11. Han, Qi, and Nalini Venkatasubramanian, "Information Collection Services for QoS-based Resource Provisioning for Mobile Applications." *IEEE Transactions on Mobile Computing,* in revision.

12. Han, Qi, and Nalini Venkatasubramanian, "Real-time Collection of Dynamic Data with Quality Guarantees." *Technical Report TR-RESCUE-04-22.* 2004. Submitted for publication.

13. Hore, Bijit, Sharad Mehrotra, and Gene Tsudik. "Privacy-Preserving Index for Range Queries. " *Technical Report TR-RESCUE-04-18*. To appear, VLDB 2004.

14. Huang, K. and M. Trivedi, "Robust Real-Time Detection, Tracking, and Pose Estimation of Faces in Video Streams," *Proceedings of International Conference on Pattern Recognition 2004,* Accepted 06/04;

15. Lazaridis, L., Qi Han, S. Mehrotra and Nalini Venkatasubramanian. "Fault-Tolerant Evaluation of Continuous Selection Queries over Sensor-Generated Data." *Technical Report TR-RESCUE-04-17*. Submitted for publication, 03/04;

16. Lazaridis, L., Qi Han, Xingbo Yu, Sharad Mehrotra, Nalini Venkatasubramanian, Dmitri Kalashnikov and Weiwen Yang, "QUASAR: Quality Aware Sensing Architecture," *ACM SIGMOD Record*, 03/04;

17. Lazaridis, L., and Sharad Mehrotra. "Approximate Selection Queries over Imprecise Data." *International Conference on Data Engineering* (ICDE 2004), Boston, 03/04;

18. Rao, B.D.; Engan, K.; Cotter, S.F.; Palmer, J.; Kreutz-Delgado, K. "Subset selection in noise based on diversity measure minimization." *IEEE Transactions on Signal Processing*. Volume: 51, Issue: 3, 03/03. Pages:760–770.

19. Srinivasan, V.; Chiasserini, C.-F.; Nuggehalli, P.S.; Rao, R.R. "Optimal rate allocation for energy-efficient multipath routing in wireless ad hoc networks." *IEEE Transactions on Wireless Communications.* Volume: 3, Issue: 3, 05/04. Pages: 891 – 899.

20. Trivedi, M. M., K. Huang, and I. Mikic, "Dynamic Context Capture using Distributed Video Arrays for Intelligent Environments," *IEEE Transactions on Systems, Man and Cybernetics, Special Issue on Ambient Intelligence,* Submitted 10/03;

21. Wickramasuriya, J., M. Datt, S. Mehrotra, and N. Venkatasubramanian. "Privacy Protecting Data Collection for Media Spaces." *Technical Report TR-RESCUE-04-21.*

22. Wu, J. and M. M. Trivedi, "Resolution Enhancement by AdaBoost" *Proceedings of International Conference on Pattern Recognition 2004,* to appear.

23. Yu, Xingbo, Sharad Mehrotra, Nalini Venkatasubramanian, and Weiwen Yang. "Approximate Monitoring in Wireless Sensor Networks." *Technical Report TR-*

*RESCUE-04-16*. Paper under submission.

24. Yu, Xingbo, Koushik Niyogi, Sharad Mehrotra, and Nalini Venkatasubramanian. "Adaptive Target Tracking in Sensor Networks." *The 2004 Communication Networks and Distributed Systems Modeling and Simulation Conference* (CNDS'04), San Diego, 01/04.

**Information Analysis:**

25. Adams, B.J., C.K. Huyck, R.T. Eguchi. "Post-Earthquake Reconnaissance using Satellite Imagery: Boumerdes Case Study, by (2003)," EERI Reconnaissance *Report on the May 21, 2003 Boumerdes, Algeria Earthquake*, EERI.

26. Adams, B.J., C.K. Huyck, R.T. Eguchi, F. Yamazaki, M. Estrada, and C. Herring. "QuickBird Imagery of Algerian Earthquake used to Study Benefits of High-Resolution Satellite Imagery for Earthquake Damage Detection and Recovery Efforts," (in press), by *Earth Imaging Journal*.

27. Afrati, Foto, Chen Li, Prasenjit Mitra. « On Containment of Conjunctive Queries with Arithmetic Comparisons." EDBT, Crete, Greece, 03/04;

28. Butts, C.T. "An Exponential Family of Permutation Models for Comparison of Adjacency Structures." *26th Sunbelt Network Conference* (INSNA), 04/04. Portoroz, Slovenia.

29. Butts, C.T. "Exact Bounds for Degree Centralization." *Institute for Mathematical Behavioral Sciences Technical Report MBS 04-09*, University of California, Irvine. 2004.

30. Butts, C. T. "Latent Structure in Multiplex Relations." *North American Association for Computational Social and Organizational Science Meeting*, 06/04, Pittsburgh, PA.;

31. Butts, C.T. and Leite, F. "Bayesian Inference from Continuously Arriving Informant Reports, with Application to Crisis Response." *Technical Report MBS 04-08, Institute for Mathematical Behavioral Sciences, University of California, Irvine.* 2004*. Also has been accepted for presentation at the American Sociological Association conference*, San Francisco, CA, 08/04;

32. Dharanipragada, S., U. Yapanel, B.D. Rao. "Robust Feature Extraction for Continuous Speech Recognition using the MVDR Spectrum Estimation Method." Submitted to the *IEEE transactions on Speech and Audio processing.*

33. Duni, E. R., Subramaniam, A. D., Rao, B. D. "Improved quantization structures using generalized HMM modeling with application to wideband speech coding." *2004 IEEE International Conference on Acoustics, Speech, and Signal Processing*. Part vol.1, 2004, pp.I-161-4 vol.1. Piscataway, NJ, USA.

34. Fidaleo, D. and M. M. Trivedi, "Manifold Analysis of Facial Gestures for Face Recognition," *ACM SIGMM Multimedia Biometrics Methods and Applications Workshop,* 11/08/03;

35. Gandhi, T., and M. Trivedi. **“**Motion Analysis for Event Detection and Tracking with a Mobile Omni-Directional Camera.” *ACM Multimedia Systems Journal, special issue on Video Surveillance*. Accepted 01/04;

36. Gandhi, T. and M. M. Trivedi, "Motion Analysis of Omni-Directional Video Streams for a Mobile Sentry," *First ACM International Workshop on Video Surveillance,* 11/07/03;

37. Gandhi T. and M. M. Trivedi, "Motion Based Vehicle Surround Analysis Using Omni-Directional Camera," *Proc. IEEE Intelligent Vehicles Symposium, 2004,* Accepted

38. Gustafsson, T.; Rao, B.D.; Trivedi, M. “Source localization in reverberant environments: modeling and statistical analysis**.”** *IEEE Transactions on Speech and Audio Processing.* Volume: 11, Issue: 6, 11/03. Pages: 791 – 803.

39. Jin, Liang, Nick Koudas, Chen Li. « NNH: Improving Performance of Nearest-Neighbor Searches Using Histograms.” EDBT, Crete, Greece, 03/04;

*40.* Kalashnikov, D. and S. Mehrotra. ”An algorithm for entity disambiguation.” *University of California, Irvine, TR-RESCUE-04-10.*

*41.* Kalashnikov, Dmitri V., and Sharad Mehrotra. “RelDC: a novel framework for data cleaning.” *RESCUE-TR-03-04.*

42. Krotosky S. and M. M. Trivedi, "Occupant Posture Analysis using Reflectance and Stereo Images for "Smart" Airbag Deployment" *IEEE International Symposium on Intelligent Vehicles, Parma, Italy* To Appear 2004;

43. McCall J. and M. M. Trivedi, "Pose Invariant Affect Analysis using Thin-Plate Splines," *Proceedings of International Conference on Pattern Recognition 2004,* to appear.

44. Ma, Yiming, Sharad Mehrotra, Dawit Yimam Seid, Qi Zhong. “Interactive Filtering of Data Streams by Refining Similarity Queries.” *Technical Report TR-RESCUE-04-15.*

45. Ma,Yiming, Qi Zhong, Sharad Mehrotra, Dawit Yimam Seid. “A Framework for Refining Similarity Queries Using Learning Techniques.” Submitted for publication, 2004.

46. Murthy, C., Roh, J. C., Rao, B. D. “Optimality of extended maximum ratio transmission.” *Sixth Baiona Workshop on Signal Processing in Communications. Servicio de Publicacions da Universidade de Vigo*. 2003, pp.47-50. Vigo, Spain.

47. Srinivasan, Vikram, Pavan Nuggehalli, Chiasserini C. F., Rao, R. R. “Cooperation in wireless ad hoc networks.” *IEEE INFOCOM 2003. Twenty-second Annual Joint Conference of the IEEE Computer and Communications Societies* (IEEE Cat. No.03CH37428). IEEE. Part vol.2, 2003, pp.808-17 vol.2. Piscataway, NJ, USA.

48. Trivedi, M. M., K. Huang, T. Gandhi, B. Hall, and K. Harlow, "Distributed Omni-Video Arrays and Digital Tele-Viewer for Customized Viewing, Event Detection and

Notification," *Proceedings of International Conference on Information Technology 2004,* Accepted 04/04;

49. Wu J. and M. M. Trivedi, "High Frequency Component Compensation Based Super-Resolution Algorithm for Face Video Enhancement," *Proceedings of International Conference on Pattern Recognition 2004,* to appear.

51. Zorzi, M.; Rao, R.R. **"**Geographic random forwarding (GeRaF) for ad hoc and sensor networks: energy and latency performance**."** *IEEE Transactions on Mobile Computing*. Volume: 2, Issue: 4, 10-12/03. Pages: 349 – 365.

52. Zorzi, M., Rao, R. R. "Energy and latency performance of geographic random forwarding for ad hoc and sensor networks." WCNC 2003. *2003 IEEE Wireless Communications and Networking Conference Record* (Cat. No.03TH8659). IEEE. Part vol.3, 2003, pp.1930-5 vol.3. Piscataway, NJ, USA.

53. Zorzi, M., Rao, R. R. "Multihop performance of geographic random forwarding for ad hoc and sensor networks." GLOBECOM '03. *IEEE Global Telecommunications Conference* (IEEE Cat. No.03CH37489). IEEE. Part vol.7, 2003, pp.3948-52 vol.7. Piscataway, NJ, USA.

**Information Sharing:**

54. Cheng, S. and M. M. Trivedi, "Occupant Posture Modeling using Voxel Data: Issues and Framework" *IEEE International Symposium on Intelligent Vehicles.* Parma Italy. To Appear 2004;

55. Gavriloaie, R., W. Nejdl, D. Olmedilla, K. E. Seamons, and M. Winslett. "No Registration Needed: How to Use Declarative Policies and Negotiation to Access Sensitive Resources on the Semantic Web." *1st European Semantic Web Symposium*, Heraklion, Greece, 05/04. To appear;

56. Hore, Bijit, Hakan Hacigumus, Bala Iyer, Sharad Mehrotra. "Indexing Text Data under Space Constraints." *Technical Report TR-RESCUE-04-23.* 2004;

57. Iyer, Bala, Sharad Mehrotra, Einar Mykletun, Gene Tsudik, and Yonghua Wu. "A Framework for Efficient Storage Security in RDBMS." E. Bertino et. al. (Eds.) *EDBT 2004, LNCS 2992*, pages 147-164. Springer-Verlag: Berlin Heidelberg, 2004;

58. Mykletun, E., M. Narasimha and G. Tsudik. "Authentication and Integrity in Outsourced Databases." *ISOC Symposium on Network and Distributed Systems Security* (NDSS'04), 02/04;

59. Narasimha, M., G. Tsudik and J. Yi. "On the Utility of Distributed Cryptography in P2P Settings and MANETs," *IEEE International Conference on Network Protocols* (ICNP'03), 11/03;

60. Roh, J.C.; Rao, B.D. **"**Multiple antenna channels with partial channel state information at the transmitter*." IEEE Transactions on Wireless Communications*. Volume: 3, Issue: 2, 03/04. Pages: 677-688.

61. Saxena, N., G. Tsudik and J. Yi. “Admission Control in Peer-to-Peer: Design and Performance Evaluation.” *ACM Workshop on Security of Ad Hoc and Sensor Networks* (SASN '03), 11/03;

62. Saxena, N., G. Tsudik and J. Yi. “Experimenting with Peer Group Admission Control. International Workshop on Advanced Developments in Software and Systems Security” (WADIS'03), 12/03;

63. Seamons. K., “TrustBuilder: Automated Trust Negotiation in Open Systems.” *CERIAS Security Seminar,* Purdue University, 02/11/04. Invited presentation;

64. Smith, B., K. E. Seamons, and M. D. Jones. “Responding to Policies at Runtime in TrustBuilder.” To appear in: *5th IEEE International Workshop on Policies for Distributed Systems and Networks (POLICY 2004)*, Yorktown Heights, New York, 06/04;

65. Van der Horst, Timothy W., Tore Sundelin, Kent E. Seamons, and Charles D. Knutson. “Mobile Trust Negotiation: Authentication and Authorization in Dynamic Mobile Networks.” *Eighth IFIP TC-6 TC-11 Conference on Communications and Multimedia Security*, 09/04. To appear.

66. Wang, Kang, Chiasserini, C. F., Rao, R. R., Proakis, J. G. “A distributed joint scheduling and power control algorithm for multicasting in wireless ad hoc networks.“ *2003 IEEE International Conference on Communications* (Cat. No.03CH37441). IEEE. Part vol.1, 2003, pp.725-31 vol.1. Piscataway, NJ, USA.

67. Wickramasuriya, J., N. Venkatasubramanian. “Middleware-based Access Control for Ubiquitous Environments.” *Technical Report TR-RESCUE-04-24.* 2004. Submitted for publication.

68. Yan, M. and; Rao, B.D. **“**Soft decision-directed MAP estimate of fast Rayleigh flat fading channels.*” IEEE Transactions on Communications*. Volume: 51, Issue: 12, 12/03. Pages: 1965 – 1969.

69. Yang, Xiaochun, and Chen Li. “Secure XML Publishing without Information Leakage in the Presence of Data Inference.” VLDB 2004.

**Information Dissemination:**

70. Bagchi, Amitabha, Amitabh Chaudhary, Michael T. Goodrich, Chen Li, and Michal Shmueli-Scheuer. “Data Gerrymandering: Efficient Push-Pull Partitioning to Support Range Queries on Dynamic Data.” Submitted to VLDB 2004.

71. Chiasserini, C. F., Rao, R. R. “Improving energy saving in wireless systems by using dynamic power management.” *IEEE Transactions on Wireless Communications,* vol.2, no.5, 09/03, pp.1090-100. Publisher: IEEE, USA.

72. Cheng, S. Y. and M. M. Trivedi, "Human Posture Estimation Using Voxel Data for "Smart" Airbag Systems: Issues and Framework" *IEEE International Symposium on Intelligent Vehicles.* Parma, Italy. To Appear 2004.

73. Deshpande, Mayur and Nalini Venkatasubramanian. “The Different Dimensions of Dynamicity.” *The Fourth IEEE International Conference on Peer-To-Peer Computing*. 08/25-27/04;

74. Deshpande, Mayur, Haimin Lee, Chen Li, Sharad Mehrotra, and Nalini Venkatasubramanian. “SPINE: Scalable Approximate Global State Maintenance in Peer-to-Peer Networks.” In Revision. 2004;

75. Lawson, G.C. and Butts, C.T. “Information Transmission Through Human Informants: Simulation.” *North American Association for Computational Social and Organizational Science Meeting*, 06/04, Pittsburgh, PA.;

76. McCall, J. and M. M. Trivedi, "An integrated, robust approach to lane marking detection and lane tracking," *Proc. IEEE Intelligent Vehicles Symposium,* Accepted 06/04;

77. McCall, J., O. Achler and M. M. Trivedi, "Design of an Instrumented Vehicle Testbed for Developing Human Centered Driver Support System," *Proc. IEEE Intelligent Vehicles Symposium,* Accepted 06/04.

### 3.2 Books or other non-periodical, one-time publications

- Smith B. “Responding to Policies at Runtime in TrustBuilder.” *MS Thesis, Brigham Young University*, 04/04.
- Cristoforetti, J., "Multimodal Systems in the Management of Emergency Situations.” *MS Thesis, University of California, Irvine*, 2005.
- Holt, J. “Logcrypt: Forward Security and Public Verification for Secure Audit Logs.” *MS Thesis, Brigham Young University*, 02/05.
- Bradshaw, R., Holt J. and K.E. Seamons. “Concealing Complex Policies with Hidden Credentials.” *Honors Thesis, Brigham Young University,* 06/04, *Eleventh ACM Conference on Computer and Communications Security*, Washington, DC, 10/04.
- Chan, T. “Preserving Trust Across Multiple Sessions in Open Systems.” *MS Thesis, Brigham Young University*, 06/04.
- Child, E. “Trust Negotiation Using Hidden Credentials.” *MS Thesis, Brigham Young University*, 07/04.
- van der Horst, T. ”Thor: The Hybrid Online Repository.” *MS Thesis, Brigham Young University,* 02/05.
- Ghighi, A. “Dissemination of Evacuation Information in Crisis”. *RESCUE Tech Report, Also M.S. Thesis, U of Bologna*, (thesis work was done while the author was an exchange student at ITR-RESCUE), 2005.
- Ghigi, A. “Customized Dissemination in the context of emergencies.” *MS Thesis, University of California, Irvine*, 2005

## 3.3 What websites or other Internet sites have been created

**RESCUE Project Website**
www.itr-rescue.org

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**RESCUE Project Website (San Diego)**
http://rescue.calit2.net/

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**RESCUE Project Website (BYU/UIUC)**
**Internet Security Research**
http://isrl.cs.byu.edu/rescue

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**Adaptive Cellular Localization System**
Mehrotra/Venkatasubramanian/J. Zhu/B. Jafaraian
http://www.itr-rescue.org/cello

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**Peer-to-Peer Middleware Infrastructure**
Sharad Mehrotra (UCI), Nalini Venkatasubramanian (UCI), Paul Blair (UCSD), LA EOC
http://www.itr-rescue.org/rapid (currently under construction)
http://www.ics.uci.edu/~mayur/rapid.html

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**SAFE - Systems-Based Accessibility for Evacuation**
Sharad Mehrotra (UCI), Nalini Venkatasubramanian (UCI),
http://www.ics.uci.edu/~dsm/suga.html

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**RelDC Project: Relationship-Based Data Cleaning Framework**
Sharad Mehrotra (UCI), Nalini Venkatasubramanian (UCI), Dmitri V. Kalashnikov (UCI), R. Eguchi (ImageCat)
http://www.ics.uci.edu/~dvk/RelDC
http://www.itr-rescue.org/eventWeb

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**PADOC**
Sharad Mehrotra (UCI), Nalini Venkatasubramanian (UCI), Bala Iyer (IBM Almaden and IBM Santa Teresa Labs), Stanislaw Jarecki (UCI Faculty in Cryptography), Calit2 UCI
http://www.itr-rescue.org/padoc

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**Evacuation Plan Simulator**
Sharad Mehrotra, Nalini Venkatasubramanian
http://www.ics.uci.edu/~projects/drillsim/

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**Trustbuilder Prototype for Trust Negotiation:**
Seamons/Winslett (BYU/UIUC)
http://dais.cs.uiuc.edu/trustbuilder/

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**Traust Authorization Service**
Seamons/Winslett (BYU/UIUC)
http://dais.cs.uiuc.edu/traust/

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**License Plate Recognition**
S. Belongie (UCSD)
http://rescue.calit2.net/lpr

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### 3.4 Specific products developed (databases, physical collections, educational aids, software, instruments)

The following software, databases and other products have been produced thus far in the RESCUE project. Many are in prototype phases and will be tested and validated in later stages of this project. Also, listed under each product are the primary developers or researchers.

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**Tsunami Dataset**
Sharad Mehrotra (UCI), Nalini Venkatasubramanian (UCI), Dmitri V. Kalashnikov (UCI), R. Eguchi (ImageCat)

We have collected interned-based information about SE Asia tsunami disaster. The primary source of information is GoogleNews articles about the SE Asia tsunami, collected during six days, starting at 12/28/04. The number of collected articles is 2998. Additional tsunami data has been collected from GoogleAlerts, and 80 Blogs. The GoogleNews articles and index files collected over a six-day period have been post-processed to collect/extract further (meta) information. From the 2998 news articles the location information stored in those datasets has been extracted (for 238 cities in tsunami-affected areas). The other meta information include the URL of news source, the Initial text taken from GoogleNews index page, the date that web page was pulled, the relative time to posting of article, the news headline, the news source, the country of news source.

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**9-11 Dataset**
Carter Butts, Remy Cross, Miruna Petrescu-Prahova (UCI)

Source of raw data: http://www.thememoryhole.org/911/pa-transcripts
The dataset contain various (police) reports filed by the participants (police officers) who participated in the events of the September 11, 2001. The reports are available as PDF files and can be grouped in the following categories:

| | # of files: | # of pages: |
|---|---|---|
| LaGuardia | 19 | 343 |
| Police Reports | 4 | 392 |
| Misc Transcripts | 50 | 1592 |
| Awards Ceremony | 3 | 279 |

We have transcribed the reports and put them into a database as free text and some basic metadata: a basic extraction has been done to extract TO, FROM, SUBJECT, and DATE fields from each of the 400 report pages. We plan to use this dataset in the future to test our algorithm on ontology-based “deep” extraction. This dataset has also been used to derive another, synthetic, datasets for our experiments on representing and reasoning on top of (uncertain) event location descriptions as provided by human reporters in free text.

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**Route Preview Software with Audio Cues for First-Responders**

Ramesh Rao, John Miller, Diep Nguyen (UCSD)

Software that assists a first-responder in both maintaining orientation and following a pre-defined route currently includes several features. The software allows marking favorite waypoints and paths. It also supports presenting waypoints via an audio description in a meaningful way. For example, it marks waypoints as visited or unvisited. It displays a list of neighboring waypoints to the user’s current waypoint and identifies the last waypoint visited using the software’s "back" feature, it allows the user to traverse a series of waypoints from the user’s current position back to the starting position. The software also presents neighboring waypoints at an intersection in clockwise order. It first lists the northern-most waypoint and proceeds listing the remaining neighboring way points in the order of East, South and West. The software’s user interface (UI) will model the UI of a cell phone application. The user selects information from a menu by entering numerical digits 0 through 9 and the UI conveys information to the user as with a standard phone menu.

The software will guide a rescue worker through any defined path. Starting out at the beginning of this path, the software will mark waypoints at an intersection that will lead him to the end of this path. With this feature, a rescue team will be able to examine a hazardous situation and guide a first-responder along a pre-defined path. In addition, the software allows the user to create a new path so that a first-responder can mark a route to a desired way point.

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**Zig-Zag: Sense-of-Touch Guidance Device**

Ramesh Rao, John Miller, Javier Rodriguez Molina (UCSD)

The Zig-Zag sense of touch hand-held prototype is an RF transmitter/receiver analog device. It is composed of a 3-channel FM 2-stick radio transmitter which sends the signal to an analog module box. The receiver standing inside the analog module box feeds the signal to the RC Switch (35 RAM). From here, the input received gets modulated in order to output the necessary square wave signal. The signal leaves the analog module through a DB9 connection to reach the hand-held box consisting of a HS 322 servo and a vibrating motor. This last box will be the output of our system. The servo will point to

the direction indicated by the transmitter and the vibrating motor will go off signifying that the final target location has been reached or the necessity of an immediate stop.
Existing technology, such as GPS, shows the position of an object in a map. It also shows the direction in which this object is pointing with respect to the North. Map quest, or car GPS systems are excellent examples of the possibilities. Both of these examples rely on the sense of vision. In emergency situations in which vision is not possible these systems would be inefficient. The Zig-Zag sense of touch device gives a promising solution for these emergency situations.

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**Humans as Sensors: Notification System via Voice and Text**
Ramesh Rao, Ganz Chockalingam (UCSD)

After being petitioned by the DOT, FCC has designated 511 (like 911) as the number for traveler information such as traffic, transit info and weather. We are developing a next-generation traveler information system that will serve as a powerful tool for first responders and commuters to relay, share and disseminate all types of critical information.

The goal is to develop a fully automated system to collect and relay freeway-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 traffic 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. 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. Also, the current technique for obtaining traffic flow information by burying loop inductors at discrete points on the freeways is expensive and does not provide uniform coverage. Our approach is to tap into GPS-equipped cell phones to obtain position and velocity information. This approach provides uniform coverage.

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**A Database of Video and Still Photographs of Cars and License Plates**
Vincent Rabaud, Louka Dlagnekov, Serge Belongie (UCSD)

The goal of this project is to develop an LPR system that achieves a high recognition rate without the need for a high-quality video signal from expensive hardware. We also explore the problem of car make and model recognition for purposes of searching surveillance video archives for a partial license plate number combined with some visual description of a car. Our proposed methods will provide valuable situational information for law enforcement units in a variety of civil infrastructures.

Many existing License Plate Recognition (LPR) systems require sophisticated video capture hardware possibly combined with infrared strobe lights, or exploit the nature of the large area and character optimizations of license plates in certain geographical regions. Our solution works well with far lower resolution images and does not require expensive hardware.

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**INLET - Internet-Based Loss Estimation Tool**
R.T. Eguchi (PI), C.K. Huyck, H. Chung, M. Mio, S. Cho (ImageCat)

INLET is a web-based loss-estimation and transportation-simulation platform that is used to quantify the efficacy of Information Technology (IT) solutions in reducing the impacts of disasters on transportation systems.

INLET combines a GIS component, a risk-modeling platform, and a transportation model to provide online estimates of transportation system impacts, building damage and casualties from earthquake. Additional features include a simulation component to model the effects of IT on evacuation routing. The model illustrates how awareness of a disaster scenario and familiarity with routing alternatives can reduce traffic congestion and evacuation times.

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**VIEWS (Visualizing Impacts of Earthquakes With Satellites) – A Decision-Support and Prioritization Tool for Disaster Response**
R.T. Eguchi (PI), C.K. Huyck, H. Chung, M. Mio, S. Cho (ImageCat)

VIEWS is a notebook-based data collection and visualization system, which integrates GPS-registered digital video footage, digital photographs and observations with high-resolution satellite imagery collected before and after a disaster. Amidst the chaos and uncertainty of a crisis situation, VIEWS streamlines the flow of information from the field to the key decision-makers. The deployment of VIEWS was done in conjunction with the Multidisciplinary Center for Earthquake Engineering Research in Buffalo, NY.

VIEWS provides the user with a visualization and analysis environment to display the GPS-linked observations, photographs and video footage, overlaid on useful base layers, including multi-resolution satellite and airborne remote-sensing imagery, and urban damage maps.

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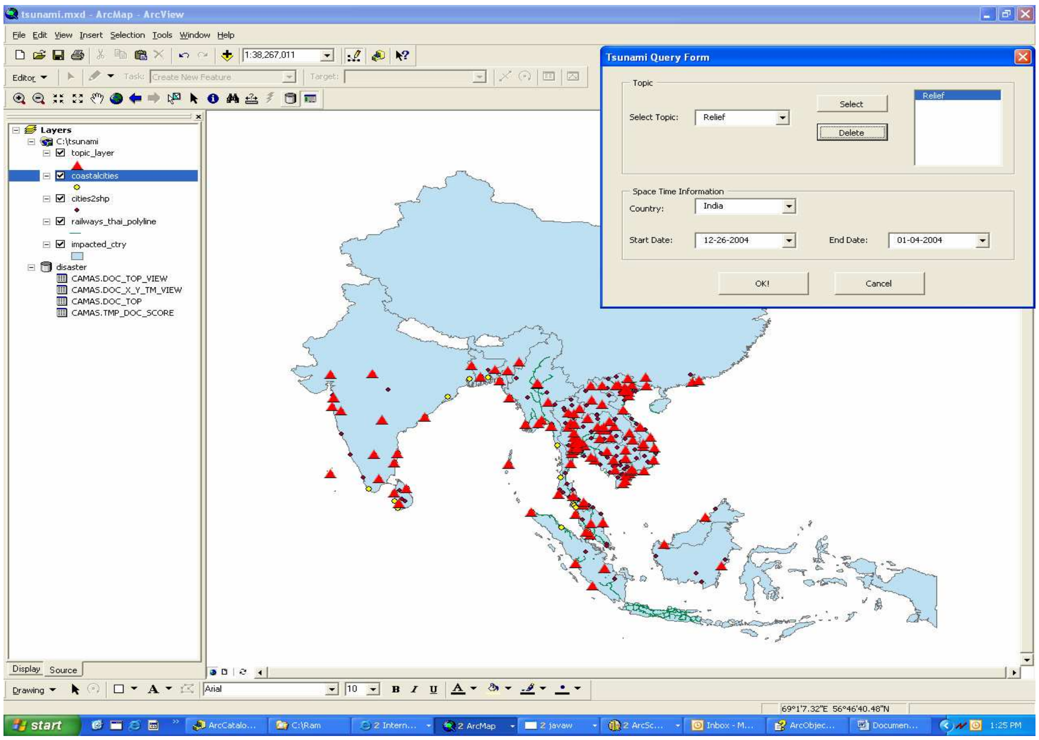
**PSAP: Personalized Situation Awareness Portal for Large Scale Disasters.**
Mehrotra/Venkatasubramanian (UCI)

A large-scale disaster can cause widespread damage; its effects can last a long period of time. Effective response to such disasters relies on obtaining information from multiple, heterogeneous data sources to help assess the geographic extent and relative severity of the disaster. One of the key problems faced by analysts trying to scope out and estimate the impact of a disaster is that of information overload. In addition to well-established sources of information (e.g. USGS), that continuously stream data, potentially useful public information sources such as Internet news reports and blogs swell exponentially at the time of a disaster, resulting in enormous redundancy and clutter. PSAP (Personalized Situation Awareness Portal) is a system that helps analysts to quickly and effectively gather task-specific, personalized information over the Internet. PSAP uses a standard three-tier server/client architecture where the server incrementally gathers data from a variety of sources (satellite imagery, international news reports, Internet blogs) and performs extraction of spatial and temporal information on the assimilated data. These materials are further organized in automatically generated topics and stored in the server database. The personalized portal interface gives analysts a flexible way to view the personalized information stored on PSAP server based on the user-specific information needs. We focus on the design and implementation issues of PSAP, and evaluate our system with the real-life analytical tasks using information gathered about the most recent tsunami disaster in Southeast Asia since its onset.

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**System Prototype on Keyword Search on GIS Datasets**
Ramaswamy Hariharan, Michal Shmueli-Scheuer, Chen Li and Sharad Mehrotra

Crisis response needs to access various kinds of GIS information, such as maps of hospitals, gas stations, weather and schools. Such GIS information is stored in thousands or millions of GIS files with different formats, and these files could be provided by organizations or crawled from the Web. To support easy and efficient access to the GIS information, we build a system that supports keyword searches on top of these files. The system allows a user to type in text keywords as the input, and can return the files that are most relevant to the keywords, possibly even displaying the relevant information on a map. Internally, the system analyzes the GIS data, and builds indexing structures to support efficient searching and ranking of different files and their records.

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**Multimodal Speech Recognition Prototype**
Mohan Trivedi, Bhaskar Rao (UCSD)

Human speech is bimodal in nature; while audio speech refers to the acoustic waveform produced by the speaker; visual speech refers to the movements of the lips, tongue and other facial muscles of the speaker. The poster discusses a lip-reading-based speech recognizer. Lip-reading, using a computer vision system could provide a useful stream of information to the speech recognizer that is independent of the background noise. The poster will discuss the issues involved in designing such a system.

Current speech recognizers use only the audio information. In the presence of background noise their performance deteriorates rapidly. The new approach uses information from the audio as well as video domain. This system will be robust to background noise and will work in the event of failure of one of the modalities. The project builds on existing state-of-the-art techniques by incorporating extra modalities and combining them intelligently.

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**DrillSim**
Mehrotra, Venkatasubramanian (UCI)

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. The DrillSim simulator, as a part of the CAMAS testbed, is 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 test 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.

Version 2.0 of the DrillSim simulator presents a simulation of evacuation inside the Calit2 building, demonstrated with the purpose of testing IT solutions. The simulator is a multi-agent simulator with agents having different roles (public, floor warden and building coordinator). The simulator will demonstrate the activity of evacuation within the building, the roles played by different agents and the information exchange between agents. The physical space of the Calit2 building will be integrated using the cameras in the Responsphere framework.

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**SAFE: Systems-Based Accessibility for Evacuation**
(Navigation Support for Users with Disabilities in Crises)
Venkatasubramanian, Mehrotra (UCI)

The goal of the system is to support evacuation of users with disabilities (or injured due to crisis) from a region that has been affected by a disaster or to get first-responders to the users in need. The system consists of both an instrumented environment to localize users and navigation systems to customize navigation and the information sent to the user from an evacuation perspective for users who are impaired.

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**UCSD Cellular Platform for Location Tracking**
Ramesh Rao, John Zhu (UCSD)

The system is built with the latest Assisted-GPS (AGPS) technology. Based on AGPS, mobile phone is used to track the position and speed of a campus bus. A real-time map is provided to view location, speed and identity of buses.

The GPS tracking is done via commercial cell phone instead of a separated GPS device. AGPS is the combination of GPS and Mobile Technology. It is small and embedded inside the mobile phone. It works indoors and outside, and the cell phone is integrated with AGPS, voice and data capable of performing lots of smart applications.

This project contributes to developmental research. The system can be applied to lots of location-tracking-based applications. For example, assets tracking, mobile work-force management, and personal safety and security.

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**Cellular Simulator**
Ramesh Rao, Babak Jafarian (UCSD); Charlie Huyck (ImageCat)

Cellular Simulator will simulate the performance of the system under the stressed situation and provide the important QoS for the system after the disaster. These include blocked calls, dropped calls, etc. This information can be useful for all other researchers for their study.

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**LogCrypt**
Kent Seamons (BYU)

Log files are an important record for auditing actions taken in emergency situations. However, these records can easily be altered to destroy evidence or cover up system compromise. Logcrypt uses cryptography to help ensure that audit records are secure against tampering, even when they cannot be publicized until after a crisis.

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**VisiResCUE: Situational Awareness for Emergency Response**
Marianne Winslett (UIUC)

In times of disasters, collaboration among emergency service providers and personnel requires effective coordination of information sharing. Presenting sensor readouts on a superimposed map gives a real-time view for making decisions.

Data sources/sensors are owned by many different entities (city, school, police) who may or may not allow access normally. VisiResCUE enables seamless data-sharing between otherwise independent entities by means of Trust Negotiation.

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Each entity defines its own policies regarding access to sensor resources. In normal situations, access is provided only to authorized clients. During emergency situations, the emergency response and command center requests access to sensor feeds using its credentials. A Trust-Negotiation session is initiated between the resource-owning entity and the emergency command using the TrustBuilder framework and the Traust servers. After mutual authentication, communication commences.

City of Champaign and the Champaign county emergency response center would utilize existing GeoSpatial data sources through off-the-shelf GIS packages. During emergency disaster situations, Sensor feedback from streetlight-mounted cameras, wind/water sensors, chemical hazard detectors and 911 call location information are combined to present a high level view of the situation.

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**The TrustBuilder Prototypes for Trust Negotiation and the Traust Authorization Service.**

K. Seamons, M. Winslett (BYU/UIUC)

To enable effective collaboration in times of crisis, emergency responders need a scalable means of access control for sharing important, yet potentially sensitive, information with authorized users from other security domains. Traust acts as a centralized service that allows previously unknown, but authorized, users to establish trust with resource providers at runtime and negotiate for access to the resources that they provide while still meeting the four goals addressed above. See website http://isrl.cs.byu.edu and http://dais.cs.uiuc.edu/traust for more information.

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**GAAL: A Language and Algebra for Complex Analytical Queries over Large Attributed Graph Data.**

Sharad Mehrotra, Nalini Venkatasubramanian, Dmitri V. Kalashnikov (UCI)

Attributed graphs are widely applicable data models that represent both complex linkages as well as attributed data of objects. We define a query language for attributed graphs that builds on a three-tiered recursive attributed-graph query algebra. Our algebra, in addition to recursively extending basic relational operators, provides well-defined semantics for graph grouping and aggregation that perform structural transformation and aggregation in a principled manner. We show that a wide range of complex analytical queries can be expressed in a succinct and precise manner by composing the powerful set of primitives constituting our algebra. Finally, we discuss implementation and optimization issues.

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**I-Skyline: A Completeness Guaranteed Interactive SQL Similarity Query Framework.**

Sharad Mehrotra, Nalini Venkatasubramanian, Dmitri V. Kalashnikov (UCI)

A query model of a similarity query combines a set of similarity predicates using an operator tree. Return set of a similarity query consists of a ranked list of objects that best matches the query model. The query model is constructed by a user, but model parameters or the model itself can be inaccurately specified in the beginning of the search. The question of similarity query completeness is whether a system can guarantee that all the relevant tuples under the ideal query model be retrieved. We address this problem by first defining the concept of similarity query completeness; we then propose a novel interactive framework called interactive skyline (I-Skyline), which only shows an optimal set of tuples to the user and always guarantees to retrieve all the relevant tuples. However, the size of I-Skyline can be large. To reduce the I-Skyline size and still be able to guarantee certain level of completeness, we introduce a progressive I-Skyline extension that explores user knowledge on the query model. Experimental analysis confirms that I-Skyline is an effective and efficient framework for guaranteeing similarity query completeness.

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**Always Best Connected**
Ramesh Rao, Rajesh Mishra, B.S. Manoj (UCSD)

Seamless interoperability among various network infrastructures to maintain constant – and the most powerful – connection to the Internet for mobile users using both licensed (e.g., cellular networks) and unlicensed (e.g., IEEE 802.11b) spectrum. This work is making it possible for user devices to seamlessly roam among varying network access technologies, including IEEE 802.11b, CDMA2000, GPRS, and Ethernet, with controlled adaptation of applications' performance to the network capabilities at hand.

One of the challenges in transitioning between these access technologies is the dramatic difference in their capacities from an application's perspective. For example, in moving from a WLAN (IEEE 802.11b) to cellular access (such as CDMA20001xRTT or GPRS), the capacity decreases, causing the application to have to adapt – and quickly – so as not to adversely affect the user. This becomes a particularly serious problem if the application is multimedia-based, with a heavy reliance on voice and/or video.

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# 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.

### 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 key 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, FEMA, 2003), 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 (Werner, et al., 2004). 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](www.responsphere.org)

A web site has been created ([http://www.itr-rescue.org](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.

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## 5. BUDGET JUSTIFICATION

### FY 2004-2005 Budget

The RESCUE project was funded at 80% of the amount requested in the original proposal for YR 2. A total of $1,877,209 was awarded to UC Irvine with $557,459 of the total budget allocated to five subcontract projects. Allocations to participating subcontractors were as follows:

| | |
|---|---|
| Brigham Young University | $82,093 |
| ImageCat Inc. | $275,175 |
| University of Colorado, Boulder | $80,324 |
| University of Illinois, Urbana-Champaign | $77,882 |
| University of Maryland, College Park | $41,985 |

### UC Irvine FY 2004-2005 Expense Justification

It was expected that the RESCUE project would be located in the new Calit2 building at the start of Year 2 funding. Due to unexpected delays the Calit2 building was unavailable for occupancy at the start of Year 2 of the project. Due to the unavailability of assigned on-campus space, the physical location for the project has been temporarily housed at an off-campus location, specifically the University Research Park (URP) located immediately adjacent to the UCI campus. In Year 1 of the project, UCI authorized the application of UCI's approved off-campus indirect rate (26%) in lieu of the campus's approved indirect rate (51.5%) during the time the project was located in the off-campus space. The new space in the Calit2 building became available for occupation April 15, 2005. The project was relocated and the indirect rate was increased to 51.5% effective April 15, 2005. The reduction in the indirect rate provided the coverage of direct costs including monthly lease, space maintenance, utility and telephone costs, minor renovations to the space. Any remaining funds from the reduction of the overhead rate also provided funding for additional students and staff needed for the project. It is estimated that approximately $83,854 was available from the difference between the approved on-campus and off-campus indirect rates from October 1, 2004 thru April 15, 2005 and has been rebudgeted to cover the above stated direct costs incurred during Year 2.

During Year 2 of the award, $67,400 was budgeted for equipment needs. This equipment was leveraged from other sources, and these funds were rebudgeted for graduate student participation on the project. As a result of the rebudgeting, there was no change in scope of the program.

During Year 2 of the project there have been changes and additions to personnel. As this project progressed it became apparent that a higher level of project management was needed in addition to the project coordinator assistance, to help Professor Mehrotra with the day to day project management issues. Mr. Quent Cassen joined the RESCUE project October 2004 as project manager appointed at 60% time. Under Professor Mehrotra's direction, Mr. Cassen is responsible for providing day to day project management support to achieve the goals of the RESCUE project. His many duties include providing leadership to the RESCUE technical staff, graduate students and subcontractors to meet project objectives and milestones; submitting internal progress reports, NSF annual reports and other related reports; and work with the project executive committee, coordinating research activities between Research Area Leaders, Test Bed Leaders, and the Software Artifact Committee.

Ms. Lynn Harris, project coordinator, resigned her position in August 2004 to pursue other opportunities. Ms. Harris's duties were covered by two temporary assistants until a new project coordinator was hired. In March 2005, Ms. Jean Chin was hired as the new project coordinator and appointed at 100% time. Her duties include maintaining the calendar for the RESCUE program and the Director, provide administrative support to both the project manager and director; organize large meetings/workshops; schedule and organize PI meetings, site visits, external speakers, as well as schedule and organize weekly and monthly research meetings. She also acts as an additional liaison to subcontractors, and assists with the coordination and support for the preparation of presentations and project reports.

Calit2 staff continue to provide support to the RESCUE project in the areas of financial/personnel administration, communications and event planning, and general project management guidance.

Dr. Naveen Ashish joined the RESCUE project in April 2005 as a visiting project scientist and appointed at 50% time. Dr. Ashish is responsible for research and development activities in information management and information integration, including supervision of RESCUE graduate students, with a particular focus in the area of information semantics and semantic-web technologies.

It is anticipated most of Year 2 funds will be spent out. Any funds remaining to be carry-forwarded to Year 3 are not expected to exceed 10%.

This year the campus has provided the project $70,000 in cost-sharing funds for use on the project. Combined with last year's contribution, the campus has provided a total of $120,000 in cost-sharing funds, bringing the allocation in line with the original budget. To date, the entire contribution has been expended in support of graduate student salaries and tuition and fee expenses. The Bren School of Information and Computer Science has continued to provide support through graduate student fellowships and appointments in Year 2.

**University of California, San Diego FY 2004-2005 Expense Justification**
A total of $700,000 was awarded to UC San Diego for Year 2. Some rebudgeting within categories occurred, specifically salaries/wages/benefits ($46,500 decrease from original budget), equipment ($5,000 decrease from original), and other direct costs ($51,500 increase from original).

*Salary*
Once we received the correct job classifications/job cards from UCSD human resources, a project manager was hired on a part-time basis in October 2004, and a software architect/systems integrator was brought on to the staff (also part-time) in March 2005. One of the two budgeted postdoctoral researcher positions was filled in February 2005. We have made an offer to another postdoctoral researcher and plan to fill that position before the end of FY 2005. All 3 budgeted Graduate Student Researchers were funded.

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 for staff members on the project.

*Travel*
Most of the budgeted travel funds will have been spent in Year 2.

*Equipment*
Equipment funds were used to purchase laptops, desktops, and servers that were used to conduct research on RESCUE.

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

It is anticipated that the majority of Year 1 and Year 2 funds will be spent out. Any funds remaining to be carried to Year 3 will not exceed 15%.

**Brigham Young University FY 2004-2005 Expense Justification**

It is anticipated the Year 2 funds will be fully expended. Minor rebudgeting occurred within categories to accommodate small increases in travel, salary, and tuition and fees.

**ImageCat Inc. FY 2004-2005 Expense Justification**

It is anticipated the Year 2 funds will be fully expended. Minor rebudgeting occurred within categories to accommodate additional purchase of data for INLET implementation.

**University of Colorado, Boulder FY 2004-2005 Expense Justification**

It is anticipated that the majority of Year 2 funds will be expended at the end of the Year 2 project period.

**University of Illinois, Urbana-Champaign FY 2004-2005 Expense Justification**

It is anticipated the Year 2 funds will be fully expended. Minor rebudgeting occurred within categories to accommodate additional salary and travel costs.

**University of Maryland, College Park FY 2004-2005 Expense Justification**

It is anticipated that a majority of the Year 2 funds will be expended at the end of the project year. Remaining funds will be used to augment Year 3 funds to support graduate student salary needs in Year 3.

**UC San Diego FY 2005-2006 Budget Request**

The current budget requests a total of $707,999 in funds awarded to UC San Diego. One change has been made to the budget request for Year 3 funds. We have requested repurposing $5K of equipment funds into the “Other” category. These funds will cover cellular phone support and service fees in support of platform and applications development activities being conducted on RESCUE. We have also repurposed $5K of salary funds into the “Computer Services” category.

**UC Irvine FY 2005-2006 Budget Request**

There is no change to the budget request for Year 3 funds. The current budget requests a total of $1,848,174 in funds awarded to UC Irvine with $560,271 of the total budget being awarded to five subcontracts. Proposed allocations to participating sites are 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 |

**FY 2004-2005 Supplemental Requests**

A recent supplemental request “Disaster Portal: A System for Situational Awareness in Large Scale Disasters,” was submitted and is currently under review. The proposed budget request is for $100,000. A second supplement is in preparation and will be submitted to request funds to host the Cyber Trust Conference in September 2005.