Fourth-Year RESCUE Annual Report – 2006 to 2007

Responding to Crises and Unexpected Events

ITR

Collaborative Research: Responding to the Unexpected

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1 OVERALL PROGRESS IN YEAR 4 – SUMMARY

Year 4 has been marked by major progress in integrative research and artifact development. **Artifacts** are methodologies or technologies that have the demonstrated potential to dramatically improve the ability of emergency response organizations to gather, process, manage, use and disseminate information during natural or anthropogenic disasters. They are also intended to serve as a legacy of the RESCUE project beyond Year 5. These artifacts are described later in this report. As laid out in our strategic plan, all research follows along one of the stated **research project areas**. They include: *Situational Awareness from Multimodal Inputs (SAMI); Robust Networking and Information Collection; Policy-Driven Information Sharing Architecture (PISA); Dissemination in the Large; and Privacy Implications in Technology.* In addition, at the recommendation of the Technical Advisory Committee (TAC) during the All-Hands meeting in January 2006, a sixth research project, MetaSIM, was added in order to emphasize the integration of micro- and macro-simulation models and different GIS data types (vector, raster, and network). The four testbeds (the transportation testbed, the CAMAS testbed at UC Irvine, the San Diego Gaslamp Quarter [GLQ] testbed, and the Champaign, Illinois testbed) have been assimilated into a more-developed set of derivative artifacts.

As part of the strategic plan (Figure 1), the Executive Committee has identified key milestones that are divided into two major categories: management and technical. The **management milestones** describe activities leading to the development of the Year 3-5 strategic plan and to subsequent partnerships with government and industry organizations. The culmination of the RESCUE project will be highlighted by a government and industry conference showcasing RESCUE artifacts to a broader audience and in which strategic partnerships with government and industry will be unveiled. The **technical milestones** involve progress on major research projects, development of testbeds and artifacts, and programs to validate artifact development. Milestones where significant progress has been made are shown as grey boxes.

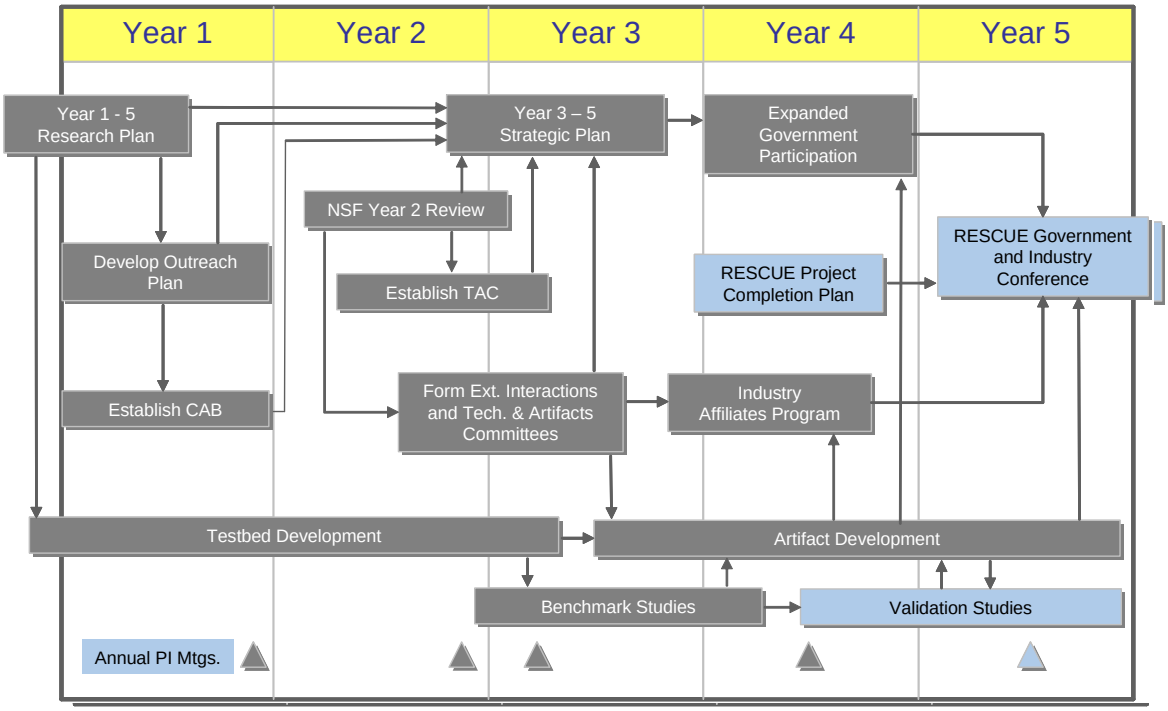

Figure 1: Key Management and Technical Milestones for the RESCUE Project

The RESCUE Project has made significant progress in all the key milestones for Year 4. Our research teams developed detailed research/implementation plans for each of the five projects (available at http://www.itr-rescue.org) that were presented during the PI meeting held in San Diego on January 9-10, 2006. The Executive Committee established a protocol requiring RESCUE artifacts to forge closer partnerships with the user community, specifically requesting advice on the design of artifacts, in addition to identifying opportunities for early adoption, testing and validation. Progress within the research projects, testbeds, and artifacts is described in Section 2 of this report. The key highlights include: (1) emergence of cohesive multidisciplinary teams for each integrative research project; (2) establishment of key partnerships with the user community for all the RESCUE artifacts; (3) the evolution of the transportation testbed into MetaSim -- an integrative simulation environment that combines into a single system multiple simulation projects within RESCUE (DrillSim – micro-level evacuation simulator at UCI, InLET macro-level transportation simulator and loss estimation tool at ImageCat, and Cellular simulation at UCSD), significantly enhancing our capability to simulate complex response scenarios in which we can evaluate the efficacy of RESCUE IT solutions; and (4) working with the city of Champaign to build a realistic and detailed disaster scenario that will serve as a motivating case study for multiple RESCUE technologies.

To maximize broader impacts of our research, RESCUE also launched new initiatives to engage industrial partnerships, new research collaborators, and the user community. Numerous discussions, presentations, and demonstrations were made to companies including Boeing, Apani Network, IBM, Convera, Sun Microsystems, Printonix, Motorola, Ether2, IBM, Conexant, Yahoo, SBC, Asvaco, VDT, CDWG, Psion Teklogic and AMD, resulting in substantial donations (e.g., 22 e-series servers donated by IBM), new strategic alliances (e.g., alliance with Convera to develop a hurricane portal), and partnership discussions and/or non-disclosure agreements (e.g., with Boeing for joint project and possible Boeing-funded research center). Funding opportunities were pursued with The School Broadcasting Company (SBC) in the form of a UC Discovery grant. In addition, conversations with SBC initiated the process of creating a non-profit nationwide consortium on disaster warning systems (which will be pursued in Year 5). New academic partnerships include discussions with research teams working on related projects at USC, Georgia Tech, Columbia, NICTA consortium in Australia, and with the Government of India for potential collaborative efforts and student exchange.

Efforts to increase participation of the user community in RESCUE include establishment of key partnerships with response organizations in the context of artifacts (e.g., City of Ontario for the Information Portal artifact (recently released at: www.DisasterPortal.org/Ontario) and expansion of the Community Advisory Board (e.g., addition of new members representing the Orange County Fire Authority & the Boeing Company). In consultation with Ellis Stanley, General Manager of the City of Los Angeles Emergency Preparedness Department and the current chair of the CAB, the project has initiated a strategic expansion of CAB to increase the likelihood of national-level impact and project continuity beyond Year 5. Key researchers within RESCUE are in discussions with representatives from the Centers for Disease Control, the Federal Emergency Management Agency, the Office of Homeland Security for California, the Department of Homeland Security – Emergency Management, Los Angeles County – Department of Health Services/Bio-Terrorism/Preparedness and Response with regard to actively engaging their members in the project's CAB. RESCUE researchers have deployed their technologies during several drills, including a full-scale emergency response exercise with the San Diego Metropolitan Medical Strike Team (MMST) that took place on UCSD's campus in August 2006.

Further efforts resulting in a strengthening of the industry/academic strategic partnerships include the creation of a school-based Center for Emergency Response Technologies (CERT). This Center, housed in the Donald Bren School of Information and Computer Sciences, was seeded

with a $50,000 gift from Fonevia (a local company specializing in emergency notifications). Fonevia currently collaborates with RESCUE on a number of research and industrial projects including: Crisis Alert notifications, Disaster Portal technologies, and a research study to analyze the efficacy of RESCUE technologies in a real-world school district (Redondo Beach School District). Fonevia is currently pursuing licensing discussions with RESCUE regarding the Disaster Portal technologies, thus brining RESCUE technologies to the marketplace.

Mitsui North America, a Japanese-based technology company, is another industrial partner actively engaged in technology licensing. We are currently in early, yet significant, technology transfer discussions with this company.

Notable remaining challenges include the following: 1) while important relationships have been established with the first-responder community, these relationships must be cultivated in order to ensure sustainability and maximum potential for utilization of research products and artifacts; 2) local collaborations must be expanded into nationally-based activities in order to test, validate and implement research findings for the broadest audience possible; 3) industry must be engaged in a manner that will promulgate the value and efficacy of RESCUE research and actively work with RESCUE researchers to be technology integrators; 4) the opportunity to "push" multidisciplinary research and technology solutions that acknowledge real and perceived gaps between end-users and technology developers must continue to be exploited; 5) focus in all five research projects must be maintained, so that the initial objectives identified with each project are met and so that the overall mission of RESCUE is achieved; and 6) the continuity of RESCUE beyond Year 5 will become a major priority. We are currently in the pre-proposal stage of an NSF-funded ERC. This ERC, if approved, would afford RESCUE the opportunity to engage not only first responders, but critical Infrastructure operators and other key stakeholder groups. The Center will extend IT research into urban planning, adaptive and reconfigurable systems, and issues related to urban lifeline interdependencies.

2 RESEARCH PROGRESS IN YEAR 4

2.1 Research Projects

Project 1: Situational Awareness from Multimodal Input (SAMI)

SAMI research has focused on three areas: 1) signal analysis, interpretation, and synthesis; 2) situational data management; and 3) analyst tools. The major findings in each of these areas in Year 4 are described below.

Signal analysis, interpretation, and synthesis. Here, our focus is on techniques for extraction of higher-level information such as facts or events from low-level input signals in text, audio, video, sensors, etc. In the area of information extraction from text, we have developed XAR, a next-generation extraction platform which provides a richer feature space for extraction applications. One of the key distinguishing features of our work on extraction from text is the exploitation of semantics in extraction. This stems from our ongoing work initially in the context of data disambiguation. We have continued work on our earlier developed approach to disambiguation of data based on relationship graphs. Over the past year, we have developed techniques for the automated learning of relative weights for different kinds of relationships in such graphs. New directions include the application of disambiguation techniques for Web people search, location disambiguation, and the exploitation of external sources (such as Wikipedia) for disambiguation.

In the area of audio event extraction, we continued our work on robust beamforming, developing variants of the "constrained robust Capon" beamformer. We have also initiated work on

beamforming algorithms that factor in speech quality information; new algorithms and approaches such as those based on Independent Vector Analysis (IVA) are being investigated as well. A scheme for detecting undesired stationary and non stationary events, as well as multiple speakers, has been formulated and tested. In the area of visual event extraction, we have developed multiple view based homography binding methods which provide view-invariant features of tracked objects -- including persons and vehicles in outdoor environments -- such as their footage area, velocity, location, and inter-object configuration. Support for view switching between multiple cameras is also provided. Finally, an integrated adaptive mechanism for multi-view switching and multi-level switching has been developed to better understand and analyze video events. In the multi-modal information fusion area, an iterative technique for information fusion from multimodal sensors based on the theory of turbo codes has been developed to achieve situational awareness.

Situational data management. The work in this area over Year 4 has focused primarily on the development of the SAT-Ware immersive environment; this is now housed under the privacy project.

Analyst tools. In the predictive modeling area, we worked on several problems centered on challenges in Bayesian networks with determinism. These include: 1) development of posterior estimation techniques; 2) development of SampleSearch, a new technique which guarantees that all samples generated will never be rejected or thrown away, thereby circumventing the rejection problem; 3) a new scheme addressing the *counting* problem for Bayesian networks with determinism, combining the above-mentioned SampleSearch scheme with the importance sampling framework and outperforming the state-of-the-art schemes by an order of magnitude; 4) generating random samples from a Bayesian network with determinism; and 5) improving the expressive power of Bayesian networks using stochastic grammars. In graph analysis, we developed techniques for multi-dimensional analysis for annotated objects (specifically documents and events). We also developed techniques for semantics-based ranked graph pattern matching. In this work, we addressed graph pattern queries where graph matching is imprecise. In GIS, we developed scalable techniques for compact representation and efficient querying of meta-data describing very large numbers of GIS data sources on the open Web. Primarily, we have developed techniques for 1) compressing the data sources with minimal information loss; and 2) indexing the data sources that can quickly retrieve relevant data sources.

Challenges. In audio-visual extraction, we are developing new approaches and algorithms to address object segmentation and tracking challenges by integrating model-based and appearance-based methods. Also, situational awareness requires systematic abstraction of semantic concepts from low-level signal processing to high-level information processing. We will develop a general model that can encompass the two processing levels in a systematic semantic pyramid. In information disambiguation a major challenge is the (lack of) availability of benchmarks for evaluation of the work. Also there is a challenge in the area of obtaining applicable ontologies for graph analysis in disambiguation.

Immediate Future Directions. In audio extraction, we plan to work on robust ICA; in visual event extraction, we will investigate methods that can relax the requirement of synchronized multiple camera inputs for homography binding; in multi-modal information fusion, we plan to implement the audio-visual fusion technique for meeting scene analysis with multiple people. In extraction and disambiguation (over text), we will continue to explore the applicability of constraints and more general semantic information in extraction. In predictive modeling, we plan to finish the work on modeling the “Travel Density Estimator and Travel Planner” artifact using stochastic grammars. Over the last year, we have developed algorithms to lower bound the counting task. In the future, we plan to use inequalities from statistics and the “AND/OR search scheme” to

achieve high-confidence upper bounds on the counting problem. In the GIS area, we will work on data compression techniques for GIS data. We will also develop an algorithm for finding top-k sources using the indexing techniques developed. Finally, we will explore the area of automated meta-data extraction to enable more meaningful indexing of GIS data sources on the open Web, with the ultimate aim of improving accuracy for GIS data search.

Key Technologies. The key technology pieces developed include: (1) The XAR information extraction system; (2) A portable two-channel microphone array speech separation system prototype; (3) An "Origin Destination Predictor" which based on a probabilistic model, given a time and the current GPS reading of an individual (if available), can predict the destination and the route to destination of the individual; and (4) A "Travel Density Estimator and Travel Planner" which given time of day, day of week and the specific highway (e.g. I-405 from Irvine to LAX), can robustly estimate how many people are on a section of a road (both currently and in future).

Project 2: Robust Networking and Information Collection

The grand challenge of this project is to develop research solutions and artifacts that can make today's communication networks perform better during crises situations. To achieve these objectives, five sub-projects were formed: (1) theoretical research; (2) Extreme Networks System (ENS); (3) Adaptive Information Collection System (AICS); (4) Adaptive Cellular Network System (ACNS); and (5) system integration. ENS and Peer-to-Peer Information Collection and Dissemination systems are the two artifacts developed under this project.

Activities and Findings. As part of our theoretical research, we proposed the concept of Sentient Networking to bring humans and computer networks closer. Our example sentient system studied a new networking approach that could recognize the emotion content in voice packet streams and prioritize voice packets originating with distressed speakers. Up to 60% performance differentiation is provided to voice streams from these sources. The proposed scheme also contained an approach for detecting the packet type in wireless networks by utilizing the spectral properties of packets instead of using the traditional approach of explicit identification of the information contained in the packet. This technique was also used for detecting network data packets without using any information from packet headers.

Another important theoretical research topic was the t non-asymptotic capacity analysis for wireless mesh networks. We developed two solutions: (a) Maximum Throughput Partition (MTP) and (b) Maximum Throughput Partition with Hops' number Constraint (MTPHC). In MTP, the ideal throughput is achieved by optimally partitioning the network with a proper number of backbone nodes. In MTPHC solution, an additional constraint on the average number of hops in the backbone network is considered. These results showed that it is critical to find an appropriate size of the backbone network for a wireless mesh network, especially when the hops' number constraint is imposed.

In collaboration with CogNet project, we developed an emergency response framework for exchanging critical network environmental information across nodes in a cooperative manner. Based on this approach, we designed a MAC protocol which shares contention information to optimally choose the parameters. Using a simulator platform, we found that a system throughput improvement of 50-60% can be achieved.

As part of the adaptive information collection systems research, we created a sophisticated vehicle telematics system that can track, and control vehicles or similar objects. This system is integrated and demonstrated with the Responsphere truck. The tracking and telematics system is implemented to support various location tracking technologies, including GPS, Assisted GPS (AGPS), and GPS with WAAS. A WAAS-capable receiver provides position accuracy of better

than three meters 95 percent of the time. We compared the standard GPS system, AGPS, and GPS with WAAS especially the availabilities and accuracy of location tracking for both indoor and outdoor. The standard GPS does not work indoors. AGPS works indoors with an accuracy of 50 to 100 meters. GPS with WAAS works indoors when the receiver is close to window. In the outdoor environment, GPS with WAAS has better accuracy than standard GPS and AGPS.

As part of our adaptive cellular networking system research, an early simulation model based on the UMTS system was built based on the OPNET simulation platform. The impact on delay and blocking on services was analyzed when base stations were put out of service due to damage to the infrastructure.

As part of our system integration efforts within the research products of RESCUE networking, we created a rich service-based architecture that incorporates data acquisition services tailored to the collaborators' instruments and feeds. The central data store is a service within a rich service-based architecture. It stores data from each of the collaborator sources, and is structured so that new collaborators and feeds can be added with minimal effort. We also created a documentation framework that readily accepts data source definitions and promotes data usage by potential integrators, analyzers, and visualizers, thereby encouraging the use of this data by investigators other than the original researchers. At present, we have integrated the vehicle telematics system and peer-to-peer traffic information dissemination system in a single framework.

Going forward, several challenges remain. The biggest challenge in sentient networking is the development of a generic framework for a host of sentient capabilities that can be enabled on to today's networking infrastructure. One of the challenges that adaptive information collection systems face, as part of the vehicle telematics system is the complexity of the specific vehicle electronic system which needs to be considered in order to integrate the telematics device. For example, different car manufacturers may have a different specification for their vehicle data bus. In ACNS, the biggest challenge is the design of integration interfaces that are not fully exposed. Although the mechanisms and interactions within MetaSIM have been identified, integration needs more clarification for APIs. In current networks, the main technical challenge was limitation in standard RACH mechanism in cellular network (basic Slotted-ALOHA). Although proposed solutions will theoretically sort out the problem, integration into real systems and standards within real carrier networks will remain an issue.

Plans for Year 5: As part of the theoretical research, we plan to accomplish the following: (1) 3 months: evaluate throughput capacity regions for finite wireless mesh networks with fixed or random back-bone topology; optimize the design of back-bone network topology; design a first responder radio with cognitive capabilities, (2) 6 months: complete the simulation platform for cognitive first responder networks; create simulation platforms for non-asymptotic transport capacity in finite node topologies for wireless mesh networks; create new applications for networked signal processing concepts proposed as part of the sentient networks, and (3) 12 months: evaluate the potentials for early prototypes for cognitive first responder networks; capacity analysis of spatial multiplexing; and spatial diversity based MIMO ad hoc wireless networks, and build new simulation platforms and prototype models for sentient networking. We also expect a number of educational outcomes include research platforms, simulation models, publications, technical reports, and other hardware and software products.

As part of the adaptive cellular network systems research, we plan to achieve the following: (1) 3 months: Finalize the simulations;, (2) 6 months: Integrate the Cellular Simulation into MetaSIM; and (3) 12 months: Analyze and create results for a simple disaster with MetaSIM; Share the results with operators and promote its use.

As part of our System Integration activity, we plan to achieve the following in the next one year: (1) 3 Months: addition of Cal-Mesh and voice systems to data source list; refactoring prototype into production system; Deployment of initial production system on public-facing servers; improvement of Google Maps ad-hoc query interface; (2) 6 Months: documentation of system; documentation system encouraging users to access data; portlets for Google and Yahoo allowing public access to data; crosscutting security/authorization functionality; direct support for Google Earth; initial implementation of ODBC external interface; demonstration of interoperability with Microsoft Office production deployment; and (3) 12 Months: video stream support; integration into Irvine-based web site; introduction to disaster community at large; completion of ODBC external interface; production deployment maintenance.

Project 3: Policy-Driven Information Sharing (PISA)

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

PISA's deliverables and milestones for Year 4 include:

1. Continue trust negotiation scalability and availability work.
2. Develop lightweight authentication approach.
3. Develop family-and-friends reunification portal
4. Conduct focus groups in Champaign.

Activities and Findings. During the past year, we addressed technical and sociological problems that were identified through the derailment crisis scenario that is the focus point for PISA. As discussed below, our main efforts during the past year were: (1) sociology focus groups in Champaign; (2) a completed version of TrustBuilder2 trust establishment software that will be integrated with DHS's Disaster Management Interoperability Services (DMIS) software to demonstrate how flexible policy-driven authorization services can be incorporated into a disaster information broker; and new work that addresses information sharing needs in family reunification (a need identified in the derailment scenario) by (3) providing user-friendly authorization facilities for crisis victims and their friends and family, and (4) by providing information integration facilities that can amalgamate friends-and-family notices taken from grass-roots and government-sponsored family reunification web sites. We describe each of these in more detail below.

(1) In August 2006, RESCUE sociologists facilitated three *focus groups for 28 first responders and other stakeholders* in Champaign, exploring how the community's public safety and emergency management organizations would interact and communicate using technology in response to the derailment with chemical spill scenario. From the data collected, several key observations have been identified, including challenges and problems the community faces in this scenario, and technology solutions and suggestions.

(2) We decided to use DHS's DMIS as the underlying information-sharing infrastructure for PISA, with policy management facilities layered atop DMIS. Given that SAMI's analysis facilities are not particularly relevant for the derailment scenario, we will not integrate SAMI with DMIS. We determined that DMIS has rigid authorization requirements that may limit its effectiveness in a

crisis, so we have chosen to concentrate on the addition of flexible authorization facilities to DMIS, as described below.

We re-architected and rebuilt TrustBuilder, our *runtime system for authorization in open systems.* TrustBuilder 2 is more flexible, modular, extensible, tunable, and robust against attack, and we are now integrating it with DMIS. We also designed, built, and evaluated an *efficient solution to the trust negotiation policy compliance checker problem*, and incorporated it into TrustBuilder 2. That is, given some authorization policy *p* and a set *C* of credentials, we quickly determine all unique minimal subsets of *C* that satisfy *p*.

(3) In response to confidentiality concerns identified in the derailment scenario for family and friends reunification, we worked to develop lightweight approaches for establishing trust across security domains. Victims need a way to ensure that messages they post are only read by the intended family members and friends, and vice versa. Obviously logins, passwords, PKI infrastructure, and other heavyweight authentication solutions are not practical in this context. *SAW* is our user-friendly alternative that eliminates passwords and their associated management headaches by leveraging popular messaging services, including email, text messages, pagers, and instant messaging. Additional server-side support integrates SAW with web technology (blogs, wikis, web servers) and browser toolbars for Firefox and Internet Explorer.

(4) Data from friends-and-family reunification web sites are extremely heterogeneous in terms of their structures, representations, file formats, and page layouts. A significant amount of effort is needed in order to bring the data into a structured database. Further, there are many missing values in the extracted data from these sites. These missing values make it harder to match queries to data. Due to the noisiness of the information, an integrated portal for friends-and-family web sites must support approximate query answering. We have worked on these and related issues in the past year; the resulting demo of our information integration technology is available at http://fr.ics.uci.edu/, with data from 16,000 missing person reports taken from three web sites.

PISA's Deliverables and Plans for Year 5 include completing TrustBuilder 2 scalability and availability work; demonstrating and benchmarking the derailment scenario that integrates DMIS, TrustBuilder 2, and selected other RESCUE artifacts, with acceptable scalability; showing robustness under attack as well as under "normal" operating conditions; and demonstrating friends-and-family reunification portal that automatically integrates information crawled from missing-persons sites and incorporates lightweight user-friendly techniques for authorization.
We also plan to include the Family Reunification Portal in SAMI's Disaster Portal.

Project 4: Customized Dissemination in the Large

The goal of this project is to develop the next generation of warning systems, using information disseminated to the public at large to encourage self-protective actions (e.g. evacuation from endangered areas or sheltering-in-place). During the fourth year of this project, we have further concretized research on 3 sub-thrusts along the two base scenarios at both ends of the warning time spectrum, i.e. short-term and longer-term warning times (as delineated in the research plan). We have also made significant progress towards the development of the CrisisAlert artifact and its utilization for both short and longer term warning case scenarios.

Progress in ***SubThrust 1 (Understanding dissemination scenarios)*:** We addressed the case where longer warning times were possible (e.g. hurricanes). By studying communications among community organizations in the Hurricane Katrina response, we developed an understanding of the structure of emergent communication networks as well as information flow within these networks. Our findings have highlighted the importance of non-routine communication channels in

disseminating information during the response when conventional infrastructure is severely degraded. Furthermore, adaptive technologies for information dissemination during disasters may not be fully utilized if they are labeled as being specifically intended to facilitate non-routine circumstances – the end user community may not mobilize technologies which are designed for that purpose. We have performed a series of simulation studies to explore the behavior of information (e.g., emergency notifications) diffusing through large-scale social networks. One application of interest which was identified by the customized dissemination team was notification within schools; to this end, we have used existing data on student networks to examine the behavior of information diffusion within this context. Our findings thus suggest that informal message passing given an initial warning will be very rapid, but will often be inaccurate for complex messages. This phenomenon may be somewhat attenuated by the use of a larger initial target population; we are currently attempting to identify heuristics for message placement to minimize signal corruption, for use in deploying customized dissemination systems.

Additionally, in collaboration with University of Colorado IT researcher Leysia Palen, who has a NSF CAREER grant, we have been studying the use of information and communication technologies among members of the public during disasters. Events studied include the 2001 World Trade Center attacks, California wildfires, the 2004 Indian Ocean earthquake/tsunamis, Hurricane Katrina, and the 2007 Virginia Tech shootings. Peer-to-peer communications behaviors in these events highlight the extent to which information/communication technologies are revolutionizing risk communication, information sharing, and collective sense-making within the public during extreme events. Despite their significance in an age of ubiquitous communication technology, emergent communications networks during crises are both under-theorized and under-researched.

We formalized a Pub/Sub framework for ***Customized Information Dissemination (SubThrust 2)*** that customizes and delivers the published content based on knowledge of end-user attributes such as receiving devices and demographic factors (e.g., language, location). Using a structured peer-to-peer overlay as a backbone, we formulated the problem of operator placement as an optimization problem that minimizes the content dissemination cost, which consists of network cost and computation cost. We have determined that achieving optimal customized information dissemination in this setting is an NP-complete problem, and proposed distributed heuristics to address the issue. To alleviate subscription management and content matching complexity of content-based pub/sub, we have proposed a novel representation of content space including subscriptions and publications by mapping multidimensional content space into a one dimensional representation using space filling curves.

Significant progress was made in ***SubThrust 3 (Robust and Scalable Delivery)*** both in wired and wireless networks. Building on last year's work on Flash Dissemination, we have formalized the problem of catastrophe-resilient flash dissemination for peer-based systems, designed and evaluated protocols to support rapid dissemination in the presence of catastrophes (i.e., significant numbers of simultaneous failures). We developed Roulette, a new protocol that works even under extreme failures (catastrophes) where a large percentage of the participating nodes in the peer network fail simultaneously. Interestingly, the application of this protocol is not restricted to just disaster scenarios. A very general use case for the Roulette protocol is to support scalability in web servers. We have addressed the issue of scalable dissemination and developed and implemented Flashback, a system for making web-servers scalable to flash/surge crowds using a P2P approach. Thorough experimentation has shown the superiority of the Roulette protocol and the Flashback system over currently used systems (BitTorrent), indicating that a multiple catastrophe resilient protocol such as Roulette is a necessity to build truly scalable web servers.

For dissemination over wireless networks, we have addressed the issue of reliable broadcast of large size application content data over wireless ad-hoc networks. We have shown that existing broadcast/multicast techniques experience severe performance degradation due to IP fragmentation as well as packet drops by IP queues. We have developed the READ (Reliable and Efficient Application-data Dissemination) protocol to enable upper-layer fragmentation and enable fragment-level reliability on individual fragments. The DREAB (Deterministically Reliable and Efficient Application-data Broadcast) protocol is able to provide deterministic reliability guarantees for the delivery of application data through (a) a push-based awareness dissemination sub-protocol (Peddler), and (b) a push/pull based data dissemination sub-protocol (Pryer). DREAB also takes into account data authentication and integrity aspects of broadcast reliability.

We have designed and developed "CrisisAlert", a software artifact for the dissemination of information to the population during an emergency. The CrisisAlert system, while primarily designed to support customized and rapid dissemination in the case of short warning times through a variety of modalities, is available to the public as part of Disaster Portal (www.disasterportal.org), making it a suitable backbone delivery and customization framework for longer term warnings as well. An initial version of a hurricane public information portal has been designed and prototyped. Talks are currently in progress to deploy and evaluate the CrisisAlert system in a phased pilot study at the Redondo Beach school district in southern California. Plans are also underway to integrate CrisisAlert functionality through a portal interface into the Ontario Disaster Portal (developed by RESCUE for the City of Ontario, California). In the final year of RESCUE, we expect to continue on our current research & further explore the infusion of the artifacts into practice, and validate the effectiveness of such technologies. We also expect in Year 5 to further advance our efforts on Case Study 2 on longer term warning systems and develop the portal based approach in the design of customized warning system for the public at large.

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

Project 5: Privacy Implications of Technology

Our research on privacy implications, initiated in Year 3, focuses on privacy in the context of following three systems where potentially identifying information about individuals may be collected to provide new/improved functionalities.

1) Observation Systems: systems that exploit variety of sensing technologies to create situational awareness that is then utilized to provide new functionalities (as in pervasive computing applications) and/or monitoring for security (as in surveillance systems). Within observation systems, our focus is on surveillance though the research has broader applicability to applications where information such as person identity, context such as location, time, and profile is captured for service provisioning.
2) Data Sharing Systems: where potentially identifying information about individuals (and/or confidential information) may be shared amongst variety of individuals (or organizations) amongst each other or with the government agencies. Our research explores a privacy and confidentiality challenges in the context of rapidly emerging data outsourcing model.

3) Data Dissemination Systems: where individual's identity/preferences/context is exploited to provide customized information dissemination. An example of such research is the privacy challenge in the context of family reunification portal where we have developed the SAW protocol described in the PISA project.

In each of these systems, our approach has been a) to understand and identify information disclosure channels that exist, b) design studies that explore how diverse user groups perceive loss of privacy through those disclosure channels, c) design privacy technologies to alleviate disclosure threats. In year 4 significant progress was made along each of the research directions identified for the privacy project including a paper that received the best student paper award at a CVPR workshop.

Observation Systems: Our effort on privacy in observation systems in Year 4 focused on a) developing Satware is an event-based middleware for sentient spaces that provides a platform for privacy studies and also for developing, testing, and validating privacy technologies. Satware is described separately in the Artifact Section of this report. We describe privacy research enabled by the Satware infrastructure:

*(1) Case study on sociological aspects comparing human behavior with and without privacy-protection techniques incorporated into applications (Socially Conscious Surveillance Systems): (*a) *Artifact Tracking and Green Comhpliance utilizing RFID and Video Technologies:* This mixed-methods research is the first privacy research project supported by the RESCUE SATware framework. The research will examine privacy implications of adopting technologies to bring new efficiencies and capabilities in social/human systems that are not possible without technologies. The focus is on human systems in the context of smart-space infrastructure created by the Responsphere deployment. During the first phase, RFID tags will be placed on coffee and drinking cups within the coffee area on the 4th floor of Calit2 and monitoring of human behavior (e.g., recycling), as well as artifact tracking, will be performed. During the second phase of this study, a qualitative case study phase, we will address the participants' concerns with artifact tracking and highly instrumented/surveilled environments. Coffee room participants will be asked general, open-ended questions regarding the phenomena and their responses coded and analyzed for recurring themes. The overall objectives of the research are to analyze the effects of highly-instrumented spaces (smart spaces) on human behavior and to understand participants' attitudes toward privacy in these spaces.

(2) Privacy Preserving People Finder: Users' evaluations of system quality also depend on conceptions of privacy. Privacy is subjective and is dependent upon various factors, including social context, location, and individual privacy preferences.. Attitudes and beliefs regarding privacy also change over time and vary across different cultural settings. Thus two fundamental problems in this area are defining users' expectations for privacy, and creating mechanisms for meeting those expectations. Our current research seeks to define QoS mechanisms for privacy which are sensitive to these issues, and which express privacy service quality to users in an intuitive manner. We are also working to define management mechanisms that allow users to define and communicate their privacy concerns with regard to technology. Finally, we seek to determine the extent to which these mechanisms are likely to be actively utilized and to provide value to the privacy consumer in realistic settings.

(3) Designing a privacy-preserving system for surveillance: We designed a sensor-based surveillance system that detects various "events of interest." including in particular events that violate rules applicable in different environments. The novelty of the system is that the identity of an individual is never revealed until he/she violates a certain rule (e.g., an access control policy). The state of the system is maintained using encrypted automatons, and a certain (pre-specified)

level of anonymity is guaranteed for every individual at all times. The key contribution of this work is to formalize the notion of anonymity and derive the necessary criteria/constraints the data representation and communication protocols need to satisfy in order to ensure the specified level of anonymity for all individuals. We designed algorithms that minimize communication overhead while meeting the privacy constraints. Our architecture is currently being integrated into the SATware system. In the near future we want to extend this work towards detection of "unexpected" or "abnormal" events where the semantics of such events might not be completely known in advance.

(4) Study of privacy-issues arising in designing applications using location-based data: Here we investigate the privacy concerns in the context of location-based service. We develop a clustering-based framework for anonymizing location data for release. Specifically, we design clustering techniques for trajectory-anonymization. A fundamental challenge in trajectory clustering is dimensionality asymmetry. The assumption of symmetry taken by most clustering techniques makes them inapplicable to this problem since the trajectories are of different lengths. The challenge is to design a similarity measure and a clustering algorithm that can deal with trajectories of different length, i.e., different starting and ending points.

Privacy & Confidentiality in Data Sharing Systems: Our goal here is to explore the privacy and confidentiality challenges in the context of data outsourcing model. After our original paper on outsourcing data management (ICDE & SIGMOD 2002), outsourcing Over the past few years, following the trend of service oriented architectures, data outsourcing has emerged as an important data management paradigm. It offers numerous benefits including reduced costs, availability and is well suited to support mobility and data sharing. The model suited for first responder organizations since it enables them access to data management without the overhead of investing into Information Technology on their own. It is particularly suited for private organizations and individuals to share data with response organization if and when the need arises. Our work in this area in year 4 focused on the following:

(a) *DataGuard:* This is a middleware that builds a secure network drive over the untrusted data storage offered by the Internet data-storage providers (IDPs). DataGuard adapts to the heterogeneity in the data models of the IDPs and utilizes cryptographic techniques to preserve data confidentiality and integrity of the client. The DataGuard middleware technology has just been released as a software platform that allows users to securely outsource their information (e.g., documents, video files, and audio files) to untrusted third parties.

(b) *DataVault*: This system is designed to provide data sharing as a service. It allows users to outsource their file system and share their data with any user on the Internet. It does not require a third party trusted PKI infrastructure for data sharing to take place. DataVault runs its own novel PKI service to securely share data on the web and allows users to enforce complex security policies at the file level. We are currently extending the DataGuard architecture to allow data sharing to take place between its users. The goal is to overcome the lack of functionality at the IDP side which currently does now allow secure transfer of data between users.

(c) Secure schemes and protocols for some common suit of operations required for data sharing, and data integration: During times of crisis, information integration across multiple agencies may be required. For instance, determining the common individuals in two separate lists of names could be an important operation. To carry out such matching securely without exposing other information is an important task. In this sub-project, techniques were developed for secure aggregation and join computation using encrypted data over secure co-processors. Previous techniques reported in the literature were shown to be vulnerable to a variety of attacks, and

therefore more robust techniques were developed. We also developed secure authentication protocols and protocols for simple device-pairing for pervasive spaces (SATware, Responsphere).

Project 6: MetaSIM

MetaSim is a web-based collection of simulation tools developed to test the efficacy of new and emerging information technologies within the context of natural and manmade disasters. MetaSim currently includes a crisis simulator, a transportation simulator, and a simulator for agent based modeling (Drillsim). Outside of MetaSim, Adaptive Cellular Network Modeling at UCSD informs the adjustment of information dissemination parameters for testing cellular technologies. The goal of MetaSim is to provide an extensible simulation platform for emergency managers and researchers to support response, recovery, and mitigation activities.

A preliminary website has been developed in HTML and stored in the backend database to produce web pages on-the-fly through Java script. The web pages call the various simulators and allow users to define parameters for the various simulations. The parameters are saved in user specified scenarios and the simulations are run through the interface. After each run, the results are stored in the database and the website calls and displays intermediate and final results.

MetaSIM's deliverables and milestones during year 4 include:

1. Continued coordination of Transportation Testbed. Focus on integration of IT solutions and merging of communication network.
2. Beta-version of transportation network model for Los Angeles and Orange Counties.
3. Technical report on the application of remote sensing technologies for crisis response. Focus on both natural and human threats.
4. Workshop on transportation planning and analysis for unexpected events.

Activities and Findings:
A key achievement of MetaSim has been the integration of incompatible spatial data models through a series of "wormholes" that pass data from one environment to another. This is achieved through the *Relational Spatial Data Model* (RSDM) which creates database links between existing spatial data types, allowing models that may have fundamentally different spatial representations of the world to communicate. A prototype implementation successfully calls the individual modeling components and transfers agents to various geographical environments. METASIM includes components that are currently run on the server provided by Responsphere, including crisis simulator, DrillSim, and the transportation simulator.

In the MetaSim prototype, users define a series of scenarios establishing the parameters leading to an evacuation of the UCI campus. During scenario definition, the *Crisis Simulator* estimates damage and casualties for a user-defined earthquake. The crisis simulator integrates the earthquake loss estimation components of InLET; the Internet based Loss Estimation Tool, created and designed under project RESCUE in Year 3. Also during scenario definition, the user is presented with the technology test bed, which allows adjustment of information available to evacuees. Information availability is simulated through parameters, such as subscription to routing support information via cell phone or email, information arrival time and update frequency, system credibility and acceptance. For the evacuees, modeled as agents, information reduces the uncertainties associated with decision making when evacuating a congested network. Cellular performance is assessed by analyzing Random Access (RACH) mechanisms for GSM/GPRS/UMTS with OPNET. Cell sites were loaded into Opnet based on input from Cingular

and internal measurements, and OpNet simulation scenarios were analyzed based on damage to the infrastructure. Results from the Opnet simulation are input directly into MetaSim.

After the scenario parameters are defined in MetaSim, the user runs an evacuation simulation. The MetaSim prototype incorporates *DrillSim*, an agent-based activity simulator that models human behavior at the individual level. Although the modeled behavior is currently limited, *DrillSim* tests IT solutions by modeling situation awareness and providing it to the agent to react accordingly. Micro simulation provides the ability to mimic agent behavior in crisis, as well as people's interactions during crisis, thereby providing a more robust framework for integrating responses to information and technology. *DrillSim* uses a grid-based representation of indoor and outdoor spaces, routing agents to pre-defined wormholes. Using the RSDM, agents are passed from a grid-based simulation to a network-based transportation simulation. The *Transportation Simulator* uses a simplified quasi-dynamic traffic assignment model, and a destination choice model to route evacuees through the road network to nodes defined outside of the evacuation zone. The effectiveness of any given technology solution is assessed by analyzing the change in the number of evacuees through time amongst various scenarios.

The results of the crisis simulator have been integrated into the Dissemination project as part of the early warning information. Results can realistically be integrated into the Disaster Portal. The technology test bed can be used to assess the implementation of Dissemination. Planned deliverables during the next year include finalizing the prototype (limited additional programming); limited validation of the individual models; Outreach, transition of artifacts; publications.

2.2 Artifacts & Testbeds

Extreme Networking System(ENS): The Extreme Networking System (ENS) is one of the two research artifacts in Robust Networking and Information Collection project. ENS is a hybrid wireless mesh network developed using the CalMesh platform. Several novel features were added during this reporting year. A graphical user interface was developed to better visualize and manage network resources. A multi-radio diversity solution was developed to improve the reliability. As part of ENS research, we proposed a radio-aware routing protocol that uses information from the MAC layer in order to provide power control and channel dependent packet forwarding. The proposed system was verified through a set of simulations in a five-node network topology and found to be providing significant performance gain compared to a system using 802.11 MAC combined with AODV routing. Among the several approaches to achieving throughput improvement, we found that link diversity and the fading awareness made the most positive performance impact. One of the biggest challenges in this scheme is designing a system for channel quality feedback. The ENS was deployed during Operation College Freedom and found to be very reliable. Extensive measurement was carried out to evaluate the performance of ENS during Operation College Freedom and the collected data is being maintained as a valuable experimental dataset. Another result we obtained was in using IEEE 802.11 in Wide Area Networking environments. In long haul communications for remote and rural terrains, the use of 802.11 MAC protocol for widely varying link distances need a lot of manual interaction while setting up each link. We studied this problem, and proposed a number of solutions that help adapt MAC protocol parameters such as ACK/CTS time out in order to dynamically adapt to link distances. .Out of the three proposed schemes, Link Round Trip Time memorization (LRM) approach was found to be the best. Future plans for ENS in Year 5 include the following: creating a modular mesh network framework and a radio-diversity based routing protocol; capacity analysis for non-asymptotic situations; developing a MIMO-based MAC protocol for ENS opportunistic mesh routing protocol; and studying the performance benefit of cognitive approaches in disaster situations.

Peer-to-Peer Adaptive Information Collection System: The peer-to-peer traffic information collection and dissemination system, an artifact from the Robust Networking and Information Collection project, is currently being used by residents of San Diego and Los Angeles. The most compelling aspect of the system is that traffic or incident information is disseminated in a targeted manner to users, with minimal delay. Currently, people call 911 if they see a severe accident and that information rarely cascades to other commuters, except through vague traffic reports on the radio with a long delay. One of the biggest challenges in the design of the system was the validation of data reported by users. Our method was to grant access only to frequent users of the system, since the frequent users find our system useful, and are less likely to abuse it. A flagging mechanism was also created to allow users to flag reported messages they believed were spam. A user-ranking algorithm was devised and a threshold set to quantify the relation between abuse and ranking. With higher values for thresholds, we found that the system is able to create an abuse-less system. However, such a high threshold permitted only a small subset of the user population to report incidents. We, therefore, devised an adaptive threshold system where the threshold is lowered over time and finally the system was opened to everyone. Our system can also detect abnormalities based on the volume of calls received in any hour. If the volume of the calls spike, we know something must be wrong on the freeways. Indirectly the commuters are acting as sensors by calling in. The future work on this artifact include: (i) extending the Peer to Peer system for the greater Los Angeles area, (ii) releasing the system to the commuters of LA, (iii) contact local community and government agency to perform the trial of the location tracking and telematics system, and (iv) unification of the San Diego and Los Angeles systems. In addition to the general public in San Diego and Los Angeles, the primary users of this work, emergency response agencies could also utilize it during crises in San Diego and Los Angeles. Our system can be used for research purposes such as studying different routing algorithms, ranking strategies, and abuse prevention mechanisms.

Disaster Portal: The Disaster Portal software consists of an easily customizable framework and set of component applications for building emergency management web portals. These portals are used by first-responders organizations (such as those within municipal governments) to provide relevant information to the public. The functionality provided by the software includes a situation overview with maps, announcements and press information, emergency shelter status, and tools for family reunification and donation management. The Disaster Portal utilizes a variety of RESCUE research, including policy-based dissemination, information extraction and data-cleaning, scalable customized publish-subscribe systems, and activity modeling. The City of Ontario, CA is the organizational champion for this artifact. The Disaster Portal was deployed to Ontario in May 2007, and the system is now used by the city Fire and Police Departments to provide information to the public and local media organizations. The city is planning a publicity campaign to expand public awareness of the site in late 2007.

The Family Reunification Portal (part of the Disaster Portal) is one-stop-shopping portal for those seeking news of loved ones during a disaster, or wishing to inform loved ones of their whereabouts. The portal incorporates information integration research from RESCUE to synthesize information from many reunification web sites and databases, and employs the SAW approach to authentication (see discussion below) to provide confidentiality for postings in a user-friendly manner.

DMIS + TrustBuilder2 + SAW: DHS's Disaster Management Interoperability Services (DMIS) provides security services that do not always meet the needs of first responders. We are enhancing DMIS with more flexible authentication and authorization facilities, based on the SAW and TrustBuilder2 research efforts from RESCUE, respectively.

TrustBuilder2 is a robust, second-generation implementation of trust negotiation, an authorization approach designed for open, interoperable systems. In trust negotiation approaches to authorization, resources are protected by attribute-based access policies, rather than explicit access control lists. Because resource administrators specify access control policies at a much higher level of abstraction than an access control list, authorized users can gain access to a resource without having a pre-established trust relationship (account) with the resource owner. Resource managers and users employ cryptographic credentials issued by third-party attribute certifiers (e.g., professional organizations, employers, or government bodies) to various attributes about themselves during authorization. Since these attributes might themselves be sensitive, these credentials can optionally be protected by release policies that describe the attributes of the individuals to whom they can be disclosed. As such, a trust negotiation session evolves into a bilateral and iterative exchange of policies and credentials with the end goal of developing new trust relationships on the fly.

SAW provides a user-friendly alternative to requiring users to provide a password at each web site they patronize. SAW eliminates passwords and their associated management headaches by leveraging popular messaging services, including email, text messages, pagers, and instant messaging. We provide server-side support that integrates SAW with web technology (blogs, wikis, web servers) and browser toolbars for Firefox and Internet Explorer.

SATware system: SATware is a multimodal sensor data stream querying, analysis, and transformation middleware that aims at realizing a sentient system. The goal of SATware is to provide applications with a semantically richer level of abstraction of the physical world compared to raw sensor streams, thereby providing a flexible and powerful application development environment. It supports mechanisms for application builders to specify events of interest to the application, mechanisms to map such events to basic media events detectable directly over sensor streams, a powerful language to compose event streams, and a run-time for detection and transformation of events. SATware is currently being developed in the context of the Responsphere infrastructure at the UC Irvine campus. The key feature of SATware is to enable development of applications on streaming data. Our goal is to provide various APIs and the corresponding hardware support for enabling variety of data transformations and security mechanisms for developing novel applications with a special focus on supporting privacy-preserving applications. In this regard, our plan is to include basic support for streaming-data encryption; key management and authentication of individuals using a combination of RFID technology and biometric information. The eventual goal is to (i) determine the fundamental properties/constraints that need to be met to achieve a specified notion of privacy (k-anonymity, diversity) in context of any event-centric application; (ii) Identify the common primitives required across various privacy-preserving applications and build APIs that allow easy integration during system development.

In the remaining part of Year 4 and Year 5, we will build a common interface to enable privacy research at large that includes an online framework and a user-configurable abstraction layer. The following are the key areas that are being addressed in SATware: (i) Sensing using heterogeneous set of sensors (ii) Scalability (iii) Fault-tolerance (iv) Extensibility (allows users/applications to add and remove sensors from the system and discovering which sensors and services are available) (v) Privacy and (vi) QoS (Quality of Service).

Crisis Alert: an Artifact for Customized Dissemination: The goal of Crisis Alert is to reduce the possibility that members of the public will either over- or under-respond to an emergency notification. The Crisis Alert artifact has the ability to send emergency notifications where the content is customized, depending on the location of the recipient with respect to the area of danger, and the type of organization. These notifications can be automatically created by the

system according to a set of rules defined during the risk-knowledge phase of deployment of a warning system, and they can contain information such as maps of the area, location of shelters or hospitals. Crisis Alert is integrated with the existing communication infrastructure: it is able to deliver emergency notifications through different modalities, such as the Rapid network based on CREW, a Peer to Peer communication protocol developed in the RESCUE Dissemination Project, PDAs and cell phones.

Notifications are delivered by taking advantage of the social networks in the emergency dissemination process: Crisis Alert integrates the emergency response plan of each organization by targeting the notifications to who is in charge of organizing the emergency response. The flexibility of the system enable us to easily integrate other types of social networks or network delivery protocols in Crisis Alert, allowing advanced solutions to be put in the hand of emergency responders and proving us important feedback on the problems faced by the emergency personnel.

Crisis Alert can act both independently and as a part of the portal based alert system to provide emergency and preparedness information to the population for disasters such as hurricanes, providing information such as simulation results for wind damage to buildings as well as emergency shelter needs, eyewitness damage reports and a suite of sophisticated search, retrieval, and analysis tools for utilizing web content to provide situational awareness.

Crisis Alert is connected with the Disaster Portal Project and it is being used by the city of Ontario for disseminating information about emergencies to the press. To continue the process of putting the system in the hands of emergency responders, we have had some preliminary contacts with the University of California, Irvine and the Redondo Beach School District. Both are interested in adopting the system, and both will allow us to perform a pilot study. The purpose of this study is to deploy the prototype in some real scenarios and to gather feedbacks from the emergency personnel and from final alert recipients in order to integrate this new knowledge with the preexisting system and to validate it with data taken from actual drills.

MetaSim: MetaSim is both a project and an artifact. We envision that large portions of the system will be transitioned to emergency managers at the state and local level. Inlet, the crisis simulator, currently functions as an operational loss estimation system for earthquakes in Southern California. Although dollar losses are not required for the test bed, estimates of building damage and casualties are produced within a minute of entering a hypothetical event. Additionally, Inlet has been linked to the USGS Shakecast system, producing estimates from a ground motion surface interpolated from a network of accelerometers automatically, so that results will be available as soon as the USGS data are ready (typically within minutes after an event). Although the agent-based modeling in *DrillSim* currently does not integrate sophisticated human behavior models, it offers a platform for integrating building-level evacuation into a larger context. Because MetaSim is an open platform, the basic behavior model in *DrillSim* can be adjusted to test various assumptions of human behavior. Additionally, the model can be expanded integrate more sophisticated assessments of human behavior as data become available. The underlying RSDM modeling structure, which enables the integration of very different modeling techniques and data types, could be expanded into a formal architecture or a system of systems standard.

Responsphere: Responsphere is an IT infrastructure set of test-beds that incorporates a multidisciplinary approach to emergency response drawing from academia, government, and private enterprise. The IT infrastructure is used to test the efficacy of RESCUE technologies and extract meaningful metrics regarding those technologies. During this reporting year, several RESCUE artifacts were designed, tested, and deployed throughout the various Responsphere test-beds. Specifically, the Ontario portal was designed and is currently deployed in

Responsphere as was Rapid, FlashBack, and the situational awareness information dashboard for Evacpack. In addition, the Extreme Networking system was deployed on the CalMesh infrastructure in several drills, including a major exercise on UCSD's campus on August 22, 2006 in conjunction with the San Diego Metropolitan Medical Strike Team (MMST) and UCSD's campus police and emergency services departments.

3 BROADER IMPACT

3.1 Community Outreach

Outreach to First Responders: Partnership and collaboration with first responders have been an important strategy in RESCUE from the very beginning of the project. Last year (Year 3), we introduced several new artifacts to our first responder partners, including the Ontario Disaster Portal, real-time alert system. During year 4, we continued with artifact development and have deployed the disaster portal with the City of Ontario, CA (www.disasterportal.org) The EH&S division at UCI continued to test RESCUE technologies at variety of emergency drills at the campuses. UCSD participated in a large-scale emergency response drill in conjunction with the San Diego Metropolitan Medical Strike Team (MMST) and the UC San Diego Police and Emergency Services departments on the UCSD campus on August 22, 2006. The ENS system and CalMesh were demonstrated and used as the backbone network for emergency response activities demonstrated during this event. UCSD fielded a deployment of cellular-based location tracking devices for the MMST paramedic team at the San Diego Gaslamp Quarter Mardi Gras, on February 20, 2007. RESCUE researchers from UIUC and CU-Boulder conducted focus groups involving 28 first responders and stakeholders in Champaign, discussing information sharing during a hypothetical derailment-with-chemical-spill scenario.

In addition to involving first responders in the research and testing aspects of the project, we continue to communicate our research progress with our partners through a monthly electronic newsletter (eNews - http://www.itr-rescue.org/enews) and through RESCUE seminars and meetings. Additional highlights of community outreach include:

Industry Interactions: RESCUE's industry partnerships have continued to develop in Year 4. Calit2 at UCI's Igniting Technology series featured the RESCUE project in March 2007, where researchers from UCI, UCSD, and ImageCat; as well as project partner the School Broadcasting Company showcased some products of their research, and demonstrated the Disaster Portal, VIEWS system and Crisis Simulator to our industry partners and some of our first responder partners. Sharad presented RESCUE research to variety of industrial partners including Boeing, Mitsui, IBM, and Microsoft. At UCSD, we worked with Cingular Wireless to identify/locate cellular base stations in order to construct the cellular network simulation study; and along with ImageCat, met with the California Office of Emergency Services, and presented several artifacts, including METASIM and the peer-to-peer information collection system. UIUC provided numerous demonstrations were given to industry of their SAW authentication software and TrustBuilder trust negotiation software.

Broader Community: RESCUE's initiative to impact the broader community comes at many levels. Some of the specific accomplishments include the deployment of the Ontario Disaster Portal and the deployment of the peer to peer traffic notification system to the San Diego community via http://traffic.calit2.net and through the number 866-500-0977. The website is also made available via Caltrans who provide a prominent link to the service at http://www.dot.ca.gov/dist11/d11tmc/sdmap/showmap.html; and also the KPBS radio station

website http://www.kpbs.org/news/local?id=4700. The system will be deployed to commuters in the Los Angeles metropolitan area by the end of summer 2007.

3.2 Education Outreach

Graduate and Undergraduate Education: RESCUE continues to have an impact on course curriculum throughout all the universities involved in the project. Specific courses and class projects have been designed to have a direct tie to the research being done at RESCUE. Details of UCI's ongoing RESCUE seminar series can be found at http://www.itr-rescue.org/outreach/seminars.php. Throughout the year, the RESCUE project has encouraged undergraduate students to be a part of ongoing research through individual study courses, honors courses, the NSF-funded California Alliance for Minority Program (CAMP), and undergraduate research appointments.

At UCI, Sharad Mehrotra and Naveen Ashish led a graduate level seminar course on semantic information extraction and synthesis (CS 290) during winter and spring 2007. Students involved in the RESCUE project have also presented their current research work at the UCI Social Network Research group, an interdisciplinary forum including faculty and graduate students from a number of fields. Research findings produced by RESCUE researchers (and related work by others) was included in two graduate seminars, one on Networks and Organizations, and another on Networks and Information Transmission. RESCUE research was also featured by Carter Butts in an introductory network analysis workshop offered to Ph.D. and Master's students in the UCI Sociology and Demographic and Social Analysis programs.

At UCSD, Ramesh Rao, BS Manoj, Rajesh Hegde, Rajesh Mishra, Javier Rodriguez, Don Kimball and Per Johansson supervised a total of fourteen undergraduate and graduate student projects during the 2006-2007 academic year as part of engineering design- based courses. Rajesh Hegde and BS Manoj respectively taught a graduate and undergraduate level course where topics directly from RESCUE research were covered. Ingolf Krüger covered the RESCUE integration architecture in two computer science & engineering graduate courses he taught.

In 2006-2007, RESCUE at UCI hosted undergraduate students to work on research projects. These included several undergraduate students in the UCI Honors program - these students participate in research projects as programmers, hardware engineers, systems designers - two of these students are writing undergraduate theses on RESCUE related topics. RESCUE at UCSD will have one of the Calit2 Summer 2007 Undergraduate Research Scholars working on CalMesh and networking technologies as part of the Robust Networking project.

K-12 Education: RESCUE continues to reach out to the K-12 community by sponsoring high school interns and participating in campus events for high school students. During summer 2006 and Summer 2007, RESCUE at UCI hosted a high school student working as an intern programmer developing software for the testbeds and research projects. During the 2006-2007 academic year, UCSD hosted 5 high school senior interns from the Preuss School, a charter school under the San Diego Unified School District whose mission is to provide an intensive college preparatory curriculum to low-income student populations and to improve educational practices in grades 6-12. In March 2007, RESCUE at UCI hosted "High School Scholar's Day" where they presented and demonstrated their technologies; this program is designed to increase awareness of computing science and engineering among graduating high school seniors.

In addition, RESCUE worked with Fonevia Inc. to initiate technology transfers of a crisis alert system to be used in school to parent dissemination. Through Fonevia, we are in discussions with

the Redondo Beach School District to pilot test RESCUE alert technologies in 2007 and 2008 using a phased deployment approach.

Internships and Student Exchange Programs: RESCUE at UCI hosted international undergraduate students through an exchange program with ENIC in France during summer 2006. Students participated in the creation and evaluation of several RESCUE technologies. At UCSD, Prof. Ramesh Rao hosted several visiting graduate students, including one from the University of Karlsruhe, Germany, who is studying disaster response there. Raheleh Dilmaghani of UCSD will spend summer 2007 working at Cisco Systems

Academic Community: Researchers from RESCUE continued to update the broader academic community on their progress by delivering keynote talks and presentations, chairing conference sessions and workshops, and participating as panelists. Sharad Mehrotra served as Program Chair for the ISI2006 conference, and general chair for the 2006 DBSEC conference. Kent Seamons was the Program Committee Chair for the 6th Annual PKI R&D Workshop (2007) sponsored by NIST. Marianne Winslett was the Security and Privacy Track Chair for the IEEE International Conference on Data Engineering (2007). B. S. Manoj co-chaired the 2nd International Workshop on Next Generation Wireless Networks 2006 (WoNGeN'06) [www.wongen.org] held along with IEEE Conference on High Performance Computing 2006 (HiPC 2006). Raheleh Dilmaghani proposed and co-chaired a special Academic/Demonstration session on "Modeling and Simulation of Communication Technology in Disaster Mitigation, Response and Recovery" in ISCRAM 2007in Netherlands, May 2007.

Ramesh Rao & Sharad Mehrotra delivered two keynote addresses each; Naveen Ashish presented a seminar, and Sharad Mehrotra, Charles Huyck, Shubharoop Ghosh, Sharad Mehrotra, all participated in panels at various conferences and workshops related to technologies for disaster response during the last year. Ramesh Rao chaired the NAS/NRC Committee on Using Information Technology to Enhance Disaster Management. The committee recently released its report, entitled *Improving Disaster Management: The Role of IT in Mitigation, Preparedness, Response, and Recovery.*

In addition to numerous journal papers and book chapters that were published in year 4, Sharad Mehrotra also guest edited a volume of the forthcoming IEEE Internet Computing Special Issue on Crisis Management. As part of the MetaSIM project, a white paper on "Random Access Channels Mechanism" for cellular systems was created for distribution to the broader community.

4 FUTURE PLANS

During the final year of the RESCUE, we plan to focus less on the creation of new systems and artifacts, and more on integrating the systems that have been developed; finalizing the prototypes; and deploying test systems during additional drills and exercises, and to our first responder partners. We are planning to host a conference for our industry, government and academic partners and collaborators towards the end of Year 5 to showcase our progress.