

Third-Year RESCUE Annual Report – 2005 to 2006

Responding to Crisis and Unexpected Events

ITR

Collaborative Research: Responding to the Unexpected

National Science Foundation Award Numbers:

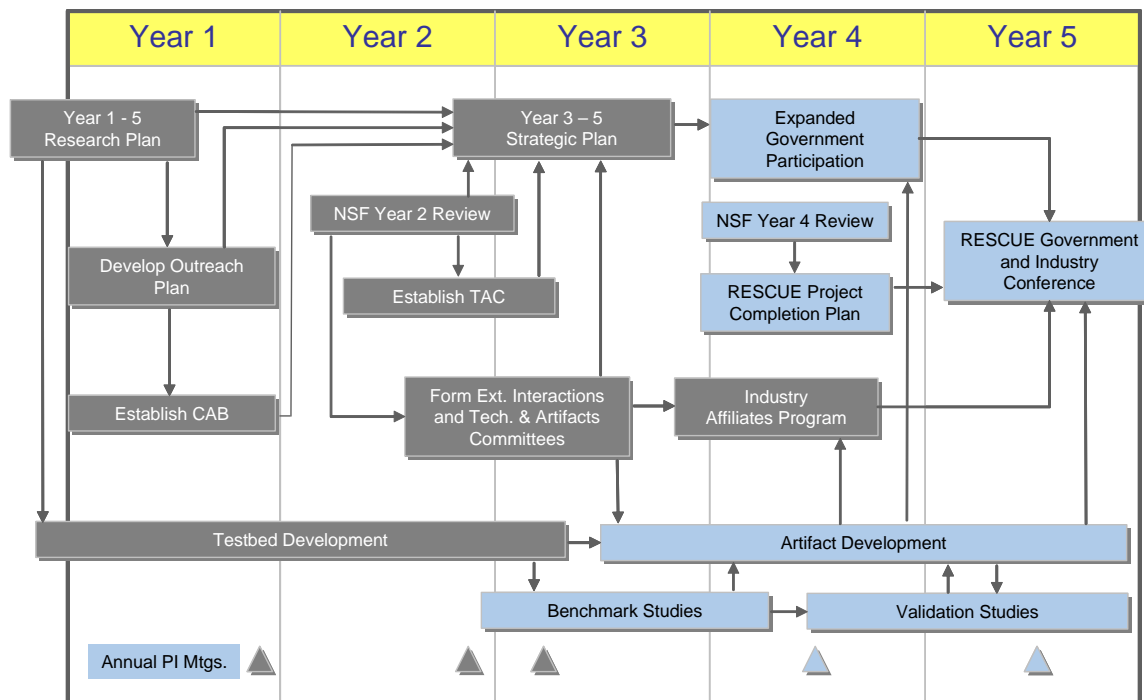
IIS-0331707, University of California, Irvine

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1 OVERALL PROGRESS IN YEAR 3 – SUMMARY

Following RESCUE’s NSF site visit in June 2005, the Executive Committee of RESCUE restructured the project to refine and redefine its goals in response to recommendations of the NSF site visit team. Working with NSF and the RESCUE advisory boards, we developed a strategic plan for years 3-5 enabling us to maximize our potential to deliver on our mission to dramatically improve the ability of emergency response organizations to gather, process, manage, use and disseminate information during man-made and natural catastrophes. The plan re-focused RESCUE along (1) **five major integrative research projects**: *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*, (2) **four project testbeds**: *the Transportation testbed*; *the CAMAS testbed at UC Irvine Campus*; *the San Diego Gaslamp Quarter (GLQ Testbed)*; and *the partner site at Champaign, Illinois*, and (3) **a set of derivative artifacts** that have direct value to response organizations and are intended to serve as a legacy of the RESCUE project beyond Year 5. This strategic plan was presented and approved by NSF in a reverse site visit held in Washington DC in November 2005.

As part of the strategic plan (Figure 1), the Executive Committee identified key milestones that were 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 subsequent partnerships with government and industry organizations. The culmination of the RESCUE project will be highlighted by a government and industry conference where RESCUE artifacts will be showcased to a broader audience and where strategic partnerships with government and industry will be unveiled. The technical milestones involve progress along major research projects, development of testbeds and artifacts, and programs to validate artifact development.



Note: Completed milestones 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 3. 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 team established a protocol **requiring** RESCUE artifacts to forge close partnerships with the user community, specifically requesting advice on design of artifacts, in addition to identifying opportunities for early adoption, testing and validation. Progress along the research projects, testbeds, and artifacts are described in Section 2 of this report. The key highlights include (1) emergence of a cohesive multidisciplinary teams for each integrative research project, (2) establishment of key partnerships with the user community for all the RESCUE artifacts, and (3) the evolution of the transportation testbed into MetaSim -- an integrative simulation environment that integrates erstwhile independent 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) into a single system significantly enhancing our capability to simulate complex response scenarios in which we can test 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.

In Year 3, RESCUE established a Technical Advisory Committee (TAC) consisting of eminent scientists from both academia and industry in related technical areas. Members of the TAC were invited to the RESCUE PI meeting in January 2006 where they were presented with the RESCUE strategic plan as well as a report on our progress. They provided valuable feedback on specific projects, and were the impetus behind the consolidation of simulation and testing efforts into MetaSim. Two new internal RESCUE committees were established in order to facilitate more direct communication between the research team and the two advisory boards (TAC and the Community Advisory Board). The **Technology and Artifacts Steering Committee** was formed to identify cross-disciplinary research opportunities that can lead to ‘big science’ and to guide the development of RESCUE artifacts. The **External Interactions Steering Committee** was formed to serve as a primary link to the first-responder community, to monitor the relevance of research to the user community, and to track other synergistic research activities. The two committees serve as the primary interface of RESCUE with the newly formed TAC and our existing Community Advisory Board (CAB) respectively. Both committees are chartered to work together to identify opportunities to test and validate technologies within the user community. The External Interactions Steering Committee met with the CAB in January 2006 to ensure that end-user needs and priorities are considered in the development the annual research plan. A full list of the TAC and CAB members are shown in Figure 2 in the Appendix.

In addition, to maximize broader impact of our research, RESCUE launched new initiatives to engage industrial partnerships, new research collaborators, and the user community. Numerous discussions/presentations/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 numerous 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 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 4). 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), 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.

Key challenges that remain include: 1) while key 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) proliferating local collaborations into nationally-based activities in order to test, validate and implement research findings for the broadest audience possible; 3) engaging industry in a manner that would promulgate the value and efficacy of RESCUE research and actively work with RESCUE researchers to be technology integrators; 4) further exploit the opportunity to “push” multidisciplinary research and technology solutions that acknowledge real and perceived gaps between end-users and technology developers; and 5) maintain focus in all five research projects so that the initial objectives identified with each project are met and that the overall mission of RESCUE is achieved.

2 RESEARCH PROGRESS IN YEAR 3

2.1 Research Projects

Project 1: Situational Awareness from Multimodal Input (SAMI)

We have progressed significantly towards realizing the SAMI goal of developing technologies that dramatically improve situational awareness for first-responders, response organizations, and the general public in each of the three technology areas identified in our strategic plan, namely signal analysis, interpretation, and synthesis; situational data management; and, analysis tools.

In signal analysis, we have made significant progress in areas that include audio-visual event extraction and synthesis where new approaches and algorithms for speech recognition (i.e., specifically in multi-microphone speech recognition and stream segregation of audio streams) are being developed. We have also developed an approach to emotion detection from audio signals. In video event detection, new capabilities for analyzing video data, (e.g., algorithms for crowd estimation and vehicle estimation from video surveillance data) are being created. In addition, a comprehensive architecture for a semantic text event extraction and management platform is being developed. In situational data management, a *multimodal event model* and a corresponding event data store is being developed. As part of this research, techniques for extraction and probabilistic representation of spatial expressions along with efficient indexing mechanisms for spatial querying are being created. In analysis tools, researchers are focusing on a new approach for document analysis by defining and implementing new operators to query document data. We are developing new approaches for GIS data searches, and are also creating innovative (probabilistic) frameworks for detection of anomalous events from sensor data.

Amongst current challenges, we are developing approaches that address complex computational and scalability issues associated with speech algorithms. Researchers are developing a formal query language and algebra for event querying. We are also completing the development of various analysis tools (for GIS and predictive modeling) and integration these tools into a situational awareness (SA) system. Future work in Years 4 and 5 will focus on completing development of robust and scalable speech recognition algorithms; development of a mobile vision platform that is part of an integrated spatial awareness system; development of semantic event extraction and management platform; development of a sensor data management system that is part of a comprehensive event analysis framework; and extending event detection to multiple sensors, prototype applications, and a GIS search engine.

Notable artifacts include a prototype version of an EvacPack mobile reconnaissance system that can capture audio, video, GPS, and text data. We have also made progress in developing a situational information dashboard, manifested as two disaster information portals. Specific progress on tasks associated with this project can be found in the Appendix.

Project 2: Robust Networking and Information Collection

The Robust Networking and Information Collection project is progressing well in each of its sub-projects: (a) Extreme Networking System, (b) Adaptive Cellular Networking System, and (c) Adaptive Information Collection System. In the Extreme Networking System, we designed and created the GLQ mesh networking testbed and used it successfully during the Mardi Gras event in February 2006 in downtown San Diego. As part of this deployment, we developed a hybrid wireless networking architecture with several innovations including a dynamic addressing scheme; identified important issues with the 802.11 MAC protocol that restrict the MAC protocol from being dynamic enough to work with link dimensions; made significant progress in the design of routing protocols that use dynamic diversity approach; identified essential services and design of such essential services is in progress; and identified the effect of MAC layer contention resolution mechanism on the end-to-end throughput in a wireless mesh network with string topology.

Progress in the Adaptive Cellular Networking System included: design of the InLET¹-based simulator for networks, now in the early stages of development and being restructured along the lines of MetaSIM development; development of resource management strategies for use in today's cellular networks during pre-, in-progress, and post-crisis situations; and development of a cellular networking simulator, also under restructuring along the lines of MetaSIM.

Researchers have made significant progress in the Adaptive Information Collection System: we developed a prototype for a peer-to-peer information collection and dissemination system, and a cellular phone-based location tracking system. A significant change in the networking research group in Year 3 necessitated the addition of two project themes: theoretical research and project integration research that spanned across all the different sub-areas. The theoretical research group is studying the capacity problem in wireless mesh networks and is developing a new networking paradigm which acts on the emotional content in the data that is transferred across the network. The project integration group is effectively integrating the cellular location tracking system with a management portal. The key artifact that is being developed as part of this project is the ENS (Extreme Networking System), which is a portable, easy to deploy, reliable, and highly dynamic hybrid networking platform which can be used for facilitating communication networks on ground zero during a disaster.

¹ Internet Loss Estimation Tool

Our progress in this project is on schedule and is consistent with the strategic plan, as far as the three sub-projects are concerned. In sub-project (a), we plan on achieving a modular routing framework that makes the ENS artifact highly flexible and hot swappable as far as networking protocol goes. In sub-project (b), we plan on integrating the InLET platform with the cellular network simulator within MetaSIM. We also plan on developing new solutions for improving the scalability of cellular networks during crises. In sub-project (c), we plan on developing the existing prototypes into production versions with more sophisticated trust algorithms built-in. The theoretical research group will focus on both building long-term theoretical solutions and a knowledge base in wireless mesh networking. Finally, one of the goals of Year 4 is the integration of the sub-projects into a single robust networking and information collection solution.

Project 3: Policy-Driven Information Sharing (PISA)

Our vision & long term goals in PISA is to design a scalable, flexible, customizable, dynamic, robust system that enables seamless policy-based information sharing across all entities involved in a disaster. Policies in such a system determine what, when, and where information is collected, with whom the collected information can be shared and how. It also specifies what processes can be applied to the information and the obligations that result from performing these actions on the information (e.g., logging of access). We recognize that the above vision is very broad, and from the start, we planned to reduce our scope by confining PISA to the aspects of the system needed for the crisis scenarios developed in Champaign.

During the past year, we worked with over a dozen organizations in the city of Champaign to develop a detailed crisis scenario involving a derailment with chemical spill, fire, and risk of explosion in Champaign. The resulting 35-page scenario serves several purposes for RESCUE: (1) scenario for discussion in focus groups run by RESCUE sociologists; (2) opportunity to identify opportunities for RESCUE technology insertion, and to integrate RESCUE artifacts in response to a single realistic crisis scenario; (3) motivating scenario for our planned work on policy-based information sharing; and (4) a source of a previously unrecognized need for privacy research (discussed in Project 5 on Privacy). We describe progress and plans for each of these in more detail below.

Sociology focus groups. Three focus groups led by RESCUE sociologists will take place in Champaign on July 31 and August 1 of this year. The discussion of the derailment scenario in these groups will lead to valuable insights into the management of disasters in mid-size cities.

Opportunities for RESCUE technology insertion. The following RESCUE research results and artifacts can be helpful in responding to the derailment scenario: how to disseminate information to the public; next-generation 911 services; information integration and privacy for family-and-friends welfare inquiry web sites; extreme networking; MetaSIM; flexible authorization services for information sharing; event analysis; InLET loss estimation; ManPacks (based on CalMesh) and EvacPacks, including data analysis and reduction facilities. During the coming year, we will work to include these technologies in an extended demonstration focusing on the derailment scenario.

Policy-based information sharing. We have analyzed the derailment scenario and identified the real-world policies for inter-organizational information sharing in the scenario. Based on our analysis, we decided to focus PISA research along the following directions – significant progress was made along each of the following directions in Year 3.

- **Run-time scalability and robustness.** The goal is to ensure that the authorization server and policy engine is not the bottleneck of the system or an attractive point for attack.

- **The theoretical underpinning of policy-based information sharing:** i.e., an approach to represent and reason about authorization, obligations, and release policies in a system with many peers.
- **Trustworthy audit trails.** The goal is to ensure that insiders cannot take advantage of a crisis to access information inappropriately, then cover up their tracks

The research described above will culminate in a PISA artifact that provides flexible, policy based information sharing capabilities. The PISA artifact is being designed on top of the US government's Disaster Management Information System (DMIS) which will serve as the information broker substrate for our system. The City of Champaign has been experimenting with DMIS; DMIS is cumbersome to set up and its authorization facilities are rigid enough to limit its use in a crisis. PISA artifact will extend DMIS to support policies for authorization, obligations (audit, notification) and release of information. It will also support enforcement of multiplicity of kinds of authentication and authorization policies (including trust negotiation) rather than just accounts and passwords. Furthermore, the artifact will integrate our research results to achieve scalable, robust policy management that supports trustworthy audit facilities. In Year 3 we have initiated the design of the basic architecture for the PISA artifact. Our focus in the next year will be to both extend the design and incorporate extensions to DMIS to realize the PISA artifact.

Project 4: Customized Dissemination in the Large

The dissemination project explores socio-technical solutions to effective & timely risk communication to the public-at-large that promotes self protective actions and reduces exposure to natural and human-induced threats. The project focuses on three interrelated goals: (1) *understanding dissemination scenarios*, (2) *supporting customization needs*, and (3) *developing scalable, robust delivery infrastructure*. This component of RESCUE's research plan has become particularly significant in light of the June 26, 2006 Executive Order requiring the Department of Homeland Security to develop an integrated, all-hazards warning system for the nation. Developing and implementing such a system requires wide-ranging knowledge on state-of-the-art communications technologies, the design of warning messages, human behavior in response to warnings, and the institutional and organizational aspects of warning systems. RESCUE's work in the area of dissemination can make major contributions to the nation's ability to effectively warn the public in extreme events of all types.

Our efforts on understanding dissemination scenarios focused this year on ***real-time seismic alerts*** which are very short-term alert technologies where timelines range from minutes/seconds before impact to hours after impact. We organized an Earthquake Early Warning (EEW) Workshop at the UCI Campus in May 2006 that brought together researchers from IT, seismology, earthquake engineering, and social science with various stakeholders including emergency managers, state & local policy makers, local community (schools & parents) and private industry. The workshop discussed the needs, challenges, and feasibility of earthquake early warning including the role of RESCUE dissemination technologies in a pilot study to deliver alerts to California schools. The workshop raised important challenges in the implementation and deployment of new technologies to disseminating earthquake alerts and warnings that we have summarized in an appendix to this report. Other efforts on understanding dissemination scenarios included detailed quantitative analysis of variety of data related to Sept 11th WTC attacks that provided insight on the role diverse organizations can play in the dissemination process. We also initiated a simulation based study on the diffusion of crisis information through interpersonal networks.

From an IT perspective, we developed a system to disseminate customized information that leverages existing organizational networks and notification systems to reach the public during crisis. Customization policies to accommodate multiple delivery modalities, geographies, disaster

contexts and recipient knowledge (language, disabilities etc.) can be specified through a rule engine. Mechanisms to exploit peer-based publish subscribe infrastructure for scalable and efficient customized dissemination & techniques for cost-based optimization of push vs. pull based dissemination were developed. Our work on robust & scalable delivery infrastructures focused on developing a flash dissemination protocol – CREW, a minimum-state peer-to peer (P2P) gossip-based protocol that outperforms state of the art dissemination systems (e.g., BitTorrent, Bullet, SplitStream) - while maintaining the stateless fault-tolerance properties of traditional gossip protocols. Further, we have also investigated centralized, global-knowledge protocols for dissemination. We also explored fast, reliable, and efficient dissemination of application-generated data in heterogeneous wireless networks that exploits multiple radio interfaces, hybrid networks and mobility patterns.

In summary, in Year 3 we have made substantial progress along both research and artifact development as specified in the strategic plan. We have developed collaborations with industry partners (SBC), government agencies (CA Governor's Office of Emergency Services), school board officials to deliver warning information to K-12 schools. Talks are in progress with other academic partners (Caltech, UC Berkeley) and government partners for RESCUE to serve as key IT provider in a pilot study that plans to implement real-time alerts within the State of California; and to establish a non-profit consortium of entities interested in public warning systems.

In Year 4, we intend to launch a study that explores dissemination scenarios with longer warning times, e.g. hurricanes. We have initiated preliminary work on the role of citizen communications such as blogs for creating awareness among the public and responders. Our plans are to build an analytical framework for describing public communications following a disaster through remote and in-field ethnographic studies of real disaster events. Examining both low- and emerging high-tech forms of citizen communications, we will develop prototypes for location-aware, and hybrid digital-physical technologies that support different forms of information seeking, provision and personal expression. We expect to leverage efforts of the SAMI effort on a hurricane analysis portal to develop a portal-based hurricane warning system for the public at large. Furthermore, our recent discussions with the city of LA and City of Ontario has helped us identify a need for disaster donor management portal that connects the public & first-responder organizations with the donor organizations willing to provide resources required. Both our community partners identified this as a primary gap where IT can significantly help. We recognize donation management as an interesting and important challenge to which our current work on publish-subscribe systems can provide a technology substrate. Depending upon resource availability (and additional funding available), we intend to explore developing a scalable and robust donation management system.

Project 5: Privacy Implications of Technology

In response to the NSF's recommendation, in Year 3 we launched a new project to explore privacy implications of key situational awareness and data sharing technologies being built in RESCUE. Our goal is to understand privacy concerns and explore if privacy technologies can be designed to alleviate such concerns. The project scope includes IT-use case studies, theoretical research on quantifying information disclosure, algorithmic approaches to control disclosure ("privacy-knobs"), and validation studies to test effectiveness of such knobs in alleviating privacy concerns.

Rapid progress was made along all the major objectives. In collaboration with Erin Kenneally (Law and Digital forensics specialist at UCSD), we launched a year-long study to explore how surveillance and situation monitoring technologies can be designed and deployed to minimize the potential privacy-invasive applications of surveillance technology, while simultaneously realizing

its utility. As a preparatory step, we designed and implemented multimedia event detection and querying middleware framework (CAMAS/VM [virtual machine]) for building situation monitoring applications. CAMAS/VM, deployed over the Responsphere camera and sensor testbed provides a rich platform for the privacy study. We also initiated discussions with VTC (a company that builds data collection and reporting software for Emergency Medical Technicians (EMT)) to study confidentiality and privacy threats in collecting & sharing medical records. In addition, in Year 4, we expect to launch a similar study for customized information dissemination technologies.

In terms of theoretical research, we made progress in defining location privacy in mobile and pervasive applications. While existing techniques focus on privacy when user identity is kept anonymous, we explored such threats in applications where the identity is pseudo-anonymous and non-anonymous which creates additional inference channels due to linkage through identity. We also characterized privacy threats in pervasive spaces when sensor data is used to detect events for situation monitoring. We designed algorithmic solutions to limit disclosure control in both these settings. We developed a novel approach to K-anonymize data using multidimensional partitioning that significantly outperforms all existing techniques. Also, we developed disclosure control mechanisms resilient to inference attacks based on pattern recognition in data. Both these works have significant implications to designing privacy knobs in data sharing and publishing. Progress was also made in designing privacy-preserving authentication (secret handshakes) and information delivery (OSBE) techniques and new research began on privacy-preserving group authentication (GSH).

We began exploring a novel data sharing architecture based on outsourcing intended for private organizations and individuals (where privacy is an utmost concern) to share critical information with first responders. This architecture builds on our effort on the PVault/Delegate system that provides secure access to personal data from both trusted and untrusted mobile platforms. We are considering 2 different case studies to drive our research privacy issues in data sharing. These include: (1) a collaboration with VTC (mentioned earlier) that collects medical information about individuals and maintains the data to help EMT provide better medical triaging, (2) a family reunification problem identified by the help of Red Cross in Champaign. In the immediate aftermath of a large disaster, there is usually a proliferation of family-and-friends disaster welfare inquiry web sites. Our ongoing research on information integration, entity resolution, and information extraction is well geared to provide the basic technology to find such sites, parse their interfaces, extract information from the databases behind them and from free-text entries, integrate the information gleaned from multiple sites, resolve the entries, and make it available through a one-stop-shopping interface. Such a family reunification system has significant privacy challenges in preventing sensitive information in falling into the wrong hands.

In summary, in our first year of the privacy project (i.e., 3rd year of RESCUE), we have launched privacy studies, explored key privacy technologies that can serve as “privacy-knobs”, and created a testbed that will serve as a validation platform. In Year 4, we expect to continue on our current research & further explore infusion of the privacy knobs in a few information sharing and situation monitoring systems, and validate the effectiveness of such technologies.

2.2 Testbeds

We have created four testbeds for the purpose of evaluating the efficacy of our research. Underlying goals with these testbeds include: (a) create a set of living laboratories and simulations to mimic real-world conditions for regional and incident level crises; and (b) provide a means to test and validate the research and artifacts being developed by each of the five research projects. The testbeds are MetaSIM (which evolved from the Transportation Testbed

and is now broader in scope); Gaslamp Quarter (GLQ) testbed in downtown San Diego; CAMAS testbed at UCI; and the Champaign, Illinois Testbed.

MetaSIM Many projects within RESCUE include a simulation component, and integration of the various simulators has a potential for tremendous synergy. The transportation testbed platform was expanded in scope to encompass existing simulation efforts at multiple research sites and has been renamed MetaSIM. MetaSIM is the result of integration of diverse simulation capabilities being developed by different RESCUE partners into a single integrated system - an amalgamation of transportation simulation with micro-level agent simulator (DrillSim being developed at UCI), ImageCat's InLET loss estimation tool, and a cellular infrastructure simulator being developed at UCSD. MetaSIM provides researchers with an effective mechanism to test and validate IT solutions in a very rich set of scenarios which none of the individual simulators could provide on their own. For MetaSIM to achieve the ultimate goals of modularity and extensibility, many integration issues must be resolved. These will be addressed by leveraging existing resources within RESCUE and focusing on a key application: modeling the benefits of integrating cellular technologies during evacuation.

The progress on the other three testbeds has remained on track, as indicated in the milestone chart. Highlights of testbed activities are described below.

CAMAS We finished indoor instrumentation of UCI's Calit2 building and began outdoor instrumentation; instrumented an entire emergency response zone around Calit2 (1 km²) with 802.11g wireless and various other technologies, and began planning for instrumentation of UCI administration buildings. Drills and training exercises carried out included EH&S Biohazard Training, evacuation of Calit2 building, and evacuation of UCI Zone 3. Research and artifacts tested included EvacPack, CAMAS Virtual Machine (VM), sensor streaming over unstable networks, mobile camera utilization, social science experiments on noise-level to crowd density correlations and on-site versus remote crowd estimations.

GLQ Testbed A mobile communications and sensor network was designed, built and installed in the GLQ testbed for San Diego's 2006 Mardi Gras on February 28, 2006. The communications network infrastructure consisted of a CalMesh network, Tropos wireless access points, a satellite dish deployment and a Mushroom network. VPN nodes fitted with cameras were connected to the mesh. Video data was streamed to the San Diego Police Department command post and the UCSD Technology Operations Center. Researchers integrated different technologies and networks to create a single, more reliable network. Other research and artifacts tested included Location Based Tracking, Mobile Vision, Call-to-Collaborate, and an audio-video system for situational awareness. Technologies and products were tested in real time, under field conditions; researchers assessed their performance and usefulness when integrated together.

Champaign Testbed enables experimentation with RESCUE artifacts, studies organizational decision-making in crises that occur in a medium-size city, and get first-responder input into artifact requirements. The PISA project worked with emergency response organizations to develop a disaster scenario that will serve as the topic for the sociology focus groups in Champaign, a source of potential applications for RESCUE artifacts, a focusing scenario for PISA architecture, and the expected basis for tabletop exercises with city agencies over the coming year. Champaign has shared a portion of their library of 911 calls for use by RESCUE researchers. RESCUE has given the city three CalMesh nodes, which will be used in conjunction with a new high-tech mobile networking trailer to extend networking out into the field during disaster response.

3 BROADER IMPACT

3.1 Community Outreach

Outreach to First Responders: Partnership/collaboration with first responders has been an important strategy in RESCUE from the very beginning of the project. In Years 1 and 2, the primary role played by first responders (through our Community Advisory Board) was advisory – e.g., providing feedback on relevance and prioritization of research, identification of key technology gaps, advice on creation of testbeds). Year 3 witnessed an evolution in the role played by first responders in RESCUE with the introduction of a few integrative artifacts (each of which was tasked to identify and establish explicit collaborations with first responders). Many new government partners were added. Examples include City of Ontario (in the context of Ontario Portal – a SAMI artifact), State of California OES (for real-time alert system – dissemination artifact), and City of Champaign (for PISA artifacts). In addition, RESCUE partners interacted with the research team in designing case studies, orchestrating drills, and providing valuable (and candid) feedback of usefulness and usability of technologies at the RESCUE PI meeting. As an example, EH&S division at UCI & its counterpart at UCSD were deeply involved in testing RESCUE technologies at variety of emergency drills at the campuses. The city of Champaign worked with RESCUE researchers on developing a detailed crisis scenario involving a derailment with chemical spill, fire, and risk of explosion in Champaign. Furthermore, multiple organizations provided a variety of datasets for use by RESCUE researchers (e.g., Orange County Fire Authority as well as the police department at Champaign provided us with 911 call transcripts). With multiple ongoing discussions (e.g., with City of Dana Point), we anticipate further technology- focused partnerships to emerge in Year 4. With the increasing role of first responders in RESCUE, multiple new partners were added to RESCUE CAB. These include addition of Fred Halenar (City of Champaign), Rich Toro – Orange County Fire Authority (OCFA), and Jacob Greene (City of Ontario, Fire Department), and Marc Gomez (UCI EH&S).

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. The RESCUE eNews features short descriptions of RESCUE developments of interest and brings light to all the different components of the project. Furthermore, RESCUE's Earthquake Early Warning Workshop (May 2006) which hosted first responder representatives from both local and state organizations, provided another conduit to seek input from the user community. During the workshop, RESCUE researchers were able to validate the efficacy of a prototype Real-Time Crisis Alert System, gain insights from discussions regarding the social, organizational, and cultural contexts surrounding technology transfer, and develop partnerships for future collaboration.

Industry Interactions: This year's cultivation of industrial relationships has resulted in many achievements. A number of strategic alliances were forged with companies such as Ether2, Printronix, CDWG, AMD, Sun Microsystems, IBM, and Psion Teklogic. Printronix generously donated most of the RFID equipment utilized in the UCI CAMAS tedbed. AMD provided 4 dual-core (8 processor) Opteron MP 875 processors at a greatly reduced price. IBM donated 22 e-series servers that are currently being used as a Beowulf cluster serving the needs of many research projects. Additionally, partnership discussions and/or non-disclosure agreement negotiations continue with Boeing, Apani Networks, Asvaco, IBM, Convera, Conexant, Vital Data Technologies, Motorola, and other information technology companies. Funding opportunities were pursued with The School Broadcasting Company in the form of a UC Discovery grant. In addition, conversations with SBC started to form a non-profit nation wide consortium on disaster

warning systems. Local industry in Orange County and San Diego frequently participate in RESCUE seminars and meetings and are also invited to RESCUE PI meetings.

Broader Community: RESCUE's initiative to impact the broader community comes at many levels. During year 3, RESCUE researchers actively participated in programs designed to reach out to diverse communities which include organizations such as the American Indian Summer Institute in Computer Science and Women in Computer Science. The PISA and Dissemination projects have engaged K-12 school administrations as part of their research. RESCUE has also generated interest from the government through visits from the California Governor's Office and San Francisco Mayor Gavin Newsom. There were initial discussions for international research alliances with representatives from Australia (NICTA, National Information and Communications Technology, Australia) and India (the US-India Summit on Education, Research and Technology).

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. Our seminar series, which hosted a variety of guest speakers from academia, industry, and first responder organizations, not only helped to educate our students but has drawn a broad audience outside the project to include attendance by the larger university population, industry, and government. Details of RESCUE seminars 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. During summer 2006, the project is taking part in sponsoring three students in the Summer Undergraduate Research Fellowship in Information Technology Program (SURF-IT) which provides these students with a unique 10-week summer research opportunity.

K-12 Education: Within K-12 Education, RESCUE sponsored a total of four student interns from the Preuss School, a charter school in San Diego whose mission is to provide an intensive college preparatory curriculum to low-income student populations. RESCUE has also been involved in K-12 diversity programs, working with organizations including Girls, Inc. and the Sally Ride Science Festival whose main focus is to encourage girls' interests in math and the sciences.

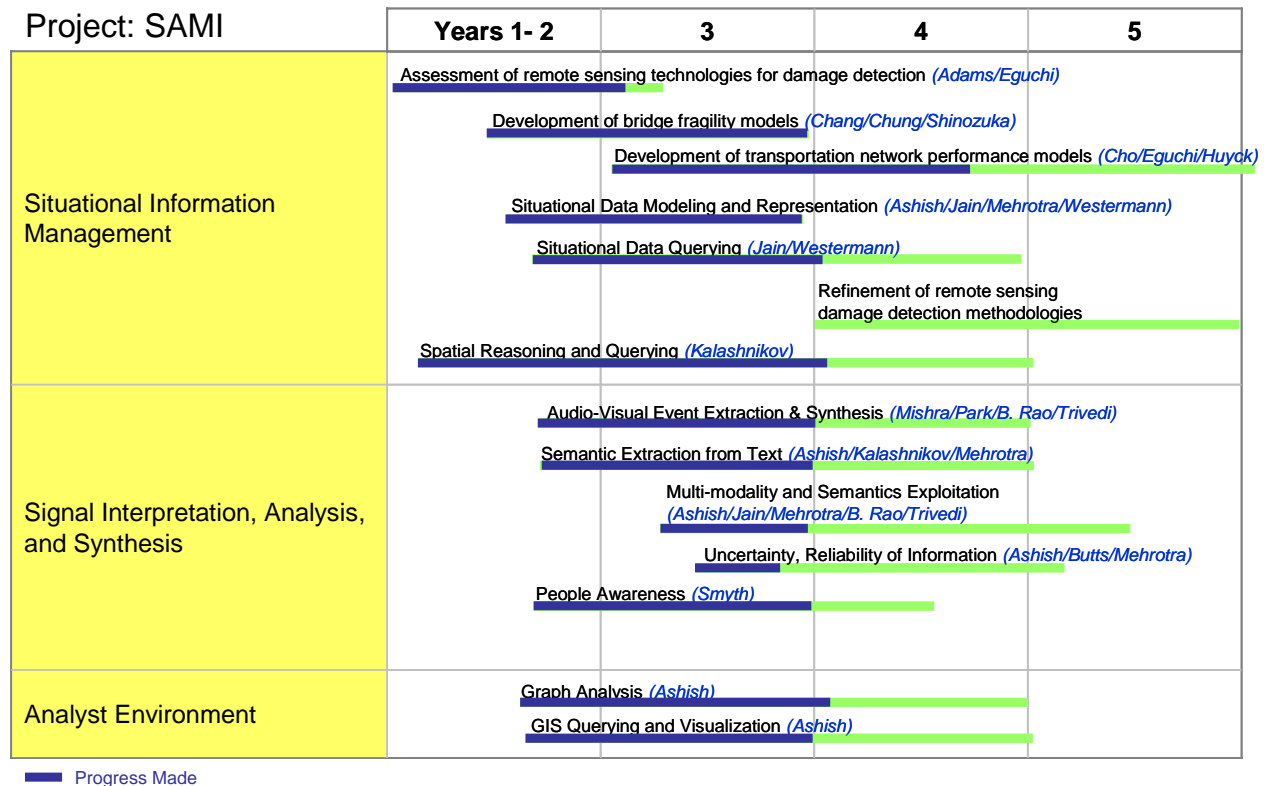
Internships and Student Exchange Programs: During the course of Year 3, RESCUE students have had the opportunity to participate in a number of internship programs. Students have had the opportunity to intern at many leading technology companies including AT&T and IBM Research Labs and Google. Internships within first-responder organizations have also resulted from our partnerships with the City of Dana Point and the Orange County Fire Authority. As part of our education outreach program, RESCUE has also welcomed six international exchange students from France and Italy. This proved to be mutually beneficial to both the project and its exchange students so much that two of the interns have returned to RESCUE after obtaining their degrees to augment our programming staff (one of whom is expected to join the Ph.D. program at UCI) and another has joined UCI as a MS student.

Academic Community: The RESCUE team was privileged to be the host for the 2005 Cybertrust Principal Investigators meeting in which more than 225 researchers participated. Cyber Trust 2005 provided a forum for NSF-supported cyber security researchers and developers to present and discuss their research with their colleagues, and interact with NSF staff, program officers and directors. In May 2006, Sharad Mehrotra served as Program Committee Co-Chair of the 2006 IEEE Intelligence and Security Informatics conference. B.S. Manoj along with Alex

Hubenko jointly organized a special session and a workshop on Communication Challenges in Emergency response at the May, 2006 ISCRAM Conference; BS Manoj co-chaired a workshop titled "Design of Wireless Networks for Reliability, Availability, and Emergency Response" at the IEEE HiPC in December 2006.

Appendix: Detailed Research Project Milestones

The following charts provide a summary of progress in each project/task. Next to the timeline for each task are the researchers associated with that task. Progress is indicated by the dark blue shading; the initial timeline – as presented in the strategic plan – is presented by the light green line. With the exception of work in the information reliability area (where a slight delay has been experienced), progress is on track in all projects and tasks.



Project: Robust Networking

	Years 1- 2	3	4	5
Extreme Networking Systems	Always Best Connected (ABC) (Mishra/Manoj/R.Rao)		Design and development of beaconing subsystems (Manoj/R. Rao)	
		GLO Mesh Networking Test Bed Deployment (Jafarian/Manoj)		
		Development of a hybrid wireless network architecture (Manoj/Mishra/R. Rao)		
			Design and development of network management systems (Mishra/Manoj/R. Rao)	
		Designing MAC layer for ENS (Mishra/Manoj/R. Rao)		
		Design of routing protocols for ENS (Mishra/Manoj/R. Rao)		
			Development of essential services for ENS (Mishra/Manoj/R. Rao)	
Robust Networking Systems		Developing an INLET based earthquake simulator for networks (Eguchi/Hyuck/Pasco)		
		Devising resource management solutions (Jafarian/Manoj/R. Rao)		
		Development of a network simulator platform (Jafarian/Manoj/Pasco)	Integration of network simulator with earthquake simulator (Jafarian/Manoj/Pasco)	
Adaptive Information Collection		High-Level Architecture Design of Two-Level Telecommunication Simulator (Jafarian/Manoj/Pasco)		
		Cell Phone as a Sensor (Ganz/Zhu)	Cellular Platform for Location Tracking (Zhu)	
		Adaptive Data Collection in Dynamic Distributed Systems (Venkatasubramanian)		

Progress Made

Project: PISA

	Years 1- 2	3	4	5
Infrastructure Groundwork	Message Bus info sharing infrastructure (Pasco)			
	TrustBuilder trust management infrastructure (Seamons)			
		Port message bus to small-organization environment (Pasco)		
		Traust 3 rd -party authorization service for trust negotiation (Winslett)		
			Authorization for Reunification Website (Seamons)	
			Information Integration for Reunification Website (Li)	
Understanding Domain Policy	LA crisis IT use study (Tierney)	Roundtable discussions with stakeholders for target scenarios (Tierney)		
		Interviews with emergency management to obtain detailed understanding of information sharing policies (Winslett)	Address human acceptability of PISA in context of the chosen disasters (Tierney)	
Modeling and Development		Identify information sources (Winslett)		
		Model information sharing policies (Seamons/Winslett)		
		Express policies using existing policy languages (Seamons/Winslett)		
		Scalability and availability work on policy engines and trust management infrastructure (Pasco/Seamons/Winslett)		
Integration		Develop information broker to facilitate sharing (Pasco/Winslett)		
		Integrate broker with SAML and message bus (Ashish/Pasco)		

Progress Made

Project: Dissemination

	Years 1- 2	3	4	5
Understanding and Classifying Dissemination Scenarios, Modalities and Needs		Modeling Information Flow Through Networks (Tierney)		
	Responder Networks in the WTC Disaster (Tierney)			
	Network Data Sets (Tierney)			
Customizable Dissemination Systems		Customizable Dissemination in Pervasive Spaces (Venkatasubramanian)		
		Rapid Pub-Sub in Peer Based Networks (Venkatasubramanian)		
Exploiting IT Infrastructure for Dissemination			Reliable, Prioritized Flash Dissemination (Mehrotra)	
	Flash Dissemination in Heterogeneous Networks (Mehrotra)			
		Dissemination in Wireless Networks (Mehrotra)		
	Push vs. pull based dissemination (Mehrotra)			

Progress Made

Project: Privacy

	Years 1- 2	3	4	5
Case Studies	UCI study of observation systems for situation monitoring			
	Champaign study on information sharing			
	OC study on Information Sharing			
	Privacy Concerns in dissemination systems			
Understanding Privacy Concerns in Technology infusion		Situation Monitoring Scenario		
		Data Sharing across govt. orgs.		
		Data Sharing across govt. & private orgs		
		Dissemination scenario		
Quantifying privacy & privacy preserving mechanisms	Information hiding by data perturbation & anonymization			
		Techniques for location privacy		
		Information hiding by spatio-temporal data		
	Inference control mechanisms			
Privacy preserving observation systems	Trigger-based pervasive spaces			
	Privacy preserving architecture			
		Privacy/Utility tradeoffs		
		Building applications, testing, validation		
Privacy preserving data sharing systems	Policy language design			
		Privacy policy enforcement Mechanisms		
		Privacy Policy realization in Data Publishing based architecture		
		System implementation, testing and validation		

Progress Made

Appendix: RESCUE Advisory Committees

Technical Advisory Committee	Community Advisory Board
Rakesh Agrawal Microsoft Fellow	City of Champaign Fred Halenar
Louise Comfort Professor of Public and Urban Affairs University of Pittsburgh	City of Irvine Dawna Finley Eileen Salmon
Mario Gerla Professor of Computer Science University of California, Los Angeles	City of Los Angeles Ellis Stanley
Fred Juang Motorola Foundation Chair Georgia Research Alliance Eminent Scholar Georgia Institute of Technology	City of Ontario Jacob Green
David Kehrlein Environmental Science Research Institute (ESRI)	City of San Diego Police Department Karen Butler William Maheu
Dick Kieburz Professor Emeritus OHSU/OGI School of Science and Engineering Pacific Software Research Center	Governor's Office of Emergency Services James Watkins (retired)
Raghu Ramakrishnan Professor of Computer Sciences University of Wisconsin-Madison	Los Angeles County Office of Emergency Management Bob Garrott
	Orange County Fire Authority Rich Toro
	SPAWAR Paulette Murphy
	UCI Environmental Health and Safety Marc Gomez
	UCSD Campus Police David Rose

Figure 2. RESCUE's Technical Advisory Committee (TAC) and Community Advisory Board (CAB)

Appendix: Challenges in Real-world Deployment of Next Generation Earthquake Alert Systems & Implications to RESCUE

In May 2006, RESCUE organized an Earthquake Early Warning (EEW) workshop (<http://www.itr-rescue.org/outreach/disseminationworkshop2006>) at the UCI campus that brought together researchers from IT, seismology, earthquake engineering, and social science with various stakeholders including emergency managers, state & local policy makers, local community (schools & parents) and private industry. Attendees included:

- Richard Allen – Assistant Professor, Seismological Laboratory, UC Berkeley
- Evan Arguelles and Jeff Briggs - The School Broadcasting Company
- Mark Bassett – State of California Governor's Office of Emergency Services, Southern Region, Program Manager
- Jim Goltz – California Institute of Technology (CalTech), Earthquake and Tsunami Program, California Governor's Office of Emergency Services
- Thomas Heaton – Professor of Geophysics and Professor of Civil Engineering, CalTech
- Wendy Milligan – Masters in Public Administration, Certified Emergency Manager. Worked in the Ventura County Office of Emergency Management.
- Deborah Riopelle – former UCLA, Center for Public Health and Disasters TriNet Project Manager. Currently at the VA Greater Los Angeles Healthcare System.

The workshop, besides discussing the needs, technological feasibility and challenges raised important issues in the implementation and deployment of new technologies to disseminating earthquake alerts and warnings. The workshop attendees concurred that Basic science is maturing in ways that indicate that it will be possible to issue real-time alerts for earthquakes occurring in well-instrumented areas in northern and southern California. Efforts to assess the feasibility of issuing real-time alerts have been under way for a number of years. At the same time, the attendees recognized that developing dissemination protocols for real-time earthquake warnings is not simply a matter of better science. Rather, dissemination is a complex process that involves scientific analysis, dissemination technologies, and a broader institutional framework that enables the implementation of science and technology in real-world settings.

RESCUE's first workshop on real-time earthquake alerts focused on both the scientific state-of-the-art and real-world conditions that must also be addressed before new systems can be put into the field. Broader societal issues that were raised in the workshop include issues related to liability for issuing warnings; the need for some specific organization or consortium of organizations to assume authority and legal responsibility for managing the seismic alert network; the need to educate users and the public regarding the uncertainties associated with real-time dissemination and to explain clearly what systems can and cannot do; the need for strategies to deal with false alarms and missed warnings, and a variety of other "non science," non technology" concerns. Systems cannot be implemented until such concerns are worked through and settled.

Despite these challenges, from the RESCUE perspective, the future looks very positive. The US Geological Survey is funding additional work on real-time assessment and information dissemination. The manager of the California Integrated Seismic Network is committed to ongoing work with RESCUE. The School Broadcasting Company, which already disseminates safety information to schools in Southern California and around the U. S., is partnering with RESCUE. Conditions seem ripe for fielding a demonstration project in the not-distant future.

It is also important to note that even if this potential is not realized (and we think it will be), RESCUE still has a great deal to contribute with respect to developing tools for rapid information dissemination immediately following an earthquake--that is, for emergency information dissemination, rather than real-time pre-event alerts. This important dissemination phase would include the provision of information on toxic spills, road closures due to earthquake damage, aftershock advisories, and other updates that the public will require in the immediate aftermath of an earthquake. Products like "Shakemap," which is operated by the USGS, already provide near-real time information on earthquake impacts, but the information provided in Shakemap deals with earthquake shaking intensities, not with other information that is needed to ensure public safety. In sum, RESCUE is moving forward rapidly to engage the scientific and emergency management community on the dissemination of real-time alerts, and we are making significant progress. Even if this particular plan does not come to fruition during the life of RESCUE, a considerable amount of work can still be done in the area of emergency information provision.