# An Interactive, Intelligent, Spatial Information System for Disaster Management: A National Model

by

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**ABSTRACT**

The proposed research addresses four criteria of high performance computing and communications. First, the research addresses the national need to increase the efficiency of preparedness, response, and recovery operations in disaster management. Disaster management represents a set of interdependent problems that require intensive communication and coordination among organizations and jurisdictions to reduce risk and losses to the nation. Unresolved, these problems become cumulative and losses increase exponentially. Recent disasters have demonstrated that investment in information technology significantly increases the capacity of local communities to respond in timely, effective ways, but the technical information infrastructure has not been developed to extend this capacity to the national level. This research continues the design and development of an interactive, intelligent, spatial information system (IISIS) that will assist practicing managers in solving the problems of disaster management at local, state, and national levels of jurisdiction. The system is distributed; that is, it activates separate knowledge bases at different locations to address a shared problem simultaneously.

Second, the proposed research specifically addresses the problem of hazardous materials management, but has implications for managing the entire range of hazards that afflict the nation: earthquakes, floods, fire, and severe winds. Managing the toxic products of our industrial society affects every US community on a daily basis. The steady accumulation of hazardous materials from industrial production and practice represents a continuing and growing threat to the environment, health, and safety of the nation. Current laws governing hazardous materials management are based upon a "community's right to know" of the presence of these materials, but the complexity of tracking the quantity, type, direction, and timing of 466 extremely hazardous materials flowing among some 86,000 communities, each with varying numbers of facilities for use and storage, throughout the nation rapidly exceeds the capacity of conventional means of monitoring. Further, the problem is dynamic, as monitoring involves both storage at fixed facilities and transportation of hazardous materials via road, rail, water, and air. These information requirements can only be met by using a carefully designed high performance computing and communications infrastructure.

Third, the number of communications within and between organizations and jurisdictions increases enormously in response to a major hazardous materials release or natural disaster, overwhelming the capacity of conventional technologies to receive, process, and transmit information in a timely, accurate manner. IISIS would provide a means of facilitating the transition between routine and disaster operations, enabling communities to assume greater responsibility for their own safety.

Finally, the University of Pittsburgh has advanced facilities in computing and experienced faculty in computer science, public management and policy, and engineering. IISIS represents a cooperative effort of public, private, and nonprofit organizations to address shared risk. Once achieved for hazardous materials, gains made from this effort may be extended to the dynamic and uncertain conditions of natural hazards.

# AN INTERACTIVE, INTELLIGENT, SPATIAL INFORMATION SYSTEM FOR DISASTER MANAGEMENT: A NATIONAL MODEL

## A Problem Solving Environment for Disaster Management

This research proposes to review, refine, and continue the design and development of a prototype interactive, intelligent, spatial information system (IISIS) that will assist practicing managers in the problem solving environment of disaster operations. The prototype addresses the problem of decisionmaking under dynamic conditions in which a system of organizations -- public, private, and nonprofit -- evolves rapidly in response to a major technological or natural disaster and then contracts as needs are met and participating organizations return to their normal routines. This sequence of rapid transitions requires timely, accurate search, processing, and integration of information from multiple sources and multiple disciplines to enable the practicing managers to mobilize response operations quickly, to allocate scarce resources of equipment, personnel, and supplies efficiently, and to de-mobilize them responsibly as needs change. The design of the system is distributed; that is, it activates separate knowledge bases at different locations to address a shared problem simultaneously.

The demands for rapid processing of information from multiple sources under the urgent constraints of a natural, technological, or civil disaster create a stressful, dynamic operating environment for practicing disaster managers, who bear legal responsibility for protection of life and property in their respective communities. Advanced computing techniques of information search, processing, representation, transmission, and logical inference from known data to possible courses of action provide the potential for significantly increasing the capacity of multiple organizations in a community to reduce risk from known hazards and to coordinate response actions more effectively when disaster does occur. Carefully designed, a network of computers accessing distributed knowledge bases and operating in parallel[1] can support a network of organizations engaging in parallel response operations activated by the same hazardous event. The technical computing and information infrastructure enables the set of practicing organizations to mobilize coordinated actions quickly and efficiently in response to a given hazard within a single jurisdiction, between jurisdictions as the response expands, and within and between jurisdictions as the response de-escalates and turns to recovery. It also enables organizations to learn more effectively from the shared experience.

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[1] Computers are said to operate "in parallel" when separate computers are activated in response to the same problem, and perform separate functions directed toward solving that same problem. Organizations engaged in hazardous materials management also are activated by the same problem -- a release of an extremely hazardous chemical -- and perform different functions directed toward minimizing risk and losses from the release.

The IISIS prototype is designed to support decision-making by practicing managers through all phases of disaster operations -- mitigation, preparedness, response, and recovery. While the IISIS may be developed for all hazards -- earthquakes, fire, flood, severe winds, civil unrest or terrorist attack -- this prototype focuses on hazardous materials management as response to a release moves through organizational and jurisdictional levels. Hazardous materials management involves the reduction of risk and response to releases deriving from the production, storage, and transportation of hazardous materials, a risk borne by all US communities. The 1995-96 Project Year will focus on interactions among organizations with information distributed at the city/county level. Subsequent project years will move the project to state and national levels. This problem includes monitoring changing states of risk at multiple locations for disaster managers with varied levels of training and responsibility and providing timely feedback from this assessment to participating managers in the community-wide system.

**A Sociotechnical Dual Use System for Disaster Management**

The IISIS prototype is designed to support a sociotechnical dual use system for disaster management. That is, managers may use the system in their respective public, private, and nonprofit organizations for daily, routine operations in managing hazardous materials: reporting what quantities of which products are used, produced, stored, or shipped within their respective areas of responsibility. When a release occurs and threatens other segments of the community, the IISIS activates a community-wide response network that creates a disaster-specific knowledge base by drawing relevant information from multiple data bases and multiple organizations to support interorganizational and inter-jurisdictional decision making in reference to that event.

The system links two types of information processing systems: 1) the technical system of computers; and 2) the human cognitive system of decision makers and their respective organizations. Both systems are amplified by networks of communication among multiple computers for the technical system and multiple decision makers for the organizational system. The load, rate, and complexity of information that is transmitted within and among organizations in dynamic disaster operations is massive. Without technical support, the information processing demands overwhelm the cognitive capacity of individual managers and organizations to absorb, process, and use the flood of incoming information as a basis for timely, informed action. Using distributed knowledge bases and a network of computers operating in parallel, the technical computing system is designed to support the human organizational system in its conduct of distributed, parallel activities in response to the hazardous event.

**Current Status of the Prototype IISIS:**

The current IISIS prototype has been under active development for the last two years, 1993-1995, funded by seed money grants from the Allegheny County Emergency Management Agency and by substantial support in equipment and in-kind services from the University of Pittsburgh. We now have the equipment and software needed to integrate our prototype, and we have a young staff that is gaining in both training and experience. By design, all of our equipment and software is fully compatible with that used by the Allegheny County Department of Computing and Information Services. We expect to have an integrated baseline IISIS system operational by the end of August, 1995.

IISIS provides information search, processing, representation, storage and retrieval functions with electronic communication, graphic mapping, and logical inference capabilities. The major functions are:

1. An interactive field status board that creates an emergency specific database to support decision-making in emergency operations

2. A graphic mapping capability that allows the spatial representation of information from the field status board to multiple organizations and jurisdictional users

3. A capacity for logical inference by the computer from information reported on the field status board to relevant knowledge bases included in the system (Comfort, Woods, and Nesbitt, 1990)

These three functions can improve the utility of information available to emergency managers engaged in separate but related tasks vital to emergency operations. The field status board uses the concept of an electronic blackboard to enable emergency managers to report changing conditions from multiple field sites to an emergency coordinating center. This information is integrated by computers in a continuously evolving record of emergency events, conditions, actions, outcomes, resources, and problems that can be accessed directly by authorized emergency managers from remote sites.

Using a graphic mapping capability, information from the field status board can be displayed graphically at remote sites, enabling managers at distant locations to visualize operating conditions in the emergency environment. Using the active indexing technique, this information can be updated on the maps as conditions change.

Data from multiple sources can be used with computerized logical inference routines to estimate a set of probabilities for likely consequences of the incident for different segments of the community, - under dynamic conditions. Emergency managers can use such routines to explore different types of risk to the community and to assess possible choices of action against different levels of risk. These three functions produce information that is stored in a layered, multijurisdictional knowledgebase by type of task, discipline, and time phase in disaster operations.

The prototype IISIS allows emergency managers to order, store, recall, and exchange information relevant to hazardous materials management in three different ways: 1) within organizations; 2) across organizations within jurisdictions; and 3) within a network of organizations that crosses jurisdictions. This capacity enables emergency managers working in positions of varied responsibility within the emergency management system to build quickly a shared information base in reference to a specific threat or release of hazardous materials. Timely, accurate information enables the participating managers to coordinate their actions more efficiently, thereby reducing the threat to the community and/or returning the community to safe operation more quickly and effectively.

**Innovative Techniques**

Two innovative techniques are being incorporated into the IISIS prototype to serve the needs of practicing managers in dynamic disaster environments. First, active indexing represents an important innovation that allows practicing managers to update their operational maps with incoming information as conditions change in the dynamic disaster environment. An active index is a dynamic index structure composed of many individual cells that store specific types of visual information and are connected by messages (Chang, 1995). The active index allows practicing managers to select visual objects in a distributed environment and enable these cells for automatic manipulation. With an active index, we can efficiently design visual objects that respond to incoming messages, queries, and other actions. In conventional database systems, keyword-based indexing techniques are adequate to support users' needs. In visual information systems, there are many applications that cannot be properly supported by keyword-based techniques. In addition to keywords, users often want to manipulate visual objects by shape, texture, spatial relationships, etc.

The basic concept of the active index is to respond to environmental changes and take corresponding actions according to user defined knowledge. An index cell accepts input messages and performs some computation. It then activates another group of index cells, and posts the output message to the selected group of index cells. When the active index is in actual computation, it consists of a time-varying collection of index cells in different states, accepting certain input messages and posting output messages to appropriate output lists.

The active index contributes two important features to IISIS knowledge management: 'active' and 'private'. The users can specify their private knowledge and then combine that with the system's knowledge, resulting in greater flexibility in IISIS's adaptive behavior. The 'private' knowledge also means that certain objects can obtain reactions different from reactions to other objects even in the same environment. For emergency message management, we can, for example, order messages by the importance of message classes so that if the recipient fails to view a particular message, a reminder will show up on both the sender's and the recipient's screens. Another interesting example is the inclusion of different levels of pre-fetching methods for the selection of data in IISIS. IISIS will provide a basic pre-fetching method, similar to the check lists used in emergency management procedures. For particular environmental conditions or types of emergency response, users can add their own data selection methods based on their special considerations.

In order to combine private knowledge with the system's knowledge, we can classify the cells included in the active index into groups to form a set ordered by characteristics of the disaster, such as the degree of certainty of information. In this ordered set, a class of index cells storing information with high degrees of certainty will share the same methods appropriate for that level, while other classes storing information at lower levels of certainty will operate on different methods appropriate to their level (Chang and Hsu, 1992; Chang, Hou, and Hsu, 1992; Chang, 1995).

Index cells can be activated at different nodes in a distributed system to respond to requests (messages) from the users. The active index structure thus facilitates distributed knowledge management and allows the parallel computation and retrieval of information. The details are described in (Chang, 1995).

Second, logical inference using fuzzy language and probability estimates is used to capture the anticipatory logic characteristic of practicing managers who seek to bring order to a dynamic, uncertain set of conditions. This prototype will integrate the technology of artificial intelligence with conventional databases to achieve a more powerful information system for decision support processes and training in hazardous materials planning and response. Since the information reported in disaster is often imprecise and incomplete, it is necessary to use fuzzy linguistic variables to describe the situation. The information stored in the database can also be imprecise and incomplete. Under these conditions, fuzzy algorithms must be used to support decision making.

The integration of incoming information with existing data in the distributed knowledge bases is done through a blackboard system. Every piece of incoming information is first posted on the blackboard. Fuzzy inference algorithms (as well as other inference algorithms) are applied to generate estimates of the impact of this information upon conditions in the community which are characterized by information previously stored in distributed knowledge bases. These estimates are again posted on the blackboard. The new information item on the blackboard may activate index cells which are already active. These active cells may again enable other index cells, thus creating an active index. The blackboard system exists at each node in IISIS, and there are index cells at each node. This technical capacity creates an index net spanning the entire distributed system, which is accessible to the emergency coordinator. This index net provides a comprehensive profile of the entire disaster, while maintaining the level of detail needed to support action at local sites.

## The Pittsburgh Oil Spill, January 2, 1988

We illustrate the use of an active index in reference to a specific disaster event, the Pittsburgh Oil Spill, in terms of the participating actors, frequency of interaction among the actors, goal of the operations, and principal operating conditions. The following set of conditions, drawn from actual events, illustrate the applicability of the active indexing technique to an evolving set of disaster operations (Comfort, Abrams, Camillus, and Ricci, 1989).

On January 2, 1988 at 5:10 p.m., a four-million gallon tank of diesel fuel collapsed at the Ashland Oil Company's tank storage site on the Monongahela River 27 miles south of Pittsburgh. Approximately 3.8 million gallons of diesel fuel No. 2 were in the tank, and force of the collapse caused the fuel to splash out of its containment area into the containment area of the neighboring Duquesne Light plant. In subfreezing temperatures, diesel fuel No. 2, with a flash point of 50 degrees, presented little danger of fire. With cautious relief, emergency operations personnel began to organize the massive clean-up operations, expecting to contain the spill at the Ashland site and adjacent properties.

At approximately 10:00 p.m., emergency response personnel, making a routine check of the spill site, discovered gasoline leaking from a nearby tank. The first tank's collapse had damaged a second tank, filled with gasoline, and caused at least four leaks in its piping structure. Leaking gasoline, with a much lower flashpoint than diesel fuel No. 2, created a more urgent danger. Emergency response personnel focused their attention and resources on identifying and plugging the leaks in the gasoline lines, fearing an explosion that would threaten the 700 residents of the Town of Floreffe, just across the highway from the Ashland Oil Company facility. Virtually all work on clean-up operations stopped as local officials ordered the evacuation of 1200 residents of Floreffe and adjacent areas as a precautionary measure. Working through the night, emergency response personnel found and plugged the last gasoline leak at dawn, and evacuated residents were allowed to return to their homes, weary, but out of danger.

At first light, emergency personnel discovered a third, and potentially more serious, danger. Throughout the night, the spilled diesel fuel had flowed into the Monangahela River through an undiscovered storm drain located on the Duquesne Light property next door. The spill, which emergency personnel had expected to contain on land, had now created an oil slick on the Monongahela River that extended bank to bank, seventeen miles long. The Monongahela River serves as the main source of water supply for some 850,000 residents in the Pittsburgh Metropolitan Region. Ordinarily, diesel fuel would float on top of the water, not endangering the water intakes located some 17 feet below the surface of the river. The fast-running Mon, however, had carried the slick over two locks and dams, and the tumbling action of the river had emulsified the oil through the water to the depth of the water intakes. Emergency personnel confronted the threat of contaminating the water supply of 850,000 area residents or shutting down the water intakes, limiting severely the supply of water available to residences, businesses, hospitals, schools, and other facilities in the area. Given the added risk of permanently damaging the water filtration systems on the river, the water authorities closed the water intakes, cutting off the water supply to several large municipalities in the area. Lack of water created a new threat to public safety, as the fire departments in the region were dependent upon water for fire suppression.

This set of actual events illustrates the type of dynamic, evolving crisis characteristic of interdependent systems in which active indexing would enable emergency managers at different locations to visualize the different conditions contributing to the escalating event in a more accurate and timely way. The following scenario illustrates the difference that advanced information technology could make in such a crisis.

**IISIS Scenario: The Pittsburgh Oil Spill**

This scenario is based on the set of problems that emergency managers confronted during the January 2, 1988 Oil Spill in the Pittsburgh Metropolitan Region. The problems are essentially the same as those that placed the City of Pittsburgh and neighboring communities at substantial risk for two weeks in early January, 1988. The difference is that emergency managers, in this scenario, have the benefit of access to current information technology. We ask that you imagine the events of January 2 - 5, 1988 occurring with access to the information technology of 1995.

The IISIS prototype is designed to facilitate the search, synthesis, representation, analysis, and dissemination of changing information in this dynamic emergency response process involving multiple agencies and jurisdictions. In the initial stages of an emergency, information is vague and incomplete. The managers' task is to verify the conditions and degree of risk to the community, and to allocate resources and mobilize action effectively in order to reduce the risk and potential losses to the community. In any given instance, managers are both responding to existing damage and anticipating the likely occurrence of escalating risk if the existing problems are not solved.

Using the IISIS prototype, we can construct a simulated event sequence, revealing the following alternatives to practicing emergency managers confronting a major release of a hazardous material in their community. Points at which the active indexing technique would be used are underlined.

1. January 2, 1988: 5:10 p.m. Floreffe, PA.
   Coordinator's Menu: Select Field Status Board
2. Select Incident List
3. Select Incident Status
4. Report vague description: large fuel spill on Rte 837 near Floreffe, PA
5. Open second window: Allegheny County GIS: show map of southern Allegheny County, locate Floreffe, PA and Rte. 837
6. Return to Coordinator's Menu with GIS map displayed:
   Open Notification Directory
7. Follow sequence for notification of hazardous materials spill

a. Notify EPA National Response Center
b. Activate mutual aid; notify local volunteer fire companies; Pleasant Hills VFC Team 13
c. Notify Allegheny County EOC of incident in Floreffe

8. In open GIS window: Locate source of spill at Ashland Tank Facility Set hot spot at Ashland Tank Facility
9. In GIS window, display Ashland facility, with site plan of tanks and fuel lines
10. In first window, Coordinator uses the active index to quickly identify available resources for hazardous materials response within a ten-mile radius of spill
11. Coordinator updates Incident Status:
    a. County Haz Mat Team arrives on scene; coordination shifts
    b. Floreffe Fire Chief Don Withers assigns John Kaus to be Coordinator; becomes user, opens user screen and continues to participate as Floreffe site coordinator
12. In IISIS window, ACEMA Field Coordinator John Kaus assumes coordination; close user screen; reopen coordinator's screen
13. In GIS window: County coordinator identifies collapsed tank and sets hot spot on tank
14. Active index uses CAMEO[2] to identify substance in collapsed tank
15. County coordinator updates information on Incident Status screen
    a. Hazardous Materials screen
    b. Incident characteristics screen
    c. Substance characteristics screen
    d. Risk Assessment: major spill
    e. County Field Coordinator transmits updated risk assessment and Site Report to US EPA Regional Response Center. Following EPA guidelines, Ashland Oil Co. has notified US EPA of spill. Nearest EPA response office is in Wheeling, WV, approximately two hours away.
16. In GIS window: update information on map of Ashland facility, showing collapsed tank and flooded containment area
17. Floreffe Site Coordinator transmits report; fuel in river
18. In GIS window: river shows small slick of fuel on water. Active index notifies Coordinator.
19. ACEMA Coordinator notifies US Coast Guard, Marine Safety Office, Pittsburgh; USCG dispatches response team to scene
20. Coordinator confirms exercise of authority in response operations: Coordinator's menu: bring up Jurisdictional Emergency Plans, Click on US EPA Pollution Contingency Plan: Sec. 300.33 Response Operations
21. In GIS window: show fuel spill on land at Ashland facility and in water in slick on Monongahela River
22. 9:00 p.m.: ACEMA Coordinator transfers authority for response operations to USCG, MSO. Cmdr. Eugene Miklaucic assumes role of on-scene coordinator; ACEMA Coordinator John Kaus becomes user; EPA will

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[2] CAMEO is a computerized knowledge base of hazardous materials that is widely used by emergency managers to identify hazardous substances and their consequent effects upon unprotected people and communities.

assume coordination of incident in morning

23. USCG On-Scene Coordinator Miklaucic brings up screen on Jurisdictional Plans: clicks on EPA Operational Response Phases for Oil Removal; Sec. 300.52 Preliminary assessment and initiation of action.
24. USCG On-Scene Coordinator brings up Notification Directory; notifies Ashland Oil Co. of its responsibility; requests plan for clean-up
25. Ashland Oil Company Manager of Terminal Operations John Welsh reports that he has contacted O.H. Materials Co. of Findlay, OH to conduct clean-up operations.
26. On-scene Coordinator updates Actions screen to state that O.H. Materials Co. is en route to Floreffe from Findlay, OH to conduct clean-up operations, approximately five hours away
27. In GIS window: show river with size of slick increasing; using database, bring up window that displays characteristics of river; fast-running current with locks and dams
28. OSC runs oil dispersion model to estimate the rate at which the slick is spreading on the river: show Coordinator's screen
29. In GIS window: OSC checks facility plans for adjacent plants; shows facility plan for Duquesne Light; sets hot spots of active index to detect possible paths of fuel flow to river; plan reveals storm drain from containment area to river
30. Active index at Ashland task facility sends alert message to OSC. OSC checks Site Report from Floreffe; gasoline leak from a second damaged tank is discovered at Ashland facility; report substance characteristics
31. OSC updates Risk Assessment screen: new threat of explosion from gasoline mixing with diesel fuel
32. In GIS window: OSC updates plan of Ashland facility to show damaged gasoline tank and piping under the pool of spilled fuel, revealing points of possible gasoline leakage
33. OSC runs Likely Events intelligent reasoning program on BB1 to identify likely consequences of explosion on population of Floreffe; hot spots previously set in potential explosion area trigger active index to highlight all areas at risk.
34. OSC evaluates threat to population of Floreffe in joint consultation with ACEMA Site Coordinator; ACEMA Coordinator orders evacuation of Floreffe area and requests state declaration of emergency from PEMA.

**Multidisciplinary Design**

The design of the IISIS prototype requires advanced skills and knowledge in both organizational and technical disciplines. Disaster environments are governed by legal requirements and professional standards of disaster management that represent a specialized field within public policy, management, and organizational design. The technical requirements for building the IISIS prototype, in turn, involve advanced knowledge and skills in computer science and systems integration. Building the knowledge base regarding the actual infrastructure within which hazardous materials are stored and transported requires specialized knowledge and skills in engineering. Each of these disciplines are critical to the informed, effective development of this prototype, and each is represented among the project investigators and graduate student research staff.

**Application Environment**

The proposed research is designed to implement the prototype in a trial demonstration in hazardous materials management in Allegheny County. We are fortunate to have had the full cooperation of the Allegheny County Emergency Management Agency for the development of the prototype to this stage. It is now time to widen the base of participation to other public, private, and nonprofit organizations at the community level. The project also has the active support of the Environmental Systems Research Institute in our implementation of the active indexing technique using the ARC/INFO software.

**Demonstration and Evaluation of the Prototype**

The trial demonstration would also serve as a critical means of evaluating the prototype for use in hazardous materials management. The demonstration would allow us to measure four factors central to improved hazardous materials management at the local level. They are:

1. the number of messages sent and received among the organizations participating in a simulated emergency response exercise

2. the number of actions initiated by informed organizations acting to reduce risk at their local sites of operation

3. the number of interactions among informed participating organizations undertaken to reduce risk at the community level

4. the rate of efficiency calculated in time and costs in the allocation of resources for response to a simulated hazardous materials release

These measures will allow an assessment of the increased rate of communication and coordination among organizations made possible by their use of the IISIS prototype and an estimate of the expected improvement in organizational performance and efficiency in managing hazardous materials.

**Expected Results**

The proposed project will support the demonstration and careful evaluation of a prototype IISIS for community management of hazardous materials. The prototype IISIS enables a sociotechnical system for hazardous materials management to adapt quickly from routine tasks of management by single organizations to networks of organizations and jurisdictions engaged in coordinated disaster response operations, returning to routine tasks when the threat is brought under control. Findings from this study will support management and training in emergency response and recovery organizations as well as contribute to our theoretical understanding of processes of transition and self organization in other areas of community policy and practice.

**Research Plan**

The primary research activities are outlined below for the 1995-1996 project year. The computing activities are listed first, followed by the organizational design and data collection activities. The two sets of research activities will be carried out with reciprocal review and feedback processes to ensure that the technical and organizational development activities are complementary and mutually supportive.

The products of both sets of research activities will be stored in a multidisciplinary knowledge base that will support continuous development of the IISIS.

Project Year 1995-1996:

* Investigate the active index for distributed objects and the management of distributed knowledge through active indexing.
* Develop algorithms to prefetch information based upon requests from the situation board.
* Integrate active index with spatial information system.
* Identify the information requirements for hazardous materials management for public, private, and nonprofit organizations in Allegheny County, Pennsylvania.
* Collect and verify data from participating organizations and multiple sources engaged in hazardous materials management in Allegheny County.
* Design and develop a multidisciplinary, layered knowledge base for IISIS at the County level.
* Test integration of system
* Plan and organize demonstration of prototype to 50 selected managers from public, private, and nonprofit organizations
* Conduct demonstration in simulated operations exercise with 50 participants at off-site locations
* Evaluate response to simulated operations exercise using prototype
* Analyze evaluation data in terms of contribution of prototype to performance of community response system
* Prepare report and disseminate findings to participating public, private, and nonprofit organizations

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**Estimated Budget, 1995-1996**

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|---|---|
| Co-Principal Investigators: | |
| L.K. Comfort: | |
| 10% time for 8 months @ $60,004 | $ 6,000 |
| 50% time for 2 summer months | 7,500 |
| | 13,500 |
| S.K. Chang: | |
| 1 summer month | $13,333 |
| Fringe Benefits, faculty @ 33.7% | 9,043 |
| Total faculty salaries and fringe: | $35,876 |
| System Administrator, 60% time for 11 mos., Skills in ARC/INFO, Oracle, Unix, systems integration | $23,760 |
| Clerical assistance, 110 hrs@$9.23/hr | $ 1,015 |
| Fringe benefits @37.7% | 9,340 |
| Total staff salaries and fringe: | $34,115 |
| GSRs @ $1100/mo for 11 mos: | |
| 1 GSR in computer science | $12,100 |
| 2 GSRs in public policy and management | 24,200 |
| 1 GSR in engineering | 12,100 |
| Total GSR salaries | 48,400 |
| 34% tuition remission for GSRs | 16,456 |
| Total GSR costs | $64,856 |
| Supplies, copying, telephone: | |
| Production of evaluation questionnaire, 100 copies @ $1.00 | $ 100 |
| Production of report, 100 copies @ $5.00 | 500 |
| 1 Upgrade to X-Windows | 400 |
| Telephone, fax, copying, supplies | $ 1,100 |
| Total supplies, copying, telephone: | $ 2,100 |
| Total Direct Costs | $136,947 |