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**The Aegis Initiative:
An Integrated, Real-Time, Environmental Monitoring and
Response Management Capability
Final Report**

J.C. Smart and Robert J. Vellinger

March 21, 1995

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The Aegis Initiative: An Integrated, Real-Time, Environmental Monitoring and Response Management Capability

Final Report

March 21, 1995

Project: 94-SR-020

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Introduction

The Aegis system at Lawrence Livermore National Laboratory (LLNL) is being developed to provide a real-time emergency response management capability for a diverse range of environmental monitoring applications. The Aegis system is designed to integrate a variety of environmental, emergency, and process monitoring sensor systems using a flexible, modular architecture that can be readily configured for any number of industrial, commercial, or government sites. Several unique LLNL technologies are being integrated via this effort that will provide tracking of environmental contaminants, real-time identification of potentially unacceptable conditions, and facilitation of emergency or measured response management operations. Potential areas of application include:

- Monitoring
 - Surface/ground water, air, radiation
 - Waste effluent & storm/drain line
 - Water quality (water storage, treatment, and distribution)
 - Fixed processes, safety systems,
- Critical facilities
- Hazardous spill management
- Rapid environmental monitoring deployment
- Watershed protection
- Ecosystem management and restoration
- Enforcement and compliance

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Background

The increasing emphasis on environmental issues, waste reduction, and improved efficiency for industrial processes mandates the development of new monitoring systems for field or in-plant use. These systems are needed for several reasons. Sites with environmental contamination require monitoring systems to control remediation efforts and to help gauge their effectiveness. Systems which carefully monitor and control chemical processes are necessary to help minimize harmful environmental wastes. The ability to promptly detect the presence of toxins, hazardous, or otherwise regulated chemicals in drinking water, storage and treatment facilities, waste effluents, and other concerns is crucial to prevention programs and long-term environmental preservation efforts.

Our concern for the quality of our environment is timely and critical. There is a genuine need for a coordinated effort toward achieving a more complete understanding of how our environment is changing, how fast it is changing, which of these changes are induced by nature and which are anthropomorphic, and how these changes, in turn, might affect the quality of our lives. A first step toward this goal of understanding, protecting, and managing our environment is to assess its current state by monitoring its condition, archiving the information, followed by a systematic process of analyzing this information.

Toward this goal, many national and international programs have been proposed and are now in various stages of planning. Many of these efforts require substantial work in theoretical modeling of the Earth-atmosphere system and collection and reduction of vast amounts of data from various platforms such as the Earth's surface, aircraft, balloons, and satellites. However, they are not applicable to analysis of local environmental conditions and therefore provide only limited utility in emergency planning and response activities.

The monitoring and analysis technology necessary for modern site operations must provide accurate, sensitive, and timely measurements of environmental conditions. Current environmental monitoring practice, however, is manpower intensive and is not well suited to rapid detection and response. Once data is obtained, few tools and methodologies exist with which to guide planners and emergency personnel in coordinating response activities. Coordinated and effective response is a rapidly growing need of both communities and commercial firms and is a critical element in the operational planning of any large governmental site. Unfortunately, emergency and measured response methodologies currently remain complex and ill defined.

The Aegis Initiative

The purpose of the Aegis Initiative is to provide an integrated, real-time environmental monitoring, analysis, and response management capability that can serve as the foundation for implementing effective environmental protection and process supervision measures. The goals of the Aegis Initiative consists of three major parts:

1. Monitoring: Integration of sensor packages and real-time data into a computerized system based on LLNL's proven process control and monitoring technology, providing distributed environmental monitoring and multi-site portability.
2. Response: Development of a response management capability, including: impact-assessment generation, emergency cordon, response-action determination, and cleanup coordination, addressing rapid-deployment issues for hazardous-spill management and emergency/measured

response coordination. Development of dynamic incident assessment and tracking interfaces to local agencies and state emergency services.

3. Analysis: Refinement and integration of analytical, simulation, and predictive models with Aegis for rapidly calculating and displaying hazards, contaminant plumes, emergency resource allocation, and response action plans.

The purpose of the Aegis Laboratory Directed Research and Development (LDRD) project was to demonstrate the feasibility of this integrated monitoring/response/analysis concept. Several major elements of the envisioned capability were included in the development effort. To illustrate monitoring of diverse environmental parameters, a variety of sensor subsystems were included in the Aegis project. These subsystems monitored the conditions of four different environmental mediums: surface water, air, waste effluent, and fixed location chemical processes. To capture the degree of flexibility required for modern emergency response applications, several monitoring configurations were integrated in the Aegis project. A fixed station platform was included for traditional monitoring applications. A buoyant platform was included for river, lake, and open water monitoring applications. For rapid deployment applications, both portable and vehicle-based monitoring platforms were also interfaced. Since these platforms in actual use would frequently be distributed across a wide geographical area, several communications technologies were used on the project including spread spectrum packet radio, cellular radio technology, and fiber optic transmission.

With a basic monitoring network in place, the Aegis project then demonstrated how this equipment can be used for emergency and measured response applications. The ability to deploy emergency resources and track their position while receiving real-time monitoring conditions was demonstrated. Location tracking was performed using Global Satellite Positioning (GPS) technology interfaced to the monitoring network. Alarm condition and incident tracking was maintained by the Aegis console software.

Given adequate monitoring and incident tracking tools, the final phase of the Aegis project was to demonstrate how this information can be interfaced with advanced modeling systems to provide analysis, prediction, and simulation functionality. This concept was demonstrated via a real-time link to the Laboratory's atmospheric modeling center.

Through the integration of all these technologies, the goal of Aegis Initiative is then to show how an environmental monitoring infrastructure could be developed and interfaced to provide an effective emergency response coordination and dispatch system. Real-time information obtained from this system could then be input into advanced models to provide accurate analysis and assessment of current conditions. Rapid availability of this information would be beneficial to the response resources. The next step in this Initiative would be to use this information to predict future conditions assuming a particular response. The ability to run predictive simulations of response resources given initial and subsequent real-time environmental conditions remains the final element of the Aegis Initiative yet to be demonstrated. A proposed follow on project would be to design a generic real-time information interface to an advanced simulation system such as that developed by the Laboratory's Conflict Simulation project.

Accomplishments

The Aegis LDRD Project has now been completed. A system prototype was constructed to demonstrate concept feasibility. A block diagram of the Aegis prototype system is shown in Figure 1. This prototype is operational in building 543 at LLNL. The prototype effectively integrates several environmental sensor systems distributed throughout the LLNL site.

Real-time monitoring information from the Laboratory's the drainage retention basin, the B196 sewer monitoring facility, a portable monitoring station, and an experimental test platform is accessible through the Aegis host user interface. This information is displayed on a computer workstation linked into the data collection network. This workstation employs a unique geographical information system (GIS) based on components developed for the Argus Security System [1]. This powerful mapped-based user interface provides an integrated solution to diverse, distributed data gathering and display by providing a single geographically-oriented mechanism for locating sensors and retrieving sensor information. A link was also established to the Laboratory's Atmospheric Release Advisory Capability (ARAC) [2] to demonstrate the integration of meteorological information and analytical modeling techniques.

Figure 1. Aegis Prototype System Configuration

The prototype system demonstrates how environmental data can be effectively collected over numerous communication media including direct communication lines (copper, fiber, LLIX, and Ethernet-Labnet), over radio, and over cellular telephone. A versatile packet-switched, spread-spectrum radio network is now in place at the Laboratory demonstrating wireless transmission and standalone, portable, and mobile environmental platform operation.

In this prototype configuration, fixed station monitoring is demonstrated via the LLNL B196 sewer monitoring facility. Current pH level and flow rate in gallons per minute data from the B196 facility are periodically collected and transmitted to the Aegis system. Current waste stream concentrations in milligrams per liter of silver, arsenic, cadmium, chromium, copper, mercury, nickel, and lead are similarly transmitted. This information is accessed by the user via an icon on a Laboratory site map displayed on the Aegis console screen. The prototype system

also contains an additional fixed location platform for testing of advances sensor packages such as LLNL's unique electrochemical sensor technology.

Remote wireless environmental monitoring capabilities are demonstrated using a boat mounted platform located in the Laboratory's drainage retention basin (Photograph 1). The platform includes a Handar data logger which records multiple parameters from a Hydrolab water quality sensor package including water temperature, conductivity and salinity, standard and ionic strength pH, dissolved and residual oxygen levels, and probe depth. Sensor information from the data logger and location data from the GPS receiver are collected by a single board computer and transmitted to the Aegis console over a radio system.

Radio communication is performed using a distributed spread spectrum packet radio system manufactured by Metricom Corporation. This network provides 9600 bits per second data throughput from the sensor platform back to the Aegis console. Radio transceivers were located at B271, in the mobile vehicle platform, in the drainage retention (lake) system, and at the T6952 test system (Photograph 2). This radio system would automatically route data messages to the appropriate destination transceiver. The interface to the Laboratory computer network was made via the B271 transceiver. A hand-carried, portable monitoring platform was also developed to demonstrate low-power wireless communication via cellular telephone technology in place of the spread spectrum equipment. (Photograph 3).

In the prototype system, each monitoring platform computer shown in Figure 1 regularly polled its sensor inputs at an approximate 1-2 second interval. Similarly, location data from the GPS receiver is also periodically scanned. Whenever this information changes appreciably, the platform computer assembles a data message and transmits the message across the communication network to an Aegis host. While the Aegis architecture allows multiple hosts computers to be installed for distributed applications, the prototype system consisted of one computer workstation located in B543. This computer communicated to the sensor communication network via an Open Labnet interface to the communication concentrator located in B271.

When a data message from the communication network is received at an Aegis host, the sensor information is examined to determine if an alarm condition exists. Sensor packages are represented as map icons on the host workstation display screen. The color of the icon is used to convey the severity of measured conditions (Photograph 4). When an unacceptable environmental condition is detected by the sensor package, its icon on the map changes color (i.e. to red) to reflect this condition. Problems of this type are automatically tracked by the host software via the creation of an "incident". The host software allows users to examine many different incidents appearing at numerous levels of the map display. Since the monitoring platforms are equipped with GPS receivers, the location of their icon on the map display is updated accordingly. The location of response vehicles equipped with these receivers can be similarly tracked (e.g. lake, mobile, and portable platforms).

When sensor conditions return to normal, the icon representation changes color (i.e. to green) to reflect this change and allows the workstation user to "resolve" the incident. As described, the workstation software provide the user with the basic tools necessary to examine environmental parameters, detect alarm conditions, and track incidents and responding personnel and equipment (Photograph 5). To aid in the analysis of incidents and perform the necessary prediction to adequately instruct the response personnel, an interface to environmental modeling services is important.

Included in the prototype system was a link to the Atmospheric Research Advisory Capability (ARAC) system. This link provided a mechanism for demonstrating access to analytical modeling tools and real-time weather conditions. Running on an ARAC workstation, a simulated tritium release from B331 was performed. The display output of this simulation was then

displayed on the Aegis workstation in B543. The display generated by the ARAC system illustrates the contaminant plume predicted using current meteorological conditions (Photograph 6). In the Aegis conceptual framework, these modeling tools could be initialized with data parameters collected from the sensor monitoring network. These tools would then allow the user to perform prompt simulations and make continuous predictions based on the most recent sensor information.

Conclusion

The Aegis Initiative effectively demonstrated the integration of numerous and diverse sensor technologies with advanced monitoring and communications services. The prototype system that was developed successfully demonstrated how real-time information from a variety of geographically dispersed monitoring platforms can be collected, organized, and displayed using an extensible architecture. The resulting integration concepts are believed to have strong application in advanced environmental and public safety monitoring situations. This work also demonstrated how state-of-the-art analytical, simulation, and predictive models developed by other organizations can be conceptually integrated with the real-time monitoring systems to provide a comprehensive environmental monitoring and emergency management package (Figure 2). This ability to integrate real-time data collection with analytical, simulation, and prediction modeling tools has the potential to revolutionize environmental and emergency monitoring practices.

Acknowledgments

The authors would like to express their appreciation to Dr. Robert Glass for his original contributions to the project regarding the interfacing of his electrochemical sensor technology, Dr. Brian Balke for his environmental monitoring expertise and support in interfacing to the LLNL B196 sewer monitoring facility, and Dr. Thomas Sullivan and Bryan Lawver of the Atmospheric Research Advisory Capability (ARAC) for providing Aegis with electronic access to their extraordinary atmospheric modeling and simulation services. The authors would like to thank Walter Sokoloski, Kevin Snyder, and Judy Thomas for their significant contributions to the hardware and software implementation. Finally, the authors would like to thank the Fission Energy and System Safety Program (FESSP) for their support of this effort.

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Conclusion

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Blackrose

Summary

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FOR INFORMATION OF THE BOARD OF DIRECTORS AND STOCKHOLDERS:

DOMAIN: AFGIS

File Edit

Domain Maps:

Bay Area

City of Livermore

Lab Site

Current Tritium Release Zone

Current Weather

Connect to UVELLA
Battery 13.8
Channel count 12
Rain 0.00
wind speed 1.8 at level 1
wind gust 3.8 at level 1
wind direction 288 at level 1
sigma theta 50.1 at level 1
temperature 14.7 58.5 at level 1
humidity 70 at level 1
wind speed 1.8 at level 2
wind gust 4.2 at level 2
wind direction 284 at level 2
sigma theta 51.8 at level 2
temperature 14.2 57.6 at level 2
TOWER: UVELLA

Connect to SANDAI
Battery 13.8
Channel count 13
Rain 0.00
Pressure 1016.3
wind speed 1.8 at level 1
wind gust 2.9 at level 1
wind direction 291 at level 1
sigma theta 26.5 at level 1
temperature 14.5 58.1 at level 1
humidity 65 at level 1

wind speed 1.8 at level 2
wind gust 3.1 at level 2
wind direction 288 at level 2
sigma theta 20.8 at level 2
temperature 13.9 57.0 at level 2
TOWER: SANDAI

Connect to SITE300T
Battery 13.9
Channel count 13
Rain 0.00
Pressure 1017.3
wind speed 2.4 at level 1
wind gust 5.1 at level 1
wind direction 48 at level 1
sigma theta 34.3 at level 1
temperature 14.3 57.7 at level 1
humidity 81 at level 1

wind speed 2.3 at level 2
wind gust 4.9 at level 2
wind direction 49 at level 2
sigma theta 24.6 at level 2
temperature 14.2 57.6 at level 2
TOWER: SITE300T

Connect to LULISDOOR
hgt cts epd dr Sdr v sw
750 542 4.07 240 21 -1.43 0.72
700 948 2.75 228 25 -0.85 0.71
650 1355 1.78 201 37 -0.23 0.87
600 1235 1.83 179 44 0.00 0.54
550 1184 1.28 188 43 -0.08 0.37
500 1084 1.21 192 38 -0.18 0.28
450 918 1.57 192 38 -0.12 0.28
400 720 1.56 201 35 -0.10 0.38
350 858 1.92 223 30 -0.09 0.48
300 709 2.56 240 22 -0.07 0.54
250 917 2.92 250 18 -0.09 0.58
200 1550 2.78 258 22 -0.18 0.58
150 1052 2.15 265 32 -0.18 0.58
100 3037 1.21 268 45 -0.18 0.58
50 3382 1.84 287 47 -0.14 0.65
slab upr = 1 at 50m
hgt etc = 1

Auxiliary

RECEPTOR INFORMATION

Station	Position	Speed	Sensor	Type	Value	Alarm
2	N37~41.65' W121~42.81'	0.00MPH	1	pH	7.36 units	No
			2	Flow	265.25 gal/min	No
			3	Aq	0.00 mg/L	No
			4	As	0.00 mg/L	No
			5	Cd	0.82 mg/L	No
			6	Cr	0.00 mg/L	No
			7	Cu	2.90 mg/L	No
			8	Hg	0.09 mg/L	No
			9	Pi	2.79 mg/L	No
			10	Pb	0.00 mg/L	No

**Aegis allows integration of analytic and predictive models
with its real-time monitoring capabilities**

Public Safety/Environment

Air/Water/Fire/Ground/Radiation