The Wisconsin Division of Narcotics Enforcement Uses Multi-Agent Information Systems to Investigate Drug Crimes

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We built a multi-agent information system (MAIS) called Sherpa using distributed artificial intelligence architecture. The system integrates distributed knowledge sources and information to help the Wisconsin Division of Narcotics Enforcement (WDNE) make decisions about the level of charges against a drug crime suspect. Sherpa outperforms the existing system in the identification of criminals.

Before drug investigators can arrest suspected criminals, they must identify suspects, collect data about them, and analyze the data. They gather information from different sources external to the drug enforcement agency, such as the Internal Revenue Service and the Division of Criminal Investigation, combining the data with that from internal sources, removing redundancies, and identifying patterns in the data. Drug enforcement agencies face conditions that hinder the use of information systems and the diffusion of information. The issues they need to address in using information systems arise from both external and internal factors. The external factors include a dependency on other agencies for funding projects, the beliefs of politicians, and the assumption that they can work during regular business hours against an enemy that works round the clock. The internal factors include agents poorly trained in use of information technology [Gupta and Bhaskar 1993], employee (or narcotic-agent) resistance to adopting new ideas, high agent turnover, and employee attachment to the status quo [Park and Bhaskar 1994].

We designed and implemented a distributed problem-solving multi-agent in-

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formation system (DPS-MAIS) called Sherpa for investigating drug crimes in the state of Wisconsin. An investigation includes various steps, such as selecting a target suspect, collecting data, evaluating the data, and analyzing and disseminating information and data. We designed Sherpa to be a decision-support tool that combines data from various sources to improve the overall drug-investigation process and to aid decision making.

What Is DPS and MAIS?

Distributed problem solving (DPS) is an approach to solving problems that can be decomposed into subproblems, which can then be solved independently by loosely coupled modules (also called agents in multi-agent systems). These modules (agents) cooperate and share knowledge in the form of tasks or data about a problem to develop a solution [Lesser and Corkill 1987; Smith and Davis 1981]. Many real-world situations can be modeled as a set of independent cooperating modules (agents) [Sian 1991]. Modeling problems as a set of independent cooperating agents is useful for solving complex problems that cross functional boundaries [Sikora and Shaw 1991].

In a distributed-problem-solving process, the analyst divides the problem into tasks and designs special task performers (agents or modules) to solve these tasks. The analyst incorporates interaction strategies to connect the agents in designing the system. Most problem-solving processes in a DPS system consist of four phases [Shaw and Whinston 1989]:

(1) Decomposition of the problem into subproblem tasks;

(2) Allocation of the subproblem tasks among agents;

(3) Solution of the subproblem tasks by the agents; and

(4) Integration of these solutions to obtain the global solution.

A DPS system has advantages over a single, monolithic, centralized problem solver: (1) it solves problems faster by exploiting parallelism; (2) it transmits only high-level partial solutions rather than raw data to a central site; (3) it increases flexibility by combining problem solvers with different abilities; and (4) it increases reliability by using functioning problem solvers to replace failed ones [Durfee, Lesser, and Corkill 1989; Weiss 1995].

The Traditional Drug-Crime-Investigation Process in Wisconsin

The drug-crime-investigation process consists of a series of interrelated components (Figure 1). A failure or weakness in any one of these components seriously impairs the entire process and reduces the quality of the investigation. The drug-crime-investigation process includes the following components:

—Targeting suspects to ensure that intelligence efforts will be worthwhile, have a probability of success, and don't require great expenditure of resources;

—Planning data collection and collecting information about suspects from both overt and covert sources;

—Evaluating the information collected, which may include facts, opinions, rumors, and inferences that may contradict other information, by assessing the reliability of sources and the validity of information;

—Recording collected intelligence promptly and placing it in a storage-and-retrieval system that permits rapid user access; selectivity of retrieval; documenta-

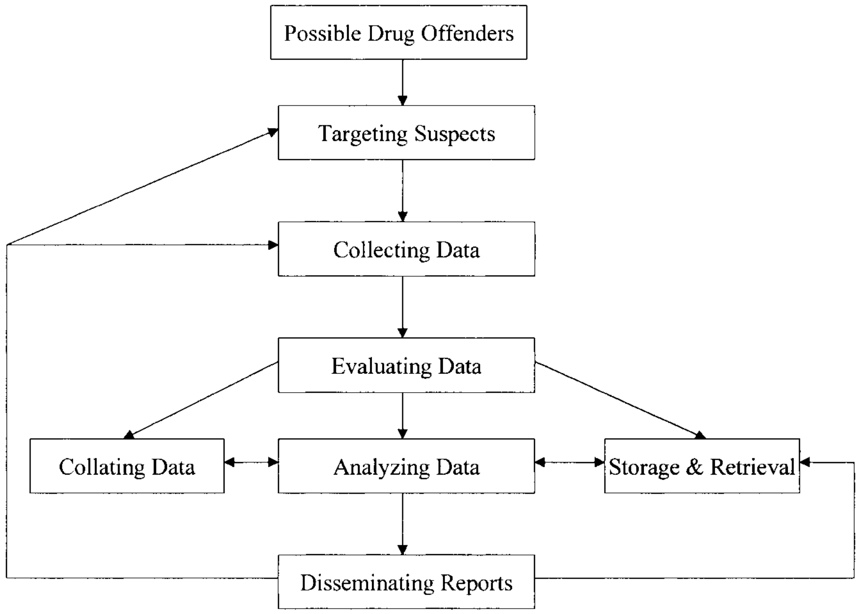

Figure 1: The drug-crime-investigation process.

tion of each dissemination; periodic system audit and, when appropriate, information purging; physical security to protect the files; and system security to restrict the access to information;

—Collating data in the proper order to discover their meaning, for example, arranging surveillance reports in chronological order;

—Analyzing, integrating, and clarifying the data, and developing, testing, and finalizing inferences; and

—Disseminating information obtained to the agency's officers in usable form.

The traditional process of investigating drug crimes in Wisconsin consists of collecting data from 30 narcotics agents across the state, generating monthly reports, identifying suspects, collecting information about the suspects, and analyzing data to obtain evidence to permit arrest. The traditional process the Wisconsin Division of Narcotic Enforcement (WDNE) uses is very cumbersome because of a combination of factors. In the current system, only two analysts serve 30 narcotics agents. The narcotics agents don't have computers and have minimal facilities for communicating with the analysts. The narcotics agents are located in Madison, Appleton, Eau Claire, and Milwaukee, and they fill out reports about suspects and mail them to the central division in Madison. The reports are then entered into a database, statisticians analyze the data, and the two analysts check it and further analyze it. The two analysts, one of whom is a senior analyst and the other the director, check for format, and integrity, consistency, and accuracy of the data. After analyzing the data, they prepare a preliminary draft of the final report and forward it to a secretary who types the final report.

The final report includes a list of suspects. Once the suspects are identified, data about suspects' activities and background are collected. WDNE is a state organization and it works with state police to gather data about a suspect. The data come from police undercover and surveillance operations and from other sources such as the Internal Revenue Service and the Division of Criminal Investigation. After the WDNE obtains data about a suspect, it analyzes them, and if it has enough evidence, arrests the suspect. After the arrest, the WDNE uses the results of the data analysis to determine the level of charges it can make against the suspect.

In the current system, only two analysts serve 30 narcotics agents.

The traditional drug-crime process has several problems. First is a security and control problem. The information acquired by the 30 agents changes hands many times for accuracy checks before it becomes part of a final report. Since each person checking accuracy focuses on only part of the report, each has unnecessary access to sensitive information. Second, the current process has many redundancies and inefficiencies. Because each report is passed physically from one person to another, only one person can work on it at a time. Further, it takes at least two people to correct errors and update information (the supervisor and the data-entry clerk).

Our project was part of a major reengineering and IT deployment effort the Wisconsin DNE undertook with IBM to redesign business processes, to develop distributed computer systems that would allow narcotics agents to file their reports by computer, to create a centralized drug-enforcement database, and to design a decision-support tool, Sherpa. We developed and implemented Sherpa.

The Wisconsin Department of Justice

The Wisconsin Department of Justice (WDJ) is the leading law-enforcement agency in the state (Figure 2). It has five major departments, the Division of Legal Services (DLS), the Division of Management Services (DMS), the Division of Criminal Investigation (DCI), the Division of Narcotics Enforcement (DNE), and the Division of Law Enforcement Services (DLES). State criminal investigators work for the DNE or the DCI. DLS prosecutes important criminal cases, DLES contains the state crime information bureau and crime state laboratories, and DMS contains the management and computing services.

The DNE leads and coordinates Wisconsin's state and local drug-enforcement efforts. The DNE concentrates on investigating individuals, groups, and organizations involved in high-level drug trafficking. The major goal of DNE is to support local drug-enforcement efforts by providing advanced investigative and technical services. The DNE has three bureaus that deal with investigative operations, special operations, and internal operations (Figure 3). The investigative operations are divided among four regions with headquarters in Appleton, Eau Claire, Madison, and Milwaukee. The special operations bureau houses the intelligence unit, the technical investigative services unit, and marijuana-eradication-programs unit. The internal operations section consists of the administrative service section, the asset forfeiture program section, the internal affairs section, the inspection program section, and the training section. The intelligence section houses the two analysts who provide services to the whole division. Direct access to intelligence data is strictly limited to the intelligence staff.

The Architecture of Sherpa

We focused on the data-analysis part of the overall drug-investigation problem. The data-analysis problem can be decomposed into a set of simpler subproblems. Each subproblem, which requires different data sources, can be solved as an independent problem. The data sources used in data analysis are (1) financial data, (2) toll records, (3) surveillance data, and (4) such sources as checks of trash and mail.

The solutions to the subproblems are combined to classify the suspect. Data from a single source can be used to classify a suspect, or data from multiple sources may be combined. An example of an analysis of a single source of data would be an analysis of telephone records to determine the relationship of the suspect with a known criminal. An example of analysis of multiple sources would be an analysis of telephone records to discover the suspect's high phone bill combined with a financial analysis to discover his or her sources of income. Based on the results of such an analysis, the analyst could classify the suspect as innocent (nonsuspect), as a possible suspect who may require further surveillance or other data, a drug seller (source), a drug buyer (customer), or a drug broker (Figure 4).

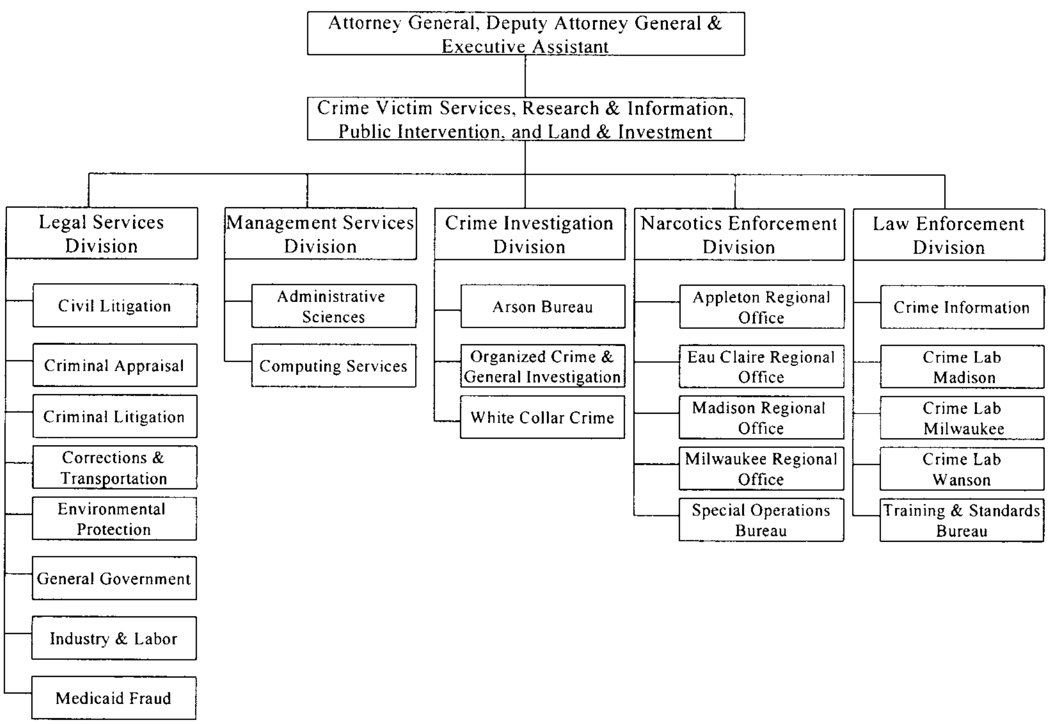

Figure 2: The Wisconsin Department of Justice organization chart.

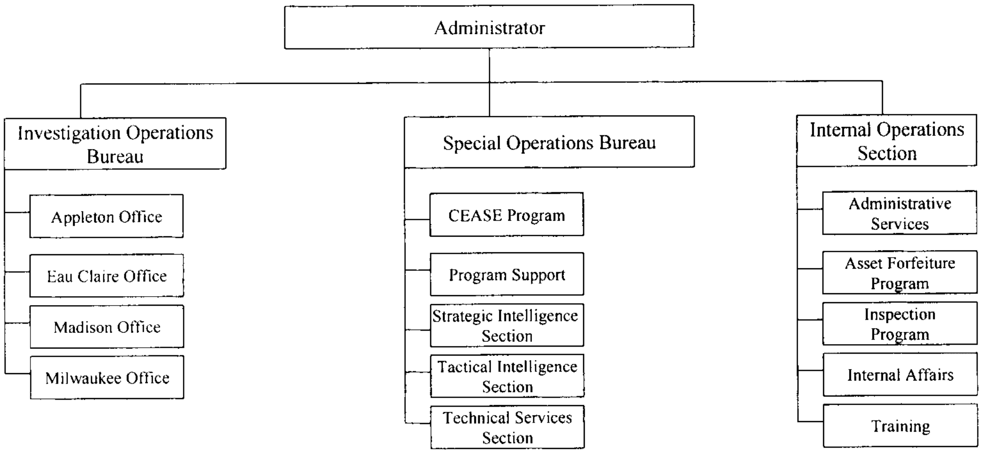

Figure 3: The Wisconsin Division of Narcotics Enforcement organization chart.

Developing DPS-MAIS Sherpa

We used DPS methodology to design Sherpa. We used three problem-solving modules (agents) to analyze the data for drug-crime investigation. Each performs a different analysis. Finally the system combines the solutions from all the modules and classifies the possible suspect. Since WDNE obtains the data from heterogeneous platforms and in different formats, we used FOCUS and dBase V to obtain data from external agencies (the Internal Revenue Service and the Division of Criminal Investigation) and Level 5 Object (an expert system shell) to design interfaces. For analyzing internal data, we used Microsoft Excel. The problem-solving heuristic within each module (agent) is written as a set of IF-THEN rules.

Sherpa includes three modules (Figure 5). Each contains a database for previous cases and a rule-based knowledge source

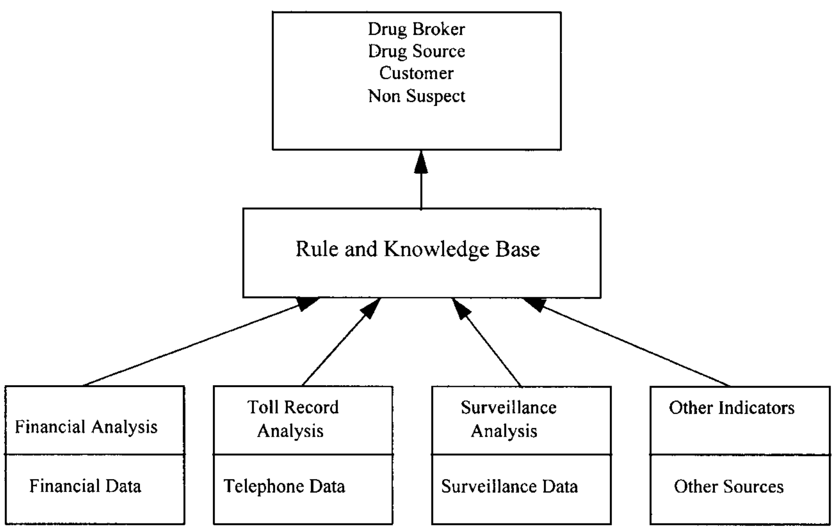

Figure 4: A dependency diagram for Sherpa.

based on an inductive, statistical, or knowledge-engineering approach. The induction learning technique we used is Quinlan's [1993] C4.5. In a recent study, Bhattacharyya and Pendharkar [forthcoming] found that C4.5 is a more accurate classification technique than nonlinear neural networks and genetic programming and linear genetic algorithms and discriminant-analysis-based classification methods over a wide range of nonparametric data-distribution characteristics. We used knowledge-engineering techniques to elicit knowledge from experts. Specifically, we used the approaches Grabowski [1988] and Hoffman [1987] suggest for eliciting knowledge.

Sherpa cannot replace the traditional decision-making process entirely.

Sherpa contains five components altogether (Figure 5). These components are the language system, the problem-processing system, meta-level knowledge, knowledge sources, and access to databases through a network. The language system component handles human-computer interaction. It is a graphical-user-interface component that is used to input data and to obtain output information.

The problem-processing system component compares past classifying information with current classifying information. It combines existing information in the system with new information and makes a report containing the combined information available to the agent. For example, in the telephone records analysis of the suspects, it matches the calls made by a suspect with the telephone numbers of known criminals and makes a report of any matches available to the investigator.

The meta-level knowledge system provides knowledge about knowledge. It determines the priority of different knowledge sources in solving the problem. Sherpa lets the narcotics agent choose the desired analysis. Using the meta-level knowledge rules, Sherpa automatically produces the correct information for decision making. Sherpa extracts the data using independent sources of knowledge. These independent knowledge sources (rules in the intelligent agents) don't invoke one another and ordinarily have no knowledge of each other's expertise or behavior. They may also cooperate in contributing solution elements to a shared problem. We developed two knowledge sources: the telephone and financial analyses. Databases feed logically and geographically distributed data to the Sherpa modules.

Performance Comparisons

Our primary aim in developing Sherpa was to increase the efficiency and effectiveness of the drug-crime data-analysis process. To compare the existing system with Sherpa, we formulated three performance measures:

—The time it takes for the DNE to obtain the results of telephone and financial analyses after receiving data;

—The identification frequency, the number of middle- and upper-level drug dealers identified after the data analyses; and

—The amount of evidence obtained on which to base and prove the classification

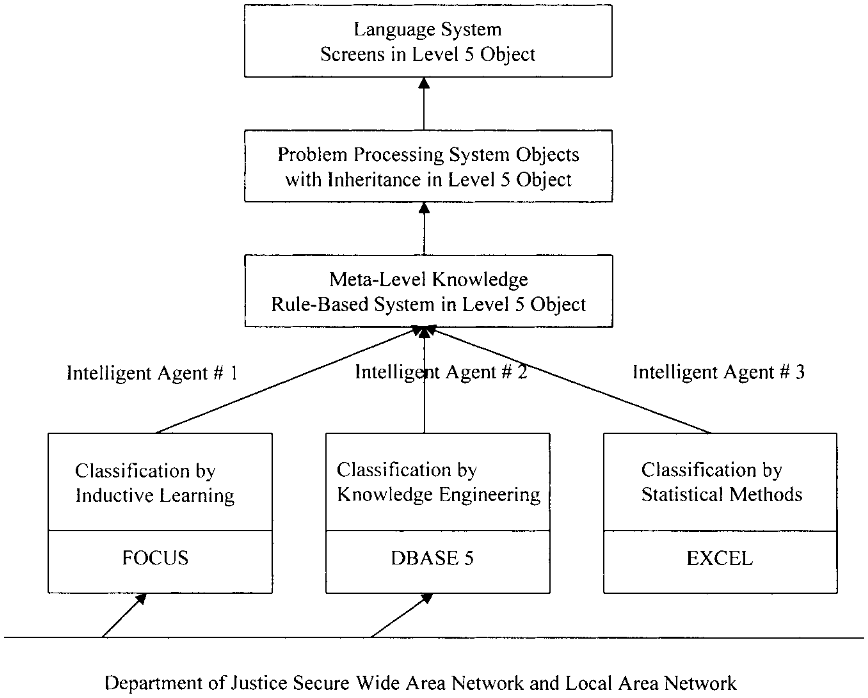

Figure 5: Sherpa architecture.

of a suspect.

We chose two DNE offices for performance comparisons, Madison and Appleton, which had similar numbers of agents with similar experience (Table 1). The two offices served different groups of counties but similar total populations (Table 2). The number of drug violations as a percentage of total population were similar at about 0.3 percent for the two offices. The Madison special agent-in-charge (SAC) was involved in the initial development of Sherpa. Therefore, to avoid any bias due to his personal interest in the success of Sherpa, we used Madison as the control office. We used the control group to measure the effects of any extraneous conditions, such as changes in organizational policy that might influence the observed results.

We chose the Appleton office as the treatment site, and we conducted the performance-comparison study over three months. We conducted a pretest at the two offices that consisted of closed cases from the previous three years. We screened

Variable	Appleton average (8 agents)	Madison average (7 agents)
Age	31.63	36.63
Years in law enforcement	8.13	7.96
Years in narcotics enforcement	5.39	6.82
Formal education (years)	15.69	14.00

Table 1: The agents at the Madison and Appleton offices have comparable backgrounds.

	Appleton DNE Office	Madison DNE Office
Adult population (1990)	805,509	899,915
Drug violations (1993)	2,019	2,744
Counties served	Brown, Calumet, Door Florence, Fond du Lac, Forest, Green Lake, Kewaunee, Langlade, Lincoln, Manitowoc, Marquette, Menominee, Oconto, Oneida, Outgamie, Shawno, Sheboygan, Vilas, Waupaca, Waushara, Winnebago	Adams, Columbia, Crawford, Dane, Dodge, Grant, Iowa, Jefferson, Juneau, La Crosse, Lafayette, Monroe, Richland, Rock, Sauk, Vernon, Walworth

Table 2: The areas under the jurisdiction of the Madison and Appleton DNE offices have comparable demographics.

cases for their telephone- and financial-analysis content (with the help of the SAC in Appleton). We selected 32 cases from a set of 500 cases that concerned real criminals and possible suspects. Of the 32 cases, 11 were fairly simple cases leading to arrests, 10 cases were difficult because the data were incomplete and conflicting, and the remaining 11 cases contained complete information that indicated that the suspect was innocent. To ensure against bias, we were careful to assign an agent to solve each case who had not worked on that case before.

To motivate the agents, we offered an unspecified amount as a prize to the best performing agent. We told the agents the SAC knew the amount but was to keep it confidential. We told agents not to discuss their cases or ask for external help. We also told them that we were measuring their performance to find out how the system worked and that we would keep the results confidential. We then provided two hours of training to all eight agents at the Appleton office, including the SAC. The training was performed in a group for two hours. We taught the agents how to use Sherpa, discussed its special capabilities, and distributed printed material that detailed its capabilities and services. The agents used Sherpa for 85 days before we conducted the posttest. We monitored each agent's performance in both tests. We asked the agents to work as usual with no time constraints. We measured variables physically by recording time and by asking agents questions after they solved these cases. Included in the time for solving the case using Sherpa was time for writing queries to obtain data about the suspect. Traditionally these data were provided in a printed report.

Using Sherpa the agents obtained the results of telephone and financial analyses in 28.5 minutes on average, a reduction of 18.5 percent from an average of about 35 minutes using traditional methods. Of the 32 cases, agents using traditional analysis identified 19 suspects as potential criminals, which led to a correct identification frequency increase of five percent. For the suspects that agents identified as possible criminals using traditional analysis, the agents identified 65 variables that led to their conviction. Using Sherpa, they identified 70 such variables, leading to an increase in evidentiary information of 7.5 percent.

Sherpa provided more evidence and identified more criminals.

Adoption and Use

We designed Sherpa to improve the overall effectiveness of drug-crime investigation. The initial performance comparisons have shown that Sherpa is a valuable tool for investigating drug crimes. WDNE decision makers use Sherpa as a decision-support tool to partly support the results of decisions they make based on traditional analysis. Criminal investigations do require some type of traditional analysis by a responsible decision maker, and Sherpa cannot replace the traditional decision-making process entirely. Currently DNE uses Sherpa to reinforce the results it obtains from the traditional analysis.

Conclusions

Our main objectives were (1) to use distributed artificial intelligence to develop a multi-module (or multi-agent) information system for decision making at the Wisconsin Division of Narcotics Enforcement and (2) to compare its performance with the existing traditional system. We developed a system, Sherpa, that analyzes financial and telephone records. Compared to the division's traditional approach, Sherpa provided more evidence and identified more criminals.

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Craig S. Klyve, Director, Special Operations Bureau, Wisconsin Division of Narcotics Enforcement, State of Wisconsin Department of Justice, 123 West Washington Avenue, PO Box 7857, Madison, Wisconsin 53707-7857, writes: "We are proud of our association with the University of Wisconsin and feel that the assistance has been of benefit to our organization.

"By using the methods described in the paper, we are bringing about changes within the organization with reengineering as our main focus. This is part of our commitment to provide quality law enforcement services to the citizens of the state of Wisconsin, and to assist in the efforts of local law enforcement throughout the state. We believe that new and innovative approaches are required to meet the challenges that we face in law enforcement today. The processes currently underway will assist us to meet our goals for the future."