GPS/GIS for Mobile Equipment Management

Y. Gao and R. Ramsaran

Department of Geomatics Engineering, The University of Calgary
Calgary, Alberta, Canada T2N 1N4

Abstract
Global Positioning System (GPS) has been widely used for precise positioning and navigation and it has also been increasingly used as a data source for Geographic Information System (GIS). This paper describes the concepts of integrating GPS, GIS and wireless communication for the development of a mobile equipment management system. Such a system could result in considerable operational cost savings for companies in the energy sector. To demonstrate the concepts, a prototype system is described with an application to the real-time maintenance of light plants in the large mining environment.

I. INTRODUCTION

Energy exploration operations involve the management of enormous mobile equipment to support the field operations. Due to the mobility of the equipment, research focus in the past has been placed on the development of cost-effective tracking systems using modern satellite navigation technology such as Global Positioning System (GPS). As the location determination becomes less a difficulty today, real-time mobile data processing and management has been crucial for the system to support field exploration operations. Taking the open pit mining as an example, the location, maintenance and scheduling of available equipment on the mining site are very critical to the day–to-day operations, since a typical open-pit mining operation may cover approximately 40,000 hectares. Each piece of equipment therefore has to be at the right place at the right time under good conditions preventing any downtime in operations. Downtime to mining industries is very costly to production and can run into millions of dollars in lost revenue [1]. Presently, some mines have completed their fleet management, machine guidance, shovel control, planning, surveying and reporting systems. However, these systems all act independent of each other and obtaining timely current information from each individual system for decision-making in planning can be quite challenging.

This paper describes the concept of a total equipment management system and a prototype system developed at The University of Calgary with an application to the maintenance of the mobile light plant equipment in the mining site. Details of the functions that have been implemented into the prototype system are provided.

II. TOTAL EQUIPMENET MANAGEMENT

Shown in Figure 1 is a conceptual diagram for a total equipment management system. It consists of three major components: field component, office component and communication component. An integration of satellite navigation, information management and wireless communication technology provides a solution to eliminate the discontinuity of the information transferred between field to office, office to office and field-office to informative decision-making. Satellite navigation technology will be applied to provide time and location information and to support non-spatial data acquisition as the field component. The data collected by the field component will be the basis for the development of the mobile database set up in the office. GIS technology will be utilized to develop transparent access to heterogeneous databases and geo-referencing resources in a network environment, which will establish the office component. Communication technology including radio tower, cellular and Internet is used for seamless information transmission and data flow.

As to system implementation, an open architecture must be employed to allow real-time heterogeneous database access and data integration as existing databases are largely incompatible to each other. Having an open system can prevent costly re-handling of massive amounts of data and it is also essential for ensuring transportability, adaptability and expandability of the current system. Operationally for such a total management system, data collection, processing, distribution and storage of pertinent information are conducted in a real-time manner.

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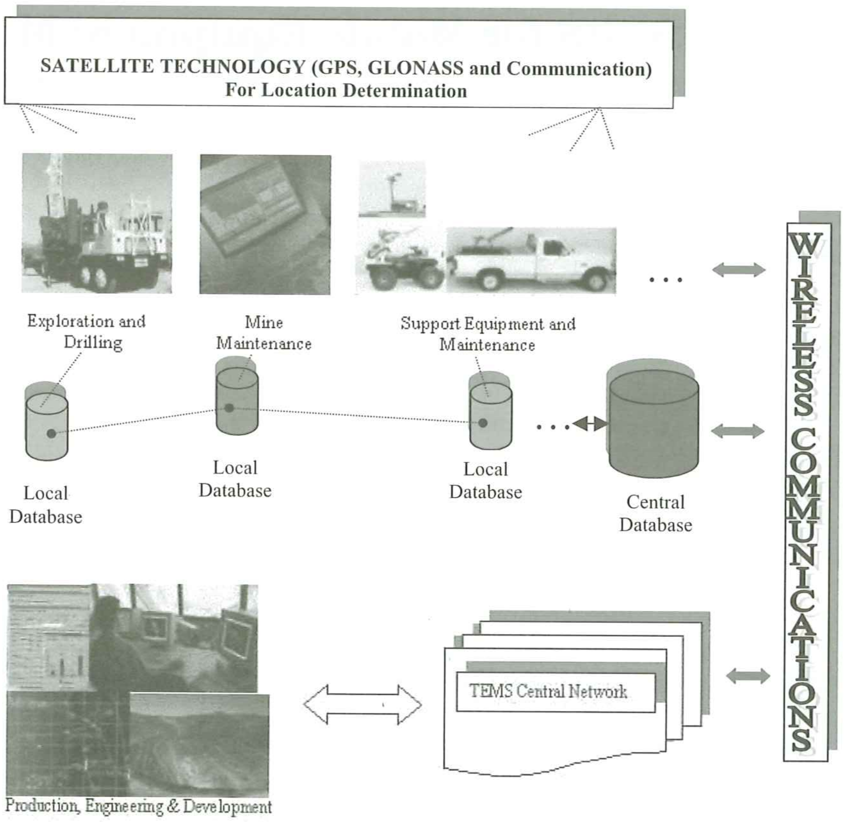


Figure 1. Architecture of a total equipment management solution

Information gathered are used to produce on-line digital plan, on-line scheduling of equipment, and on-line preventative maintenance on equipment. Every decision-making process within the system is considered an informed decision, transparent to all departments. Users can be assured that the system will utilize timely and current information available from different databases. Real-time information flow and access makes it possible for a significant reduction of the time delays in decision-making and subsequently support timely operational decision-makings.

III. DEVELOPMENT OF A PROTOTYPE SYSTEM

A prototype system has been developed based on the total equipment management concept described in the last section. The focus in the prototype development has been respect to a specific equipment type, namely the light plants in the open-pit mining site. A large mining site could have over one hundred of light plants in the field and they are primarily used to support mining operations during the night times (open-pit mining operations run on a 24-hour non-stop basis). Although focused on a specific equipment and served for feasibility assessment, the developed prototype system can be easily adapted to other equipment types and expanded for larger equipment management operations due to the employment of an open system architecture.

Field system: data acquisition

The data acquisition component consists of a rugged Pentium laptop computer with NT 4.0 operation system and the equipment management data collecting software, an Ashtech GG24 receiver, an active antenna and a Pacific Crest UHF/VHF radio are used for the data link.

The equipment management data collecting software is specifically design to cut down on human errors in the field. The software is used to collect spatial and non-spatial information. The spatial information is the direct recorder from the GPS/GLONASS receiver to the laptop. After recording this information the user can now input the non-spatial information into the software. There are several data quality checks implemented to ensure correctness of the entered information. By simply pressing a send key the user can now transfer his/her information to the master computer located in the main office via wireless communications. This computer also acts as a server where other users such as planners, dispatchers, mechanics, etc can retrieve the information from it.

Office system: data management

The office system is comprised of a network server and a Pacific Crest UHF/VHF radio used for the data link to retrieve the information from the field. In the development of the office software, defining data structures and choosing the right data access technology have optimized the system architecture for efficient database retrieval. This made the application faster, easily maintained and left room for future enhancements.

The office system does not retrieve its information only from a single database. Instead, it uses an extensive set of Component Object Model (COM) to interface with several distributed databases to draw upon diverse information. This employs an open modular system architecture. Since many existing systems are largely incompatible to each other, an open environment allows real-time transactions with a database that can be easily interfaced and integrated with other databases. Figure 2 shows the concept for typical application in an open-pit mining equipment management. One component of the system as shown in Figure 3 will provide the internal users with the ability to store, edit, maintain, retrieve, manipulate, analyze, present, represent and make specific decisions. Client users can graphically display their information to show not only the current but also historical location status of their equipment. The graphical user interface provides the clients with information on the particular piece of equipment by pointing and clicking on the object.

Equipment maintenance personnel can now maintain the database information with functions as shown in Figure 3. Clients such as planners or operation's personnel can now view the same information in a spreadsheet like format where one can query a certain piece of equipment by the unit identification or have an overall view on the map showing the equipment location. On the graphical interface the users have the option to view the current location or the historical locations of every light plant as shown in Figure 4. The current status allows the user to query an individual light plant or view all the light plants at the same time. Also the metadata for any of the light plants can be viewed on the graphical interface also shown in Figure 5.

Viewing the historical information shown in Figure 6 allows the user to track the movement of every light plant. Users also have the advantage of performing a query for a specific unit during a certain time period. This information can assist in determining the equipment usage and also determine the efficiency for scheduling that piece of equipment since one can map and track its movement. The office data management software also provides back up copies of all incoming files from the field and functions for database repairs.

Office system: decision making

The driving philosophy behind a Total Equipment Management System for the management of light plants is shown in a flow diagram format given by Figure 7. It is effective for direct information exchange between involved parties. This section of the software system will provide a sequence of events that, when followed, allows the light plants to be at the right place at the right time in the right working condition. Figure 8 shows the main software for making such important decisions. This piece of software would provide its users with the functionality for determining fuel,

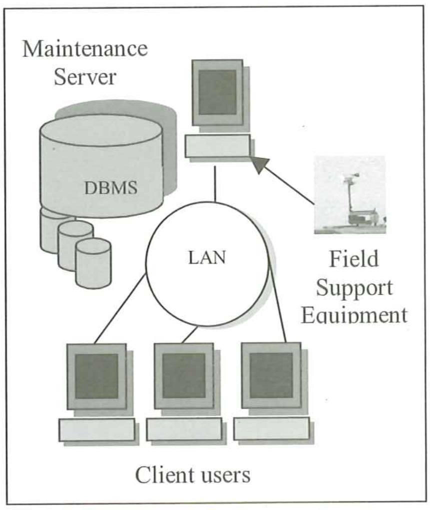


Figure 2. Office system

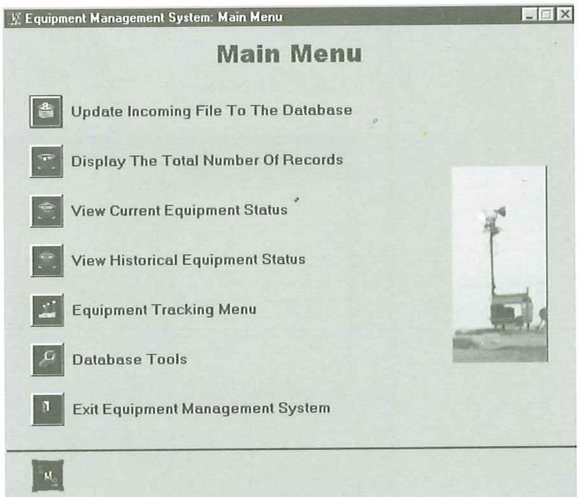
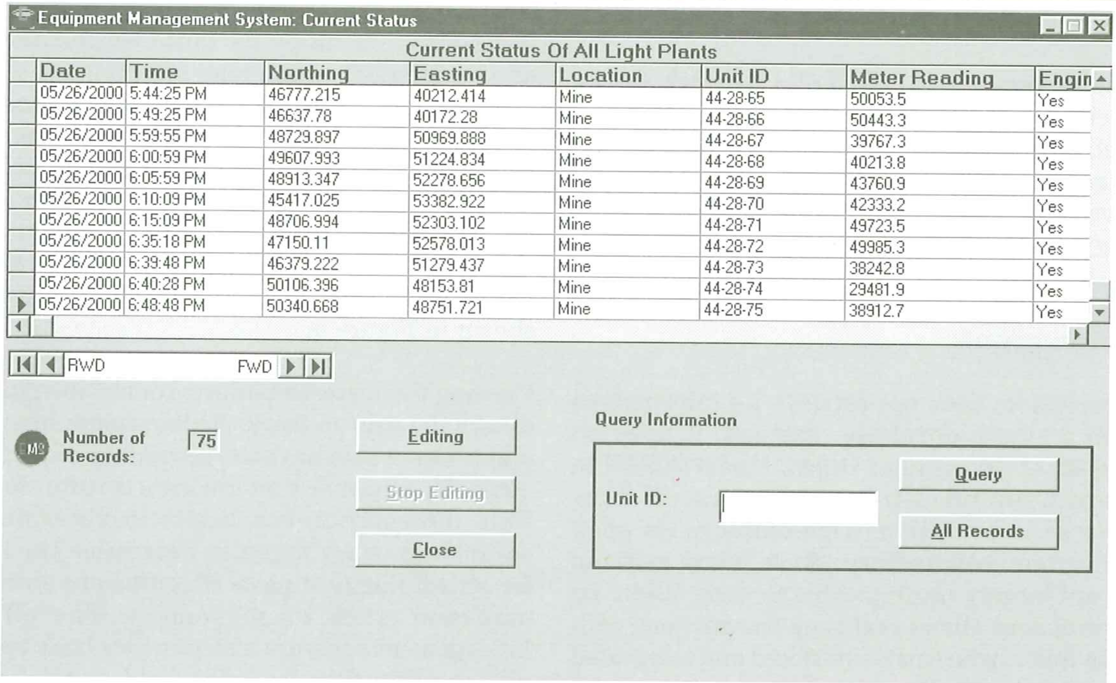


Figure 3. Data management menu



Date	Time	Northing	Easting	Location	Unit ID	Meter Reading	Engin
05/26/2000	5:44:25 PM	46777.215	40212.414	Mine	44-28-65	50053.5	Yes
05/26/2000	5:49:25 PM	46637.78	40172.28	Mine	44-28-66	50443.3	Yes
05/26/2000	5:59:55 PM	48729.897	50969.888	Mine	44-28-67	39767.3	Yes
05/26/2000	6:00:59 PM	49607.993	51224.834	Mine	44-28-68	40213.8	Yes
05/26/2000	6:05:59 PM	48913.347	52278.656	Mine	44-28-69	43760.9	Yes
05/26/2000	6:10:09 PM	45417.025	53382.922	Mine	44-28-70	42333.2	Yes
05/26/2000	6:15:09 PM	48706.994	52303.102	Mine	44-28-71	49723.5	Yes
05/26/2000	6:35:18 PM	47150.11	52578.013	Mine	44-28-72	49985.3	Yes
05/26/2000	6:39:48 PM	46379.222	51279.437	Mine	44-28-73	38242.8	Yes
05/26/2000	6:40:28 PM	50106.396	48153.81	Mine	44-28-74	29481.9	Yes
05/26/2000	6:48:48 PM	50340.668	48751.721	Mine	44-28-75	38912.7	Yes

Figure 4. Current status of all equipment

location and maintenance scheduling along with some loss management applications.

The prototype system created for the tracking of light plants has the capability of integrating into present systems for requesting information. Currently the system retrieves information from two databases with the capability of linking to others. One database supplies the spatial information along with the mechanical information for the light plants and the other supply the fuel and repair information. Given a combination of information relating to specific light units, location and availability schedules can now be understood by incorporating mechanical, service and downtime information. For instance, planners can now locate a unit by several different instances:

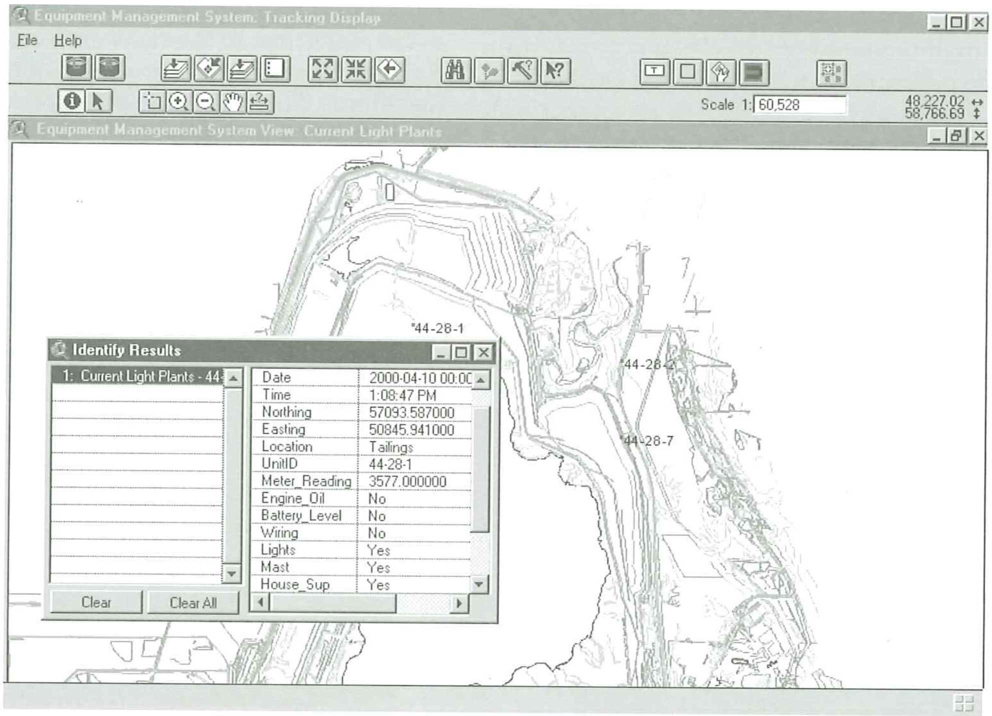
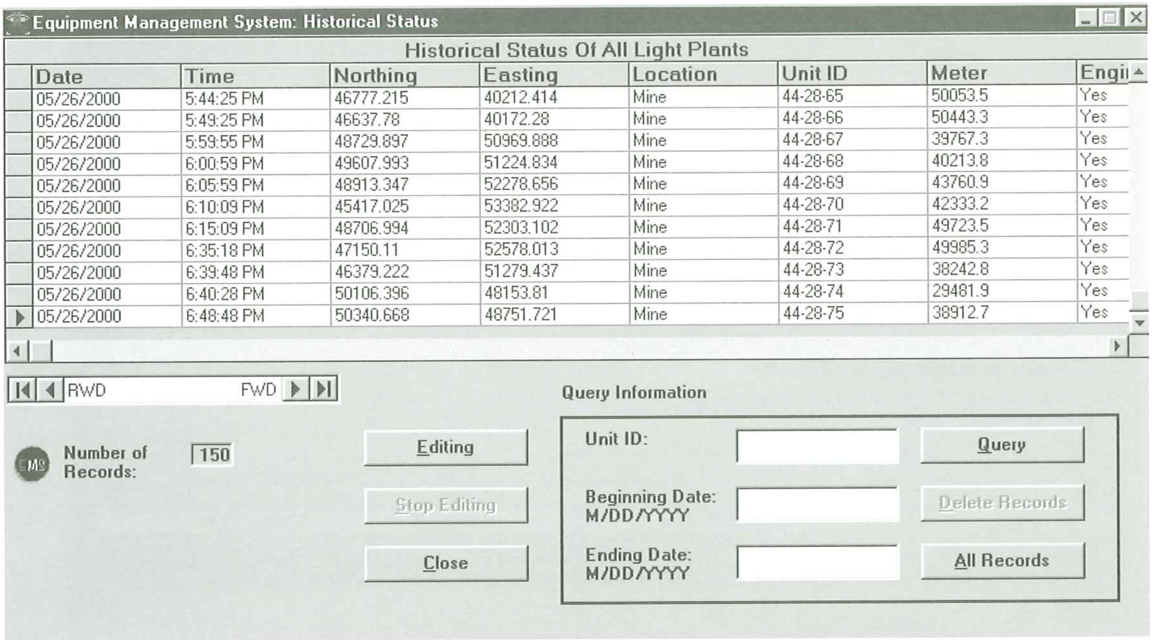


Figure 5. Current status of specific equipment



Date	Time	Northing	Easting	Location	Unit ID	Meter	Engi
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05/26/2000	5:59:55 PM	48729.897	50969.888	Mine	44-28-67	39767.3	Yes
05/26/2000	6:00:59 PM	49607.993	51224.834	Mine	44-28-68	40213.8	Yes
05/26/2000	6:05:59 PM	48913.347	52278.656	Mine	44-28-69	43760.9	Yes
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05/26/2000	6:40:28 PM	50106.396	48153.81	Mine	44-28-74	29481.9	Yes
05/26/2000	6:48:48 PM	50340.668	48751.721	Mine	44-28-75	38912.7	Yes

Figure 6. Historical status of all equipment

a) within the specified radius;
b) entering the latitude and longitude for the job; and
c) search by unit identification.

It is guaranteed that the unit of choice is not scheduled for service or has a history of breakdowns after working for a number of hours, see Figure 9. Initial parameters are set causing the software to guard against repetitive breakdowns or unavailability due to service and other misfortunes. Hence, ensuring that the equipment is operating at peak efficiency for the ongoing project.

Personnel from the maintenance shop can now create efficient schedules for fuelling the light plants to ensure they are usable for the long duration. The maintenance personnel can operate the software by choosing one of the two instances as shown in Figure 10:

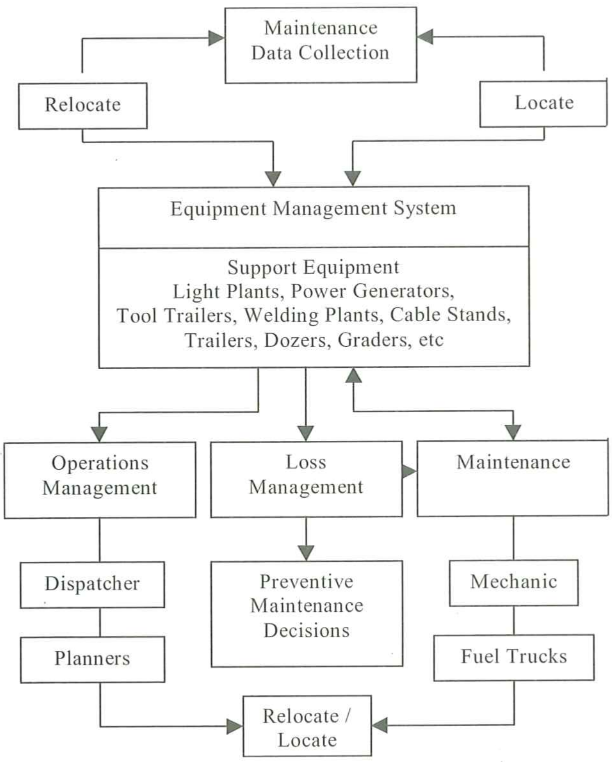

Figure 7. Light plant management model

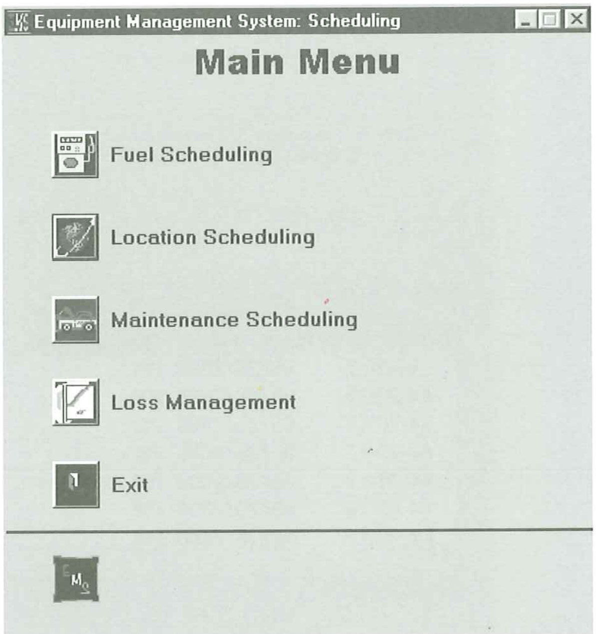

Figure 8. Decision-making menu

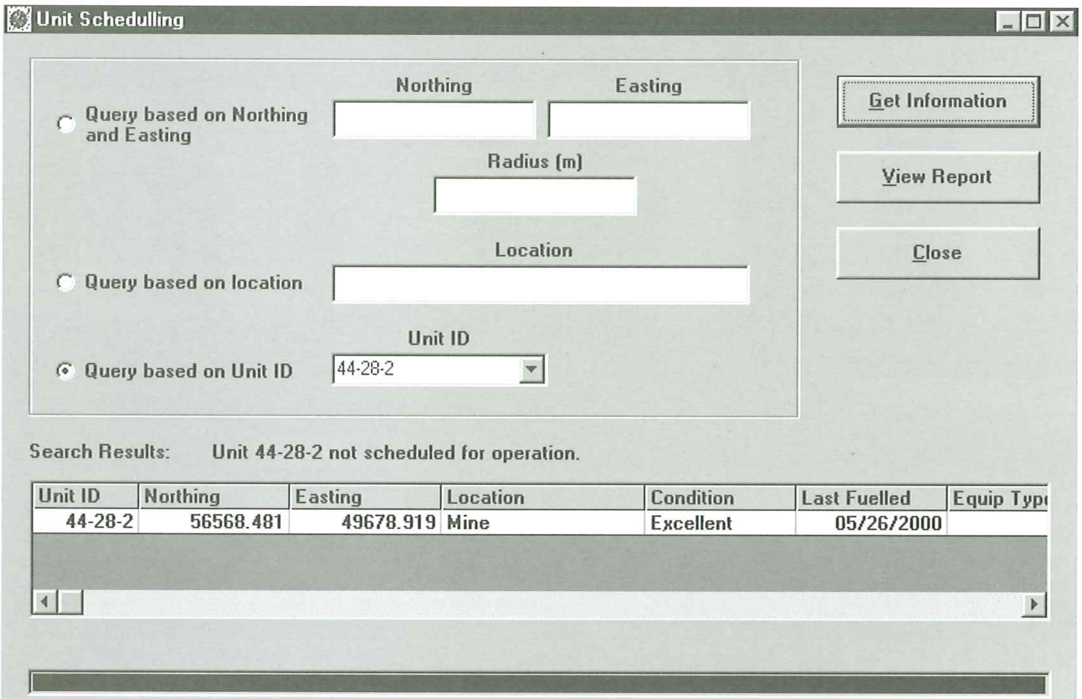

Figure 9. Location scheduling

a) query based on the fuel efficiency and the number of days lapsed; and
b) query based on the number of days lapsed between last fuel date.

Having done so the operator's daily routes are now effectively generated and planned eliminating unnecessary driving within the perimeter of the mine. This system also helps by giving the exact up-to-date location for that unit, therefore the operator does not have to rely on where last the unit was seen or left.

The equipment management software also assists in providing service history for the light plants. For this

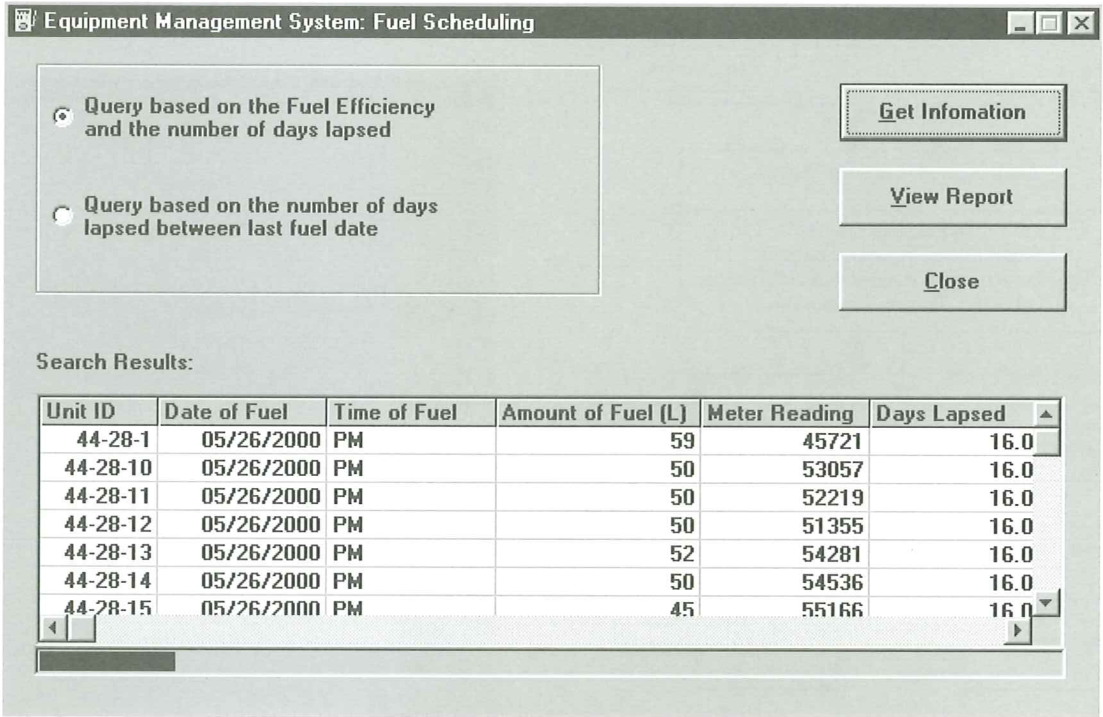

Figure 10. Fuel scheduling

instance the maintenance personnel would set the criteria for the number of hours lapsed between meter readings. Shown in Figure 11, the user has entered a criterion of 10 hours. This ensures that the units are properly maintained and serviced. Very expensive engines run these light plants and constant monitoring of these engines are necessary since they are in operation for long continuous hours. Also during shift change of personnel, people are misinformed or even the information is incorrectly filed or even not recorded. This creates mishaps and many times some pieces of equipment are overlooked creating downtime or expensive repairs. Having the flexibility this software provides will ensure the proper maintenance schedule is followed. All work carried out to any light plant will be stored in the database.

Preventative maintenance is always an issue with large organizations who owns million of dollars worth of fleet and support equipment. Ensuring that these assets are well maintained is not an easy task. Hundreds of person hours are been spent keeping track of every piece of equipment to ensure that there are no costly repairs or maintenance. Some mining companies have instituted the Loss Management program to help employees manage themselves and company equipment. In prototyping the equipment management software it was necessary to incorporate preventative maintenance for the light plants, this fell under the loss management section of the program. Using fuel consumption specification and determining downtime, utilization time and not-in-use time for the light plants gave the opportunity for determining fuel efficiency during equipment utilization. The results shown in Figure 12 helps in the decision-making process about the optimization for that piece of equipment. It also determines the operation cost and whether it's in the best interest of the maintenance shop to replace it or perform upgrade on that piece of equipment. Figure 12 shows that equipment 44-28-9 has been utilized more during the winter months where daylight is limited. It also shows that the fuel efficiency has decrease during those months of inclement weather conditions. In the overall picture unit 44-28-9 has been maintained and utilized efficiently. Therefore, the software would not flag this unit hence the blank area in the top left corner of Figure 12.

IV. SUMMARY

The system architecture of a total equipment management system has been described in this paper which will offer numerous benefits to applications involved in the use of a large number of mobile equipment. The prototype system was designed for the area of mine maintenance where all large and small pieces of equipment can be located, maintained and scheduled efficiently for the day-to-day operations. This would assist in crucial decision making and help maintain a smooth flow of up-to date information between, and even within, different areas of a large open-pit mining operation.

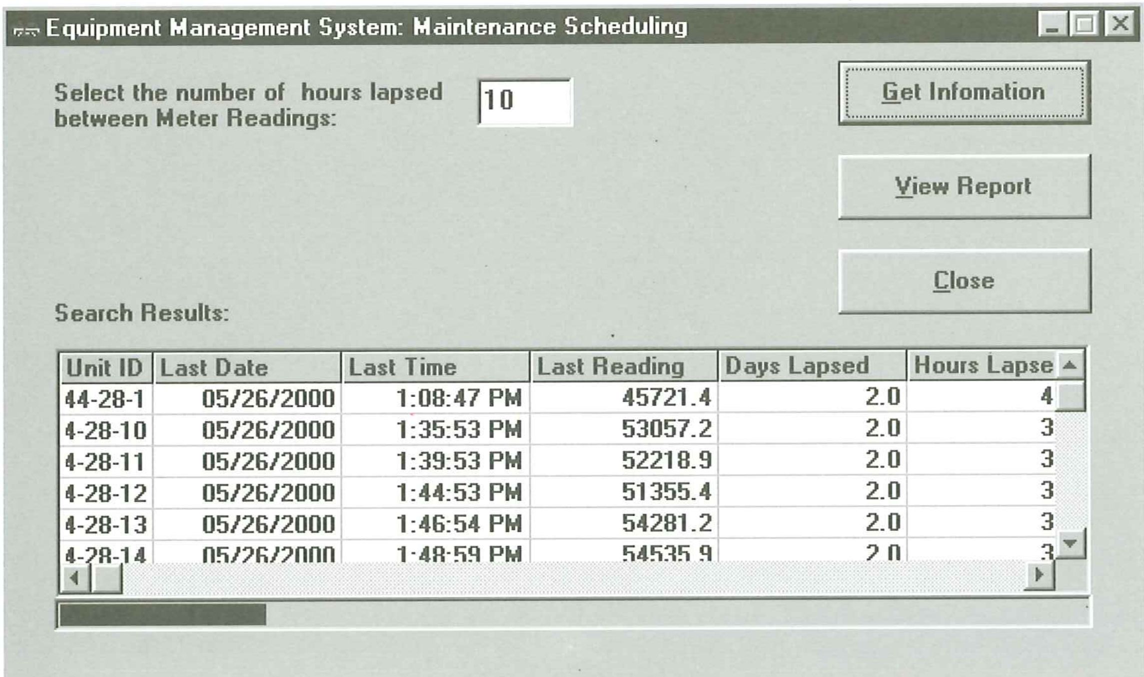

Figure 11. Maintenance scheduling

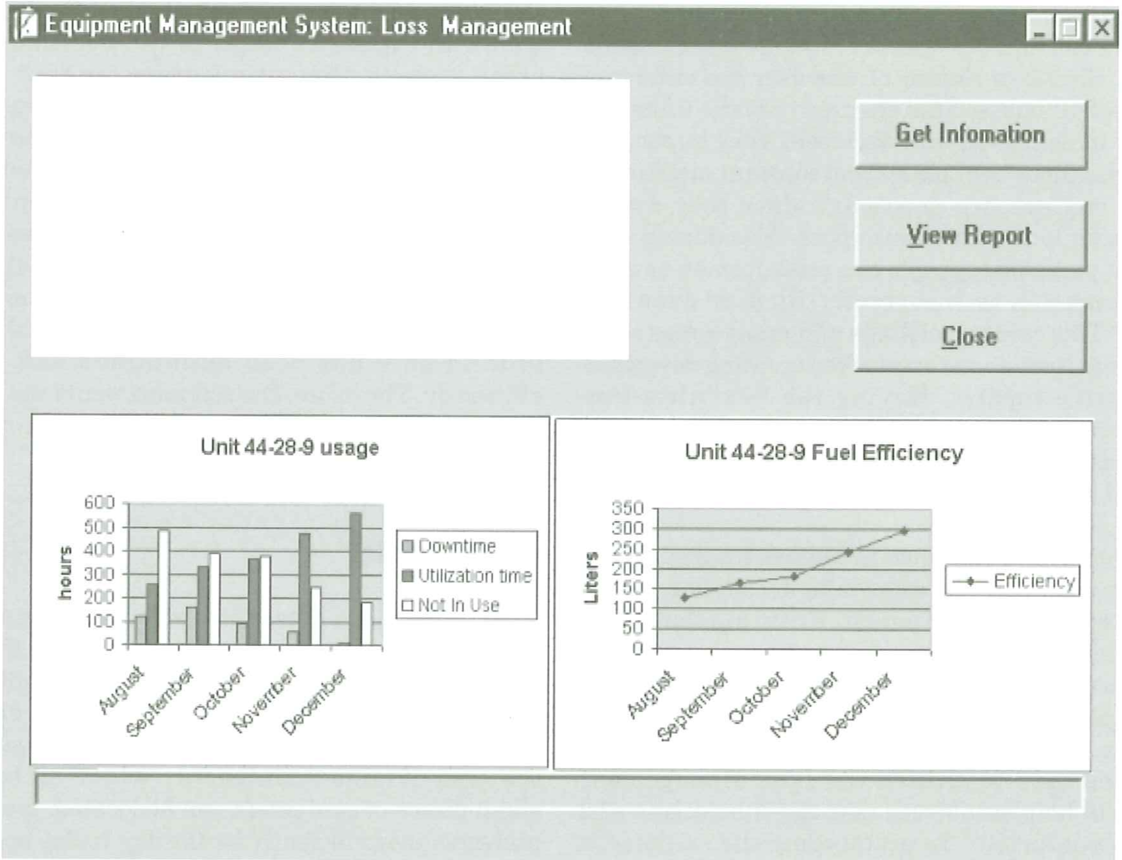

Figure 12. Preventative maintenance

REFERENCE

[1] Carter, J., 1999, *Mine Maintenance Equipment*, Unpublished report for Syncrude Canada Ltd., Mildred Lake, Alberta, Canada.

News on Remote Sensing, Earth System Science and GIS

Establishment of the International Institute for Earth System Science, Nanjing University

About 100 scholars gathered from many parts of the world on November 19, 2000 at Nanjing University to celebrate the establishment of the International Institute for Earth System Science (ESSI). The goal of ESSI is to promote interdisciplinary research on the systematic interactions between the biosphere, lithosphere, atmosphere and hydrosphere based on modern multiscale observation and measurement techniques including remote sensing, global positioning systems and GIS by scientists from all over the world with an interest in the role of China in global change. Minister Xu Guanhua, Academicians Wang Dezi, Wu Rongsheng, Professor Lu Zewei from the National Natural Science Foundation of China, Directors of various organizations inside China including professors Wang Ying, Guo Huadong, Liu Jiyuan, Yu Xiaogan attended the ceremony. President Jiang Shusheng of Nanjing University, Dr. Wanchang Zhang, Professor Zhanqing Li from University of Maryland, and Professors Guo Huadong and Liu Jiyuan made speeches at the ceremony. Professor Chen Shupeng send a letter and a poem wishing the success of ESSI. The left photo shows attendents at the establishment of ESSI.

(Peng Gong)

New Hong Kong Base of National Remote Sensing Center of China

National Remote Sensing Center of China (NRSCC) built up its new base for research, development and training in Hong Kong on December 9, 2000. This new base will promote remote sensing research and applications in Hong Kong and south China, with the support from the Joint Laboratory for Geoinformation Science of Chinese Academy of Sciences and The Chinese University of Hong Kong. With Hong Kong's geographical advantages and multiple culture environments, this new base will also enhance the international cooperation between NRSCC and its partners in other countries and regions. The Hong Kong Base will work together with related institutes in Peking University

Photo: Professors Xu Guanhua, Chen Shupeng (center) and young scholars in the opening ceremony.

and Wuhan University to form the International Institute of Spatial Information Technology (IISIT).

Over 100 officials, scholars, representatives of industries attended the opening ceremony from the mainland, Taiwan, Hong Kong and Macau. Academician Xu Guanhua, vice minister of State Ministry of Science and Technology, Mr. Liu Shanzai, deputy director of The Liaison Office of The Central People's Government in HKSAR, Mr. Zhou Dexi, Secretary of Commerce and Industry of HKSAR Government, Professor Li Guozhang, president of CUHK, officiated the opening ceremony of the new base.

(Hui Lin)

GeoInformatics 2000 Conference

The Geoinformatics 2000 was successfully held at the California State University-Moneterey Bay from June 20 to 23. As the first GeoInfomacics conference in this millennium, this annual meeting was a landmark experience. The multidisciplinary approach was designed to foster intellectual, professional and cultural interactions among individuals and groups interested in spatial information science and technology. A total of 15 sessions was scheduled, featuring around 100 domestic and oversea speakers from educational institutions, government, and industry. There are plenty of interesting topics, such as "Modeling and Mapping Service Regions to Predict Access to Social Programs"; "Landscape Accessibility as a Measurement Function of Urban Green System"; "Web-based GIS"; "Data Model for Multi-Modal Mass Transit System"; "GIS and Land-Use Planning"; "GIS in Regional Development and Marketing"; "GIS and Sustainable Development"; and "GIS and Natural Hazards." The wide variety of papers gave the attendees the opportunity to see and hear the latest development in research, application, and education of geographic information systems (GIS), remote sensing, and global positioning system (GPS). Professor Emeritus Duane F. Marble, an inspiring pioneer and a legendary figure in GIS, delivered the keynote speech entitled "Challenges for GIS Research and Education in the 21st Century". For complete information about the conference, including the conference proceedings, please visit the GeoInformatics 2000 conference web site at: http://www.monterey.edu/geoim2000). Photo1 is part of members of CPGIS and Photo 2 is a session in the conference of the Geoinformatics 2000.

(Yong Lao)

(Photo 1)

(Photo 2)