EQUIPMENT LOCATION SYSTEMS: PROVIDING INTERMODAL TERMINAL OPERATORS WITH ACCURATE INFORMATION

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ABSTRACT

Intermodal container terminal operators perform three primary tasks when handling containers: identification, location, and assignment. Numerous tools are available that facilitate assignment of containers, such as computer software programs designed to manage container location, placement, and routing within a container terminal. However, these software tools depend on manual input for identification and location data. Automatic identification and positioning technologies are available that can readily identify and locate equipment, but to date, no attempt has been made to integrate these technologies to provide a comprehensive resource for intermodal operations.

By integrating automatic equipment identification (AEI) and differential global positioning system (DGPS) technologies into container handling equipment, terminal operators can receive container identification and location in an automatic mode. This information update can be completed via wireless data communication, which provides a high-speed, bidirectional data link between the master station and mobile remote units located on container handlers. This communication backbone forwards the DGPS correction factor to all mobile units and carries the identification and location information to the master station.

The Cargo Handling Cooperative Program (CHCP), a cooperative organization made up of American President Lines, Ltd.; Crowley American Transport, Inc.; Matson Terminals, Inc.; and the U.S. Maritime Administration, is sponsoring a proof-of-concept test that will demonstrate the feasibility of integrating AEI, DGPS, and wireless area networks into an equipment location system (ELS) that will provide accurate real-time identification, location, and data communication. ELS will provide terminal operators with information in a near real-time mode to facilitate planning, management, and quality programs that improve terminal productivity and enhance customer service.

INTRODUCTION

The rapid growth of intermodal services in the transportation industry has made efficient intermodal operations a cornerstone for a global transportation infrastructure. Research conducted in 1993 by Mercer Management Consulting for the Association of American Railroads (AAR) indicates that intermodal traffic will grow between 4.7 and 7.6 percent annually through the end of the century (1). With such amazing increases, questions arise concerning the efficiency of intermodal operations.

Despite difficulties, intermodal facilities are beginning to investigate methods for improving their efficiency. According to the Mercer study, advancements made in internal operations and infrastructure offer more cost-effective means of improving throughput in an intermodal facility versus increasing the size of a facility. To perfect and improve intermodal operations, terminal operators must be supplied with the most advanced information systems available.

An equipment location system (ELS) provides terminal operations with real-time container and chassis information, allowing intermodal terminals to achieve productivity gains and offer a new level of efficiency to carry intermodal operations well beyond the year 2000.

DEFINING THE ELS

Through a grant from the Cargo Handling Cooperative Program (CHCP), a cooperative organization made up of American President Lines, Ltd.; Crowley American Transport, Inc.; Matson Terminals, Inc.; and the U.S. Maritime Administration, advanced information technologies have been integrated to demonstrate the feasibility of an ELS to provide accurate real-time identification, location, and data communication. An ELS compiles terminal facility data in real time and supplies the information to terminal operators. The ELS does this by integrating automatic equipment identification (AEI), differential global positioning system (DGPS) technologies, and a wireless data communication network. With the information provided by the ELS, terminal operators are able to facilitate planning, management, and quality programs that improve productivity and customer service. (Amtech Corporation of Dallas is the project manager and NOW Solutions of Santa Clara, California, is the systems integrator for the CHCP project.)

THE INTERMODAL DILEMMA

In any business operating as part of a global market, delays mean increased expenditures, reduced productivity, and lost revenues. For intermodal operations, delays affect every aspect of the transportation chain. When these delays occur at an intermodal yard, the reduction in efficiency is passed on to others involved in the process. The result is a system in which the various parties working together via the intermodal facility do not work as smoothly as possible with each other.

Improved management procedures and contributions by systems such as ELS can increase the capacity of available terminal resources while eliminating handling delays. Increased capacity coupled with fewer delays drive down intermodal facility operational costs exponentially.

Improving Operations

As throughput demands on intermodal terminals increase rapidly, a typical initial response is to expand the facility. Although increasing the scope of the operation may produce more area in which to conduct operations, increasing the size of a facility that is inefficient usually creates a larger inefficiency. Terminal expansion, therefore, may not be the answer for improved operations. As the Mercer study concluded, "Internal operating and infrastructure improvements typically offer more cost-effective means of improving throughput capacity than facility expansion."

The average turnaround time for a drayage operator in an intermodal facility is 30 to 45 minutes. Waits as long as 90 minutes are not uncommon, and every delay means money wasted. Operating costs such as fuel and maintenance typically are about 45 cents a mile. Overhead, including insurance, taxes, vehicle depreciation, and operator salary averages about $25 per load (1). The costs for drayage operations can average $40 per hour whether the operator is delivering a load or waiting in line (1). Even if terminals have sufficient gate operations to avoid lengthy delays, unexpected problems can slow throughput, causing longer gate lines and increasing the number of drayage operators being delayed. When terminal operations create delays, entrance wait time for other drayage operators increases, reducing the cost-effectiveness and synchronization of terminal operations. Lengthy queue times are costly, particularly in ports such as New York, where charges are assessed every 15 minutes an operator exceeds a 45 minute wait limit (1).

At Matson Navigation's Sand Island Terminal, gate operations that took 1 minute using a manual method, take just 15 seconds with an automated system. With more than 250,000 transactions a year, the time saved can exceed 3,000 hours annually.

Compared with gate operations, inefficiency in crane operations creates more disabling characteristics for an intermodal facility. Research conducted by Sea-Land Service, Inc., found that crane operators at their marine yards average about 25 lifts every hour. With an increase of just 1 lift per hour, operators save $250,000 to $1 million each year (Fig. 1) (2). Because a crane operating at full capacity can complete a lift in about 1 minute, cranes can achieve operations of up to 45 to 50 lifts each hour. Often, however, cranes are idle as operators wait for the appropriate container to be located, moved, and finally positioned before loading. If a crane operating team were able to double the average number of lifts per hour, the savings would be staggering.

By reducing the amount of time lost searching for specific containers, available parking slots, and empty chassis, productivity of an entire intermodal facility would improve. Crane run time can be enhanced by increasing the efficiency of loading and unloading logistics and reducing the overall wait time for crane supply vehicles. Container drayage schedules can be improved and perfected by automating, cutting, costly delays, and improving turnaround times. Automated notification of container arrival would allow drayage operators to streamline schedules and develop just-in-time operations. An ELS delivers the capability to enhance all these aspects of terminal operations in a real-time, automated format.

Resolving Equipment Shortages

The rapid growth of intermodal as the preferred method of transportation has exceeded the supply of containers

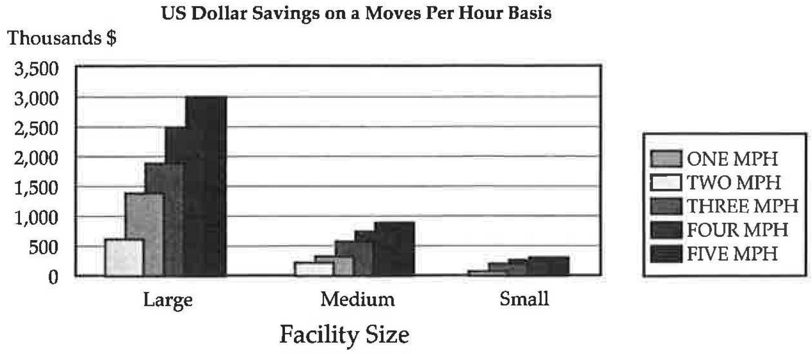

FIGURE 1 Typical benefits of increased crane production.

and cars. Forecasts at the beginning of 1994 estimated that an additional 30,000 to 40,000 trailers and containers would be added to the infrastructure by the end of the year. The addition of this equipment and the construction or expansion of intermodal facilities throughout North America offer only a temporary solution to the issue of efficient terminal operations.

Intermodal terminals must develop the most efficient operations possible. ELS provides an opportunity to reduce the need for additional equipment by developing improved asset management techniques to make terminal throughput, capacity, and synchronization more efficient.

INTEGRATING AVAILABLE TECHNOLOGY

Intermodal terminal operations must have container and equipment identification, location and assignment to manage inventories efficiently. ELS integrates AEI, DGPS, and wireless area network technologies to provide automated information to terminal operations and management systems.

AEI Systems

One system already being used in numerous intermodal applications is Amtech's AEI system. Systems using radio frequency identification have been developed specifically for use in the intermodal transportation market. These AEI systems are capable of reading electronic radio frequency tags installed on intermodal equipment and automatically reporting the identification data to a controlling computer.

AEI systems consist of tags installed on intermodal equipment and readers deployed in strategic locations, such as at a gate, on a gantry crane, or in mobile inventory vehicles. AEI systems operate by scanning the tags that pass by the readers or by reading tags as vehicle-mounted readers pass (Fig. 2). Terminals use this information to track vehicles, ensure timeliness and accuracy, and improve scheduling.

Information exchanged between the tag and the reader uses a communication technology called modulated backscatter. In backscatter technology, the tag on the vehicle acts as a field disturbance device, sending information to the reader by modulating and reflecting a constant carrier wave signal transmitted by the reader. This enhances the tag's capability to be frequency agile. For equipment that travels globally, the capability of AEI tags to operate at multiple frequencies is mandatory because every country has its own regulations governing radio frequencies and power levels. Because various frequencies are used throughout the world, a single tag with compatibility for all frequencies and power levels is essential for global operations.

AEI systems using backscatter technology have a misread rate of less than one in 800 million, and systems typically exceed 99.95 percent performance accuracy. Backscatter technology is not affected by environmental concerns such as other radio signals, cellular communications, and adverse weather conditions and does not increase pollution in the communication environment. This technology is used in a variety of applications including intermodal operations for companies such as American President Lines, Matson, Maher Terminals, Union Pacific, and the Port of Singapore Authority; fleet management applications for users including Consolidated Edison of New York, Star Enterprise (Texaco) of Dallas, and The Vons Companies of Los Angeles; and rail applications including the Mass Transit Rail Corporation, in Hong Kong; Pantograph Monitoring System, in Cheddington, England; and the AAR mandate to tag all equipment in North America.

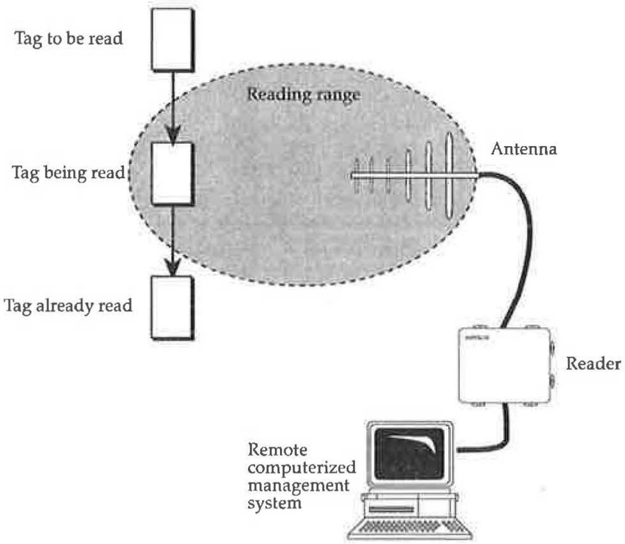

FIGURE 2 Typical operation of automatic equipment identification technology.

Global Positioning Systems

The U.S. government has invested more than $10 billion in the Global Positioning System (GPS) to provide location information. GPS receivers use satellite ranging to calculate a position. Each of the system's 24 satellites transmits its own position, time, and long psuedorandom noise code, which is used by the receiver to calculate range. After obtaining similar range information from multiple satellites, receivers calculate location, and even altitude, by triangulation.

Satellites contain on-board celestial navigation equipment and atomic clocks to provide accurate information. These data are transmitted in a lengthy sequence of random bits to a receiver, which aligns the stream with its internal stream to calculate travel time from the satellite. With travel time and satellite positioning compiled from three satellites, a simple triangulation calculation can provide two dimensional location. Information from a fourth satellite can be used to enhance position calculations to within several meters.

For intermodal facilities, GPS receivers select the appropriate signals from the satellites to calculate position. To improve the accuracy of GPS, a differential factor is used to correct readings and obtain submeter accuracy. A differential global positioning system (DGPS) uses a stationary base to calculate position and compare calculations with known coordinates, with the difference becoming the correction factor. This correction factor is sent to mobile GPS receivers to use in a correction algorithm. Testing indicates DGPS consistently provides submeter accuracy in an intermodal container terminal under defined guidelines (Fig. 3).

Wireless Area Networks

Essential to the real-time operations of ELS is rapid, bidirectional communication between stationary and moving vehicles throughout the terminal and the central station. A wireless area network transmits DGPS corrections to all operating vehicles. When not being used to communicate DGPS corrections, the network relays bidirectional messages from the vehicles in the facility and the central station.

The wireless area network that will be used in the proof-of-concept test will apply spread-spectrum technology to provide wide-band high data rate communication between the central station and mobile vehicles. The rep speed local area network will provide extended coverage to large facilities.

Combining Technologies

Integration of AEI technology, DGPS, and a wireless local area communication network creates an ELS that reports the exact location of equipment and cargo within the intermodal terminal in near real-time mode. The ELS being demonstrated for CHCP integrates these technologies to create an accurate map of a wheeled container storage environment. The map will include information on storage area occupancy and status of parking slots—whether unoccupied or occupied chassis—and accurate identification of all tagged equipment.

In the ELS, DGPS provides exact yard location information, AEI provides equipment identification, the wireless network completes terminal communication, and a sonar mapping system (Fig. 4) provides occupancy status of chassis. A processor mounted on the mobile inventory vehicle integrates the technologies, controls communication, and processes all information. A central data terminal positioned in a strategic location within the intermodal terminal monitors all activity, provides communication throughout the facility, controls DGPS updates, and provides the host or user interface.

DEMONSTRATING THE ELS

The CHCP grant established the proof-of-concept project to test the validity and accuracy of an ELS. The test focuses on the wheeled method of container storage,

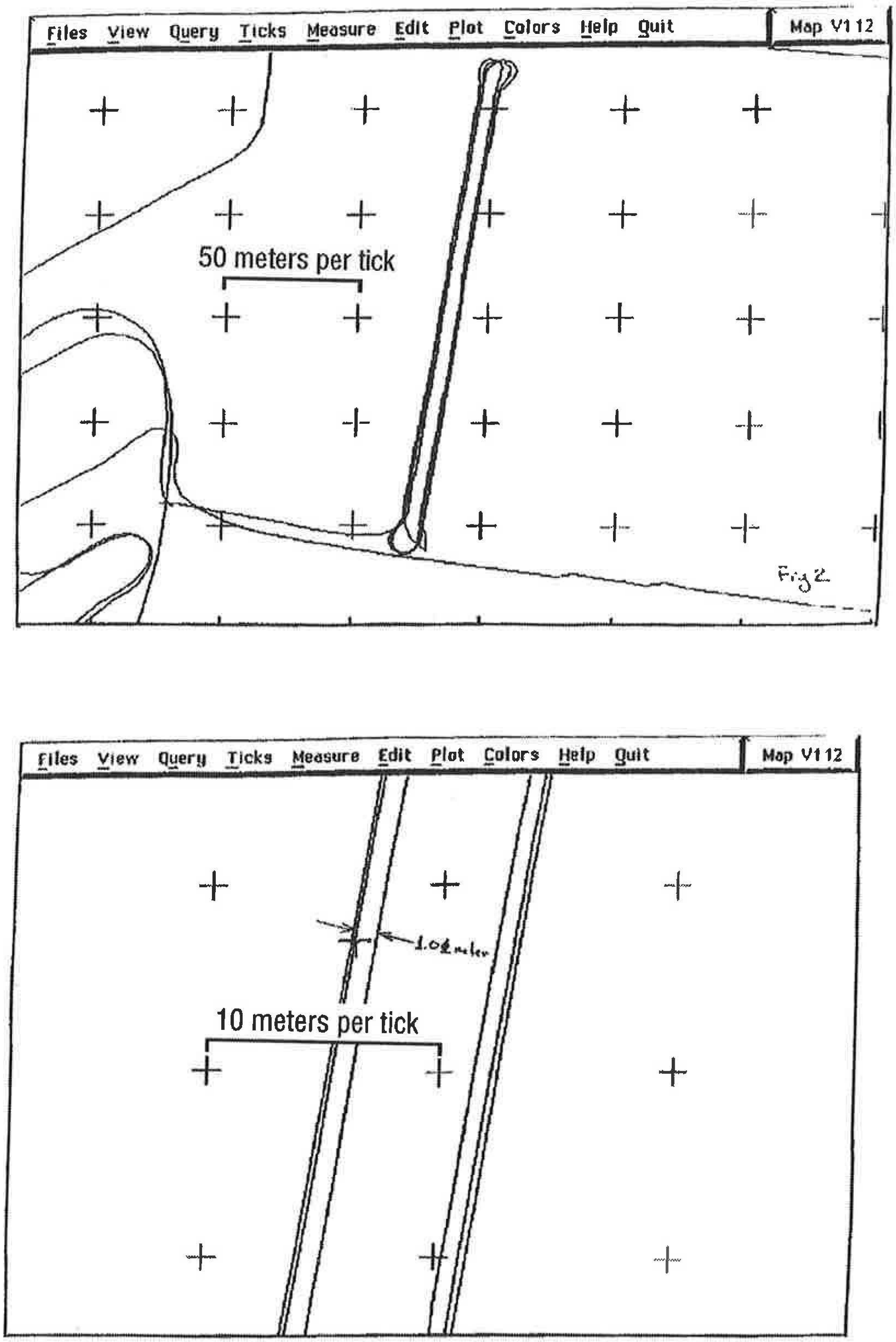

FIGURE 3 Accuracy range of typical differential global positioning systems.

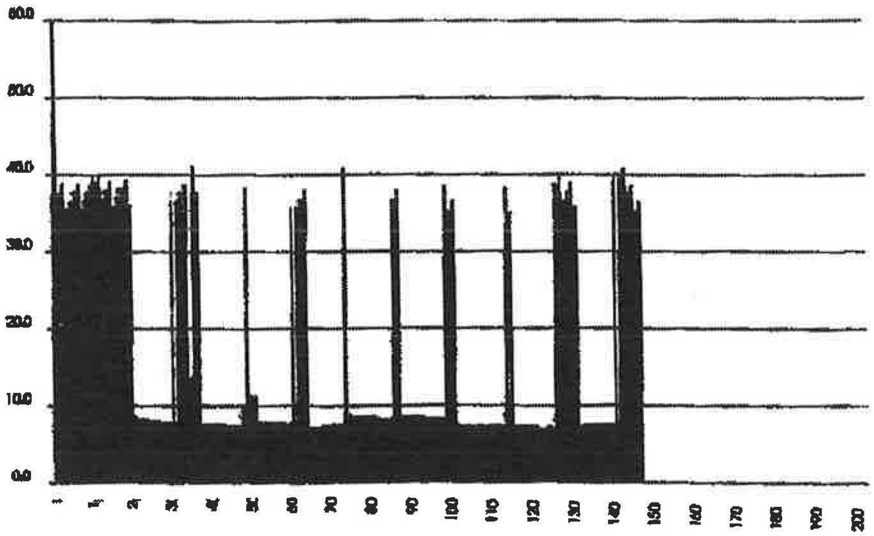

FIGURE 4 Sonar mapping capabilities.

specifically containers stored on chassis. By automatically reporting identification and location of tagged chassis and containers and occupancy status of parking areas, the ELS gives terminal operators access to real-time, accurate information, which can facilitate optimal terminal operations.

The ELS Project

The objective of the project is to demonstrate that an ELS vehicle traveling at approximately 5 mph (8 km/h) can produce an accurate map of a defined wheeled container storage area. Unlike in previous demonstrations, the ELS integrates technologies such as AEI and GPS that were not commercially available even 10 years ago.

At the American President Lines (APL) terminal facility in Oakland, California, a wheeled storage environment contains equipment placed in uneven, often random, rows. For the demonstration, an ELS is placed on one mobile inventory vehicle (Fig. 5 and 6). A master controller at a central workstation in a fixed location in the intermodal terminal contains a personal computer, a multichannel DGPS and antenna, and a wireless network radio and antenna.

As the mobile inventory vehicle moves throughout the terminal, an accurate map is created indicating the occupancy state of the parking slots, identification of the chassis and containers in the slots, and whether the chassis are occupied (Fig. 6). Data gathered by the mobile inventory vehicle is forwarded to a central workstation via the radio and compiled in a data base. The workstation also controls the DGPS base receiver and the wireless network and converts the incoming data into terminal-specific location nomenclature. The workstation is capable of interfacing with the terminal's host computer and yard management system.

"Real-time inventory systems and automatic equipment identification...promise much better knowledge and control of terminal inventory and parking," the Mercer study concluded (1).

ELS in Operation

The base DGPS calculates a GPS correction factor by comparing the calculated relative position of the base station to the known coordinates. The correction factor is then forwarded to the mobile GPS receiver for calculation of location data accurate to 1 meter. The ELS workstation (Fig. 7) is responsible for data communication control, DGPS interface and interface with the host computer, terminal-specific coordinate development, and wireless data network control.

In a typical ELS operation, GPS receivers (incorporating the correction factor) calculate position within the intermodal terminal. Using an antenna array, the AEI system reads each container and chassis tag as it moves through the wheeled environment. The on-board ELS controller integrates identification, position, sonar map, operator terminal, and data communication systems. The mobile operator's data terminal monitors activity, offers the means to input data manually and provides communication between operators, dispatchers, and controllers. The integration process provides

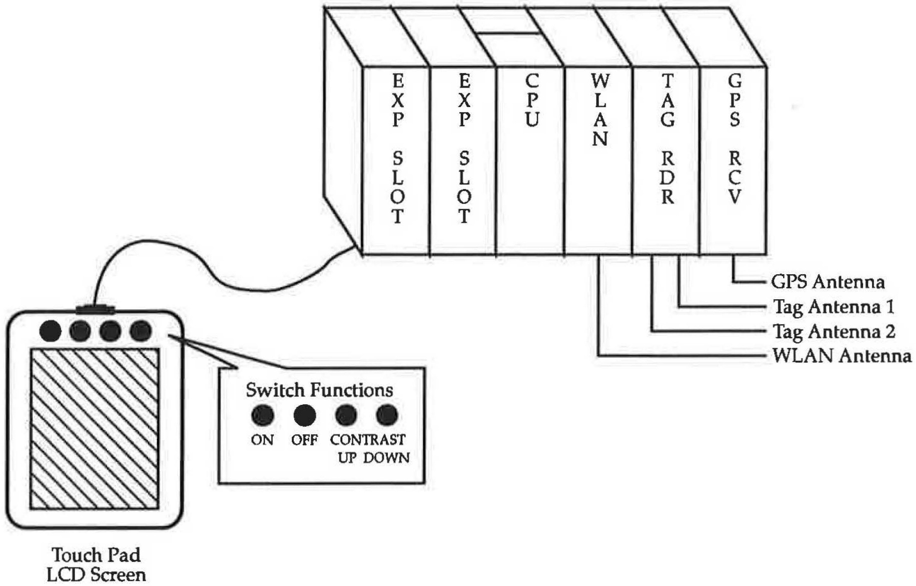

FIGURE 5 Mobile unit mounted equipment.

accurate, real-time information that can be transmitted to and received from mobile vehicles via the radio network.

DEMONSTRATION RESULTS

Following 17 weeks of preparation and 6 weeks of demonstration, the ELS proof-of-concept project was tested September 21, 1994. The project was funded by CHCP and contracted to Amtech Corporation. Overall project management services were provided by PRC, Inc., and system development was performed by NOW Solutions, Inc., under contract to Amtech.

Test Objectives

Before initiating the ELS demonstration, Amtech defined its objectives and requirements for the system to make it valuable for use in an intermodal facility. Four aspects of the ELS were the focus of the test: location independence, time independence, configuration agility, and basic functionality.

To demonstrate that the ELS operated efficiently in a variety of wheeled locations within a given intermodal yard, the test specified that two different areas in the terminal be tested. Each area was required to be 20 slots long, but because the ELS is capable of processing information for longer rows, complete rows of 40 to 50 slots were tested. Rows 25 and 26 were designated as one test location, and rows 27 and 28 were chosen as the second location.

Time independence was necessary to demonstrate that an ELS can be used at various times of the day when GPS satellite constellations are at their best and worst configurations, when aggregate errors for a given configuration can affect calculated yard locations. Tests were conducted during best- and worst-case configurations. Four inventory runs using both locations were performed under near-best GPS configurations for the specified test day, and later another run was made for row 27 during a best-case configuration. Two runs were made during worst-case configurations—one for row 25 and one for row 26. Because of this requirement, the test required two sessions.

The project was designed to determine the configuration agility of the ELS by testing the system under different wheeled environments and equipment configurations. A parallel slot configuration in which 20-, 40-, and 45-ft containers were located was tested. Most of the larger containers were rear-dressed, whereas the smaller containers had a mix of rear- and front-dressed configurations.

Basic functionality was required to demonstrate system functions such as on-board display, communication to the central subsystem via radio network, empty slot determination, and indication of tagged and untagged containers and chassis. The basic configuration of the ELS demonstration included all these considerations. Equipment locations were required to be determined within one slot of their actual

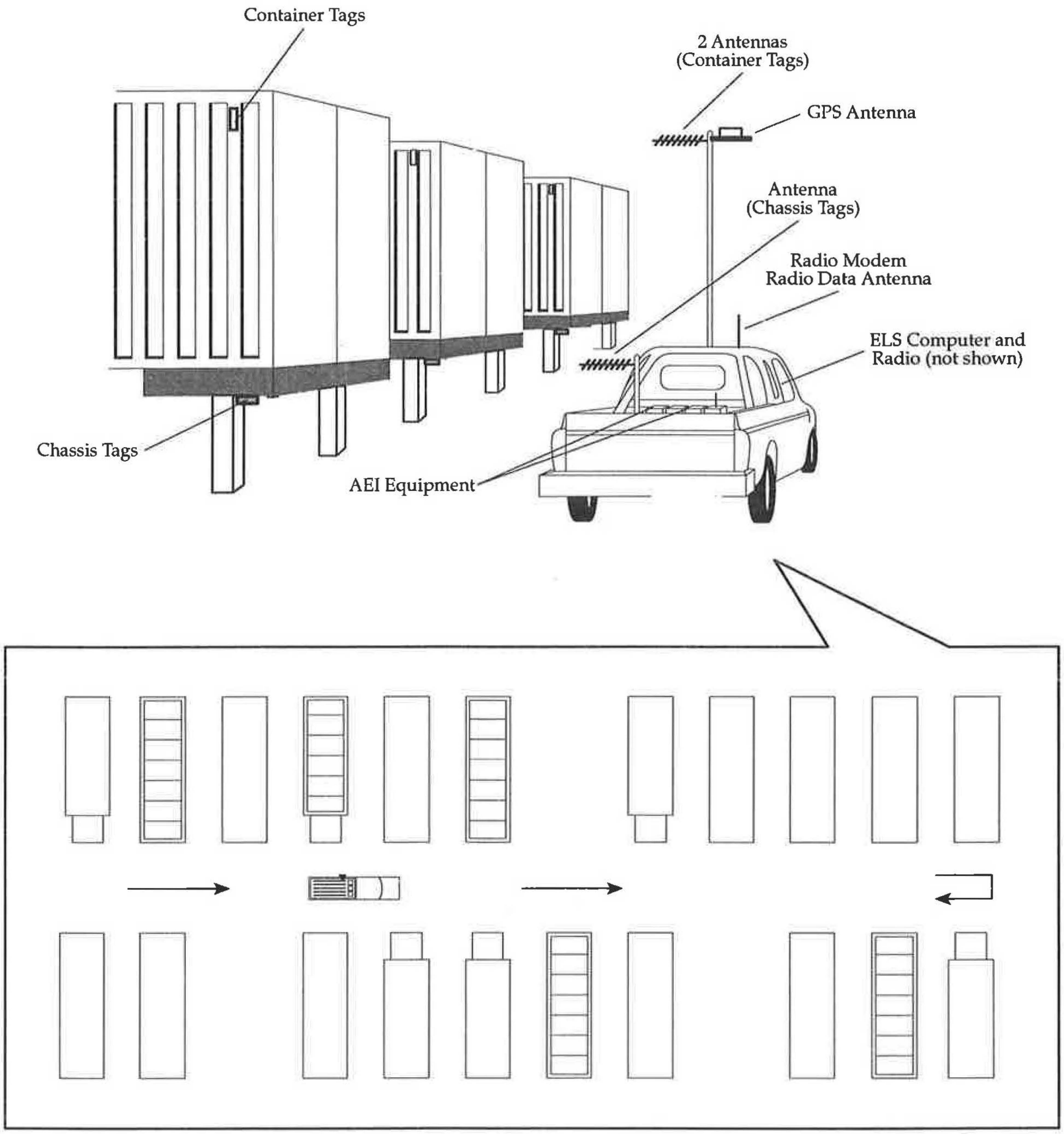

FIGURE 6 Typical mobile ELS configuration and mapping of terminal facility.

locations. For example, if an identified container occupied slot 25, and the ELS located the container in slot 24, 25, or 26, the accuracy requirement for the demonstration was met.

Test Conditions

Seven separate mobile inventory vehicle (MIV) runs were conducted during the official test day with the vehicle traveling about 5 mph, though evaluation suggested that a top speed of about 7 to 8 mph would be possible. The MIV traveled in a path opposite normal lane traffic to allow the most direct view of each tag.

Containers with AEI intermodal tags, mounted according to International Standardization Organization (ISO) requirements, and chassis with APL approved tag mounting were test assets. Damaged and improperly mounted tags were disregarded when pretest inspections

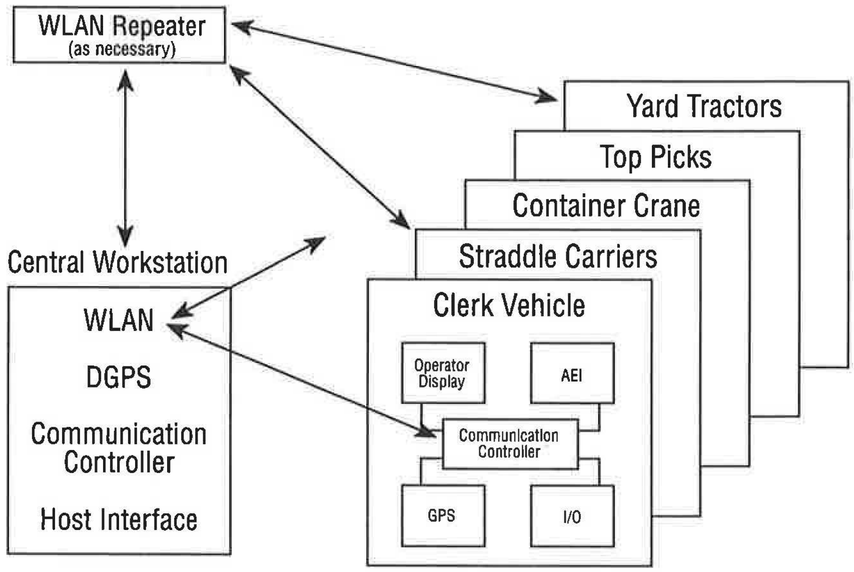

FIGURE 7 Typical ELS central workstation interface.

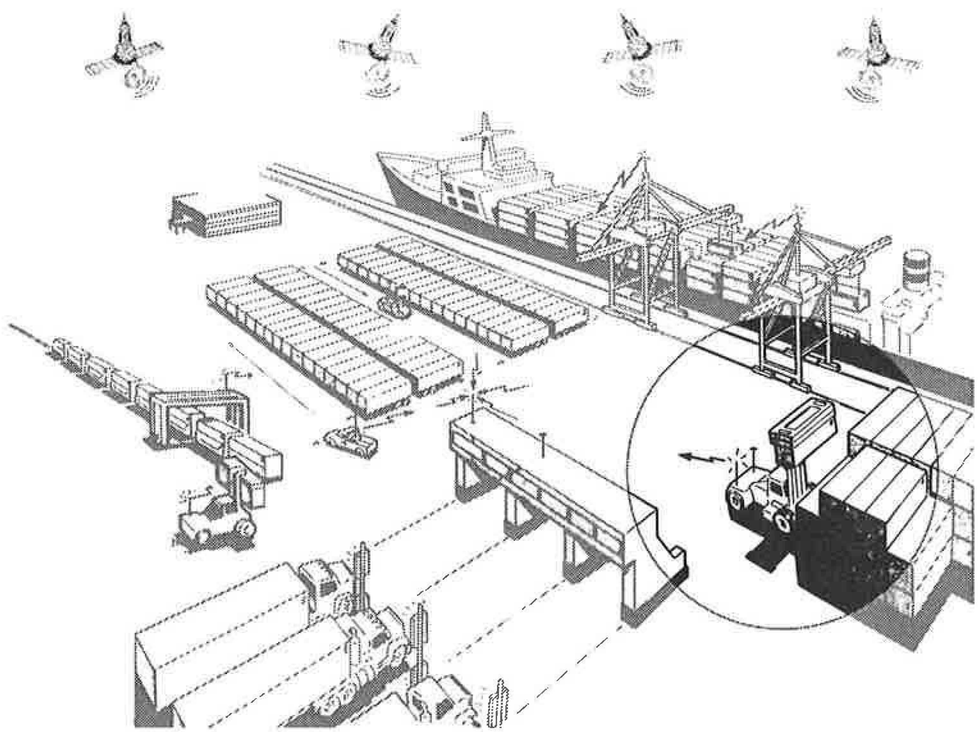

FIGURE 8 Depiction of terminal operations with an ELS implemented.

discovered instances of each. Programming errors, in which tag data did not match the identification number of the chassis or container, also were discovered. In addition, some containers were skewed severely in the slot with less than 4 in. between containers near the tag mounting area, which made it impossible for an AEI reader to handle problem tags. The number of tags excused from the test for damage, mismounting, or programming errors or for being hidden was 11 out of the total 162 tags tested, meaning 93.21 percent of the tags in the selected area were tested.

The areas used for ELS tests were surveyed using GPS and manual methods before testing to generate a data base of slot positions within the terminal. About

TABLE 1 CHCP EQUIPMENT LOCATION SYSTEM MIV TEST RESULTS FOR CONTAINERS

Run	Row #	# Slots	# Tags	# Excused	# Error	# +/- 0	# +/- 1	% +/-0	% +/- 1
1	25	45	26	2	1	38	42	88.89	97.78
2	26	52	25	1	0	49	51	96.15	100.00
3	27	54	26	1	0	43	53	81.48	100.00
4	28	51	17	2	2	47	48	96.08	98.04
5	27	54	26	1	0	53	53	100.00	100.00
6	25	45	22	2	1	38	42	88.89	97.78
7	26	52	20	2	1	49	49	98.08	98.08
Total		353	162	11	5	317	338	92.92	98.87

TABLE 2 CHCP EQUIPMENT LOCATION SYSTEM MIV TEST RESULTS FOR CHASSIS

Run	Row #	# Slots	# Tags	# Excused	# Error	# +/- 0	# +/- 1	% +/-0	% +/- 1
1	25	45	8	0	0	45	45	100.00	100.00
2	26	52	5	0	0	50	52	96.15	100.00
3	27	54	8	0	0	54	54	100.00	100.00
4	28	51	7	0	0	47	51	92.16	100.00
5	27	54	8	0	0	54	54	100.00	100.00
6	25	45	8	0	0	45	45	100.00	100.00
7	26	52	4	0	0	50	52	96.15	100.00
Total		353	48	0	0	345	353	97.73	100.00

TABLE 3 ROW STATUS REPORT EVALUATION LEGEND

Symbol	Meaning
↕	Swapped
↓ or ↑	Moved
●	Error (missed tag)
○	Excused (missed tag or human error during the manual inventory)
▼	Error (extraneous tag or position error greater than +/- 1 slot)
△	No Container

TABLE 4A STATUS RUN REPORT FOR ELS-MIV RUNS 1-2

ROW STATUS REPORT

Row: 26
Number of slots: 52 RUN 2

Date	Time	Chassis	Length	Container	Slot
09/21/94	13:42	untagged	R	untagged	100
09/21/94	13:42				98
09/21/94	13:42	untagged		untagged	96
09/21/94	13:42	untagged		untagged	94
09/21/94	13:42	untagged	40'	APLU788430	92
09/21/94	13:42	untagged		untagged	90
09/21/94	13:42	untagged	40'	APLU788237	88
09/21/94	13:42	untagged	40'	APLU690189	86
09/21/94	13:42	untagged		untagged	84
09/21/94	13:42	untagged	40'	ICSU161141	82
09/21/94	13:42	untagged		untagged	80
09/21/94	13:42	untagged		untagged	78
09/21/94	13:42	APLZ153781	45'	APLU457380	76
09/21/94	13:42	APLZ155483	40'	ICSU161000	74
09/21/94	13:42	untagged		untagged	72
09/21/94	13:42	untagged		untagged	70
09/21/94	13:42	untagged	40'	APLU702636	68
09/21/94	13:42	untagged		untagged	66
09/21/94	13:42	untagged	40'	APLU702947	64
09/21/94	13:42	untagged		untagged	62
09/21/94	13:42	untagged	40'	APLU980727	60
09/21/94	13:42	untagged	40'	APLU140073	58
09/21/94	13:42				56
09/21/94	13:42	untagged		untagged	54
09/21/94	13:42				52

Row: 25
Number of slots: 45 RUN 1

Slot	Container	Length	Chassis	Date	Time
85	untagged		untagged	09/21/94	13:38
83	untagged		untagged	09/21/94	13:38
81	APLU990356	40'	untagged	09/21/94	13:38
79	APLU885994	40'	APLZ133148	09/21/94	13:38
77	untagged		untagged	09/21/94	13:38
75	APLU597445	40'	untagged	09/21/94	13:38
73	APLU702143	40'	untagged	09/21/94	13:38
71	GSTU768311	40'	untagged	09/21/94	13:38
69	GSTU634253	40'	untagged	09/21/94	13:38
67	APLU453878	45'	untagged	09/21/94	13:38
65	APLU889524	40'	untagged	09/21/94	13:38
63	untagged		untagged	09/21/94	13:38
61	APLU884383	40'	untagged	09/21/94	13:38
59	APLU966033	40'	untagged	09/21/94	13:38
57	untagged		untagged	09/21/94	13:38
55	untagged		APLZ111383	09/21/94	13:38
53	APLU982715	40'	untagged	09/21/94	13:38
51	APLU981590	40'	untagged	09/21/94	13:38
49	APLU702466	40'	untagged	09/21/94	13:38
47	untagged		APLZ145284	09/21/94	13:38
45	untagged		untagged	09/21/94	13:38
43	untagged		untagged	09/21/94	13:38
41	untagged		untagged	09/21/94	13:38
39	APLU450825	45'	untagged	09/21/94	13:38
37	APLU450407	45'	untagged	09/21/94	13:38

half of the containers in the terminal were tagged, and less than one-tenth of the chassis were tagged. Each row consisted of a mix of container types representing actual storage scenarios encountered in the terminal's wheeled environment. An observer in the test area maintained the accuracy of the inventory by noting any changes during normal yard activity.

Results and Conclusions

The MIV inventories for all runs appear in Tables 4 to 7. The data are printed in a manner similar to the CRT display on the central workstation, with interpretation marks added to reflect manual inventory verification. Empty slots and slots with an untagged chassis are defined as empty. The container length is included in the reports when the container and/or chassis tags contain this information. Data from the MIV ultrasonic ranging system were used to determine whether the 20-ft containers were parked toward the rear of the slot or toward the front, and appropriate notations on the results were made.

For each row, the following information has been calculated from the Row Status Reports (Tables 3 to 8) for containers and chassis:

- #Slots = total number of slots in the row.
- #Tags = total number of tags in the row.
- #Excused = pieces of equipment missed due to extenuating circumstances. Some missed tags were on containers parked too closely to others, and some tags were defective and did not read a nominal range.
- #Error = pieces of equipment wrongly placed by the system. Either the tag was missed completely by the MIV or was placed by the system more than one slot away was from its actual position.

TABLE 4B STATUS RUN REPORT FOR ELS-MIV RUNS 1-2

R O W   S T A T U S   R E P O R T

Row: 26
Number of slots: 52 RUN 2

Date	Time	Chassis	Length	Container	Slot
09/21/94	13:42	untagged	40'	APLU788463	50
09/21/94	13:42	untagged		untagged	48
09/21/94	13:42	untagged	40'	APLU803157	46
09/21/94	13:42	untagged	40'	APLU702278	44
09/21/94	13:42	untagged	40'	IEAU452298	42
09/21/94	13:42	untagged	20' F	APLS276274	40
09/21/94	13:42	untagged	40'	APLU800667	38
09/21/94	13:42	untagged		untagged	36
09/21/94	13:42	untagged	40'	APLU881045	34
09/21/94	13:42	untagged	40'	APLU982673	32
09/21/94	13:42	untagged	40'	APLU703281	30
09/21/94	13:42	untagged		untagged	28
09/21/94	13:42	APLZ110579			26
09/21/94	13:42	untagged		untagged	24
09/21/94	13:42	untagged		untagged	22
09/21/94	13:42	untagged	40'	APLU788724	20
09/21/94	13:42	untagged		untagged	18
09/21/94	13:42	untagged	40'	APLU705550	16
09/21/94	13:42	untagged		untagged	14
09/21/94	13:42	APLZ153918		untagged	12
09/21/94	13:42	untagged	40'	APLU962324	10
09/21/94	13:42	untagged		untagged	8
09/21/94	13:42	untagged	40'	APLU789078	6
09/21/94	13:42	untagged		untagged	4
09/21/94	13:42				2
09/21/94	13:42	untagged		untagged	0
09/21/94	13:42	APLZ138544	40'	APLU991769	-2

Row: 25
Number of slots: 45 RUN 1

Slot	Container	Length	Chassis	Date	Time
35	APLU702471	40'	untagged	09/21/94	13:38
33	untagged		untagged	09/21/94	13:38
31	untagged		untagged	09/21/94	13:38
29	untagged		untagged	09/21/94	13:38
27	ICSU174697	40'	APLZ113954	09/21/94	13:38
25	TPHU451028	40'	untagged	09/21/94	13:38
23	APLU982484	40'	untagged	09/21/94	13:38
21	untagged		untagged	09/21/94	13:38
19	APLU802803	40'	untagged	09/21/94	13:38
17	untagged		untagged	09/21/94	13:38
15	untagged		APLZ137288	09/21/94	13:38
13	APLU703642	40'	untagged	09/21/94	13:38
11	untagged		untagged	09/21/94	13:38
9	untagged		APLZ110081	09/21/94	13:38
7			APLZ139722	09/21/94	13:38
5	untagged		untagged	09/21/94	13:38
3	APLU457259	45'	untagged	09/21/94	13:38
1	untagged		untagged	09/21/94	13:38
-1	untagged		APLZ142876	09/21/94	13:38
-3	ICSU160862	40'	untagged	09/21/94	13:38

- #+/-0 = total number of slots with correct occupancy status and container identification.
- #+/-1 = total number of slots with occupancy status and identification (if tagged container) within one slot of actual location.
- %+/- 0 = ([#+/- 0 + #Excused] / #Slots) x 100.
- %+/- 1= ([#+/- 1 + #Excused] / #Slots) x 100.

This information is summarized in Tables 1 and 2.

Analysis of Test Runs

Specific anomalies occurred during each test run. Anomalous test results include the following:

- Run 1 (row 25, time 13:38).
- Slot 85—the tag was read by the system, but the number of reads and the distance over which the tag was read were very small. This could be due to a blocked tag or a weak signal from the tag, which is an AEI radio frequency issue.
- Slot 55–a tag was mounted to this container, which was within 4 in. (10.16 cm) of the adjoining container; therefore, the tag could not be seen by the AEI equipment.
- Slot 17—same occurrence as in slot 55.
- Run 2 (row 26, time 13:42).
- Slot 78—a tag was mounted to this container, which was within 4 in. (10.16 cm) of the adjoining container; therefore, the tag could not be seen by the AEI equipment.
- Run 3 (row 27, time 14:18).
- Slot 81–this was a refrigerator unit. The gap between this unit and the adjoining unit was between 4

TABLE 5A STATUS RUN REPORT FOR ELS-MIV RUNS 3-4

R O W   S T A T U S   R E P O R T

Row: 28
Number of slots: 51   RUN 4

Date	Time	Chassis	Length	Container	Slot
09/21/94	14:35	untagged		untagged	76
09/21/94	14:35	untagged		untagged	74
09/21/94	14:35	untagged		untagged	72
09/21/94	14:35	APLZ153155		untagged	70
09/21/94	14:35	untagged	40'	APLU701093	68
09/21/94	14:35	untagged		untagged	66
09/21/94	14:35	untagged		untagged	64
09/21/94	14:35	untagged		untagged	62
09/21/94	14:35	untagged		untagged	60
09/21/94	14:35	APLZ144382		untagged	58
09/21/94	14:35	untagged		untagged	56
09/21/94	14:35	untagged		untagged	54
09/21/94	14:35	untagged	40'	APLU969419	52
09/21/94	14:35	untagged		untagged	50
09/21/94	14:35	untagged	40'	APLU980646	48
09/21/94	14:35	APLZ114924	40'	APLU690048	46
09/21/94	14:35	APLZ181106		untagged	44
09/21/94	14:35	untagged	40'	APLU788333	42
09/21/94	14:35	untagged	40'	APLU889660	40
09/21/94	14:35				38
09/21/94	14:35	APLZ155528		untagged	36
09/21/94	14:35	untagged	40'	APLU968581	34
09/21/94	14:35	untagged	40'	APLU803170	32
09/21/94	14:35	untagged		untagged	f
09/21/94	14:35	untagged	40'	APLU802561	e

Row: 27
Number of slots: 54   RUN 3

Slot	Container	Length	Chassis	Date	Time
103	untagged		untagged	09/21/94	14:18
101	GSTU738531	40'	untagged	09/21/94	14:18
99	untagged		untagged	09/21/94	14:18
97	untagged		untagged	09/21/94	14:18
95	GSTU633271	40'	APLZ133733	09/21/94	14:18
93	untagged		untagged	09/21/94	14:18
91	APLU981484	40'	untagged	09/21/94	14:18
89	untagged		untagged	09/21/94	14:18
87	GCEU663215	40'	untagged	09/21/94	14:18
85	APLU892906	40'	untagged	09/21/94	14:18
83	untagged		APLZ130013	09/21/94	14:18
81	untagged		untagged	09/21/94	14:18
79	APLU982998	40'	untagged	09/21/94	14:18
77	TRLU408096	40'	untagged	09/21/94	14:18
75	untagged		untagged	09/21/94	14:18
73	GSTU840849	40'	untagged	09/21/94	14:18
71	untagged		APLZ153293	09/21/94	14:18
69	untagged		untagged	09/21/94	14:18
67	APLU703056	40'	untagged	09/21/94	14:18
65	APLU802979	40'	untagged	09/21/94	14:18
63	APLU988950	40'	untagged	09/21/94	14:18
61	GSTU863971	40'	APLZ155607	09/21/94	14:18
59	untagged		untagged	09/21/94	14:18
57	APLU702666	40'	APLZ143109	09/21/94	14:18
55	untagged		untagged	09/21/94	14:18

in. (10.16 cm) and 6 in. (15.24 cm). The number of reads were very small for this container; therefore, the MIV did not assign the tag number to the container. Small gaps between containers and weak tag signals can cause missed tag reads.

- Run 4 (row 28, time 14:35).
- Slot 76–the MIV stopped before reaching the end of the slot, and the ultrasonic data from the previous slot were interpreted incorrectly. A software fix has been added to eliminate this problem.
- Slot A–the ultrasonic data for this slot have been examined carefully, and the data indicate that there was a container in this slot when the MIV inventory was performed. It has been determined that a container was removed after the MIV inventory but before the manual inventory.
- Slot 24—a tag was mounted to this container, which was within 4 in. (10.16 cm) of the adjoining container; therefore, the tag could not be seen by the AEI equipment.
- Slot (-)2—tag APLU982464 was read over a large distance before and after tag GSTU849377 was read. The missing tag, GSTU849377, was read only a few times. The MIV, therefore, assumed that this tag was read from a reflection. The reasons for this kind of problem are distance between containers, signal strength of the tag, and other issues associated with RF signals during tag reads.
- Run 5 (row 27, time 14:55).
- Slot 81—this is the same container and same problem for this slot in Run 3 at time 14:18.
- Run 6 (row 25, time 18:27).
- Slot 55—this is the same container and same problem described for this slot in run 1, at time 13:38.
- Slot 31–the tag was read 12 times at a distance of 15 ft. Because this is a significant number of reads for

TABLE 5B STATUS RUN REPORT FOR ELS-MIV RUNS 3-4

R O W   S T A T U S   R E P O R T

Row: 28
Number of slots: 51 RUN 4

Date	Time	Chassis	Length	Container	Slot
09/21/94	14:35				d
09/21/94	14:35	untagged	20' F	APLS282310	c
09/21/94	14:35				b
09/21/94	14:35	untagged		untagged	a
09/21/94	14:35	untagged	40'	APLU701184	30
09/21/94	14:35	untagged		untagged	28
09/21/94	14:35	APLZ153074	40'	APLU885717	26
09/21/94	14:35	untagged		untagged	24
09/21/94	14:35				22
09/21/94	14:35	APLZ141230		untagged	20
09/21/94	14:35				18
09/21/94	14:35	untagged	40'	APLU990666	16
09/21/94	14:35	untagged		untagged	14
09/21/94	14:35	untagged		untagged	12
09/21/94	14:35				10
09/21/94	14:35	untagged	40'	APLU887701	8
09/21/94	14:35	untagged		untagged	6
09/21/94	14:35	untagged		untagged	4
09/21/94	14:35				2
09/21/94	14:35				0
09/21/94	14:35	untagged	40'	APLU982464	-2
09/21/94	14:35	untagged		untagged	-4
09/21/94	14:35	untagged	40'	APLU970845	-6
09/21/94	14:35				-8
09/21/94	14:35	untagged		untagged	-10
09/21/94	14:35	untagged		untagged	-12

Row: 27
Number of slots: 54 RUN 3

Slot	Container	Length	Chassis	Date	Time
53	untagged		untagged	09/21/94	14:18
51				09/21/94	14:18
49	GSTU849369	40'	untagged	09/21/94	14:18
47	APLU459570	45'	APLZ155549	09/21/94	14:18
45	APLU887305	40'	untagged	09/21/94	14:18
43	untagged		untagged	09/21/94	14:18
41	TPHU480365	40'	untagged	09/21/94	14:18
39	untagged		untagged	09/21/94	14:18
37	APLU962777	40'	untagged	09/21/94	14:18
35	untagged		untagged	09/21/94	14:18
33	untagged		untagged	09/21/94	14:18
31	untagged		untagged	09/21/94	14:18
29	APLU890167	40'	APLZ114321	09/21/94	14:18
27	APLU892989	40'	untagged	09/21/94	14:18
25	untagged		untagged	09/21/94	14:18
23	APLU455188	45'	untagged	09/21/94	14:18
21	APLU788162	40'	untagged	09/21/94	14:18
19	APLU990267	40'	APLZ144148	09/21/94	14:18
17	untagged		untagged	09/21/94	14:18
15				09/21/94	14:18
13	untagged		untagged	09/21/94	14:18
11	APLU100242	40'	untagged	09/21/94	14:18
9	untagged		untagged	09/21/94	14:18
7				09/21/94	14:18
5				09/21/94	14:18
3				09/21/94	14:18

the MIV, the tag was assigned to a container. The tag actually was located in Row 26, Slot 30, about 6 slots away on the other side of the aisle. This problem is due to excessively strong signals from the tag or constructive interference. It is also an AEI RF issue that occurs on rare occasions.

- Slot 17—this is the same container and same problem described for this slot in Run 1 at time 13:38.
- Run 7 (row 26, time 18:32).
- Slot 100–a tag was mounted to this container, which was within 4 in. (10.16 cm) of the adjoining container; therefore, the tag could not be seen by the AEI equipment.
- Slot 88—the ultrasonic data for this slot showed a single read of an object at close range. This read caused the MIV to assign a container in the slot. A software fix has been added to eliminate the problem.
- Slot 78—this is the same container and same problem described for this slot in run 2, at time 13:42.

PROVIDING ACCURATE INFORMATION

Advancements in technology lead to the development of systems capable of identifying, locating, and tracking inventory and movements within an intermodal facility. The integration of technologies will make yard activity efficient and cost-effective for intermodal terminal operators and provide them with an automated system for equipment identification and location.

The capability of operators to obtain accurate information in real time improves the overall efficiency of terminal operations. Although the initial demonstration for CHCP focused on containers in a

TABLE 6 STATUS RUN REPORT FOR ELS-MIV RUN 5, ROW 27 (BEST GPS)

ROW STATUS REPORT

Row: 27
Number of slots: 54 RUN 5

Slot	Container	Length	Chassis	Date	Time
103	untagged		untagged	09/21/94	14:56
101	GSTU738531	40'	untagged	09/21/94	14:55
99	untagged		untagged	09/21/94	14:55
97	GSTU633271	40'	untagged	09/21/94	14:55
95	untagged		APLZ133733	09/21/94	14:55
93	untagged		untagged	09/21/94	14:55
91	untagged		untagged	09/21/94	14:55
89	APLU981484	40'	untagged	09/21/94	14:55
87	untagged		untagged	09/21/94	14:55
85	GCEU663215	40'	untagged	09/21/94	14:55
83	APLU892906	40'	APLZ130013	09/21/94	14:55
81	untagged		untagged	09/21/94	14:55
79	APLU982998	40'	untagged	09/21/94	14:55
77	TRLU408096	40'	untagged	09/21/94	14:55
75	untagged		untagged	09/21/94	14:55
73	GSTU840849	40'	untagged	09/21/94	14:55
71	untagged		APLZ153293	09/21/94	14:55
69	untagged		untagged	09/21/94	14:55
67	APLU703056	40'	untagged	09/21/94	14:55
65	APLU802979	40'	untagged	09/21/94	14:55
63	APLU988950	40'	untagged	09/21/94	14:55
61	GSTU863971	40'	APLZ155607	09/21/94	14:55
59	untagged		untagged	09/21/94	14:55
57	APLU702666	40'	APLZ143109	09/21/94	14:55
55	untagged		untagged	09/21/94	14:55

Row: 27
Number of slots: 54 RUN 5

Slot	Container	Length	Chassis	Date	Time
53	untagged		untagged	09/21/94	14:56
51				09/21/94	14:55
49	GSTU849369	40'	untagged	09/21/94	14:55
47	APLU459570	45'	APLZ155549	09/21/94	14:55
45	APLU887305	40'	untagged	09/21/94	14:55
43	untagged		untagged	09/21/94	14:55
41	TPHU480365	40'	untagged	09/21/94	14:55
39	untagged		untagged	09/21/94	14:55
37	APLU962777	40'	untagged	09/21/94	14:55
35	untagged		untagged	09/21/94	14:55
33	untagged		untagged	09/21/94	14:55
31	untagged		untagged	09/21/94	14:55
29	APLU890167	40'	APLZ114321	09/21/94	14:55
27	APLU892989	40'	untagged	09/21/94	14:55
25	untagged		untagged	09/21/94	14:55
23	APLU455188	45'	untagged	09/21/94	14:55
21	APLU788162	40'	untagged	09/21/94	14:55
19	untagged		APLZ144148	09/21/94	14:55
17	APLU990267	40'	untagged	09/21/94	14:55
15				09/21/94	14:55
13	untagged		untagged	09/21/94	14:55
11	APLU100242	40'	untagged	09/21/94	14:55
9	untagged		untagged	09/21/94	14:55
7				09/21/94	14:55
5				09/21/94	14:56
3				09/21/94	14:55
1	GSTU836723	40'	untagged	09/21/94	14:55
-1	untagged		untagged	09/21/94	14:55
-3	untagged		untagged	09/21/94	14:55

wheeled environment, production ELS will include systems for more static operating environments, such as terminal container handling equipment. ELS static systems deployed on top-picks, trans-tainers, and straddle-carriers will be capable of updating a host computer with location and identification data in a stacked storage area as containers are stored or removed (Fig. 8).

Information updates, which could take hours with manual searches, will be done in seconds with ELS. Instead of encountering costly delays at terminal gates or in staging areas, drayage operators will reduce turnaround times and increase efficiency. Crane operators will no longer have to deal with costly delays as searches are conducted for a missing container. Terminal operators will develop efficient operations, and intermodal facilities will become more productive. Most important, ELS will provide the means by which improved terminal synchronization can be achieved for an enhanced yard management system.

ACKNOWLEDGMENT

The authors would especially like to thank Mr. Ali Bologlu and his associates from NOW Solutions for their valuable contributions to this project.

TABLE 7A STATUS RUN REPORT FOR ELS-MIV RUNS 6-7

R O W   S T A T U S   R E P O R T

Row: 26
Number of slots: 52   RUN 7

Date	Time	Chassis	Length	Container	Slot
09/21/94	18:32	untagged	R	untagged	100
09/21/94	18:32				98
09/21/94	18:32	untagged	20' F	APLS277210	96
09/21/94	18:32	untagged	R	untagged	94
09/21/94	18:32	untagged	40'	APLU788430	92
09/21/94	18:32	untagged		untagged	90
09/21/94	18:32	untagged		untagged	88
09/21/94	18:32				86
09/21/94	18:32				84
09/21/94	18:32	untagged	40'	ICSU161141	82
09/21/94	18:32	untagged		untagged	80
09/21/94	18:32	untagged		untagged	78
09/21/94	18:32	APLZ153781	45'	APLU457380	76
09/21/94	18:32	APLZ155483	40'	ICSU161000	74
09/21/94	18:32	untagged	40'	APLU967861	72
09/21/94	18:32				70
09/21/94	18:32	untagged	40'	APLU702636	68
09/21/94	18:32	untagged		untagged	66
09/21/94	18:32	untagged	40'	APLU702947	64
09/21/94	18:32	untagged		untagged	62
09/21/94	18:32	untagged		untagged	60
09/21/94	18:32	untagged		untagged	58
09/21/94	18:32				56
09/21/94	18:32	untagged		untagged	54
09/21/94	18:32				52

Row: 25
Number of slots: 45   RUN 6

Slot	Container	Length	Chassis	Date	Time
85				09/21/94	18:27
83	untagged		untagged	09/21/94	18:27
81	APLU990356	40'	untagged	09/21/94	18:27
79	APLU885994	40'	APLZ133148	09/21/94	18:27
77	untagged		untagged	09/21/94	18:27
75	APLU597445	40'	untagged	09/21/94	18:27
73	APLU702143	40'	untagged	09/21/94	18:27
71	GSTU768311	40'	untagged	09/21/94	18:27
69	GSTU634253	40'	untagged	09/21/94	18:27
67	APLU453878	45'	untagged	09/21/94	18:27
65	APLU889524	40'	untagged	09/21/94	18:27
63	untagged		untagged	09/21/94	18:27
61	APLU884383	40'	untagged	09/21/94	18:27
59	APLU966033	40'	untagged	09/21/94	18:27
57	untagged		untagged	09/21/94	18:27
55	untagged		APLZ111383	09/21/94	18:27
53	untagged		untagged	09/21/94	18:27
51	APLU981590	40'	untagged	09/21/94	18:27
49	APLU702466	40'	untagged	09/21/94	18:27
47	untagged		APLZ145284	09/21/94	18:27
45	untagged		untagged	09/21/94	18:27
43	untagged		untagged	09/21/94	18:27
41	untagged		untagged	09/21/94	18:27
39	APLU450825	45'	untagged	09/21/94	18:27
37				09/21/94	18:27

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TABLE 7B STATUS RUN REPORT FOR ELS-MIV RUNS 6-7

R O W   S T A T U S   R E P O R T

Row: 26
Number of slots: 52   RUN 7

Date	Time	Chassis	Length	Container	Slot
09/21/94	18:32	untagged	40'	APLU788463	50
09/21/94	18:32	untagged		untagged	48
09/21/94	18:32	untagged	40'	APLU803157	46
09/21/94	18:32	untagged	40'	APLU702278	44
09/21/94	18:32				42
09/21/94	18:32	untagged	20' F	APLS276274	40
09/21/94	18:32	untagged		untagged	38
09/21/94	18:32	untagged	40'	APLU800667	36
09/21/94	18:32				34
09/21/94	18:32	untagged	40'	APLU982673	32
09/21/94	18:32	untagged	40'	APLU703281	30
09/21/94	18:32	untagged		untagged	28
09/21/94	18:32				26
09/21/94	18:32				24
09/21/94	18:32	untagged		untagged	22
09/21/94	18:32	untagged	40'	APLU788724	20
09/21/94	18:32	untagged		untagged	18
09/21/94	18:32	untagged	40'	APLU705550	16
09/21/94	18:32	untagged		untagged	14
09/21/94	18:32	APLZ153918		untagged	12
09/21/94	18:32	untagged	40'	APLU962324	10
09/21/94	18:32	untagged		untagged	8
09/21/94	18:32	untagged	40'	APLU789078	6
09/21/94	18:32	untagged		untagged	4
09/21/94	18:32				2
09/21/94	18:32	APLZ135196	R	untagged	0
09/21/94	18:32				[illegible]

Row: 25
Number of slots: 45   RUN 6

Slot	Container	Length	Chassis	Date	Time
35	APLU702471	40'	untagged	09/21/94	18:27
33	untagged		untagged	09/21/94	18:27
31	APLU703281	40'	untagged	09/21/94	18:27
29				09/21/94	18:27
27	ICSU174697	40'	APLZ113954	09/21/94	18:27
25	TPHU451028	40'	untagged	09/21/94	18:27
23	APLU982484	40'	untagged	09/21/94	18:27
21	untagged		untagged	09/21/94	18:27
19	APLU802803	40'	untagged	09/21/94	18:27
17	untagged		untagged	09/21/94	18:27
15	untagged		APLZ137288	09/21/94	18:27
13	APLU703642	40'	untagged	09/21/94	18:27
11	untagged		untagged	09/21/94	18:27
9	untagged		APLZ110081	09/21/94	18:27
7			APLZ139722	09/21/94	18:27
5	untagged		untagged	09/21/94	18:27
3				09/21/94	18:27
1	untagged		untagged	09/21/94	18:27
-1	untagged		APLZ142876	09/21/94	18:27
-3	ICSU160862	40'	untagged	09/21/94	18:27

TABLE 8 SV CONSTELLATIONS FOR SEPTEMBER 21, 1994

SV Constellations

Point: MHT Lat 37:48:0 N Lon 122:18:0 W Ephemeris: D94262.EPH 9/19/94
Date: Wednesday, September 21, 1994 Threshold Elevation 10 (deg) Time Zone Pacific Std USA' -8
25 Satellites considered : 1 2 4 5 6 7 9 12 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 31
Sampling Rate: 2 Minutes

Constellation	T Rise	T Set	dT	PDOP Rise	PDOP Set
2 16 18 19 27 31	0:00	0:12	0:12	2.6	2.4
2 7 16 18 19 27 31	0:12	0:18	0:06	2.1	2.1
2 7 16 18 19 26 27 31	0:18	1:00	0:42	1.6	1.5
2 7 16 19 26 27 31	1:00	1:12	0:12	1.7	1.7
2 7 15 19 26 27	1:12	2:18	1:06	2.1	2.3
2 7 12 15 19 26 27	2:18	2:26	0:08	1.8	1.8
2 7 12 15 26 27	2:26	2:30	0:04	2.5	2.5
2 7 9 12 15 26 27	2:30	2:36	0:06	2.4	2.3
2 4 7 9 12 15 26 27	2:36	3:20	0:44	1.6	1.8
2 4 7 9 12 26 27	3:20	3:22	0:02	2.6	2.6
2 4 5 7 9 12 26 27	3:22	3:42	0:20	2.3	2.5
2 4 5 7 9 12 24 26 27	3:42	3:46	0:04	2.4	2.4
2 4 5 7 9 12 24 26	3:46	4:32	0:46	3.0	2.2
2 4 5 7 9 12 24	4:32	5:12	0:40	2.6	2.5
2 4 5 7 9 12 20 24	5:12	5:14	0:02	1.7	1.7
4 5 7 9 12 20 24	5:14	6:00	0:46	2.4	2.4
4 5 6 7 9 12 20 24	6:00	6:12	0:12	1.8	1.7
4 5 6 7 9 12 16 20 24	6:12	6:14	0:02	1.4	1.4
4 5 6 9 12 16 20 24	6:14	7:24	1:10	1.7	1.7
4 5 6 9 12 16 20 24 25	7:24	7:34	0:10	1.5	1.4
4 5 6 12 16 20 24 25	7:34	7:36	0:02	1.6	1.6
5 6 12 16 20 24 25	7:36	7:40	0:04	2.0	2.0
5 6 12 16 17 20 24 25	7:40	7:52	0:12	1.9	1.9
5 6 16 17 20 24 25	7:52	8:58	1:06	2.1	1.8
5 6 16 17 20 24	8:58	9:08	0:10	2.7	2.7
5 6 16 17 20 23 24	9:08	9:20	0:12	2.3	2.5
5 6 16 17 20 22 23 24 26	9:20	9:26	0:06	1.5	1.5
5 6 16 17 20 22 23 26	9:26	9:32	0:06	1.6	1.7
6 16 17 20 22 23 26	9:32	10:32	1:00	1.8	1.8
6 16 17 20 21 22 23 26	10:32	10:42	0:10	1.6	1.6
6 16 17 21 22 23 26	10:42	10:44	0:02	1.7	1.7
6 17 21 22 23 26	10:44	11:12	0:28	2.3	2.5
6 17 21 22 23 26 28	11:12	12:22	1:10	2.1	1.9
1 6 17 21 22 23 26 28	12:22	12:32	0:10	1.8	1.8
1 6 17 21 22 23 26 28 31	12:32	12:36	0:04	1.5	1.5
1 17 21 22 23 26 28 31	12:36	12:52	0:16	1.6	1.6
1 17 21 23 26 28 31	12:52	12:56	0:04	1.8	1.8
1 17 21 23 28 31	12:56	13:04	0:08	2.4	2.5
1 9 17 21 23 28 31	13:04	14:18	1:14	1.9	2.4
1 9 12 17 21 23 28 31	14:18	14:36	0:18	2.2	2.0
1 9 12 21 23 28 31	14:36	14:38	0:02	2.6	2.6
1 9 12 21 23 25 28 31	14:38	14:42	0:04	1.9	1.9
1 9 12 15 21 23 25 28 31	14:42	15:00	0:18	1.5	1.6
1 12 15 21 23 25 28 31	15:00	15:02	0:02	1.6	1.6
1 15 21 23 25 28 31	15:02	15:34	0:32	1.8	1.9
1 15 21 25 28 31	15:34	15:54	0:20	3.4	3.7
1 15 21 25 31	15:54	16:06	0:12	4.4	4.1
1 14 15 21 25 31	16:06	16:34	0:28	2.8	2.4
1 14 15 21 25	16:34	16:40	0:06	2.9	2.9
1 14 15 21 25 29	16:40	17:26	0:46	2.3	2.2
1 14 15 25 29	17:26	17:42	0:16	3.4	3.3
1 14 15 22 25 29	17:42	18:26	0:44	2.4	3.2
14 15 22 25 29	18:26	18:34	0:08	5.9	5.6
14 15 18 22 25 29	18:34	18:58	0:24	2.3	2.2
4 14 15 18 22 25 29	18:58	19:22	0:24	1.9	1.7
4 14 15 18 19 22 25 29	19:22	19:40	0:18	1.6	1.6
4 14 18 19 22 25 29	19:40	19:50	0:10	1.8	1.9
4 14 18 19 22 29	19:50	20:56	1:06	2.6	2.3
4 14 18 19 22 27 29	20:56	21:02	0:06	2.1	2.1
4 14 18 19 22 27 28 29	21:02	21:08	0:06	1.7	1.7
14 18 19 22 27 28 29	21:08	21:22	0:14	1.9	1.9
14 18 19 22 27 28 29 31	21:22	21:56	0:34	1.8	1.7
14 18 19 27 28 29 31	21:56	22:02	0:06	2.3	2.3
18 19 27 28 29 31	22:02	22:06	0:04	2.8	2.8
16 18 19 27 28 29 31	22:06	22:12	0:06	2.2	2.3
2 16 18 19 27 28 29 31	22:12	23:36	1:24	1.6	1.8
2 16 18 19 27 28 31	23:36	23:48	0:12	2.2	2.1
2 16 18 19 27 31	23:48	24:00	0:12	2.8	2.6