AN INNOVATIVE PLANNING AND CONTROL SYSTEM FOR MAERSK PACIFIC, LONG BEACH

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ABSTRACT

This paper discusses a successful bid to use advanced information technology to enhance productivity and maximize throughput at the West Coast's premiere multimodal facility, the Maersk Pacific Terminal in Long Beach, California. Taking a case study approach, we describe the specific technology that was implemented, review the operational procedures under the system, and detail the benefits that have been derived.

INTRODUCTION

In April 1993, Maersk Pacific commissioned its newest multimodal terminal, a 107-acre green-field site at Pier J, in Long Beach, California. The terminal was designed with the expectation of eventually reaching 250,000 vessel moves per year, the majority of which were expected to originate from or be destined to the on-dock rail ramp. The terminal comprises three vessel berths, six quay cranes, and 25,000 ft of rail organized into nine tracks. Yard handling equipment includes three rubber-tired gantries (RTGs), a fleet of utility tractors (UTRs), and several top-picks.

Soon after opening the terminal, Maersk Line introduced new services to Latin America. Together with a general recovery in cargo volumes, this led to a rapid increase in handlings well beyond expectations. By mid-summer it became clear that new information systems would be required to achieve the desired level of productivity and control of the rail operation. It was also evident that yard dwell time would have to be reduced to move the anticipated volume through the terminal. Management believed that this could be achieved only through better yard planning and real-time inventory control.

Recognizing the prohibitive time, cost, and risk that would be inherent in undertaking an in-house software development to address this need (1), the board of directors gave Maersk Pacific the authority to out source the system. This was an unprecedented event in the history of the company, which is known for its high-quality in-house systems.

After a careful search, Maersk determined that the Synchronous Planning and Real-Time Control System (SPARCS) product from Navis Corporation would provide most of the required functionality. Promising to meet Maersk's additional requirements within a 6-month time frame, Navis undertook the project in October 1993.

SYSTEM REQUIREMENTS

The vision held by terminal management was that the system would provide better control of every aspect of the operation, particularly better use of yard space through coordinated rail, yard, and vessel planning. A key objective was to coordinate vessel discharge sequencing with rail loading to meet train departure schedules.

To achieve this goal, a number of advanced technologies were implicit in the system's specification. First, the system would be highly visual, making use of a modern graphical user interface. It would also deliver a high-level of responsiveness through client-server architecture. To provide maximum availability, the system would use the concept of distributed processing, with all hardware located on-site. It would therefore be immune to communication failures, deemed to be the most fragile aspect of existing systems. Finally, it would incorporate a radio frequency data network so that yard activity would be captured in real-time, with increased accuracy.

Existing data processing systems were to largely remain intact. This included CTOS, an IBM mainframe-based terminal management system developed and supported by Maersk Data in New Jersey. CTOS provides the crucial gate processing, bookings, and electronic data interchange with Maersk's enterprisewide systems, including its global equipment tracking system, RKEM. Because SPARCS would depend heavily on data originating in the mainframe, it was a requirement that data would be shared in real-time between the two systems.

LABOR IMPLICATIONS

All clerks, crane operators, UTR drivers, and rail planners at the terminal are members of the ILWU. At

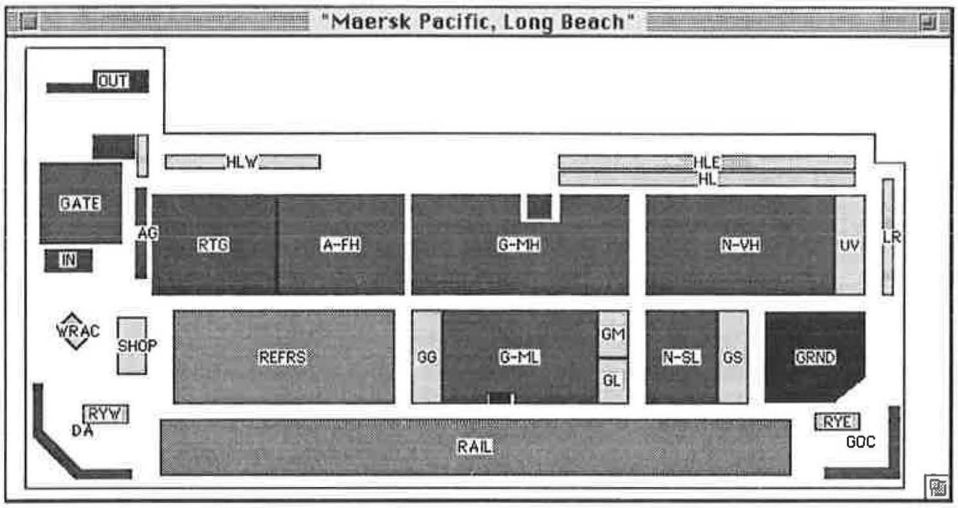


FIGURE 1 Yard overview window.

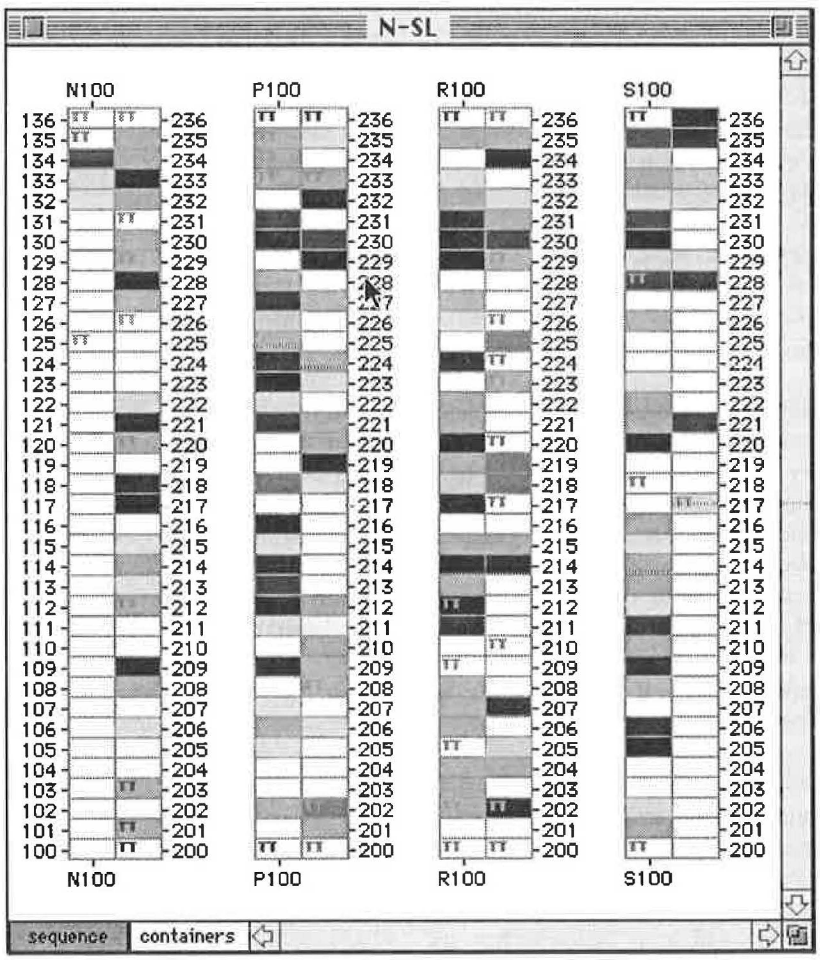


FIGURE 2 Overview of wheeled storage area.

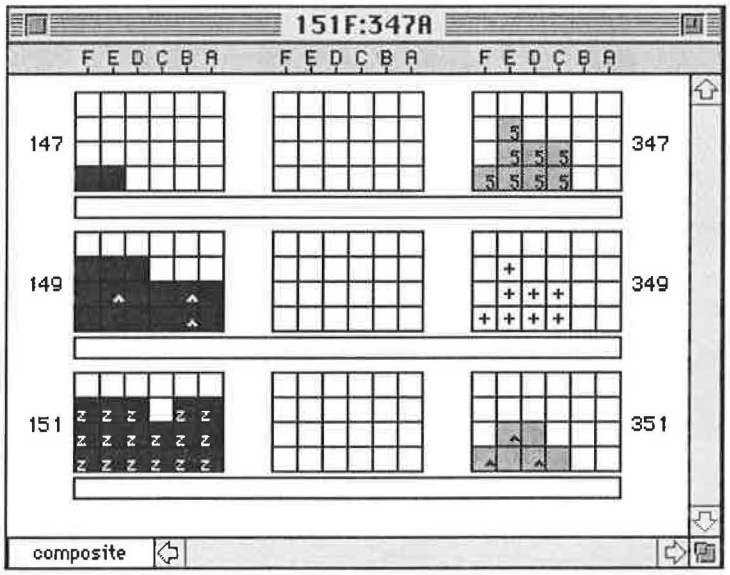


FIGURE 3 Cross-section view of RTG area.

present, union work rules limit the ways in which automation can be applied. One fundamental constraint is that equipment operators cannot be expected to perform any data entry. This largely precludes using a modern "computer-directed operation" in which equipment operators receive and confirm movement instructions directly from the computer system.

Instead, the system and accompanying work processes had to be carefully designed to achieve management's objectives without violating labor contracts. In some cases this meant keeping people in the loop where they might otherwise have been eliminated through automation. Rather than accept this as a suboptimal outcome, the design focused on how to empower these people to obtain better results than could be anticipated from a totally automated system.

SYSTEM OVERVIEW

The SPARCS application suite, which was originally developed in the late 1980s, has been under continual expansion and refinement ever since. It is the most widely used application in its class, now licensed to more than 40 marine terminals worldwide (2,3,4,5,6,7,8,9,10).

Still, each implementation of SPARCS is unique, and the Maersk Pacific Terminal is a milepost, being the first installation at a major intermodal facility. In the following we will briefly outline the principal SPARCS modules installed at Maersk, emphasizing the rail planning portions that are unique to this site.

Yard Module

The basis of SPARCS is the yard module, which provides a detailed computer representation of the terminal facility. Not only does it describe the yard layout, but also it includes such items as the location of light poles and reefer plugs required to automate decisions about the availability of individual storage positions. Highly graphic displays, arranged within windows, provide the user with a variety of views of the yard and its contents (Figs. 1–3).

Container Query Module

The container query module gives the user the ability to obtain on-screen lists of containers, based on any user-defined criterion. The lists can be sorted by any combination of container attributes, recapped on-line, and printed in user-defined formats. This general feature is used by planners and terminal management for various planning tasks, strategic decision making, and on-line management of information.

Figure 4 shows information available by clicking the mouse on any displayed container within the system.

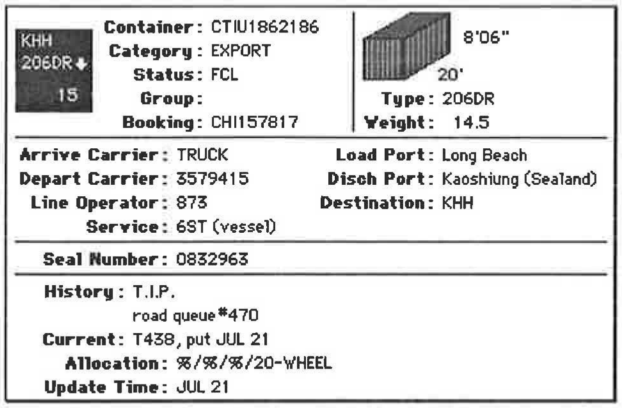


FIGURE 4 Container information pop-up display.

Figure 5 shows the dialog through which the user can issue a query against the data base. Figures 6 and 7 show the query results in list and recap format.

Yard Planning and Control Module

The yard planning and control module provides management with a "yard allocation plan" within the system. The yard allocation plan dictates how yard space is to be used. Based on this plan, the system will automatically determine the best location to store a container in response to a real-time request. These requests typically originate at the in-gate or on discharging a container from a vessel or train.

Vessel Planning and Control Module

The vessel planning and control module includes a suite of functions that are used for planning and executing all aspects of vessel load and discharge. This module is widely used worldwide and has been described in detail elsewhere (1,2). Figure 8 shows a typical vessel cross-section view available within the system. Note that icons rather than text are used as much as possible to keep the display concise and allow planners to use their innate pattern recognition abilities.

Rail Planning and Control Module

The SPARCS rail planning and control module has been under continued refinement and development for 4 years. Initially developed for Australian stevedores to suit the needs of the Port Botany Container Terminal in Sydney, the module was first extended to handle North

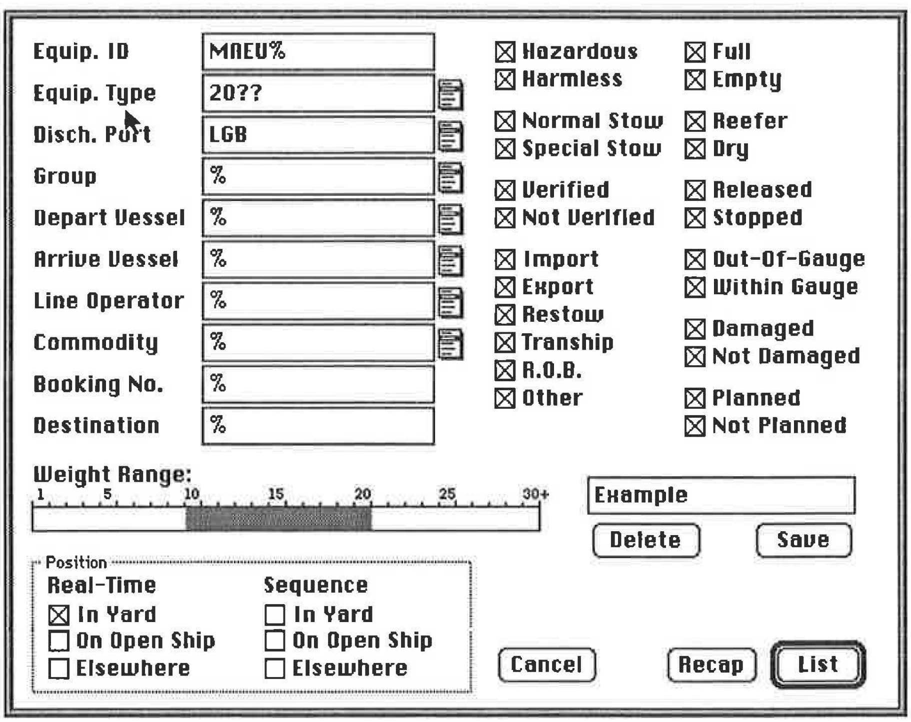
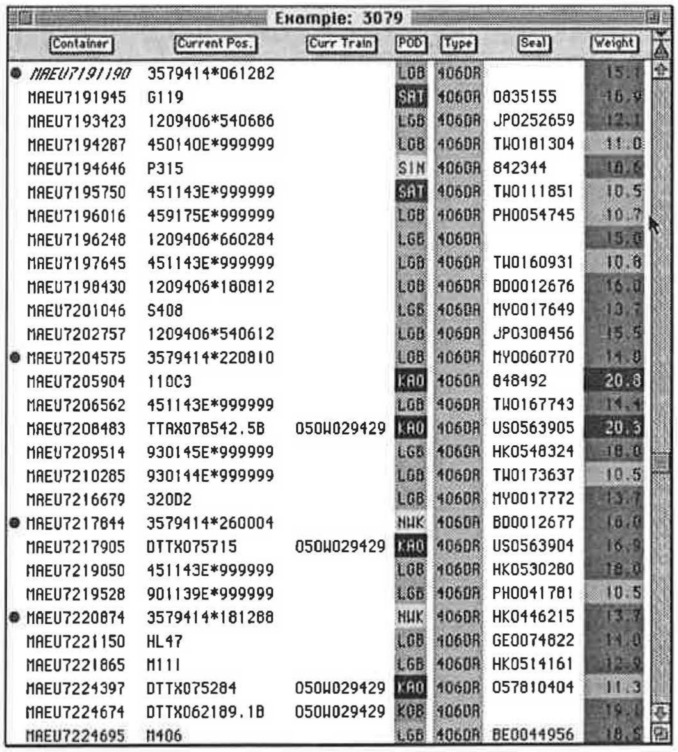


FIGURE 5 Container query dialog.



Example: 3079

	Container	Current Pos.	Curr Train	POD	Type	Seal	Weight
●	MAEU7191190	3579414*061282		LGB	4060R		15.1
	MAEU7191945	G119		SAT	4060R	0835155	16.9
	MAEU7193423	1209406*540686		LGB	4060R	JP0252659	12.1
	MAEU7194287	450140E*999999		LGB	4060R	TW0181304	11.0
	MAEU7194646	P315		SIN	4060R	842344	10.6
	MAEU7195750	451143E*999999		SAT	4060R	TW0111851	10.5
	MAEU7196016	459175E*999999		LGB	4060R	PH0054745	10.7
	MAEU7196248	1209406*660284		LGB	4060R		15.0
	MAEU7197645	451143E*999999		LGB	4060R	TW0160931	10.8
	MAEU7198430	1209406*180812		LGB	4060R	BD0012676	16.0
	MAEU7201046	S408		LGB	4060R	MY0017649	13.7
	MAEU7202757	1209406*540612		LGB	4060R	JP0308456	15.5
●	MAEU7204575	3579414*220810		LGB	4060R	MY0060770	14.0
	MAEU7205904	110C3		KAO	4060R	848492	20.8
	MAEU7206562	451143E*999999		LGB	4060R	TW0167743	14.4
	MAEU7208483	TTAX078542.5B	050W029429	KAO	4060R	US0563905	20.3
	MAEU7209514	930145E*999999		LGB	4060R	HK0548324	18.0
	MAEU7210285	930144E*999999		LGB	4060R	TW0173637	10.5
	MAEU7216679	320D2		LGB	4060R	MY0017772	13.7
●	MAEU7217844	3579414*260004		NWK	4060R	BD0012677	16.0
	MAEU7217905	DTTX075715	050W029429	KAO	4060R	US0563904	16.9
	MAEU7219050	451143E*999999		LGB	4060R	HK0530280	18.0
	MAEU7219528	901139E*999999		LGB	4060R	PH0041781	10.5
●	MAEU7220874	3579414*181288		NWK	4060R	HK0446215	13.7
	MAEU7221150	HL47		LGB	4060R	GE0074822	14.0
	MAEU7221865	M111		LGB	4060R	HK0514161	12.9
	MAEU7224397	DTTX075284	050W029429	KAO	4060R	057810404	11.3
	MAEU7224674	DTTX062189.1B	050W029429	KOB	4060R		19.0
	MAEU7224695	M406		LGB	4060R	BE0044956	18.5

FIGURE 6 Typical on-screen container list.

American double-stack operations for the Port of Portland. Significant additional enhancements were made in the course of implementing the system at Maersk.

The underpinnings of the rail module is a detailed model of railcars. Figure 9 shows the dialog in which a user can define and edit railcar types. Detailed physical information is entered so that the system can validate stowage plans. The validation also considers route restrictions, allowing users to define weight, height, and width limits as a function of routing and inland destination.

Figure 10 shows the train consist display. Users can edit a number of fields in this view directly, including car type, track, and spot. Cars can be added to the view by selecting them in the "Available Cars List" and then clicking on the "add" button in the window's header. Also available in the header are other controls to open related train views, control printing, and issue primary commands.

Figures 11 and 12 show two different graphic views available for railcar stowage. The diamonds displayed over several platforms in these examples indicate that the weight limit has been exceeded.

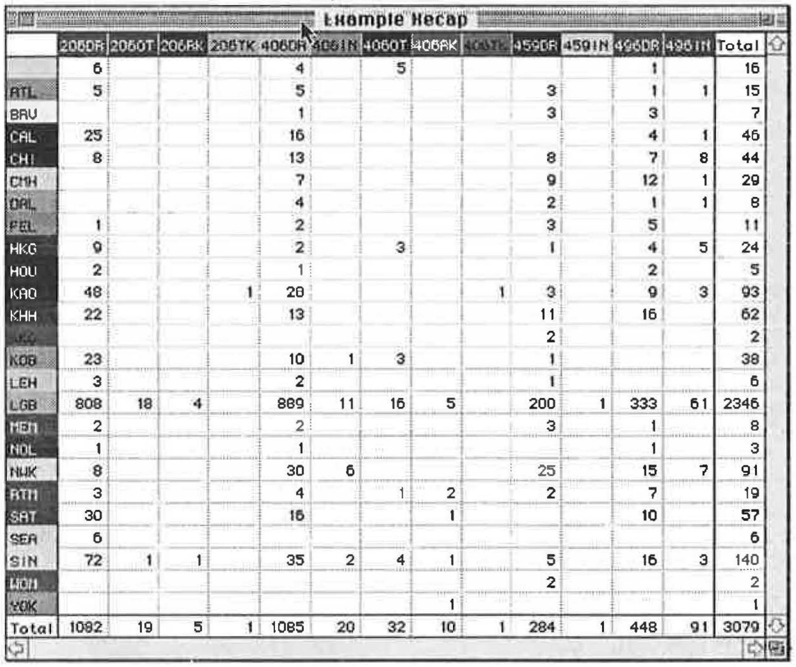
Technical Details

Hardware and System Software

SPARCS is accomplished through a network of Apple Macintosh workstations, laser and serial printers, and a radio data network provided by LXE and tightly interfaced to SPARCS. Figure 13 provides an overview of the principal hardware.

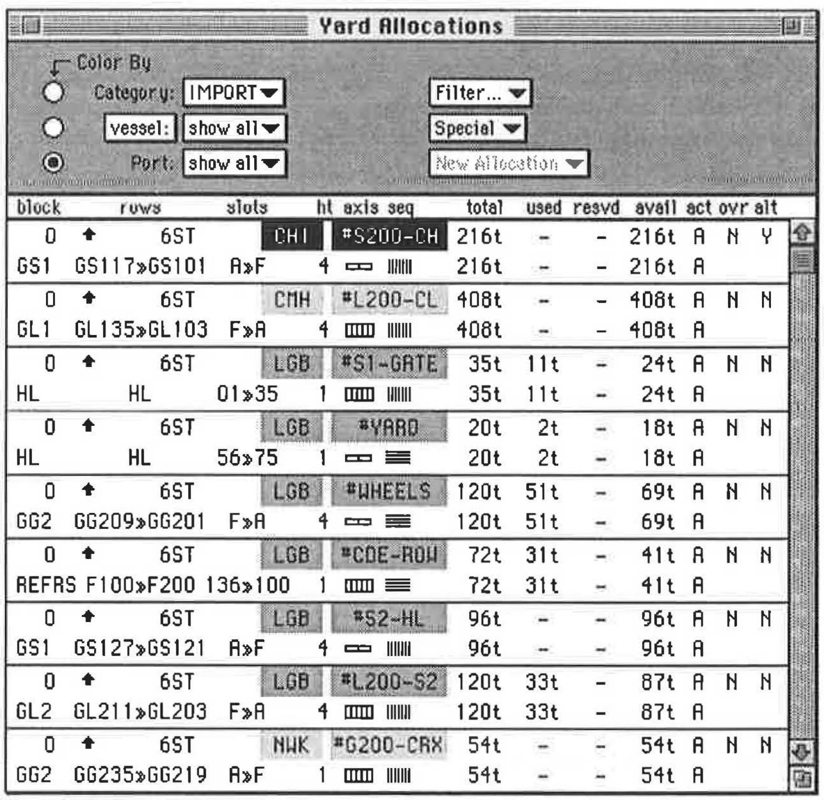
The existing Token Ring local area network (LAN), which links the major buildings at the terminal, was used as the backbone for SPARCS. A TCP/IP-based communication protocol runs over the LAN for peer-to-peer communication between the SPARCS workstations. Coexisting on the LAN is support for IBM's SNA services, such as 3270 terminal emulation and APPC capability. This gives each workstation direct access to the Maersk Data mainframe.

Each Apple Macintosh workstation is equipped with a 21-in., high-resolution color graphics monitor, 20 MB of RAM, and network software to interface with the terminal's Token Ring LAN. The system software is Apple's System 7.1 together with MacTCP, Apple's implementation of the TCP/IP network protocol.



	206DR	2060T	206RK	206TK	406DR	406IN	4060T	406RK	406TK	459DR	459IN	496DR	496IN	Total
	6				4		5					1		16
ATL	5				5					3		1	1	15
BRV					1					3		3		7
CAL	25				16							4	1	46
CHI	8				13					8		7	8	44
CMH					7					9		12	1	29
DAL					4					2		1	1	8
FEL	1				2					3		5		11
HKG	9				2		3			1		4	5	24
HOU	2				1							2		5
KAO	48			1	28				1	3		9	3	93
KHH	22				13					11		16		62
[illegible]										2				2
KOB	23				10	1	3			1				38
LEH	3				2					1				6
LGB	808	18	4		889	11	16	5		200	1	333	61	2346
MEM	2				2					3		1		8
NOL	1				1							1		3
NWK	8				30	6				25		15	7	91
RTM	3				4		1	2		2		7		19
SAT	30				16			1				10		57
SEA	6													6
SIN	72	1	1		35	2	4	1		5		16	3	140
WON										2				2
YOK								1						1
Total	1082	19	5	1	1085	20	32	10	1	284	1	448	91	3079

FIGURE 7 Typical on-screen container recap.



block	rows	slots	ht	axis seq	total	used	resvd	avail	act	ovr	alt
0	⬆ 6ST		CHI	#S200-CH	216t	-	-	216t	A	N	Y
GS1	GS117»GS101	A»F	4		216t	-	-	216t	A		
0	⬆ 6ST		CMH	#L200-CL	408t	-	-	408t	A	N	N
GL1	GL135»GL103	F»A	4		408t	-	-	408t	A		
0	⬆ 6ST		LGB	#S1-GATE	35t	11t	-	24t	A	N	N
HL	HL	01»35	1		35t	11t	-	24t	A		
0	⬆ 6ST		LGB	#YARD	20t	2t	-	18t	A	N	N
HL	HL	56»75	1		20t	2t	-	18t	A		
0	⬆ 6ST		LGB	#WHEELS	120t	51t	-	69t	A	N	N
GG2	GG209»GG201	F»A	4		120t	51t	-	69t	A		
0	⬆ 6ST		LGB	#CDE-ROW	72t	31t	-	41t	A	N	N
REFRS	F100»F200	136»100	1		72t	31t	-	41t	A		
0	⬆ 6ST		LGB	#S2-HL	96t	-	-	96t	A	N	N
GS1	GS127»GS121	A»F	4		96t	-	-	96t	A		
0	⬆ 6ST		LGB	#L200-S2	120t	33t	-	87t	A	N	N
GL2	GL211»GL203	F»A	4		120t	33t	-	87t	A		
0	⬆ 6ST		NWK	#G200-CRX	54t	-	-	54t	A	N	N
GG2	GG235»GG219	A»F	1		54t	-	-	54t	A		

FIGURE 8 Display of yard allocations in a list format.

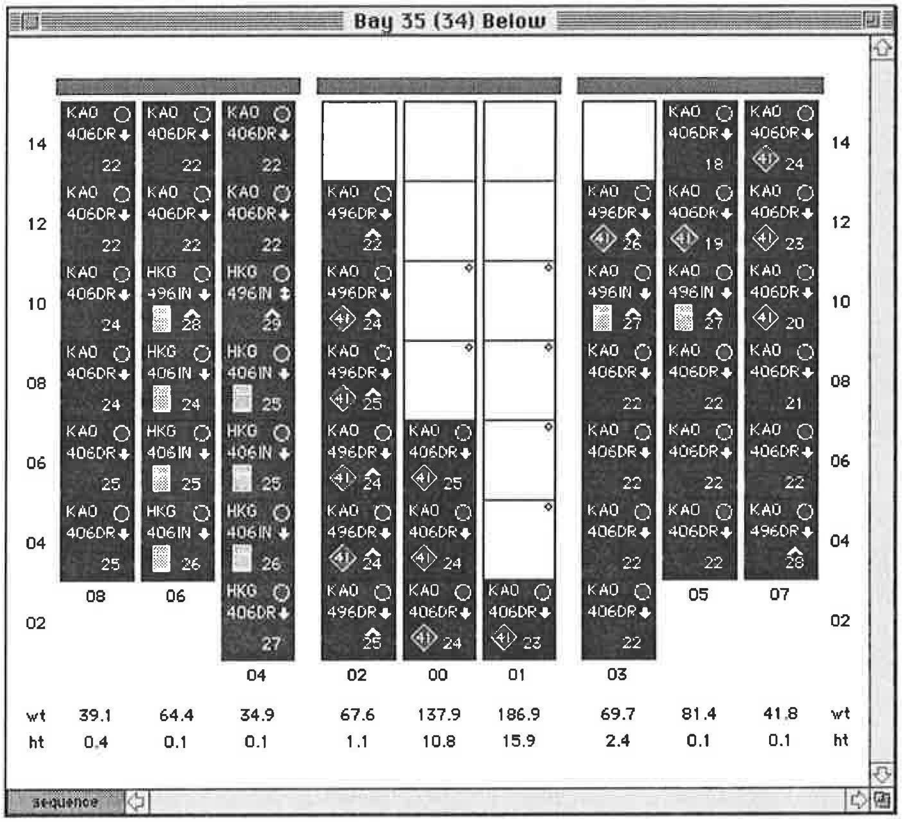


FIGURE 9 Vessel cross-section display, showing planned containers.

High-resolution laser printers are installed at each building for printing railcar plans, vessel stow plans, and other reports. Serial printers are available as well, which are dedicated to printing "wheel tickets."

Multiuser, Real-Time, Distributed Data Base

A key aspect of SPARCS is that it is built around a real-time data base that is distributed across all workstations. This gives each user immediate access to all information, without any network performance penalties. To achieve this, one workstation acts as a dedicated server, arbitrating the distribution of all state and planning data to clients. This allows multiple users to plan operations concurrently without conflicts.

With this distributed client-server architecture, SPARCS also obtains a high degree of fault tolerance. In the event of server failure, any client can take over the server's duties because it already contains a complete copy of the data base.

LXE Radio Data Network

The LXE radio data network consists of one base station and 10 vehicle-mounted and 7 hand-held radio data terminals (RDTs). Because of the cluttered airways in the port area, it was decided to use a spread-spectrum protocol rather than the more common narrow-band approach. Although this technology was relatively unproven in the container terminal industry, it has performed superbly.

The LXE controller is driven by a dedicated SPARCS client workstation, designated as the "radio server." All control of RDT screens is handled by the radio server, which in turn relays container updates from the RDTs to the rest of the network.

Real-Time Link with CTOS

The SPARCS server performs the additional task of maintaining a real-time link with Maersk's CTOS

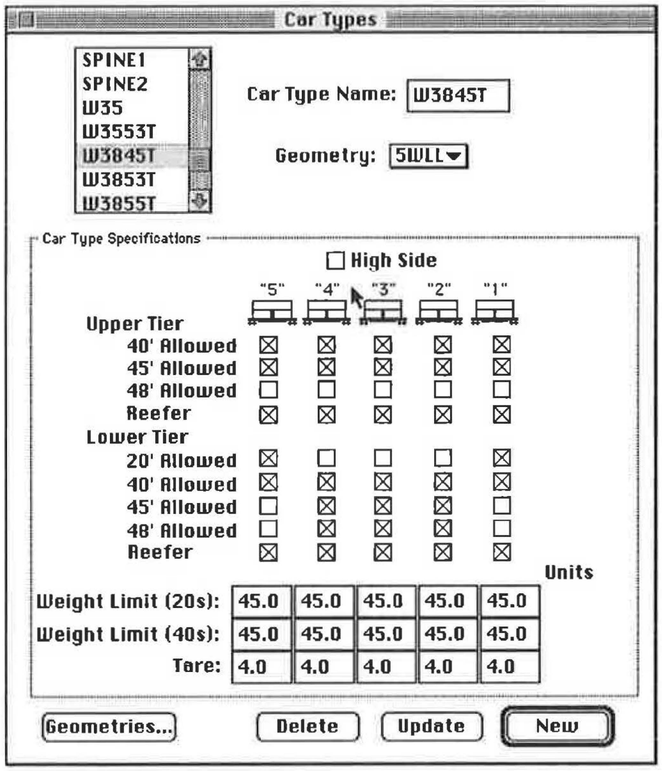


FIGURE 10 Car type maintenance window.

terminal operating system. Because CTOS is an IBM mainframe application, this link was forged using IBM's LU6.2 standard for peer-to-peer communication. This way any update occurring within CTOS or SPARCS is relayed to the other system in a matter of seconds or less.

The real-time link is a crucial part of the system, and its development was the critical path in the installation process. Close cooperation between Navis and Maersk Data and a thorough test program were essential to the successful development of this part of the system.

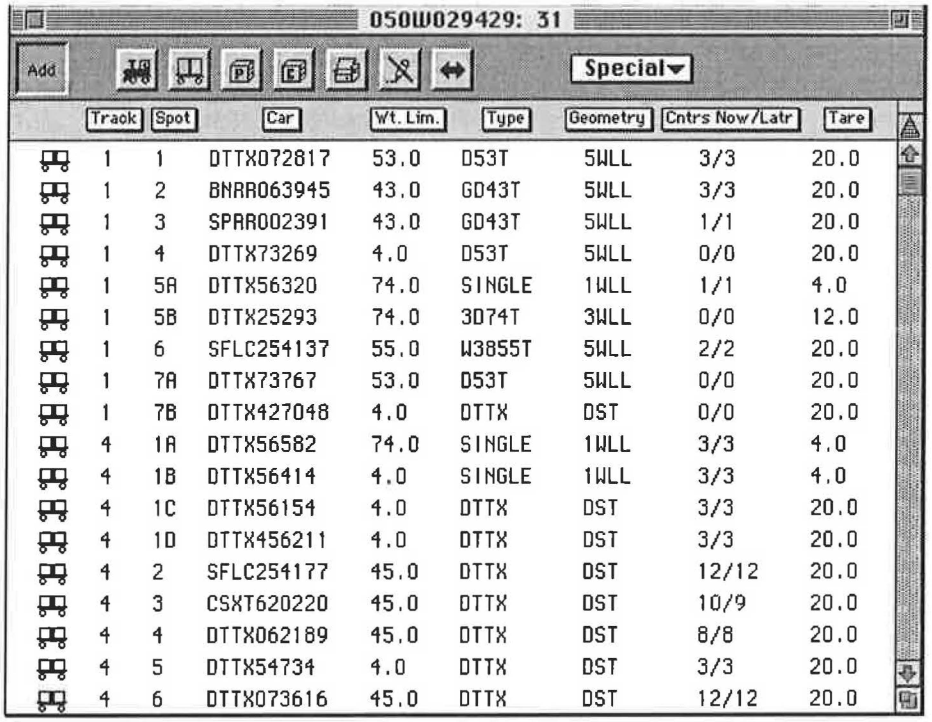
The principal dialogue between SPARCS and CTOS concerns container status. Whenever there is a change in status of a container at the terminal, or a container under way to the terminal by train or vessel, CTOS sends an immediate update message to SPARCS, thereby providing the changes. In turn SPARCS informs CTOS of any change in status originating within SPARCS or the LXE radio data network controlled by SPARCS. Both sides of this conversation have store and forward logic, allowing each side to transparently recover from a communication failure.

OPERATIONS FLOW

Gate Receival

SPARCS plays a key part in the process of receiving containers arriving by road, of which there are up to 600 per day. Maersk uses a two-stage gate at which support from remote video cameras and an intercom allow the truck driver to remain within the cab for the entire process.

At the first stage the driver is queried by a gate clerk for the details of her or his transaction. These details are entered into and validated by CTOS. Once all data appears valid, CTOS issues a "position request" to SPARCS through the real-time data link with the server. The server responds to CTOS in a fraction of a second with a selected yard position for the container, which then prints on a "routing ticket" for the driver. The driver tears off this ticket from the pedestal and drives forward to the second stage in which inspections will be performed and the equipment interchange receipt will be issued.



	Track	Spot	Car	Wt. Lim.	Type	Geometry	Cntrs Now/Latr	Tare
	1	1	DTTX072817	53.0	D53T	5WLL	3/3	20.0
	1	2	BNRR063945	43.0	GD43T	5WLL	3/3	20.0
	1	3	SPRR002391	43.0	GD43T	5WLL	1/1	20.0
	1	4	DTTX73269	4.0	D53T	5WLL	0/0	20.0
	1	5A	DTTX56320	74.0	SINGLE	1WLL	1/1	4.0
	1	5B	DTTX25293	74.0	3D74T	3WLL	0/0	12.0
	1	6	SFLC254137	55.0	W3855T	5WLL	2/2	20.0
	1	7A	DTTX73767	53.0	D53T	5WLL	0/0	20.0
	1	7B	DTTX427048	4.0	DTTX	DST	0/0	20.0
	4	1A	DTTX56582	74.0	SINGLE	1WLL	3/3	4.0
	4	1B	DTTX56414	4.0	SINGLE	1WLL	3/3	4.0
	4	1C	DTTX56154	4.0	DTTX	DST	3/3	20.0
	4	1D	DTTX456211	4.0	DTTX	DST	3/3	20.0
	4	2	SFLC254177	45.0	DTTX	DST	12/12	20.0
	4	3	CSXT620220	45.0	DTTX	DST	10/9	20.0
	4	4	DTTX062189	45.0	DTTX	DST	8/8	20.0
	4	5	DTTX54734	4.0	DTTX	DST	3/3	20.0
	4	6	DTTX073616	45.0	DTTX	DST	12/12	20.0

FIGURE 11 Train consist window.

In the position assignment process, SPARCS evaluates the container being received against the yard allocation plan and current inventory. In most cases containers arriving by road remain on wheels. Because containers parked on wheels are randomly accessible, yard planning is fairly trivial. Dry loads are segregated by container length, with reefers, hazardous, and empty containers allocated to special areas. When possible within the allocation plan, SPARCS attempts to minimize traffic congestion by sending succeeding containers to alternating aisles.

The yard allocation system also supports detailed segregation, allowing grouping by any combination of equipment type, vessel/voyage, discharge port, commodity, weight class, and so on. This capability is used when containers are received at stacked locations.

When the planned yard location is a grounded position, the terminal's labor force stacks the container in the designated position. However, when the planned position is a parking stall, proper placement is less likely because the visiting truck driver will park the container. Maersk knew this would be a source of errors, but found that the level of accuracy was tolerable: about 80 percent of the time the container is parked in the correct row and about 50 percent of the time in the correct spot. These errors cannot be left uncorrected, because the inventory degrades as time goes on and mistakes compound.

Mobile Inventory Control

To maintain accurate real-time control of inventory, a simple, reliable, and effective (but not exactly high-tech) solution is employed. A small, brightly colored magnet is attached to the container at the in-gate, which serves as a marker to clerks who rove the yard in utility vehicles. When a marked container is found, the clerk removes the magnet and confirms the yard position with an RDT mounted in her or his cab. If the container is in its proper place, this process involves as few as seven keystrokes.

The clerks can also use a "verification mode" to maintain yard inventory. In this mode the RDT screen is formatted to show five consecutive parking stalls at once. The clerk can overtype what is displayed to make corrections, then request a new screen for the next five stalls in the row. This method has proven to be very efficient for steady clerks, but requires more operator training and is not used frequently by less dependable clerks.

A window within the SPARCS application lists all units that have been received but are not yet confirmed

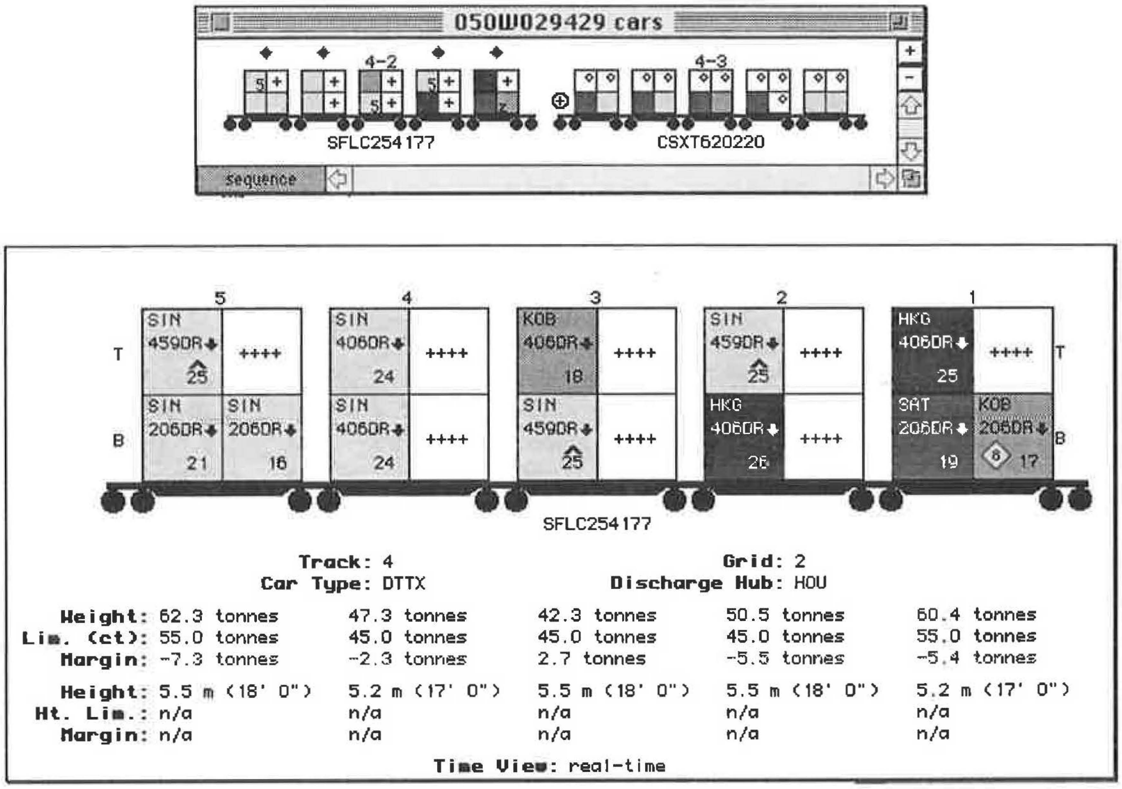


FIGURE 12 Car plan views.

in the yard. This allows management to oversee the progress of yard inventory clerks and allocate labor as needed.

It is crucial for SPARCS to be aware of the locations of bare chassis within the yard so that it can assign parking spaces. However, the effort required to track these locations on a chassis-specific basis was deemed prohibitive. Instead, a simple concept is implemented in which the inventory clerk indicates slots occupied by bare chassis via RDT, but does not input the chassis number. As a result, a situation exists in which CTOS keeps track of the exact chassis inventory within the yard and SPARCS keeps track of what slots are occupied by chassis, but neither system can provide the exact location of a particular bare chassis. Fortunately, this information is not needed to run the operation, and all parties are satisfied that the right trade-off was made.

Train Discharge

Once a westbound train has departed the final inland hub and its loading has been recorded, CTOS will transmit to SPARCS a record for each inbound container. This transmission includes the container's number, size/type, vessel on which it will be loaded, and discharge port and train identification and the car (but not the exact spot) on which the container was loaded. Using this information, SPARCS builds a data model of the inbound train, which the train planner can pull up onscreen (Fig. 10).

If the car has already been to the terminal, SPARCS will have full detail on its geometry and loading constraints. If the care has not been to the terminal, SPARCS will assume a general five-platform, double-stack geometry. This will be corrected later by the user once the car is examined, but it is not a prerequisite for continuing.

The cars are spotted to the tracks, and this information is recorded in SPARCS. Rail clerks then perform a physical inventory of the train, using RDTs to record the location of each container. This function was carefully designed for the greatest ergonomics and allows two clerks to inventory a full-length double-stack train in about 30 minutes.

The advantages of having an exact inventory of the train are twofold. First, it allows a precise discharge sequence to be planned, allowing operations to proceed smoothly. Second, it provides a convenient double check of the accuracy of the data received from the railroad.

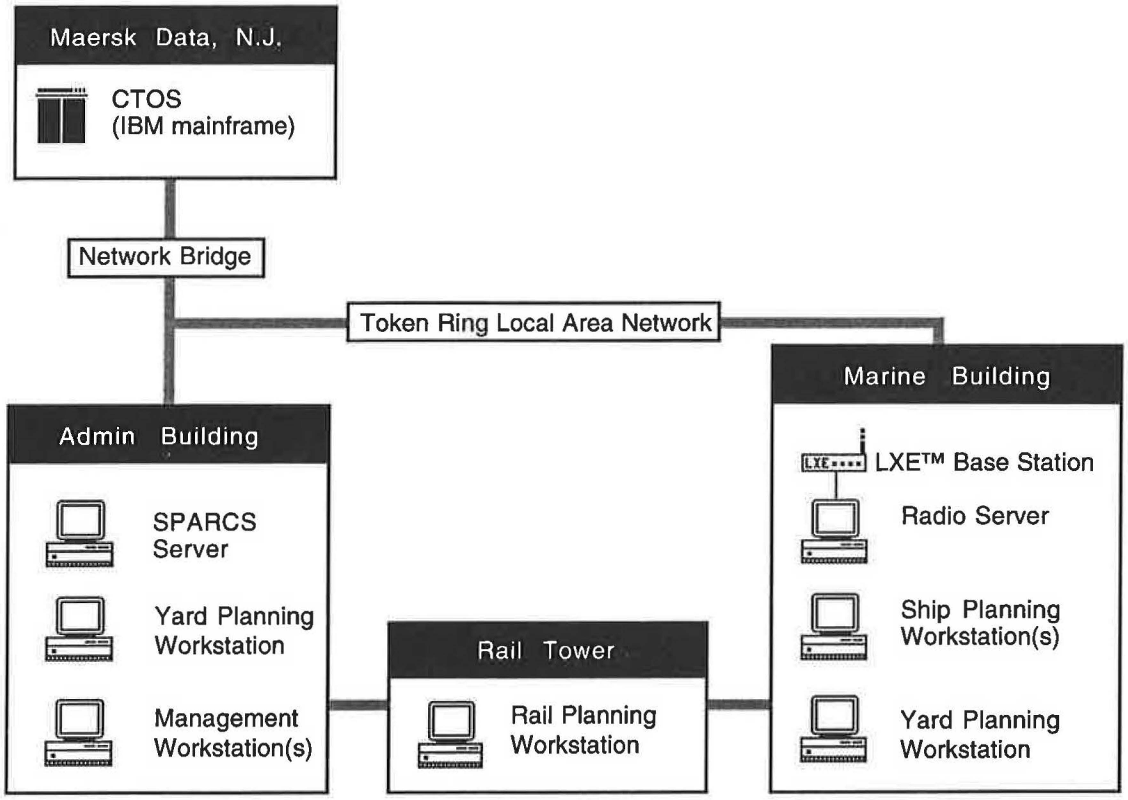


FIGURE 13 Network diagram.

Within SPARCS, users can quickly obtain a list of preadvised containers not physically located—containers that were expected but did not arrive for one reason or another—as well as identify any unexpected containers.

Containers arriving by train are generally parked on wheels. The locations are planned in SPARCS, and a one-page car plan is printed for the operations foreman showing the container details and planned position for each. The discharge plan is driven by the needs of the vessel loading operation. In particular, the order of discharge may be determined by a need to provide certain types of containers to the quay cranes for immediate loading.

The process proceeds with UTR drivers bringing bare chassis to the ramp, the top-pick driver discharging the containers to the chassis, and the foreman directing the UTR driver to the proper yard area. The foreman also places a magnet on each container for the inventory clerks (as described for the gate receival process).

Vessel Discharge

The vessel discharge process is similar to the train discharge process. The yard location of each container can be determined automatically by the SPARCS yard allocation module or can be directly chosen by the planner using the "Direct Allocation Group" feature. The planner selects a group of containers to be discharged from the vessel, then prescribes a range of yard locations to which the group should be discharged—with a stroke of the mouse. This creates a work instruction for each container to that range.

SPARCS prints paper documents used in the operation, including discharge plans for each vessel bay and discharge sequence sheets. Containers discharged from the vessel that will be departing by train are frequently grounded rather than mounted on chassis. Maersk found that the efficiency is higher overall with this approach for the following reasons:

- It is faster to discharge to a bomb cart than to a road chassis because less precision is required by the crane operator.
- It is faster for a top-pick to remove the container from a bomb cart and stack it than for the UTR driver to park and drop the chassis.
- The UTR driver's average driving distance is less, and the operation seems to go faster when repeating a cycle between a crane and a specific yard area.

- The UTR driver does not have to find and connect to a bare chassis for each new move.
- Yard space is used more efficiently.

With this type of operation, each work unit achieves 40 moves per hour. Similar efficiencies are realized for the ensuing loading of the train.

Before implementing SPARCS, grounding was avoided because of the complexity it introduces to the subsequent move to the train. However, with SPARCS tools these difficulties have been completely eliminated. First, the precise grounded locations of each discharged container is immediately recorded by a clerk in the yard with an RDT. With this information available, the train planner can use the graphic interface to visualize the train and the stacked containers in the yard on her or his screen. As a result, the process of determining an efficient load sequence for the train becomes very simple.

Within SPARCS the tools exist to plan moves directly from the vessel to the train, without the intermediate move to the yard. A number of labor and coordination barriers exist that preclude this type of operation for now.

Train Loading

Based on the containers that are to be loaded, the train planner determines a blocking plan for the train, selecting available cars from those on hand. This process is executed within SPARCS by first creating an outbound train, then adding cars to that train from among those available at the terminal.

The planner can raise a train load list within SPARCS, select containers from this list, and flow them to the train with the mouse. SPARCS validates the loading plan interactively, alerting the planner to any violation of car constraints and height or weight limits imposed by the train's intended route. If the containers being loaded are stacked, the planner can plan from a graphical display of the stacking area rather than from a list of available containers to ensure that the sequence will not cause digging and rehandles.

Before implementing the system, Maersk was keen to automate the load planning process. Now that the "manually guided" planning system is in place, Maersk has found that the system is so fast that there is no need to further automate it. Furthermore, we believe that it is unlikely that a computer can be programmed (for a reasonable cost) to construct a better plan than having an intelligent person use a powerful tool such as this. However, if the objective is to eliminate the job function (with some trade-off in plan quality), it may be feasible.

Once the plan is constructed, wheel tickets and car plans are printed. Each wheel ticket is essentially a movement instruction, giving the container number, yard location, and planned train position. The tickets are printed in the intended order of loading and a clerk (located trainside) hands these out to UTR drivers in sequence, who proceed to fetch the loads from the yard. If the loads are coming from the ground, another clerk with a sequence list will direct a top-pick in the yard to fetch the containers.

Upon loading of a container to a car, a clerk with a hand held RDT will confirm the move. Immediately upon move confirmation, SPARCS clears the yard position so that the yard allocation module will be able to reuse it for incoming containers as needed.

Vessel Loading

Before implementing SPARCS, vessel load plans were generated by Maersk Line in San Francisco, using Maersk's in-house vessel planning system, SCOPE. As volumes increased, however, it became desirable to stack export containers in RTG areas. The SCOPE system does not permit planning a ship from a stacked yard; therefore, stacking export containers in RTG areas was no longer feasible. Now the SCOPE plan is used only as a "preplan" that stowage coordinators use as a guideline when sequencing loading within SPARCS.

SPARCS provides a rich set of features that help the ship planner. The result is a sequence of loading for each vessel bay, represented on printed sequence sheets; vessel loading stowage plans; and wheel tickets similar to those used for train loading. The loading operation proceeds in a manner similar to the train loading operation as previously described.

Yard Operations

To provide the best possible truck turnaround time within the terminal, Maersk's current operating strategy dictates that export loads received from the road be initially left on chassis. Later, certain loads are be moved to grounded positions within the RTG area. The decision to ground loads is made by management and depends on a number of factors. Grounding is carefully planned within SPARCS so that all containers within one RTG bay will be loaded to the same vessel bay for maximum productivity. Once a grounding plan is made, it is directed with wheel tickets and confirmed by RDT data entry in the yard in the same manner used in the vessel and train loading processes.

BENEFITS

Within only a few months, Maersk Pacific realized significant benefits from the system.

Subjective Benefits

From management's perspective, the system provides a higher degree of "control and order" in the daily operations of the terminal. This is likely to result in incremental increases in efficiency, although these benefits are difficult to quantify. Still, there have been a few occasions when management believed that sudden changes to operational conditions would have resulted in a crisis without the system.

One example was a disruption of communication lines (caused by nearby construction) that resulted in a 7-hr loss of support from CTOS. All road received and delivery came to a halt, but operations within the terminal proceeded without disruption under SPARCS control. When communication was reestablished, SPARCS automatically updated CTOS with all movements that occurred during the outage.

Another example is when a large number of received loads are rolled to a different train or vessel after they have been planned for loading. In the past, these events caused confusion, including service failures where up to 200 containers were left behind. Now such occurrences are easily dealt with.

Measured Increases in Performance

The higher degree of order and control is likely to lead to increases in efficiency. One barometer of overall terminal efficiency is net quay crane productivity, and this is measured closely by Maersk. A 10 percent increase has been realized since implementation.

Ability to Support New Operational Strategies

SPARCS makes it possible for the terminal to support new operational strategies that are essential to accommodate increasing volume. In particular, grounding of export containers and trainloads is now the norm. Although this was motivated by a need to use yard space more effectively, it has been found to have other operational advantages.

Labor Factors

Labor reduction was not an objective, and no jobs were eliminated with the introduction of the system. All processes have been unified and streamlined by the system, allowing planners to concentrate more on planning and less on tedious bookkeeping tasks.

The generation of paperwork for the rail loading operation was used to be a time-consuming manual process, especially when changes or updates occurred after work was started. Now all reports are just a mouse click away, and this alone has been estimated to save easily 20 personnel hours per week. These time savings, together with the radical increase in flexibility afforded by the system, have allowed rail planners to experiment and obtain better plans. Planning used to be a stressful and chaotic process focused on sending trains out on time, with optimization being a distant second priority.

Response to the system by management and union personnel has been very positive due to the system's simplicity, high-level of visualization, and powerful planning tools. This has led to a more rewarding work experience and, ultimately, better results for Maersk Pacific.

WHAT'S MISSING?

The international trend in terminal control is toward the concept of a "computer-directed operation." The idea is to have the computer direct the container handling equipment rather than print plans or wheel tickets issued by clerks or controllers. SPARCS has such a capability through the equipment control module, and it has been successfully implemented at terminals in Dubai and Auckland, New Zealand (10). Significant benefits have been obtained through equipment control, including increased productivity of container handling equipment, better yard use, and major decreases in labor.

Unfortunately, union work rules on the U.S. waterfront prevent this type of system from being fully implemented. Only at the Port of Tacoma, where a favorable labor climate exists, has the SPARCS Equipment Control Module been put to limited use.

It is the opinion of this author, therefore, that the true "terminal of the future" from an operations control standpoint will not be realized in the United States. Because equipment control is not as highly leveraged at terminals such as Maersk Pacific, whose primary storage is on wheels, the author believes that Maersk's SPARCS implementation is near optimal as it stands.

REFERENCES

1. Shields, Jonathan J. "Select Stow." *Port Development International,* vol. 10, no. 5, May 1994, pp. 87–91.
2. North, Mark. "Bright SPARCS." *Cargo Systems International,* vol. 18, no. 10, October 1991, pp. 75–77.
3. Drogus, Valerie. "Stowage by Computer." *The Pacific Maritime Magazine,* vol. 9, no. 5, November 1991, pp. 7–11.
4. White, Rachael. "Caps Off to Navis." *Container Management,* issue 85, February 1992, pp. 27–29.
5. Woodbridge, Clive. "Navis SPARCS Off a Good Idea." *Cargoware International,* vol. 4, no. 2, February 1992, pp. 53–54.
6. Blenkey, Nicholas. "SPARCS Software Finds Customers Worldwide." *Marine Log,* vol. 97, no. 5, May 1992, pp. 57–58.
7. "SPARCS Plans Ship Loading/Unloading and Allocates Yard Space." *Asian Shipping,* no. 164, August 1992, pp. 20–21.
8. Osborne, Alistair. "Planning Ahead." *Port Development International,* vol. 8, no. 9, September 1992, p. 57.
9. Carding, Tony. "Emphasizing Efficiency: European Ports Go Lean." *Intermodal Container News,* vol. 27, no. 12, December 1992, pp. 31–31.
10. Kay, Emily. "Transport Companies Turn to Mac for Keeping Track of Vehicles, Cargo." *MacWeek,* vol. 7, no. 29, June 19, 1993, pp. 34–37.