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PORTSIM: AN OBJECT-ORIENTED PORT SIMULATION

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ABSTRACT

The development of an object-oriented port simulation (PORTSIM) that addresses military mobility issues will be described, with a brief description of the tool selection process. This system provides users with (1) a graphical user interface, (2) the ability to simulate military units through a specified port, with each individual cargo item (i.e. piece of equipment) represented, (3) utilization statistics for all port resources (e.g. gates, staging areas, berths, inspectors, and material handling equipment), (4) utilization statistics for ships that arrive at the port, and (5) a graphical dynamic animation that allows for identification of bottlenecks and facilitates the playing of what-if scenarios to maximize throughput. Cargo is simulated from the time it arrives at a gate or end ramp to the time it is loaded onto a ship. Animation is directly integrated with the simulation to allow for modifications to the scenario while the simulation is running and to have the new parameters used from that point forward in time. The simulation is flexible and allows for multiple cargo types (breakbulk, container, and roll-on/roll-off) and multiple ship types.

1 INTRODUCTION

Planning military movement of forces through seaports is a labor intensive process that involves the analysis of a large number of variables. Until now, this analysis has primarily been manual, aggregated, and is prone to error due to the complexity of all factors involved. With the increasing need of forces to deploy to worldwide destinations in a minimum amount of time, it is becoming more critical to develop automated methods to ensure accurate planning is completed at the proper level of detail and to consider alternative scenarios.

1.1 Background

The Port Simulation (PORTSIM) system is a discrete-event, time-stepped simulation that facilitates analysis of military unit equipment movements through worldwide seaports and allows for detailed infrastructure analysis. PORTSIM assists planners in comparison of multiple ports and port selection, determines port throughput capability and utilization of critical resources, and animates port processes to identify problems. PORTSIM is designed to answer the following questions:

- How long does it take the forces to move through the port (closure)?
- What and where are the bottlenecks to movement of the forces through the port?
- Why are the forces not closed by the required time and what are current force locations within the port?
- What are the implications if certain port resources are constrained or not available?

1.2 PORTSIM Overview

Figure 1 illustrates the major components of PORTSIM. The user develops a simulation scenario by selecting a port, a ship arrival list, and a military force equipment arrival list. This process is facilitated through linkages to appropriate databases and allows for development of default scenarios which can be used as a foundation for customization of scenario parameters. Specifically, PORTSIM provides linkages to the Joint Flow and Analysis System for Transportation (JFAST) to obtain ship characteristics and the Transportability Analysis Reports Generator (TARGET) to obtain military force equipment characteristics. Once the scenario has been developed, the PORTSIM engine performs a discrete-event,

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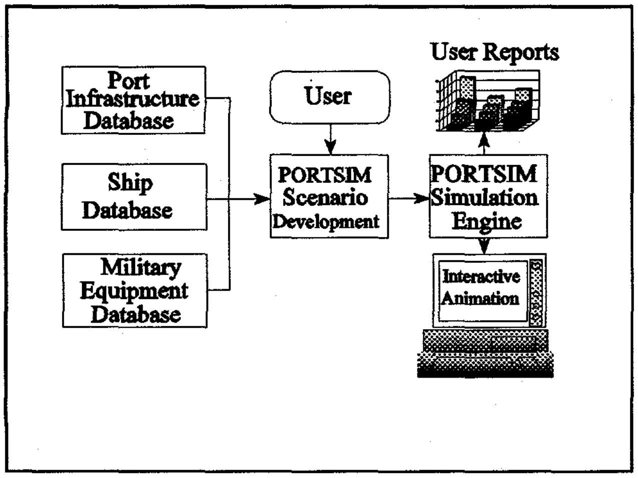

Figure 1 PORTSIM Overview

time-stepped simulation. PORTSIM provides users an interactive animation with the capability to modify simulation parameters while the simulation is executing as well as the ability to query on port, ship, and force equipment objects to retrieve time-dependent statistical information. Finally, PORTSIM produces user reports that identify port throughput capability, resource utilization, loading times for individual force equipment items, and ship contents lists and capacities.

2 CHOICE OF SIMULATION TOOL

PORTSIM is an object-oriented simulation system. Object-oriented programming solutions lend themselves well to simulation problems (Dahl and Nygaard 1966, Joines *et al.* 1993). Object-oriented programming allows for data abstraction and encapsulation, code reusability, and inheritance, (Meyer 1988) all of which are important factors in leveraging from existing efforts and which facilitate integration of PORTSIM to other mobility simulation systems. Integration is a key factor in development of PORTSIM because the seaports represent only selected nodes in the overall transportation network. Selection of a simulation tool appropriate for the implementation of PORTSIM involved evaluation of several commercial simulation products. These tools were evaluated against numerous criteria: (1) capability to link the simulation to other simulation systems, (2) capability to establish dynamic linkages to data sources, (3) ease and naturalness of simulation process problem expression and representation, (4) conformance to graphical user interface (GUI) standards, (5) graphical output reporting capabilities, (6) vendor support, (7) cost, (8) robustness, (9) portability, and (10) interactive capability of simulation (i.e., start/stop with parameter changes). The MODSIM II programming language (CACI, 1994) was ultimately chosen as the product best suited for PORTSIM implementation.

3 SIMULATION PROBLEM

The scope of the problem modeled by PORTSIM is defined by the entry and exit points to the port. Gates and end ramps are the entry and exit points to the port for military force equipment. Berths are the entry and exit points for the ships. Military equipment that arrive via highway transportation (e.g. containers on chassis, convoyed vehicles) utilize the gates as entry to the port. Equipment that arrives via railway transportation utilizes the end ramps as entry. PORTSIM simulates the flow of military equipment from the gates or end ramps to the staging areas and ultimately onto the appropriate ships. PORTSIM also simulates the ships from arrival at the berth to the time that they leave the port with the appropriate cargo. This process typically takes several days, depending upon the size of the force to be deployed and the port and ship assets that are available.

4 TECHNICAL APPROACH

PORTSIM performs a detailed analysis of all critical military port operations and has the requirement of processing a large number of items in an efficient manner. The typical force being analyzed is made up of up to 6000 pieces of equipment (Military Traffic Management Command Transportation Engineering Agency, 1994). The simulation is time-stepped in minutes and represents all equipment, port resources, and ship resources as individual objects. These objects consist of appropriate attributes and methods that define what the objects can do.

4.1 Process Design

Figure 2 illustrates an example of the general process representation for movement of military equipment. The example shown is for convoyed vehicles arriving via highway transportation. Similar representation diagrams are used to identify the processes for container operations, railcar operations, and ship operations. Processes have been developed to accept the following transportation assets:

Highway
- Flatcars carrying vehicles
- Chassis carrying containers
- Boxcars carrying palletized equipment
- Convoyed vehicles

Rail
- Railcars carrying vehicles
- Railcars carrying containers
- Railcars carrying palletized equipment

Water
- Ships

Operations performed for military equipment include gate processing, offloading of railcars at end ramps and docks, transit to and parking in staging areas, inspection of vehicles in preparation for loading, container handling, transit from staging areas to berths, and ship loading. All queues are represented and ensure that equipment items wait when needed resources are not available.

4.2 Simulation Components

Resources. Resources are the critical port elements that constrain the ability of the port to process cargo. Port resources include infrastructure at the port as well as machinery and manpower. Infrastructure assets include (1) open and covered staging areas, (2) gates, (3) berths, (4) end ramps, and (5) docks. Machinery and manpower assets consist of: (1) cranes, (2) forklifts, (3) locomotives, (4) container handlers, (5) inspectors, and (6) drivers. These resources are utilized at appropriate points in the defined processes and limit throughput capability. Maximizing the utilization of these resources maximizes throughput.

Queues. Queues provide the mechanism for items that need to wait for processing. Queues within the port are represented as finite and have a maximum size. The queues for entry to the port (i.e. gates and berths) are represented as infinite queues and can hold as many items as need to wait. For example, if vehicles arriving at the gate need to wait for processing, it is assumed that there is an unlimited area outside of the port in which the vehicles can wait.

Event List and Scheduler. The event list is the mechanism for processing events requested by items that are flowing through the system. Items are generated and put onto the event list in relation to the simulation clock. The event list

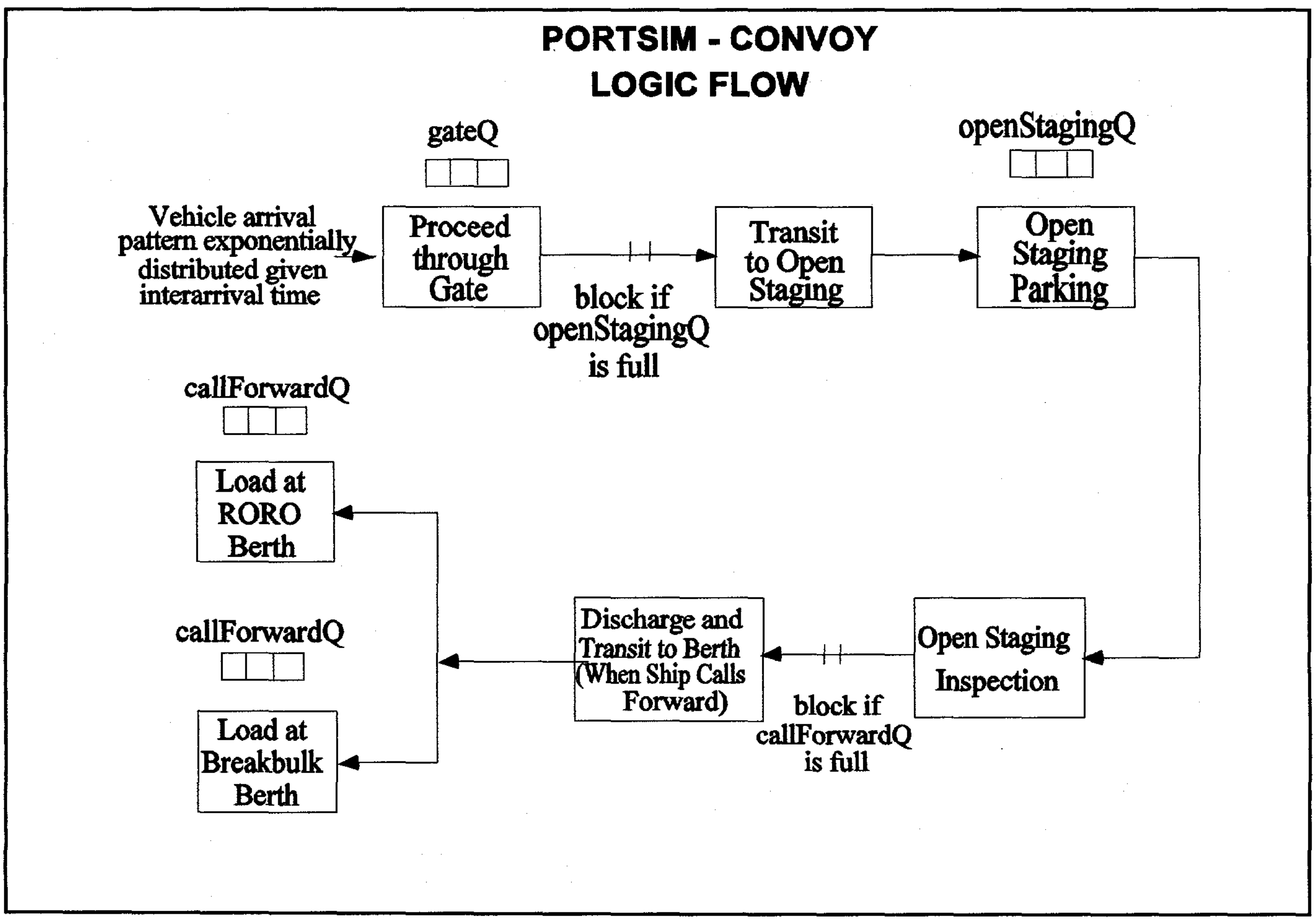

Figure 2 Convoy Process Representation

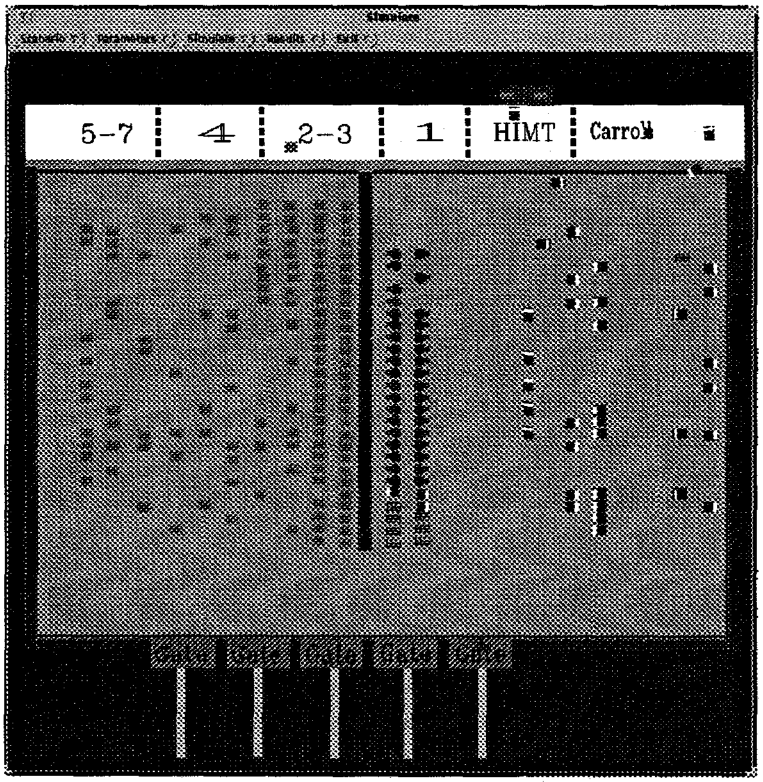

Figure 3 PORTSIM Animation

processes events based upon the time associated with the request, and, in addition, allows for events to be interrupted and rescheduled when higher priority events request processing.

4.3 Animation

PORTSIM currently provides an interactive, two-dimensional animation of port processes as illustrated in Figure 3. The animation utilizes a generic port layout, incorporating the correct number of each resource into the graphical representation. Individual port, ship, and military equipment cargo items can be queried to obtain statistical information, and modifications to parameters can be made while the animation is executing. Modifications to parameters take effect from the current time forward in the simulation. This feature eliminates the need for the user to restart the animation. A group of icons is used to distinguish different families of military equipment being processed in the animation. Icons exist for wheeled vehicles, tracked vehicles, towed vehicles, palletized cargo, and containers. These icons are also color coded to represent *ready to load* states. For example, vehicles that have not yet been inspected are colored red, and when inspection is completed on those vehicles the color is modified to green.

5 INPUT

Port. The MTMCTEA port database (MTMCTEA, 1994) provides detailed information on port resources. Data critical to PORTSIM are resource characteristics and availability. These characteristics include (1), number of gates, (2) number of berths, (3) staging capacities, (4) mapower and machinery capability, and (5) distances between port infrastructure resources.

Military Force Equipment. Currently, the arrival profile of military force equipment to PORTSIM is a data feed from the TARGET equipment characteristics database (Computer Sciences Corporation, 1993). TARGET provides *what* equipment will arrive at the port and *how* the equipment will arrive (i.e. highway or railway transportion), but does not provide *when* the equipment will arrive. PORTSIM, therefore, needs to apply stochastic methods to develop realistic arrival profiles. An exponential distribution with a user-defined mean interarrival time is the current mechanism to generate realistic arrival patterns of military force equipment.

Ships. Accurate ship data is vital to the development of a port simulation. The arrival profile of ships to PORTSIM is a data feed from the JFAST ship database (Oak Ridge National Laboratory, 1993). The JFAST ship database provides ship name, fleet designation, class, maximum speed, ship length, beam, boom, maximum draft, and designation of whether the ship is self-sustaining or not. In addition, maximum capacities for breakbulk, roll-on/roll-off, and container cargo are identified. These parameters are modifiable by users for customization of scenarios. PORTSIM utilizes these parameters to determine ship/berth matching and to inform the simulation how much of each type of cargo can be loaded.

6 OUTPUT

Outputs from PORTSIM provide planners with a detailed analysis of port, ship, and military equipment items. Timing information is collected during the simulation and is stored for convenient retrieval. Planners can obtain detailed breakdowns of individual items as well as aggregated reports that illustrate overall port throughput capability. In specific, the types of statistical reports that can be displayed are:

Cargo Item Report
- Time item arrived at the port
- Time parked in the staging area

Time item is available to load
Time call-forwarded to the berth
Time loaded onto ship
Ship loaded onto
Time waited in queues

Port Resource Report
Utilization of gates, berths, inspectors, container handlers, drivers, cranes, end ramps, docks, staging areas
Number of items processed per day

Ship Report
Time arrived at berth
Berth arrived at
Cargo contents list
Percent full
Available capacities by cargo type

7 FUTURE DIRECTIONS

Future development of PORTSIM includes enhancement of the animation as well as refinement of processes to provide a more detailed simulation of the rail subsystem of the port operations. Figure 4 illustrates continuing efforts. A two-dimensional animation that is tied directly to scaled maps of specific ports is the next step. Actual routes at the port being modeled will be constructed and stored in computer aided drawing (CAD) format, port resources will be placed in appropriate locations with relation to other port elements, and cargo items will flow through the system along the paths defined by the graphical port file.

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PORTSIM INCREMENTAL PHASES

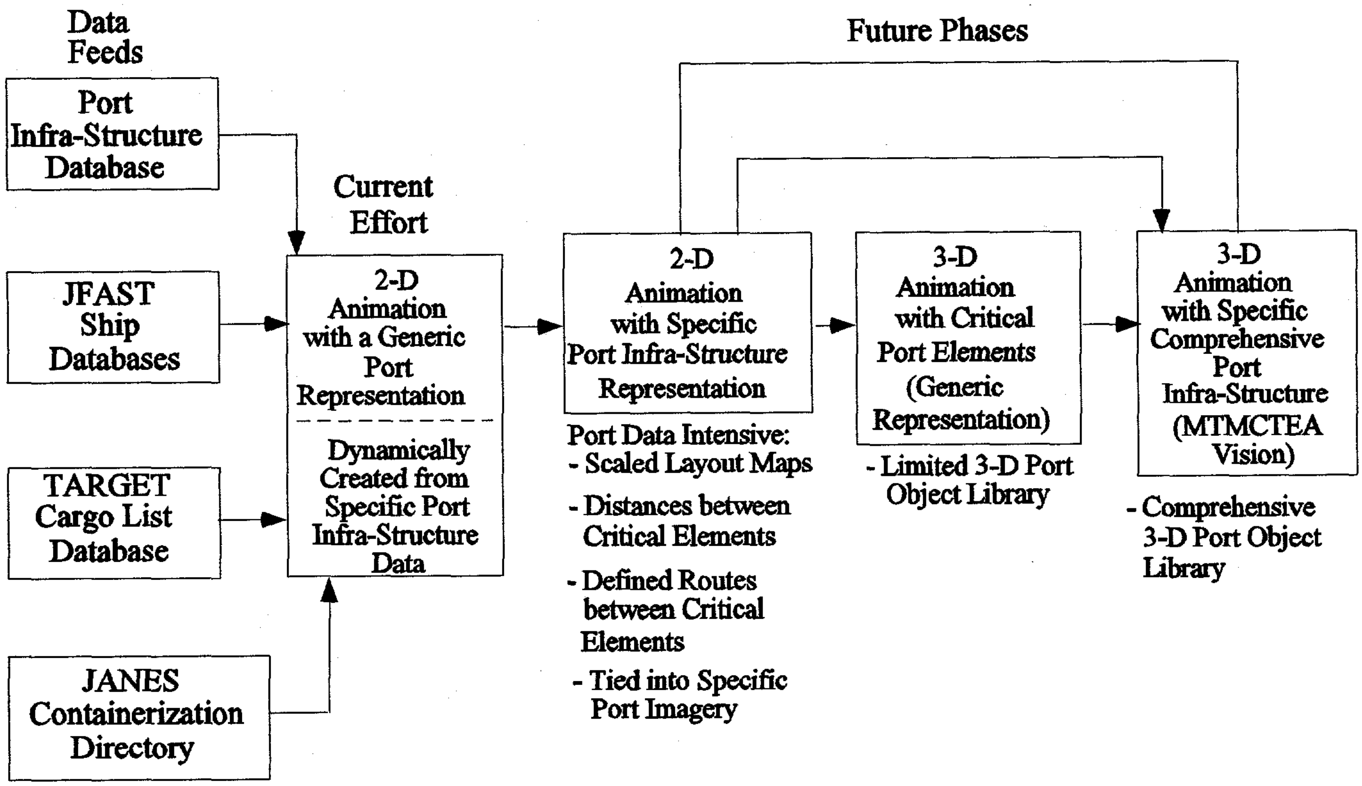

Figure 4 PORTSIM Future Direction