

# REPORT DOCUMENTATION PAGE

Form Approved  
OMB No. 0704-0188

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1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE	3. REPORT TYPE AND DATES COVERED	
		June 1996	Final	
4. TITLE AND SUBTITLE			5. FUNDING NUMBERS	
Strategic Sealift Analysis System (SEASTRAT)				
6. AUTHOR(S)				
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)			8. PERFORMING ORGANIZATION REPORT NUMBER	
Commander, Military Sealift Command (N9) Washington Navy Yard, Bldg 210 901 M Street S.E. Washington, DC 20398-5540				
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)			10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
Same as Number 7			19961021 182	
11. SUPPLEMENTARY NOTES				
N/A				
12a. DISTRIBUTION/AVAILABILITY STATEMENT			12b. DISTRIBUTION CODE	
Approved for Public Release; Distribution is unlimited.				
13. ABSTRACT (Maximum 200 words)				
The Military Sealift Command, a component of the United States Transportation Command, is responsible for the sealift of military cargo during a crisis. Conceptual plans for these complex moves, called deliberate plans, are continually being prepared. A computer-based scheduling system, the Strategic Sealift Analysis System (SEASTRAT), has been developed to assist in the production of these plans. The ship scheduling portion of this system, the Scheduling Algorithm for Improving Lift (SAIL), combines linear optimization and heuristic methods to determine ship routes and cargo loadings which honor a variety of complex operational constraints. The prototype system was developed in 1986 and the operational model came into operation in 1992, although not all components of SEASTRAT have been developed. Current plans				
14. SUBJECT TERMS			15. NUMBER OF PAGES	
MORS SEASTRAT Mobility Model Sealift Computer Model			20	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT	
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)  
Prescribed by ANSI Sta. Z39-18  
298-102

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12a. DISTRIBUTION/AVAILABILITY STATEMENT		12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) Continuation: call for SAIL to migrate into USTRANSCOM's Joint Flow and Analysis System for Transportation (JFAST) and for the SEASTRAT at MSC to be terminated. This paper provides a general description of SEASTRAT with emphasis on SAIL and discusses issues related to its planned migration to JFAST.			
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18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT	

## STRATEGIC SEALIFT ANALYSIS SYSTEM (SEASTRAT)

[ Viewgraph 1 ]

The Military Sealift Command is the Navy component of the United States Transportation Command. As such, MSC is responsible for the sealift of military cargo in contingencies as well as in peacetime. To accomplish its mission, MSC operates a fleet of government-owned and chartered U.S.-flag ships and contracts with U.S.-flag liner companies for scheduled liner service. To ensure that MSC will be able to carry out its mission in the event of a contingency, major planning activities are conducted continually to reassess the resources needed to support a wide variety of potential military options.

[2]

Deliberate Planning is the term used to describe the activities concerned with this detailed planning. The purposes of such planning include; identifying forces and resources needed to respond to a particular crisis, discovering how the many military and civilian organizations involved would need to interact, and gaining insight into the feasibility of the plan. Clearly, the ability to move personnel and material to the crisis area in a timely manner is a key element in this assessment.

For the sealift problem, Deliberate Planning involves the detailed examination of the movements required by the cargo ships, including the number of ships required, ports to be used, pick-up and delivery times, and the effective utilization of shipping resources.

The Strategic Sealift Analysis System (SEASTRAT) is the computer model used by MSC to support the deliberate planning process.

Today, I want to discuss the development of SEASTRAT, its current employment with particular emphasis on the ship scheduler and then SEASTRAT's future.

[3]

As you can see from this viewgraph, development of SEASTRAT was a long drawn out process.

In 1980, as a result of the steadily mounting workload in the deliberate planning area and the increasing inability of the model in use at that time (called SEACOP) to respond to the rapidly changing environment within the planning community, MSC initiated a complete reevaluation of its ADP support requirements. It was decided that a new

system needed to be developed. A requirements analysis and broad based systems concept was completed in early 1983, but before the RFP for SEASTRAT development could be released, MSC was caught in a systems-development contracting freeze which was imposed while the issue of an MSC/MTMC merger was debated. MTMC, the Military Transportation Management Command, is MSC's Army counterpart. No work was done on SEASTRAT during that two year freeze.

After the freeze ended, development began and SEASTRAT finally became operational in May 1992. This was a significant improvement from the previous outmoded system in terms of speed and flexibility. Where SEACOP had computation times of from 2 to 26 hours, SEASTRAT has computation times of from 2 to 90 minutes. Also SEASTRAT allows planners to interact directly (on-line) to make immediate changes and adjustments to planning parameters (for reruns) and to review the results in a matter of minutes.

[4]

The MSC Strategic Sealift Analysis System (SEASTRAT) is a transportation model designed to assess the sealift feasibility of a CINC's Operations Plan (OPLAN). SEASTRAT permits the plans analyst to generate multiple sealift schedules using the Oplan's Time-Phased Force and Deployment Data (TPFDD) requirements, a given set of ship assets, selected port characteristics data, and user specified parameter variables. SEASTRAT originally ran on an IBM 3090 mainframe. In 1995 it was transferred to a SUN 2000 LAN-based system.

[5]

SEASTRAT is composed of two functional modules; Oplan Analysis and the Scheduling Algorithm for Improving Lift. The Oplan Analysis module performs the data management for the inputs to SAIL. SAIL is the key to the system because it develops the ship schedules. The objective of the scheduler is to find an allocation of shipping resources that delivers the sealift portion of the movements on time and with effective utilization of resources. SAIL was developed by the Oak Ridge National Laboratory and much of the material used in this presentation comes from the SAIL documentation manual prepared by the Oak Ridge Lab.

[6]

The first subsystems of SAIL accept the data which has been gathered, arranged and edited by the data management system. This data includes: what the cargo is, when and where it is available to be shipped, and when and where it is needed, the ships that are available to carry the cargo, the types of cargo the ships can carry, capacities of ships compartments, ship speeds and when and where the ships will become available, port locations, capacities and physical characteristics are also important. These subsystems also compute interport distances by using a world network, locate

ships on this network and compute their availability dates at ports and aggregate cargoes to reduce the size of the problem.

[7]

The next subsystem develops routes for the ships. There are a very large number of possible routes for the ships and so some procedure must be used to pare down the number to a relatively few routes that can be refined. A linear optimization problem (the standard transportation problem) is formulated to aid in this process.

The transportation problem is formed by a set of demands and a set of supplies. In this problem, the demands are channels which are aggregations of cargo. Deployment data identify cargo in too much detail to be feasibly processed in the transportation model. Individual cargoes are therefore aggregated into larger entities called channels. A channel will contain all cargo that is of the same cargo class, involves the same ports and that needs to be shipped at about the same time ( the analyst can control the variation in time that is acceptable for aggregating cargoes into channels.) The set of supplies for this transportation problem are shipping resources.

Both the demands and supplies have known capacities, and in this formulation, the total of all demands must equal the total of the supplies. If that equality is not inherent in the problem, as is generally the case, a "dummy" supply or demand is added to balance the total quantities.

There is a cost, or penalty, associated with assigning a unit of any supply to a unit of any demand. A very large cost is placed on any disallowed combination. The objective is to assign supplies to demands in such a way that the total of all costs are minimized. The cost associated with any channel-capacity pair is a function of the various objectives of the planning analyst. On time delivery of cargo is generally of first importance; avoiding lateness will thus dominate the cost function. Other objectives are limiting early delivery, reducing the number of ships used and miles sailed, and achieving desired matches of cargo classes and ship types.

Once the transportation problem is completely formulated, a solution is found using a tailored version of a standard algorithm for finding a minimum cost solution. The solution gives the amount of each channel to place in specific compartments of each trip of each ship. However, incompatible channels may be placed on a ship because the linear model does not consider the interactions among the variables. Decision rules are used to find a dominant or prime channel assignment for each ship. Then the ship with the largest such assignment is selected for sailing. Geographically incompatible assignments are eliminated by raising their cost. Then the problem is reoptimized and other compatible channels are added to the ship up to its capacity.

When the current trip of a selected ship is sailed, two things happen; first, the cargo quantities carried by the ship are removed from the problem and second, knowing the

route the ship will take allows the ship's availability dates for its next trip to be computed.

The problem is reoptimized again and the procedure continues until all channels are completely assigned to ships that have sailed or are forced onto the dummy ship by the inability of the procedure to find a compatible assignment on a real ship. So the scheduler uses these two techniques (optimization and heuristics) alternately until all ship routes are established.

[8]

This optimization-based routing system permits simultaneous evaluation of many options and thus gives some intuitive assurance that short-sighted allocations of resources have been avoided. The penalty paid for this assurance is computation time. As a result, an optional heuristic-based routing system has been developed. The problem is set up in precisely the same way as the optimization-based system including the formulation of the cost matrix. But the optimization problem is never solved. Instead a decision strategy is employed. This approach attempts to assemble a "good" shipload of cargoes, including the next most critical channel (the channel that, by some set of criteria, most urgently needs to move).

When this is done, the ship is then sailed, and the process begins again, continuing until all cargoes are moved or it is determined that they cannot be moved. Computation time can be reduced by a factor of ten in some cases by using the heuristic-based system and there appears to be very little loss in routing efficiency.

[9]

The next phase of SAIL is the ship loading subsystem which attempts to more effectively allocate cargoes to ships now that routes have been established for all ships. Two steps are involved in accomplishing this objective; first, simulation is used to obtain accurate estimates about the time each ship departs each port on its route. Then, costs of lateness or earliness can be found for all feasible combinations of channels and ship trips. A new optimization problem is then constructed ; but because the routes are known, the number of variables in the problem is much reduced from the ship routing formulation. Also, unlike the routing problem, the loading problem can be formulated as a single optimization problem; since the routes are established, it does not require the intervention of rules to resolve conflicts. The structure of the problem is that of a general network problem.

The problem is formed around the following ideas. First, each potential assignment of a channel to a compartment, as indicated from the routing solution, becomes a variable in the linear program. This variable represents the amount of the channel which will be carried. All feasible combinations of channels and ships will be in direct competition on

the basis of cost. The objective will be to deliver all of the cargoes at the minimum total cost. A dummy capacity is introduced so that each channel has the opportunity of being placed there, but at a high cost. This assures that non-delivery is the last resort for all cargoes.

There are two kinds of constraints, the first requires that the total quantity of each channel must be placed in a real ship or the dummy ship, while the second type of constraint limits the quantity of channels in a compartment to the compartment's capacity.

The result of this Ship Loading subsystem is a set of assignments of channels to routed ships which maximizes on-time deliveries, given the ship routes established in the Ship Routing subsystem. This solution is then passed to the Simulation subsystem for the addition of detail and the refining of the timing of events.

[10]

Of the major computational subsystems in SAIL, this is the simplest in concept and the most intricate in implementation. The principal tasks reserved for the simulator are:

- 1) refining the time at which events occur,
- 2) refining the sequence of port visits on a route,
- 3) disaggregating channels back into individual cargoes,
- 4) de-scheduling cargoes that would be unacceptably late,
- 5) removing from the schedule ships that are too lightly loaded, and
- 6) removing port stops for which there is too little activity.

[11]

The Reporting subsystem develops summary statistics of the schedule. These numbers are intended to facilitate comparisons of quality among differing schedules of the same plan. The principal product of this subsystem and hence of the SAIL model is an itinerary of each ship's schedule.

The output from SAIL is provided to the Oplan Analysis module. This information along with the other data accumulated by the Oplan Analysis module enables SEASTRAT to produce a number of reports, some of which are shown here.

So then, this is how SEASTRAT is used by MSC to support its deliberate planning activities. The results and analyses of SEASTRAT runs are conveyed to TRANSCOM and the area CINCs and presented to them at length at Plans conferences to show, in detail, the feasibility and supportability of the OPLANs.

[12]

Over the past few years, TRANSCOM has developed its own set of automated tools to support analysis of Operation Plans and mobility studies. The Joint Flow and Analysis System for Transportation (JFAST) was developed to support not only USTRANSCOM operations and planning functions, but also the unified commands in their evaluation of the transportation feasibility of operations and contingency plans.

JFAST, also developed by Oak Ridge National Laboratory, is a windows-based computer model that performs; air, land and sealift analysis from the origin to port of debarkation (POD). For its sealift analysis, JFAST originally used a version of SAIL, but now the scheduler is a rule-based heuristic scheduler that attempts to maximize cargo delivery and minimize lateness. The objective of the scheduler is to find a solution that is "good" and that is constrained by the rules established by the planner. The scheduler is a non-optimal algorithm. It is also requirements-based; ships will only be scheduled if there is a cargo requirement to move.

JFAST does not have the capability to produce the detailed reports, such as ship itineraries, that SEASTRAT produces.

[13]

As far as the future of SEASTRAT is concerned, TRANSCOM has decided to expand JFAST to include the transportation planning functions currently found in SEASTRAT as well as in the land scheduling model currently operated by MTMC. So TRANSCOM has directed that SEASTRAT will "migrate" into JFAST and then be terminated as an independent system. Basically, this will give JFAST the report capabilities currently in SEASTRAT.

If the migration plan remains on schedule, SEASTRAT will be terminated at the end of FY97.

[14]





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# Strategic Sealift Analysis System (SEASTRAT)

Bob Elwell  
Military Sealift Command



## Deliberate Planning for Sealift

- ★ Movements by cargo ships
- ★ Number of ships required
- ★ Ports
- ★ Pick-up and delivery times
- ★ Utilization of ships



# SEASTRAT System Development

- ★ 1980 - 82      Concept Defined
- ★ 1983 - 84      Moratorium
- ★ 1985 - 91      Development
- ★ 1992            Implementation



## SEASTRAT Mission

- ★ Support deliberate planning functions
- ★ Analyze CINC OPLANs
  - ◆ Assess sealift feasibility
  - ◆ Optimize use of sealift resources
  - ◆ Produce detailed movement schedules



## SEASTRAT Modules

- ★ OPLAN Analysis
  - ◆ Data management
- ★ Scheduling Algorithm for Improving Lift (SAIL)
  - ◆ Compute ship availability dates
  - ◆ Generate sealift schedules



## SAIL Early Subsystems

- ★ Accept data inputs
- ★ Compute interport distances
- ★ Locate ships
- ★ Compute availability dates
- ★ Aggregate cargoes



## Optimization-Based Routing

- ★ Standard Transportation Problem
  - ◆ Linear optimization
- ★ Primary objective - On-time delivery
- ★ Other objectives - Limit early delivery, reduce number of ships used and miles sailed, achieve desired match of cargo class and ship types
- ★ Decision rules used
- ★ Relatively long computation time



## Heuristic Routing

- ★ Optimization problem set up but never solved
- ★ Decision rules instead
  - ◆ Prime channel chosen
  - ◆ Other appropriate channels clustered to it
  - ◆ Cost function determines ship to carry cargo
- ★ Significantly shorter run time





## Ship Loading

- ★ More effectively allocates cargo to ships
- ★ Uses simulation and optimization algorithm (general network problem)
  - ◆ Reduced number of variables.
- ★ Maximizes on-time deliveries, given ship routes established



## Simulation

- ★ Refines time at which events occur
- ★ Refines sequence of port visits
- ★ Disaggregates channels
- ★ De-schedules late cargoes
- ★ Removes lightly loaded ships
- ★ Removes little used ports



## Reports

- ★ 50 Detailed and Summary (hard copy)
- ◆ Data validation
- ◆ Lift requirements
- ◆ Ship characteristics
- ◆ Ship availabilities
- ◆ Port characteristics
- ◆ Distance tables
- ◆ Ship usage summary
- ◆ Cargo scheduling statistics
- ◆ Ship itineraries
- ◆ Port workload



## Joint Flow and Analysis System for Transportation (JFAST)

- ★ Transportation Feasibility Estimator
- ★ Air, Land & Sea modes
- ★ Quick response
- ★ Summary graphical displays
- ★ Notional requirements generator
- ★ Air & Sea distance calculator
- ★ Map display



## SEASTRAT's Future

- ★ Migrate to JFAST
  - ◆ Data edits
  - ◆ Parameter selections
  - ◆ Report generation
  
- ★ Terminated at MSC