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SYSTEMS ANALYSIS OF AMPHIBIOUS ASSAULT CRAFT

ANALYSIS OF PRESENT CRAFT IN FUTURE ENVIRONMENTS

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STANFORD RESEARCH INSTITUTE

Menlo Park California

NAVAL WEAPONS LABORATORY

Dahlgren, Virginia

Prepared for:

NAVAL SHIP SYSTEMS COMMAND
OFFICE OF NAVAL RESEARCH

WASHINGTON, D.C.

SYSTEMS
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The work this report describes was performed jointly by the Naval Warfare Research Center, Stanford Research Institute, and the Naval Weapons Laboratory, Dahlgren, Virginia. It does not necessarily represent the conclusions or opinions of the Department of the Navy or any part thereof.

February 1969

Prepared by:
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PREFACE

This report describes Phase II of the Systems Analysis of Amphibious Assault Craft that is part of the Navy's Amphibious Assault Landing Craft Program (Project S14-17X). The overall systems analysis is concerned with developing measures of craft effectiveness and craft cost and with applying these measures to sets of proposed advanced craft. Phase II is concerned with developing and testing analytical tools for measuring craft effectiveness and with applying those tools to present-day craft. The knowledge gained in this analysis has been used to develop a procedure presently being used for comparing sets of advanced craft on the basis of their preliminary designs.

The work described in this report was performed jointly by the technical staffs of SRI's Logistic Systems Research Program and the Warfare Analysis Division (Code KW) of the Naval Weapons Laboratory, Dahlgren, Virginia. Responsibility for the contents of the report rests with SRI. Technical direction of this joint effort was provided by Mr. James L. Schuler, NavShips Code 03412, who manages the Navy's Amphibious Assault Landing Craft Program. Mr. Paul S. Jones of SRI was project leader, and Mr. Oliver F. Braxton, Head of NWL's Warfare Analysis Division, was responsible for the NWL work. Administrative direction of SRI's work was provided by Mr. J.R. Marvin, Director, Naval Analysis Programs, through the Institute's Naval Warfare Research Center.

Principal technical contributions were made by Mr. Jerome I. Steinman who was responsible for SRI's computer analysis including preparation of STSTAPE, EDIT, and PLOT programs, as well as preparing PREBOAT from the SELECT routine written by Dr. Fred R. McFadden and FIT written by Dr. Shaler Stidham Jr. Mr. Steinman also developed the measures of effectiveness and did the analysis of the STS-2 runs in Chapter V. Mr. Stanley J. Davenport modified and expanded the EMBARK model written by Dr. McFadden and prepared REVISER. The Marine Force Description Model was prepared by Mr. Edward H. Means. Mr. Means and Mr. Donald Vaughn prepared the landing plans. Mr. Albert Lynch, Jr., was responsible for NWL's modifications to the STS-2 model and for the STS-2 runs. Mrs. Lottie Anderson and Mr. Wendell Anderson directed NWL's programming effort.

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I INTRODUCTION

Background

Amphibious landing craft have played important roles in almost every amphibious assault since the start of World War II and are likely to continue to perform important tasks in future amphibious operations. However, the nature of the tasks assigned to landing craft has changed with the development of helicopters and armored amphibious tractors (LVTs). In general, the role of landing craft in assault operations has become more specialized. However, much of this specialization represents efforts to live with the limitations of present landing craft. In today's operational planning, landing craft are expected to concentrate on the following tasks:

1. Carrying heavy loads that exceed the capabilities of helicopters.

2. Carrying the vehicles, equipment, and personnel of the shore party, engineer, support, and other units that have missions on or near the assault beach.

3. Holding in floating reserve special equipment and units that may be required on short notice.

The effectiveness of today's landing craft is properly measured in terms of the above tasks. New craft designs might be directed toward performing only these tasks more efficiently. If they were, the craft could be expected to emphasize deadweight carrying capacity, moderate speed, and cargo wells that are large with respect to the craft's overall dimensions--characteristics that are largely available in present-day craft. High deadweight carrying capacity would assure the ability to carry heavy vehicles and equipments. Moderate speeds would be adequate for the distances that craft might expect to travel in an amphibious assault today, especially when one considers that a significant fraction of a craft's operating time is spent loading and unloading. Large cargo well areas with respect to outside dimensions would assure that the craft carried by any given amphibious fleet would have the largest possible cargo-carrying capacity. This large capacity would maximize the amount of vehicles and cargo that could be held in floating reserve. One might assert, with some justification, that the tasks assigned to landing craft today have been derived directly from their capabilities.

In brief, such a narrow viewpoint would lend to the selection of present-day craft. However, new craft are potentially capable of providing much more than present-day craft. Measures of their effectiveness should not be limited to the jobs now being performed by landing craft. Rather, advanced craft should be allowed to perform all missions that they are capable of performing that improve amphibious assault operations. The systems analysis has adopted the broader view of landing craft effectiveness. We are seeking to define new roles for advanced craft and to measure their effectiveness in terms of the broad amphibious assault objectives.

The designation of appropriate tasks for advanced landing craft clearly depends on the nature of future amphibious assaults and on the interactions among the major components of the assault force: the forces to be projected ashore, the ships that carry them, the landing plans to be followed, the helicopters and LVTs that participate in the ship-to-shore movement, the cargo handling systems, and the landing craft themselves.

In Phase I of the systems analysis of amphibious assault craft, we investigated the various means by which advanced assault landing craft might be analyzed and compared.* We concluded that the scope of the study must be broad to encompass the many changes that advanced craft can bring. Specifically, this scope includes (1) all amphibious assault activities that take place from the embarkation of the assault force on amphibious shipping until that force has been delivered to or near its objective areas; (2) the impact of advanced landing craft on amphibious operations can best be measured by means of computer simulation models; (3) changes in the effectiveness and cost of different sets or mixes of advanced landing craft can best be measured if a datum plane or baseline system is established; (4) the baseline system should consist of present-day landing craft operating in the same future environments in which we expect future landing craft to operate; and (5) the computer simulations can best be accomplished by using NWL Dahlgren's Ship-to-Shore Program (STS-2) as a basis.

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* Arguments supporting this statement are given in "Systems Analysis of Amphibious Landing Craft; Phase I: Problem Definition and Research Plan," by Paul S. Jones, May 1966.

This report describes the development of the computer simulations and their use in evaluating the baseline system and in planning advanced craft comparisons. At this time, the advanced craft comparisons are under way. Many of the recommendations made in this report have been or are being implemented. Revisions to the advanced craft designs are being implemented, as a result of technical criticisms, the findings described in this report, and the early results of the advanced craft comparisons.

Objectives

The objectives of Phase II of the systems analysis of amphibious landing craft were to:

1. Develop computer-based analytical techniques for comparing alternative sets of landing craft.

2. Use the analytical procedures to measure the performance of present-day displacement craft in future environments and test the sensitivity of simulated amphibious assaults to changes in operating procedures and environmental conditions.

3. Develop procedures for using the models and techniques to compare alternative advanced landing craft designs.

Scope

Since landing craft effectiveness and landing craft cost are derived from the effectiveness and cost of the amphibious operations that the landing craft support, the scope of research needed to measure landing craft effectiveness is as broad as the planning and execution of amphibious assaults. It begins with the planning of the assault forces and includes the selection of the amphibious fleet, embarkation of the Marine force aboard the fleet, deployment to the objective area, transfer of men and material from the amphibious fleet to the assault beach and other objective areas, and the dispatch of vehicles and cargo from the assault beach to points inland from which they can be employed in the assault or stored for future use.

The detail with which the different amphibious assault components and the assault activities are simulated in the analytical techniques approximately correspond to the impact that these components and activities have on landing craft effectiveness and cost. Some activities have been omitted altogether. For example, no consideration has been given to shore fire support, aerial bombardment, the work of underwater demolition teams, or the support requirements of the amphibious fleet while en route to the objective area. At the other extreme, components and activities with heavy landing craft interactions have been analyzed in great detail. Of particular importance is the ship-to-shore movement via landing craft, helicopters, and LVTs. Still other activities, such as the naval craft used for wave guides, marker boats, salvage boats, and other missions whose impacts cannot be determined at this time have been postponed until more information is available on advanced landing craft.

To the extent possible, we have separated the analysis from the tactical development of the assault. The tactical situation will affect the delivery of men and material ashore, but the effects can be represented analytically without developing elaborate scenarios or war games. The principal impacts of tactics on the ship-to-shore operation are:

1. The schedule for delivering particular serials ashore will be modified by changing the sequence of delivery or by speeding up or slowing down the time schedule.

2. Landing craft, helicopters, and LVTs will be lost, damaged, or delayed because of enemy action, mechanical failures, personnel errors, or communication errors.

3. Operations at the beach will be modified by the ease with which materiel can be moved to inland destinations.

4. Distances traversed by cargo-carrying vehicles will change.

Several possible changes in the sequence of delivering combat units ashore were arbitrarily introduced into the ship-to-shore model. Units selected for delivery earlier than scheduled included tank units, anti-tank units, and engineer units, the early need for which might not have been predictable. In all cases, short intervals were used between the scheduled times for successive units to be delivered ashore. This procedure placed a heavy burden on the landing craft. No slack periods were introduced for maintenance of craft or other purposes.

Damage to and loss of landing craft were introduced by computing attrition rates based on different levels of combat intensity and the best available data on mechanical reliability and personnel errors.

Perfect communication was assumed throughout. Beach operation and inland movement of cargo were modified over a range of situations to determine their effect on landing craft operations.

The simulated amphibious operations are idealized in that the model executed each operation substantially as it was planned rather than as it might be executed. In practice, amphibious landings are rarely executed as planned because of unexpected forms of enemy action, failures of ships and equipment, poor communications, drastic changes in the physical environment, and other causes outside the control of the officers in charge of planning or executing the landing. This reality does not invalidate amphibious planning. In fact, one senior retired Naval officer recently remarked: "If I were planning Operation Overlord* again, I would still plan it as it was planned and not as it was executed." However, the reader should be cautious and not compare the results of the simulations with actual landings he may be familiar with. Both the assault and general unloading phases of the simulated landings may be of much shorter duration than real life experience. Nonetheless, we believe that the simulated results provide a valid comparison of craft of different sizes and types. Little would be gained by introducing a random catastrophe generator to bring overall results more in line with actual historical experience, because the purpose of this study is comparison not prediction.

Marine Forces

When planning for amphibious assaults, the Navy and Marine Corps must be prepared to meet the most challenging objective that can reasonably be expected in the future. Political and military uncertainties stress the need to be prepared for a broad spectrum of potential amphibious environments. These will probably vary from shows of force requiring only small assault forces such as MEUs built around batallions, to large scale assaults against strongly held enemy positions. It is generally believed that future amphibious assaults will not be on the scale of World War II landings, and thus today's planning focuses on forces that do not exceed MEF (Marine Expeditionary Force) size.

The present work has been based on MEF-size forces assaulting enemy-held positions. These forces are large enough to present almost all of the problems likely to be encountered with smaller forces, and they

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* The invasion of Normandy.

pose some very challenging problems of their own. The use of a large force requires us to consider the substantial interaction among different fleet and force units. Smaller forces can, in general, be carried ashore in some scaled-down mix of landing craft designed to meet the tremendous variety of demands faced by an MEF size operation. Similarly, light combat presents fewer obstacles than heavy combat.

In present planning, MEFs are organized for combined surface and air assault. The air assault units are equipped with relatively small numbers of light, air liftable vehicles, and a minimum of supplies. The surface units include all of the heavy vehicles, engineering equipment, SATS (Short Airfield for Tactical Support) equipment, and logistic support. The assault echelon of a typical MEF might include 35,000 men, 5,000 vehicles, and 40,000 measurement tons of cargo.

Because of the specialized nature of amphibious assaults, the Marine Corps has not developed tables of organization or other descriptions of MEFs that are sufficiently detailed to provide the information needed for detailed simulation. The Marine Corps MEDS program has provided descriptive data on present organizational units in punched card form, and some amphibious assault planning has been based on the use of these data. However, the MEDS data describe Marine units as they are organized and equipped today, not as they might be organized and equipped in the future.

Therefore, the analysis reported here is based on five MEF-size forces developed by the Center for Naval Analysis in its Research Contribution 44. These forces are described in sufficient detail that further breakdown could be performed without the risk of serious error. Although not officially sanctioned by the Marine Corps, the Center for Naval Analysis forces have been so widely reviewed that professional planning officers are generally familiar with them. The modifications that we have made to the Center for Naval Analysis forces were the subject of another report and will not be repeated here.*

For purposes of the baseline system analysis, the composition of engineering and shore party units was held constant. However, different types of advanced craft will have different requirements for surf cranes, rough terrain fork trucks, bulldozers, beach matting, and other engineering equipment. Therefore, force composition will have to be modified regularly to match the types of craft used.

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* Means, Edward H. and Donald Vaughn, "Marine Assault Forces and Amphibious Operation Plans (U)," SRI, Menlo Park, Calif., August 1967, CONFIDENTIAL (NWRC/LSR-RM42).

Landing Plans

Several modifications of a basic landing plan* have been used to schedule the assault force ashore and to describe the assault environment. All variations are based on joint air and surface operations, although the number and composition of the air assault units varies from plan to plan. In all cases, two distinct beaches are used, but the number of craft that can be accommodated at one time has been changed. Where the surface assault force consists of a single RLT, initial assault waves are carried ashore in LVTs followed by landing craft carrying the serialized units. If the surface assault force has more than one RLT, there are landing craft in some of the later assault waves.

The landing schedule is typically divided into assault and general unloading phases. During the assault phase, scheduled waves and most of the serialized units are delivered ashore. When half of the landing craft are available for nonserialized cargo, general unloading begins and continues until all supplies and equipment have been delivered to the beach or landing zone and thence to the first destination ashore. During the serialized off-loading, serials are loaded in the prescribed sequence. No craft carries parts of more than one serial, and an effort is made to keep craft carrying a single serial together so that the entire serial can be delivered to a specific beach at about the same time to allow early and effective use. Some selected serials may be called out of order to simulate the requirement for delivery of serials to the beach earlier than planned. Palletized general cargo is treated by type without identifying specific cargo groupings. Landing craft are loaded to their volume or cubic capacities and proceed independently ashore without reference to any other cargo movements.

Four LST causeways are included in the landing plans; these are launched as soon as the beach is cleared and are used to off-load all of the LSTs.

A temporary dump is established on the beach to receive nonwheeled equipment and cargo if no cargo-carrying vehicles are available to receive cargo directly from landing craft. This dump is cleared as quickly as possible using transport vehicles to carry equipment and cargo to preassigned destinations or to a logistic support area inland. The beach dump has limited capacity and is manned by limited materials-handling equipment.

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* Means, *op. cit.*

For close-in assaults, the ships of the amphibious fleet, except LPHs, are anchored from 5,000 to 11,000 yards offshore between designated fire support areas. LPHs operate in a sea echelon mode, and for longer stand-off distances, all ships operate in sea echelon mode.

The amount of enemy opposition is varied. In some instances, no enemy fire is directed against landing craft or beach or transport equipments. In others, some degree of enemy fire is presumed. The methods used to calculate the effectiveness of enemy fire are reported elsewhere.*

Amphibious Fleet

The amphibious fleet was selected from among the ships expected to be in the amphibious fleet in 1975. The selection was limited to classes of ships that are now in the fleet, because of the need for considerable detail to (1) calculate the load that each ship would carry and describe the cargo configuration, (2) to calculate the number of landing craft that could be carried by each ship, and (3) to estimate the productivity of each ship when handling craft and cargo. Thus, the 1179 class LST, 113 class LKA and the LHA were not included in the baseline system analysis. Additional data now on hand and expected will allow LST 1179 class, LKA 113 class, and LHA ships to be included in the analysis of advanced craft, which is now being conducted. The baseline system is being updated to preserve the validity of the comparison.

The composition of the amphibious fleet is based on shipbuilding plans current when the analysis was begun. We used approximately half of the LPH, LPD, LSD, and LST types expected to be in the fleet in 1975. This is an optimistic supposition, but not completely out of line with planning during these times of tight fiscal restrictions.

The characteristics of individual ships were based on the more modern units of each type--those that are likely to be in service in 1973 and beyond. Old ships, particularly World War II ships like the Boxer (LPH 4), were excluded from the fleet. The analysis considered detailed configuration and performance constraints of the more modern classes of each ship type selected.

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* Grant, Andrew R., "Analysis of Landing Craft Vulnerability," Stanford Research Institute, Menlo Park, Calif., February 1969.

Even with rather liberal projection of available amphibious shipping, it is necessary to supplement the fleet with MSTS and other ships to accommodate all of the equipment and cargo needed to support the MEF.

Assignment of Marine Cargo to Ships

Embarkation of the forces aboard the ships of the fleet was accomplished with the assistance of the EMBARK computer program. However, considerable hand analysis was required to reflect all of the force constraints and still achieve efficient ship loading. The assignment of assault units to amphibious ships was based on unit missions, the need for unit integrity, the desire to deliver the force ashore as quickly as possible, and the need to make maximum use of the available shipping. For example, forces scheduled for air delivery ashore were assigned to LPH and LPD types of ships. Personnel serials scheduled for surface assault were assigned to LPDs. Several different assignments were investigated for LVTs. In some instances, several serials were grouped to form tactical units to ensure that these serials would be embarked on the same ship. Ship types or specific hull numbers were designated for some serials. Within these imposed constraints, the EMBARK program attempts to spread the load among the different ships so that the maximum number of loading positions will be available at any given time. The EMBARK program also assigns cargo and vehicles to specific spaces aboard the ships of the fleet. The characteristics of these spaces are detailed to the extent necessary to ensure that particular serials can be accommodated and to provide locational information that affects craft loading. However, we did not undertake template fitting into particular spaces.*

Broken stowage factors were used to develop space capacities, and these were validated against actual load plans for Operation Steel Pike.†
Small errors in the number of vehicles carried in a particular space have little if any effect on landing craft operations.

Selection of the Craft Mix

The analytical procedures used for selecting the mix of landing craft to be carried by the amphibious fleet differ markedly from

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* NWL Dahlgren is preparing programs for detailed ship loading. To date, LKA, LPA, LST and LSD types have been completed.

† An MEF size landing exercise conducted in Spain in 1965.

operational practices. We believe that preselecting the craft mix on the basis of availability, rule of thumb, or other measures can inadvertently skew craft performance. As a result the mix of landing craft is generated by the ship-to-shore simulation model (STS-2) as needed to carry individual serials ashore. The mix of craft generated, in each instance, is the mix of sizes that can most efficiently carry the serial. Craft are generated for serials in order of scheduled time of delivery ashore up to the maximum number that can be carried by the amphibious fleet.

Once the desired mix of craft has been selected, those carried by well-type ships can be preloaded with cargo and vehicle serials that are needed early in the assault or with other contingency serials, such as tank and antitank units. As many as possible of the serials designated for preboating are loaded in the selected craft in order of priority.

Ship-to-Shore Movement

The ship-to-shore movement of men and material was simulated with a modified version of NWL Dahlgren's STS-2 model.* Two versions of the model were used, one to simulate surface movements and the other to simulate helicopter movements. The model considered loading of landing craft and helicopters, movement-to-beach unloading positions or drop zones, unloading, cargo movement across the beach, and craft and helicopter return for successive loads. Landing craft queueing is considered at the ships and at the LOD (Line of Departure). A boat pool is maintained for landing craft that are not required at the moment, and a vehicle fleet is managed for moving cargo inland. Craft operations are simulated in particular detail to provide a basis for comparisons among craft.

LVT movements are not specifically identified in the STS-2 model. However, by providing for LVTs aboard the ships of the fleet by scheduling assault waves principally made up of LVTs and by starting the STS-2 model after initial assault waves are ashore, LVT movements can be included in the analysis.

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* Braxton, Oliver F., "The Ship-to-Shore Model (STS-2) Users Guide," NWL, Dahlgren, Va., June 1964.

Method of Approach

Phase I of this research by SRI identified the principal models needed to accomplish the analysis and determined that a modified version of NWL Dahlgren's STS-2 model should be used in the ship-to-shore analysis. The first and principal task of Phase II was to prepare the necessary models and to ensure their compatibility. Thereafter, a series of runs was made to establish the performance of present-day craft and to measure sensitivity to different operating and environmental parameters. Finally, the results of the present-day craft analysis were used to develop procedures for comparing advanced craft.

Model Building

The objective of the model-building task was to prepare a set of simulation models that are sufficiently mechanized to permit a large number of runs to be made with a minimum amount of data preparation for each individual run. Ten major programs, based on these models, were prepared or adapted for this analysis:

1. Marine Force Description (FORCE). This is essentially a data base that has been designed for easy modification. Punched cards with data for individual vehicles or items of cargo are assembled into serials, tactical units, and other organizational units.

2. Amphibious Ship Embarkation (EMBARK). This program loads the Marine force aboard the amphibious ships.

3. Landing Craft Selection (SELECT). This program uses the FIT* routine, which dimensionally fits vehicle and cargo into landing craft, recognizing size and weight limitations and some Marine Corps loading maxims. The SELECT program selects landing craft of the types specified in the input to load serials onto craft. As many craft are generated as is necessary to carry the force. The results of this program provide a preliminary estimate of the relative numbers of each type of landing craft required to land the force.

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* For a complete description of FIT see Chapter IV of this report or Stidham, Shaler Jr., "Preliminary Analysis of Cargo Spaces for Assault Craft," Stanford Research Institute, Menlo Park, Calif., Oct. 1966.

4. Landing Craft Loading (PREBOAT). This program is a modification of the SELECT program. Here the number of each type of craft to be used is specified. The program loads as much of the force as it can on the specified craft mix. In addition to printed output, tables are produced that are in the format accepted directly by STS-2 (see below). The program is used to get loads for craft that are transported to the assault area in well-deck type ships.

5. REVISER. This program checks the validity of the output from EMBARK and transforms it so that it is in the input format required by STS-2.

6. MERGER. This program takes the STS-2 compatible output from REVISER and PREBOAT and merges it with hand prepared input. The result is a magnetic tape with data and control cards that can be used to run STS-2 without any further modification.

7. STS-2. This program simulates ship-to-shore movement and provides basic data for craft comparisons.

8. Tape Consolidation (STSTAPE). This program reorders the STS-2 output for easy editing and packs it onto one to three magnetic tapes for ease of storage and future use.

9. EDIT. This program extracts data from the STS-2 output, combines it, and summarizes it to facilitate craft comparisons.

10. PLOT. This is a program to display graphically the EDIT output in more easily interpreted form.

These programs are described in Chapter IV.

Base System Analysis

Typical LCM-6, LCM-8, and LCU craft were identified as the base system.* LCVPs were not included in the analysis because of their

* Naval Ship Research and Development Center, Annapolis Division, "Amphibious Landing Craft Program (S14-17) Prior Craft Review," April 1968.

extremely limited vehicle-carrying capability and because LVTs were used exclusively for the initial assault waves. Most serialized units included both vehicles and personnel, eliminating LCVPs from consideration. In general, serials made up solely of personnel were so large that LCVPs would not represent efficient carriers.

Present-day craft performance was measured when landing the different Marine forces under a variety of environmental conditions. Specific analyses were completed for variations in stand-off distance, sea state, attrition rates, beach environment, distance from beach to logistic support area, craft mix, and embarkation procedure. Results for each set of variations were compared to determine those variations that most influence craft performance.

Craft performance was measured in terms of several measures of effectiveness. Early in the work, we concluded that there is no single universal measure that could satisfactorily be used to compare craft performance. Rather, a set of performance measures was selected that are meaningful to military planners and can be used to select craft on the basis of tactical objectives as well as specific performance. In general, these measures concern the rate of build-up ashore, specific craft response, and service to cargo of different priority categories.

Techniques for Advanced Craft Comparisons

The results of the sensitivity analysis suggest that several different runs need to be made to evaluate each specific craft mix. In addition, each mix can be made up of one to three different sizes or kinds of craft. Thus, as many as 4,000 runs may be needed to evaluate appropriately all 18 of the advanced craft approved for analyses together with three present-day craft in all possible combinations. Clearly, this number of simulations is out of the question because a single run takes as much as 10 hours of computer time and costs over $2000. Instead, a screening scheme has been devised to keep the analysis within feasible bounds. Initially, we will test to determine the most effective craft sizes and the most effective mixes of craft sizes. Thereafter, individual craft of the selected sizes will be compared within the few selected mixes. The results of this work will be carefully catalogued so that new craft can be introduced into the classification scheme and evaluated as quickly and easily as possible. The advanced craft comparisons will be the subject of a later report.

II CONCLUSIONS

Simulation Models

The set of simulation models and programs that were developed present an accurate representation of landing craft operations within the range of amphibious assault environments explored. The performance of individual simulation events is consistent with performance observed in amphibious exercises. These events include embarkation of the force on amphibious shipping, landing craft loading, the relative efficiency of craft loads, landing craft movement and control between ships and the assault beach, craft unloading, and beach operations. Detailed study of the simulation output reveals congestion where experience tells us that it occurs. Unexpected simulation results are all explained by arguments that account for the irregularities.

The set of simulation models is larger and more cumbersome than was expected. Machine running times and the elapsed time required to execute a complete simulation run are both considerably longer than were originally expected and planned for. The problems of coordinating operations between NWL Dahlgren's and SRI's computer facilities, have been significant. Nonetheless, effective operating procedures have been developed. We have bunched groups of runs to reduce overall analytical time, we have written programs to reduce manual labor at the interfaces, and we have developed satisfactory methods to interchange data. The product of this effort is a workable set of computer simulations that can be used effectively throughout the advanced amphibious assault craft program.

Measures of Effectiveness

Six measures of effectiveness were developed that appear to express differences in performance between alternative mixes of craft. These are:

1. Force-time effectiveness--For any reference time, the force-time effectiveness measure is proportional to the size of the Marine force delivered ashore multiplied by the length of time that each unit has been ashore. This measure, expressed in vehicle-square foot-hours emphasizes the desirability of early delivery ashore of a sizable part of the force.

2. Marine forces or cargo lost--This is the total area, in square feet, of vehicles on board landing craft sunk en route to the beach.

3. Response time--The elapsed time from the request for a particular Marine serial until it is delivered on the beach, unloaded from all craft it is loaded on, and ready for use.

4. Time to deliver 250,000 square feet of assault vehicles ashore--This is a measure of time to complete the assault phase. The specific number 250,000 square feet was selected for comparability of runs.

5. Mean productivity per craft by type--This measures the square feet of vehicles delivered ashore per square foot of outside craft area. It is accumulated up to a reference time. This is a measure of craft performance relative to the well area that they occupy en route to the objective area.

6. Mean cargo transfer rates--The rates are expressed in pallets per hour. They reflect the general unloading phase performance in terms of craft loading, craft unloading at the beach, and moving cargo inland to the logistic support area.

To avoid misinterpretations, these measures of effectiveness must be supplemented with careful examination of simulation results. The most meaningful results are displayed graphically by the computer for easy comparison.

Parameters

Of the seven parameters investigated, landing craft performance is extremely sensitive to three: fleet stand-off distance, sea state, and landing craft attrition. It is relatively insensitive to two: Marine force composition and beach operations. New simulation procedures have been developed from the study of embarkation procedures.

Table 1 lists the effectiveness measures for all of the base system simulations except the two craft attrition runs. The craft attrition factors used in these runs were selected arbitrarily, and in the light of subsequent developments, the run results would be misleading. The effect of stand-off distance is clearly shown by the response time, time to offload 250,000 square feet of vehicles and the mean productivity figures. The differences in force-time effectiveness are masked by the short reference time (7 hours) used for comparisons with the reference run. By this

Table 1

EFFECTIVENESS MEASURES--BASE SYSTEM ANALYSIS

	Simulation Runs													
	Reference	Marine Force		Embarkation Procedure			Fleet Stand-Off Distance			Craft Order	Sea State		Beach Operations	
	R	A1	A2	B1	B2	B3	C1	C2	C3	D1	E1	E2	G1	G2
Force-time effectiveness* (vehicle square foot-hours x 10^3	1,100	1,080	1,080	820	990	1,135	664	558	545	1,130	954	790	1,125	1,100
Lost cargo (square foot)	None	None	None	None	None	None	None	None	None	None	None	None	None	None
Response time (minutes)														
Mean	92	98	80	95	96	80	171	249	323	70	96	[illegible]	81	92
Variance	357	428	198	368	433	409	290	309	313	505	294	n.a.	225	357
Time to deliver 250,000 square foot of vehicles ashore (hours)	6.15	6.20	6.10	8.45	6.60	5.95	14.1	21.9	29.6	5.85	7.97	7.96	6.00	6.15
Mean productivity (vehicle square foot/craft square foot*)														
LCM-6	0.904	0.829	0.824	0.924	0.960	0.952	0.397	0.233	0.192	0.947	0.709	0.503	0.907	0.904
LCM-8	0.721	0.718	0.843	0.801	0.798	0.750	0.405	0.240	0.224	0.723	0.622	0.490	0.741	0.721
LCV	0.595	0.606	0.711	0.717	0.622	0.657	0.452	0.342	0.332	0.582	0.617	0.528	0.608	0.595
Mean cargo transfer rates (pallets/hour)														
Standard pallets														
Ships to craft	623		544	564										
Craft to beach	459		496	442										
Beach to LSA	257		231	250										
Special pallets														
Ships to craft	142		139	124										
Craft to beach	138		138	123										
Beach to LSA	78		113	80										

* Reference time = H+7 hours.

time, only the preboated laods are ashore on Runs C-2 and C-3, and the second craft loads have just arrived in Run C-1. A better comparison of force-time effectiveness for these runs is given in Figure 1. The greater effectiveness of large craft at long stand-off distances is evident from a comparison of the craft productivity figures, although these too are influenced by the short reference time. The craft performance shown in Figure 2 gives an indication of the relative changes in the square footage of vehicles delivered ashore on LCU and LCM-6 craft for Run C-2 compared with the reference run. The results of the simulation runs for different sea states is as expected. There is an overall decrease of productivity in heavier seas, but a relative increase in productivity of large craft over small craft.

A two-step procedure has been developed for comparing the preliminary advanced craft designs. We hope to first determine whether any of the six sizes selected for the advanced craft can be eliminated. At this writing, the 70,000-pound payload size has been eliminated. In the second step of the comparison, we will compare specific craft characteristics to determine whether they should be incorporated in the advanced craft. These characteristics will include hull type for individual craft sizes, design speed, and whether drive-through capability with both bow and stern vehicular access is needed. We will also make a more thorough investigation of the effects of fleet stand-off distance and sea state. The attrition rates used in all runs will be those calculated for the individual craft and reported elsewhere.*

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* Grant, op. cit.

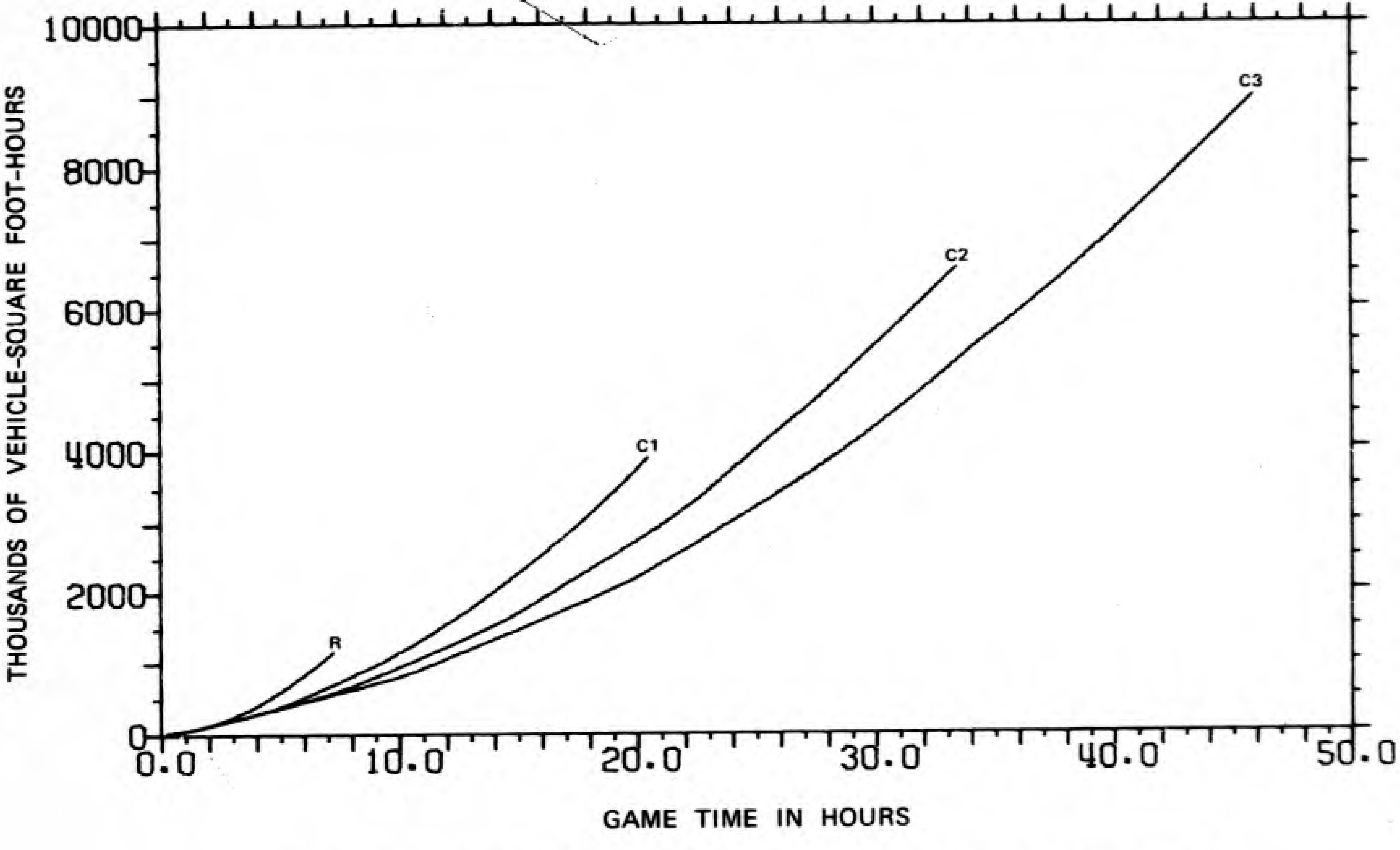

Figure 1 FORCE-TIME EFFECTIVENESS FOR DIFFERENT STAND-OFF DISTANCES

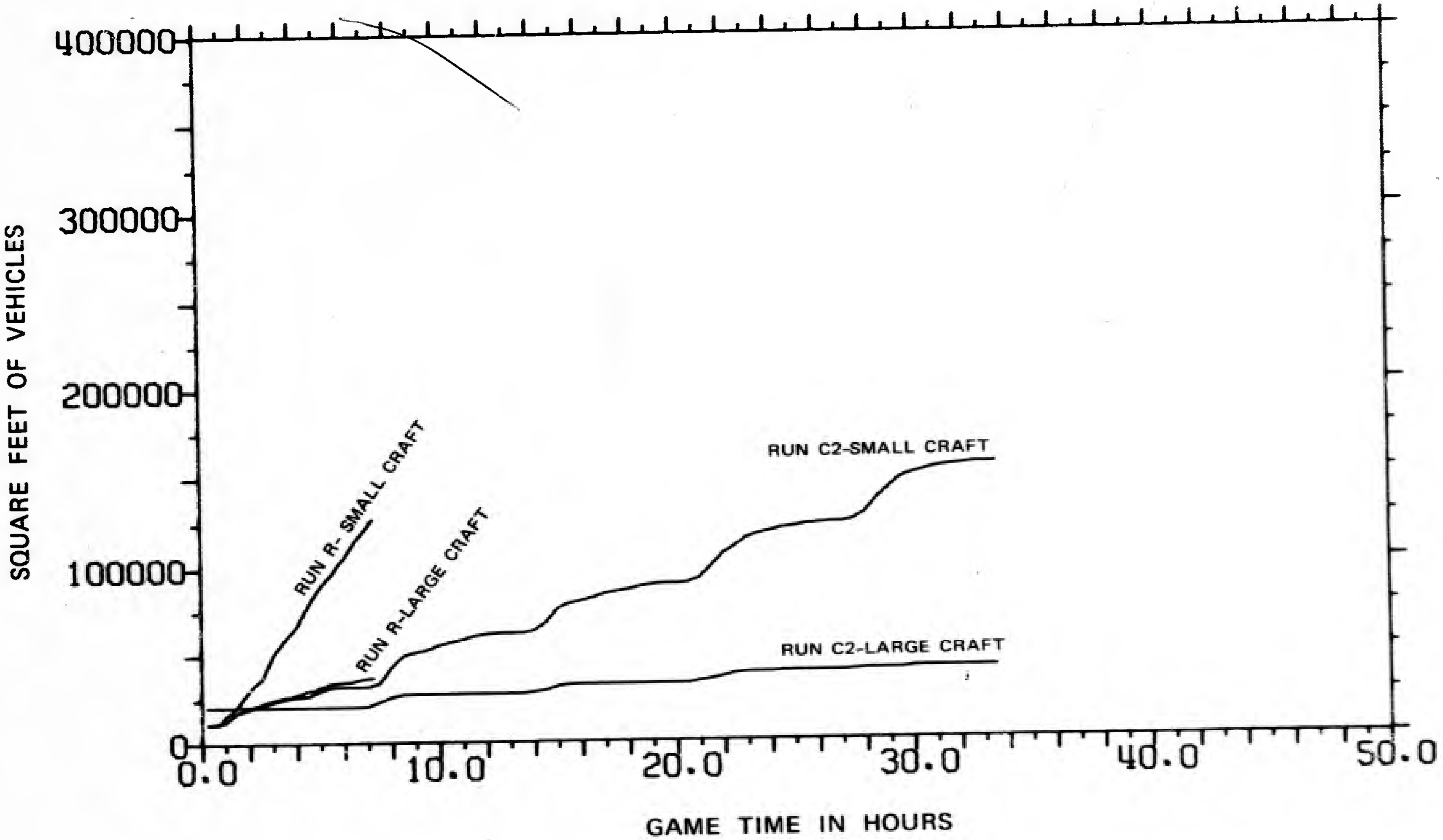

Figure 2 VEHICLES ON SMALL AND LARGE CRAFT – ASSAULT PHASE FOR REFERENCE RUN AND RUN C2

III EFFECTIVENESS AND COST MEASURES

Introduction

In the analysis of effectiveness and cost, we have sought to identify the value of advanced landing craft to future amphibious operations and to measure their cost. A landing craft's value depends not only on its performance capability (e.g., speed, load capacity, maneuverability, mechanical reliability, vulnerability to enemy action, and crew skill) but also on the jobs assigned to it, the environment in which it must work, and the nature and availability of supporting services such as cargo handling and fueling. Because of the large number of external influences, we do not believe that a single measure of effectiveness can adequately reflect craft performance for the entire range of diverse landing craft assignments. We have, therefore, developed several complementary measures of effectiveness.

Landing craft cost also depends on the extent of use, the operating environment, the nature and extent of supporting services, and the requirements of other craft in the landing craft mix. To balance these external influences, we have taken a dual approach to measures of cost: a wartime approach and a peacetime approach. The wartime approach is based on the costs necessary to deliver an amphibious fleet to an objective area, complete with the craft and craft support services needed to land the force successfully. The peacetime approach reflects the continued support needed to operate and maintain craft over their expected lifetimes; it follows accepted life cycle costing techniques.

Neither landing craft effectiveness nor cost is measured for an individual craft. Rather they are measured for a mix of craft selected to support a specific operation.

Environmental Factors

The effectiveness of a selected mix of landing craft is heavily influenced by a number of factors external to the craft and their employment. These include the nature of the amphibious operation; the nature of ships in the amphibious fleet; the assignment of ship-to-shore duties to landing craft; participation of LVTs, and helicopters; and the on-site schedule for delivery of men and materiel ashore. Even when these environmental influences have been identified and the landing crafts' jobs have been carefully defined, there remain important influences on the performance of a particular craft that are completely beyond the control of the craft's crew. These include:

1. The nature of the cargo in a load--e.g., vehicles, trailers, skid mounted equipment, palletized cargo, loose cargo.

2. The type of ship from which the cargo will be loaded--e.g., LPD, LSD, LKA.

3. The time that the craft must wait for a loading station.

4. Wind and sea states.

5. The type of cargo handling gear available for use and the skill and size of the loading crew.

6. The distance to the beach.

7. Delays en route, e.g., waiting for an open unloading position, or delays becuase of poor communications.

8. Delays in waiting to be unloaded.

9. The performance of unloading equipment, if any--including delays in unloading vehicles because of swamping, etc.

10. Delays in attempting to retract from the beach.

11. The likelihood that the craft will be disabled or sunk as a result of enemy action, mechanical failure, or operator error.

We have considered all of these external influences in the analysis of landing craft performance except for delays in communications. Effective communications with landing craft are exceedingly important, particularly when considering long stand-off distances. The Naval Electronics Laboratory Center is examining command, control, communications, and navigation requirements for advanced landing craft. The results of this work will be introduced into the systems analysis when they are available.

Measures of Effectiveness

Six measures of effectiveness were selected for the analysis. The first five measures concern the assault phase of the landing. The last measure concerns the general unloading phase. In the order of their importance, the measures of effectiveness are:

1. Force-time effectiveness

2. Marine forces lost because of destruction of craft

3. Response time in delivering on-call serials to the beach

4. Time to deliver 250,000 square feet of assault vehicles ashore

5. Mean productivity per craft, by type

6. Mean cargo transfer rates

Force-Time Effectiveness

The force-time effectiveness measures the size of the Marine force available for combat at different times during the assault phase. In this measure, we have emphasized early delivery ashore because the Marine force is most vulnerable when only a small fraction of the force is deployed and because the success of an amphibious assault may depend on delivering sufficient men and material ashore to secure a beachhead before the enemy can move defensive units into position.

Force-time effectiveness is expressed in terms of square feet-hours of vehicles that have been available for service up to any specified time after H-hour. Thus at time, t, the force-time effectiveness is equal to the area in square feet of each vehicle that has been delivered ashore multiplied by t minus the time of its delivery ashore, or:

$$E_t = \sum_{i=1}^{n} v_i(t - t_i)$$

where

E_t = force-time effectiveness in square foot-hours at time t

v_i = area in square feet of the i^{th} vehicle

t_i = time in hours after H-hour that the i^{th} vehicle was delivered ashore

n = total number of vehicles that have been delivered ashore at time t.

Alternatively, force-time effectiveness can be viewed as the area under the curve of square feet of vehicles delivered ashore vs. time (see Figure 3). In Assault A, a large fraction of the force was delivered ashore before H+1, and thereafter the rate of delivery ashore was relatively slow. In Assault B, a much smaller fraction of the force was delivered ashore before H+1, but the subsequent delivery rate was sufficiently high that, at H+7, the same quantities of materiel were delivered ashore for both assaults. Although the mean build-up rates are identical, Assault A is distinctly superior to Assault B in terms of force-time effectiveness because a larger portion of the force is available for early use. Reflecting this, the area under Curve A is about one-quarter larger than the area under Curve B.

Square feet of vehicles delivered ashore is used as a basis for measuring force-time effectiveness because of the overwhelming dominance of vehicular cargo during the assault phase. The initial assault troops would be carried ashore in LVTs and helicopters and thus would not significantly influence the productivity of landing craft.* All but a small fraction of the cargo carried ashore in landing craft during the assault phase would be combat loaded aboard vehicles. In the forces examined to date, no more than two cargo serials are included in assault phase operations. Many personnel are delivered ashore with their vehicles; while pure personnel serials, after the scheduled waves, represent less than 2 percent of the landing craft loads.

The use of square feet of vehicles presumes that all vehicle-square feet have equivalent values, which is clearly not true. However, the sequence of delivery ashore does not change appreciably for different craft mixes and from force to force, thus, cumulatively the set of vehicles included in this effectiveness factor are very nearly the same for all of the craft mixes being compared, hence, square feet of vehicles represent a meaningful as well as a convenient measure.

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* If, for long stand-off distances, LVTs were carried to or near the shore on landing craft, this would reflect on vehicle delivery productivity because the craft carrying the LVTs would have to return to the ships for their first vehicle loads. Vehicle delivery ashore would be delayed by the time required for the craft to return to the ships and load.

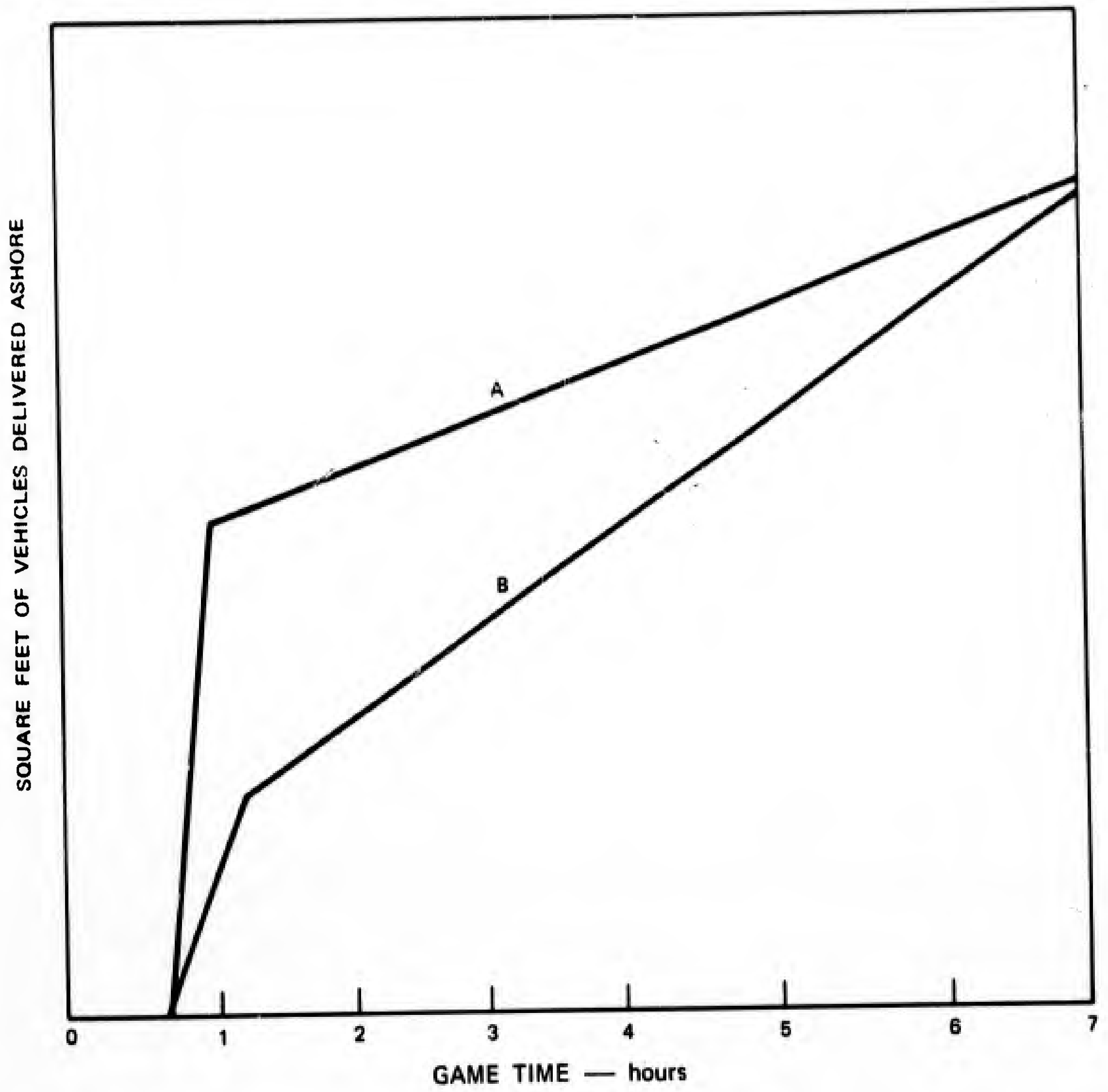

Figure 3 COMPARISON OF TWO ASSAULTS IN TERMS OF EARLY DELIVERY ASHORE

In this and other measures based on vehicles delivered ashore, we have considered loading from ships, vehicle unloading at or beyond the beach line, and vehicle transit over the soft sand of the beach. We have not considered vehicle travel to areas of initial employment. This somewhat restricted scope was selected because most vehicles have tactical assignments and can proceed from the beach to these assignments under their own power. In the analysis of advanced craft, full credit will be taken for craft (e.g., ACVs) capable of transiting the beach by recognizing the shorter unloading times that are possible when vehicles drive on to hard ground and do not have to drive through water. We have assumed that those vehicles that need to be delivered inland for use by helicopter delivered units are included in the helicopter lift serials. To avoid this assumption would require a deeper involvement in the tactics of the assault than seems reasonable for this study.

Force-time effectiveness can be plotted as a function of time after H-hour. However, when comparing a large number of craft mixes and environments, it is more convenient to deal with a single number. For this purpose a single time, H+7 hours, was selected. The portion of the force delivered ashore at this time includes a substantial part of the force to be delivered during the assault phase for all runs but the long stand-off distance runs. The time used for this comparison may have to be revised during the analysis of advanced craft if some mixes are able to complete the assault phase in less than seven hours.

Marine Forces Lost

Vulnerability and reliability should play important roles in the selection of advanced craft because high performance has little value unless it is accompanied by mission completion. Attrition rates have been developed for both present-day craft and advanced craft that predict the probability that a craft will be damaged or lost as it executes each function in its operating cycle.* However, these attrition rates are not related to the productivity of the different craft. Thus, a large craft is a better target than a small craft, but it is also potentially more productive.

When a craft is disabled while en route to the beach, the delivery of its cargo is delayed as is the delivery of subsequent loads in this

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* Andrew R. Grant, "Analysis of Landing Craft Vulnerability," Memorandum Report, Stanford Research Institute, Menlo Park, California, February 1969.

particular craft. These delays are reflected in the force-time effectiveness. Similarly, if a craft is sunk while returning from the beach or destroyed at the beach after it has been unloaded, the loss of future productivity will be reflected in the force-time effectiveness. However, if the craft is sunk en route to the beach, its cargo is lost and the effectiveness of the Marine assault force is reduced by the loss of that cargo.

The quantitative measure of Marine forces lost is expressed in two ways: (1) the number of vehicles lost during the assault phase of the landing and (2) the aggregate area in square feet of those vehicles. These measures do not recognize the obvious differences in value among different types of vehicles, but neither does the computer simulation. The computer simulation selects craft for attrition at random based on the attrition probabilities assigned to each craft type for the different legs of its operating cycle.* Thus, the simulation does not recognize the priorities that enemy gunners might assign to different cargoes. We therefore judged that these priorities could not meaningfully be recognized by the measures of effectiveness.

Response Time

Response time measures the amphibious system's response to emergency demands in the form of delivery of on-call serials. The measure of effectiveness adopted is response time, which is the interval between the call from the beach for a serial and the time that the last vehicle of the serial is available for service on the beach. The beginning of the interval is quite clearly defined; but the end is less distinct. We intend to include in this response interval the time required to unload all vehicles from the landing craft and the time required for them to drive across the soft sand of the beach to hard ground from which they can be driven to the point of need. In instances where landing craft can cross the beach line and travel to hard ground, the response interval includes time for craft to transit the beach and vehicle unloading time.

Specifically, response time includes the following time elements:

- Time for the selected craft to travel from the boat pool to their assigned ships. If an insufficient number of craft are available in the boat pool, time for the craft to travel from the beach to assigned ships may be included.

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* Grant, op. cit.

- Time waiting for a loading station to become available. It is assumed that craft loading on-call serials will precede other waiting craft, but they will not displace craft being loaded.

- Time to maneuver into loading position, loading time, and maneuvering time to clear ships. This includes ballast and deballast time for well-type ships if appropriate.

- Transit time to the LOD.

- Time waiting for an unloading position. Again craft carrying on-call serials would have priority over other waiting craft but would not displace craft unloading at the beach.

- Transit time from the LOD to the beach including beaching time and beach transit time as appropriate.

- Unloading time including time to pull vehicles out of soft sand and water as appropriate.

- Time for vehicles to drive to hard ground with or without assistance.

There is a wide spectrum of response times for each amphibious operation. In the base system, almost all on-call serials are preboated aboard landing craft. For these serials, response time is made up of transit time from waiting stations to the LOD, waiting time, transit time LOD to beach, beaching time, unloading time, and time for vehicles to cross the beach.

Individual response times depend on the situations existing when the serial is called. We have established reference data from the baseline system examples that will be used to evaluate advanced craft systems. This reference value for performance comparisons is expressed as a mean or expected response time calculated for all serials and a variance that expresses the differences among individual serials. For each advanced craft system, we will measure the mean and variance of the response time and determine the significance of differences from the value of the reference performance.

We expect this measure to be significant when we begin to compare advanced craft with radically different speeds and over-the-beach capability.

Time to Deliver 250,000 Square Feet of Assault Vehicles Ashore

Elapsed time to complete a substantial part of the assault phase (delivery of 250,000 square feet of vehicles ashore) was selected as a measure of effectiveness to balance the early delivery bias of force-time effectiveness. It is conceivable that a craft mix might have excellent early delivery capability but thereafter have such a low delivery rate as to delay the completion of the landing unduly. Present-day landing craft constitute such a mix. They have high preboat capability but suffer from low speed and relatively poor supporting systems both on the beach and on board ships, thus subsequent loading and unloading are slow.

To assure uniformity in measurement, an arbitrary definition was adopted for the completion of the assault phase. In the simulation, as in practice, there is no abrupt end to the assault phase. Rather, toward the end of the assault phase, as the number of available craft exceeds the available serialized unloading assignments, surplus craft are dispatched to begin unloading general cargo. The resulting overlap between the assault and general unloading phases may last for several hours. To avoid the influence of the overlap period on the comparison, the time to unload 250,000 square feet of vehicles was selected as the basis for measuring relative time to complete the assault phase. The figure of 250,000 square feet represents approximately three-quarters of all vehicles in the assault phase. In none of the base runs was there a substantial surplus of craft available for general unloading before the discharge of 250,000 square feet of assault phase vehicles.

This measure should be augmented by careful visual inspection of the assault build-up curves. Only by considering all of the major events of the assault phase can we understand the differences between two mixes of craft. These differences may not always be evident from a single measure of effectiveness.

Mean Productivity per Craft by Type

The measures of effectiveness discussed above relate only to a craft mix of two, three, or more craft types working with LVTs and helicopters to land the landing force. In the course of the analysis, each individual craft appears in several different craft mixes. The manner in which the different craft in a mix complement each other is reflected in the measures of effectiveness. However, to help plan future mixes to be analyzed, it is desirable to know something about relative effectiveness of the different craft types included in the mix. For this purpose, a measure of productivity by craft type has been devised.

The productivity measure for each craft type is expressed as the square feet of vehicles delivered ashore up to a specified time (t_o) per square foot of craft. However, since different craft types use up shipping space differently according to their inherent design, a simple summation of cargo delivered does not reflect true productivity of the craft type. Accordingly, this measure is computed as follows:

1. Select the common time for the performance measure. For base system runs, we have used $t_o = 7$ hours.

2. Determine the square feet of vehicles delivered ashore by craft type k up to time t_o.

3. The productivity measure for craft type k is the square feet of vehicles delivered ashore divided by the number of craft type k multiplied by the platform area of one craft, or

$$P_k = \frac{V_k}{N_k A_k}$$

By considering performance over a specific time period, the productivity reflects craft speed, the efficiency of successive loads, craft attrition including time out of action, and loading and unloading times. Platform area is used in an effort to reflect the relative amounts of amphibious ship cargo-well area required by the different craft types. These measures should be viewed with caution because of the interpendence of the craft in support of an amphibious operation.

Mean Cargo Transfer Rates

Mean cargo transfer rates express system performance during the general unloading phase of the assault. The system includes the complete craft mix, the loading equipment and procedures of all ships carrying general cargo, the unloading equipment and procedures used on the beach, and the equipment and procedures used to deliver material to inland logistic support areas. This broad definition was adopted to reflect the importance of support systems to cargo off-loading, to ensure that the preferred systems are capable of carrying cargo across the beach to inland destinations, and to ensure a uniform basis for comparing craft of all types and for comparing craft with helicopters.

Mean cargo transfer rates are measured at three transfer points (1) from amphibious ships into landing craft, (2) from landing craft onto the beach, and (3) from the beach to the logistic support area. Transfer rates from the ships of the amphibious fleet into landing craft reflect the productivity of shipboard equipment and crews, as modified by the availability of craft for loading and the time needed for one craft to depart and the next to get into position. Similarly, the transfer from craft to the beach measures the performance of the beach party, as modified by craft availability and difficulties in beaching and retracting. Transfer rates from the beach to the LSA depend on vehicle loading and unloading rates; on the numbers of vehicles available to move cargo; and on the distance, road conditions, and road capacity between the beach and the LSA.*

Mean cargo transfer rates are used to provide a single number for each transfer situation. In practice, the cargo transfer process is not likely to reach an equilibrium. There are no bottlenecks facing the first cargo to move ashore with the result that it tends to be handled expeditiously although not always efficiently because handling procedures are still being developed to meet the tactical situation. Later, congestion and fatigue become important elements. The variations in cargo handling rates are discussed in Chapter V.

Measures of Cost

The cost of an amphibious operation is open to a wide variety of interpretations. The capital investment in combat and amphibious ships, aircraft, and landing craft necessary to deliver a Marine Expeditionary Force to a hostile objective area is measured in billions of dollars. The Marine vehicles, equipment, and supplies may be valued at $500 million standing on the dock before loading, but that money value is materially enhanced as the force is moved toward the enemy shore. The value of the 75,000 to 100,000 men engaged in the operation is even more difficult to express, as is the cost to keep this force in readiness for some possible future need.

In the systems analysis we are attempting to measure comparative costs and values. The cost includes expenditures necessary to accomplish an objective--in this case to land a landing force or to be capable of landing one. Value includes costs and intangibles that are not directly reduceable to money terms. Thus value is subjective. For the comparative cost and value determinations, we have assumed that the amphibious forces are in existence and are equipped with present-day landing craft in adequate numbers. This has been identified as the base system. The capital

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* In the analysis and in this report, we treat the LSA as a single entity with a fixed location. In practice, there would probably be several LSAs, and their size and location would depend on the tactical situation.

cost to provide the initial fleet and craft is assumed to be zero--that is, it is the figure against which the marginal costs of other systems can be measured. The marginal capital costs of advanced craft systems include:

1. The capital cost of the initial purchase of advanced craft.

2. The cost of ship alterations for fueling, handling, and maintaining the advanced craft.

3. The cost of ship alterations to improve cargo handling so that the advanced craft system can realize high productivity.

4. The cost of new shore party equipment to support the advanced landing craft.

5. The cost of special or additional shore facilities to support the landing craft and to train crews.

Operating costs for advanced craft systems will also be compared with the operating costs of the base system. However, in this case, operating costs will be estimated for the base system. The more important operating costs include those related to:

1. Periodic replacement of landing craft, because of normal peacetime attrition and losses incurred in a specific amphibious operation.

2. Fuel and operating supplies.

3. Maintenance and repair.

4. Crews.

Operating costs will be calculated for two environments: (1) an assault evnironment in which the craft are supporting a specific amphibious operation and (2) a peacetime or training environment.

The organization and collection of the cost data have not been part of the base system analysis and therefore will not be reported here. Cost analysis will be the subject of a future memorandum report.

IV AMPHIBIOUS OPERATION MODELING

Overview of Models and Programs

The set of computer programs was designed to simulate the performance of alternative landing craft systems in a variety of amphibious environments and to develop data from which the measures of effectiveness and cost could be computed. The purpose of this chapter is to describe the more important models and their corresponding programs in the simulation set. We are not attempting to provide sufficient information so that the reader can use these programs, but we do want to convey enough information about the nature of the members of the program set and their input and output data requirements to give the reader an appreciation of the nature and quality of the results.

The major determinant of the structure and relationships of the computer simulations was the selection of NWL Dahlgren's STS-2 model for the key ship-to-shore simulation. Because of its central role in the simulation process, the STS-2 model dictated the form of output required from programs preceding it in the simulation process and the level of detail required from and available for all programs. Modifications were made to the STS-2 model to improve its representation of landing craft operations, and special programs were written to ease the difficulties of interfacing with other programs and computers used in the simulation set.

STS-2 is programmed in STRAP machine language for NWL's IBM 7030 (STRETCH) digital computer. All other programs were written in ALGOL for the Burroughs B5500 digital computer. Processing time for the full set of models and programs is extremely long and therefore costly. Typical running times are:

Program	Computer	Running Time (minutes)
SELECT	B-5500	20
PREBOAT	B-5500	10
EMBARK	B-5500	20
REVISER	B-5500	10
MERGER	B-5500	5
STS-2		
Assault phase	IBM 7030 (STRETCH)	120
General unloading phase	IBM 7030 (STRETCH)	360
STS TAPE	B-5500	10
STS EDIT		
Assault phase	B-5500	30
General unloading phase	B-5500	120
PLOT	B-5500	5

The flow of information and logical structure of the entire simulation process is illustrated in Figure 4. There are three principal manual operations identified in the lefthand column: (1) problem description, (2) hand fit craft into ship, and (3) compute measures of effectiveness. None of these requires manual manipulation of the mass of data that describes the Marine force.

In the first manual operation, problem definition, the principal characteristics of the problem to be simulated are specified. These characteristics include (1) the nature of the Marine force (i.e., number and type of RLTs and BLTs, number of RLTs and BLTs to be air-lifted, the number of tank and artillery units, and the general composition of the combat service support units); (2) the types of landing craft to be used (i.e., LCU 1610 class, LCM-8, LCM-6); (3) the ship types in the amphibious fleet (i.e., LHA, LPD, LSD, LPH, LST, LKA); and (4) the environment (i.e., beach width and length, beach profile, anchorage area, stand-off distance, sea state, general landing tactics). This first manual step provides sufficient information with which to begin the simulation process. Selection of the gross Marine force composition identifies the number and nature of the force that will be assembled into the Marine force deck by the Marine

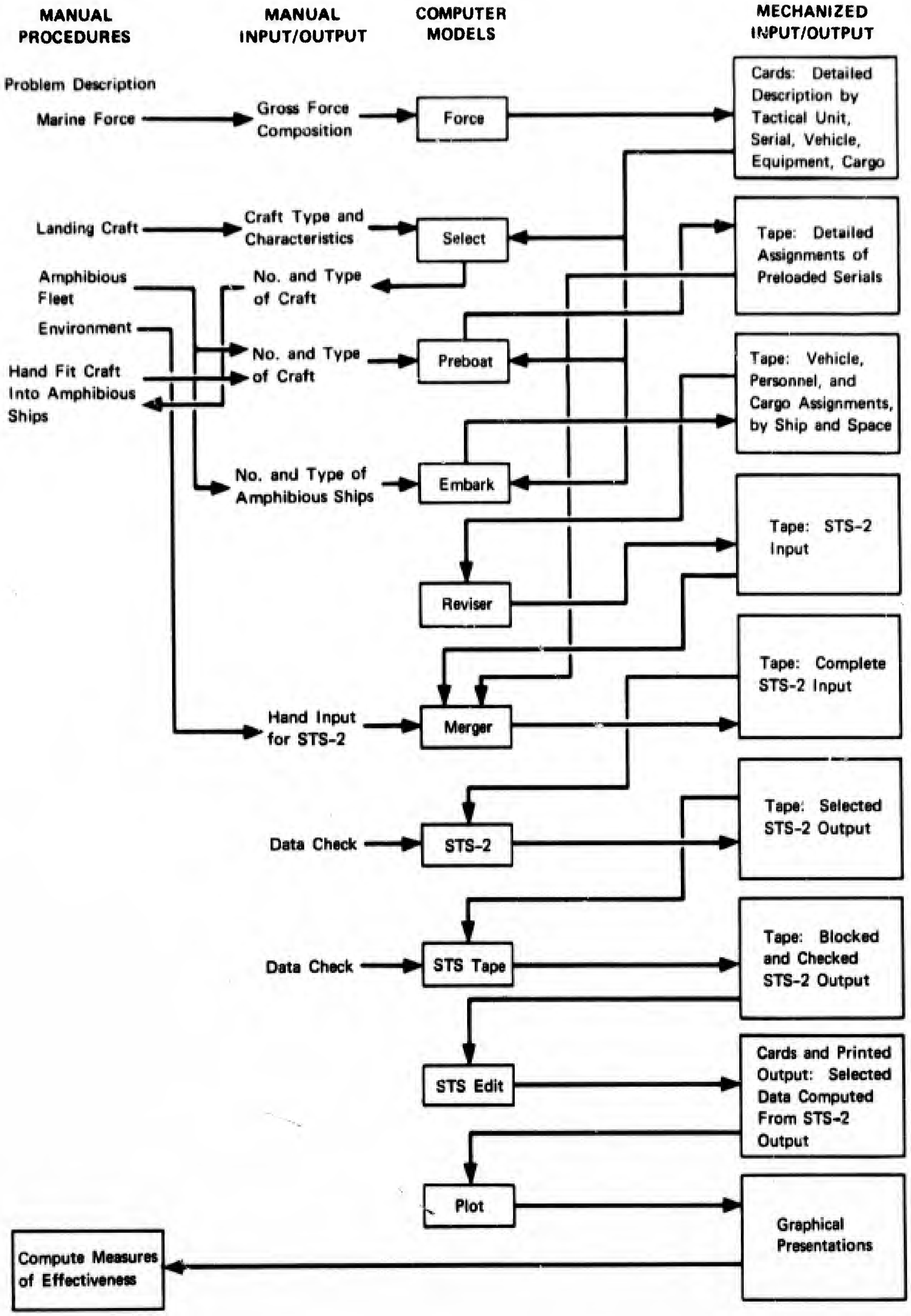

Figure 4 SIMULATION PROCEDURE

Force Description Model. The Marine force deck completely defines the Marine force down to characteristics of each individual vehicle and its combat load. In fact, each vehicle in the force is described on a 80-column punched card that contains its line item number, abbreviated description, length, width, height, gross weight (including combat loaded cargo and personnel riding in the vehicles), and type (e.g. wheeled prime mover, towed trailer, tracked prime mover, untowed trailer, the serial number to which the vehicle is attached, and whether it is available for moving cargo ashore).

The force is organized into serials for tactical and administrative integrity, and serials are associated in tactical units when it is desirable to load two serials onto the same ship or designate a specific ship or ship type for a serial. On-call serials are identified and divided into those that must be preboated (preboat definite) and those that are preboated if possible (preboat optional). All personnel are attached to serials, and all items of cargo are either loaded on vehicles or accounted for separately.

The types, but not the numbers, of landing craft selected for each mix are determined manually from among those types available for each particular simulation run. Thus all base system runs use craft now in service. The first advanced craft comparison runs use craft selected from the preliminary design studies. For each run, a balanced craft mix is selected. This mix includes at least one craft capable of carrying the heaviest individual vehicle load in the force (the tank retrievers) and at least one craft that can be deck loaded on LKAs. In addition, the two or three craft in each mix should complement each other with respect to operating characteristics and effective use of ship well areas.

The number of each craft type to be included in the mix is determined through an iterative process that includes the SELECT and PREBOAT programs and hand fitting craft into (or onto) amphibious ships. Initially, the SELECT program is used to fit individual serials of the force dimensionally into the selected craft types. This program considers each serial in turn and selects for it the most efficient combination of craft to carry it ashore, based on area of cargo well occupied by the load. When all serials have been examined, the total craft selection yields the proportion of each craft type that gives most the efficient transport for all serials. This procedure does not include considerations of speed and vulnerability, which are introduced manually to augment the computer selection. The selected craft types are hand fitted into the available ships in a mix that efficiently uses the ships' carrying capability and closely approximates the selected proportions.

PREBOAT is run, using the hand-fitted craft mix, to fit dimensionally the serials to be preboated in order of priority into those craft that will be carried in well-type ships. In this procedure, preboat definite serials must be loaded, together with as many preboat options as possible. It is also necessary that no serial be only partially preboated. When a poor fit occurs, adjustments are made in the priority of the desirable preboat serials or in the mix of craft, or both. Several trials are sometimes needed to select the most efficient combination of serials and craft. PREBOAT produces a magnetic tape as output that later is used to construct the final tape input data for the STS-2 program.

The EMBARK model follows PREBOAT and loads the balance of the force into the amphibious ships. It recognizes ship preferences and makes assignments to specific hull numbers as required. Ships are described to EMBARK in terms of the areas available in each ship for carrying portions of the force and the limitations on the type of vehicles or cargo that can be carried in each area. Broken stowage factors are used for each area that reflects the physical layout of the area. EMBARK loads vehicles aboard ships by an algorithm that obeys the restrictions for each area (e.g., weight limitations, height limitations, areas restricted to non-tracked vehicles). As each vehicle or item of cargo is loaded aboard, the remaining available space in that part of the ship is reduced by the area occupied by the vehicles that have been loaded. Palletized cargo of different types is loaded in a similar manner. EMBARK spreads the serials among the ships of the fleet to provide a maximum number of parallel loading stations throughout the assault. The results of EMBARK are written on tape and run through REVISER for verification and preparation of additional input data for the STS-2 program.

Additional input data for STS-2 are prepared by hand. These data include craft performance characteristics which determine complete operating cycle data for each craft, including craft speed, maneuvering time, beaching and retracting time, loading and unloading rates, and attrition factors. A geographical description of the landing is developed to include ship locations, beach width (including number of unloading stations), and other data. The sea state is reflected in the craft performance characteristics. The MERGER program assembles all of the necessary input data consisting of hand input and the tapes from PREBOAT and REVISER onto a single tape for transmission to NWL Dahlgren. This input tape can be run directly on the IBM 7030 (STRETCH) without the need for additional input.

The STS-2 model is an event type model that was originally designed for war gaming. It has also been used extensively to check out operational plans and to assist in the training of amphibious planners. As modified for this analysis, the model accounts for all of the important landing craft-related events in the movements of an amphibious force from the ships of the amphibious fleet to its first destination beyond the assault beach. A separate version of STS-2 also accounts for helicopter lift of vertical assault forces and the subsequent movement of cargo by helicopter. Because the two versions of the model are distinct, specific assignments are made to landing craft and helicopters before the simulation runs. In addition to landing craft and helicopter movement, the STS-2 program keeps track of ship positions and movements and simulates craft and helicopter loading operations, including queues awaiting loading stations. It simulates beach unloading operations, including craft queues for unloading positions and cargo queues (beach dumps) awaiting movement inland. STS-2 can handle objective areas as large as 500 nautical miles square. Landing craft and helicopter damage and destruction are simulated by attrition of landing craft and helicopters at specified rates that depend on the individual craft's position and vulnerability. The output of the STS-2 program is in the form of status tables for selected times throughout the operation.

The selected STS-2 output is transmitted on two to eight magnetic tapes to SRI for further processing. The data are first checked and packed onto one or two tapes for more efficient storage. The tapes are edited to extract specific data of interest from the standard STS-2 tables to provide time histories for items of interest, compute rates, and other values and to tabulate selected distributions. Finally, some of the data are displayed graphically by the PLOT program for ease of interpretation. Edited data and graphs are used to calculate manually the measures of effectiveness.

The paragraphs below describe the FORCE, SELECT, PREBOAT, EMBARK, REVISER, MERGER, STS-2, STSTAPE, STSEDIT, and PLOT programs. The Marine Force Description (FORCE) and Landing Craft Mix Selection (SELECT) programs have been described previously but are repeated here for completeness.

Marine Force Description (FORCE)

The Marine Force Description (FORCE) is a computer program designed to mechanize the production of detailed descriptive data about any Marine amphibious assault force. The forces used in the base system analysis were derived from CNA's NAVWAG-44 forces.* To give some appreciation of the detail of the force description, the extensions that were applied to the NAVWAG forces are discussed below together with characteristics of the computer model.

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* Means, op. cit.

NAVWAG Extensions

Six specific extensions were used to add detail to the NAVWAG forces. The details of each extension were developed through interviews with knowledgeable Marine Corps and Navy personnel. Because some latitude of judgment was possible, an attempt was made to distill a consensus from the answers and to conform details of the force to the consensus. The extensions that were made to the NAVWAG force data to permit analysis of the movement of the Marine force from ship to shore are outlined below.

Serial Construction. The NAVWAG study presents the Marine forces in terms of "loading elements." These loading elements represent tactical groupings that cannot be further divided for embarkation purposes--i.e., all portions of any loading element must be embarked on the same ship. There are several reasons for this requirement, including en route training and coordination and equipment maintenance. However, loading elements do not necessarily correspond to serials; for example, a loading element may consist of an amphibian tractor unit. The tractors and crews will be required early in the assault, but the maintenance shop equipment will not land until considerably later. Thus, this loading element will be subdivided into two or more serials. The reason for including the entire unit in one loading element is to permit repairs, maintenance, and preparation of the tractors while en route to the objective area. Therefore, the first extension to be made to the NAVWAG forces was to serialize them.

As a starting point for serial construction, serials were made to correspond to NAVWAG loading elements except in cases in which it could be determined that parts of the loading element would be required ashore at different times. In such cases, the NAVWAG elements were broken into the fewest possible subdivisions. In no case was more than one, or parts of more than one loading element, combined to form a serial, although this could be done if the different elements were loaded aboard the same ship.

One significant change from previous practice--but not from doctrine--was made in constructing serials. The practice has been to size and configure serials with factors in mind that are additional to the doctrinal definition. The additional factors are the characteristics of the landing craft available for a specific operation. This practice is essential when dealing with a known set of landing craft, but, if the practice were used in the study, there would be a high probability that the next generation of landing craft would have about the same mix of sizes as the present generation. This may or may not be desirable. This problem was lessened by structuring serials to be as large as possible within the constraints imposed by the doctrinal definition.

Vehicle Dimensions and Weight. The second extension to be made to the NAVWAG force was to attach to each equipment and supply item its individual dimensions and weight. The NAVWAG loading elements are described in terms of total personnel, a list of equipment, total vehicle area mobile-loaded supply volume, and nonmobile loaded supply volume. This description is adequate for embarkation planning because the aggregate figures for a loading element are usually small compared with the capacity of a ship. For the ship-to-shore movement, however, the aggregate figures for a serial may be large compared with landing craft capacities; in fact, several craft may be required for one serial because of the convention of constructing large serials.

Towed Vehicles. It is not important that towed vehicles be attached to their prime movers while loaded aboard amphibious ships. For the assault, however, towed vehicles should be attached to their prime movers. For the ship-to-shore movement, the prime mover and trailer should be considered as a unit, or "vehicle system," with length and weight equal to the sum of the individual lengths and weights and height and width equal to the greater of the two individuals' heights and widths. Thus, the third extension of the NAVWAG force data required determining which towed vehicles were attached to which prime movers.

Mobile Loading. The fourth extension to the NAVWAG forces was to determine which vehicles would be mobile-loaded and what the weight of each mobile load would be. This weight had to be added to the weight of the vehicle system. Further, some mobile loads protrude from or overhang the vehicle in which they are carried; such mobile loads had to be identified and the dimensions of the vehicle systems carrying them changed accordingly.

Personnel. The fifth extension to the NAVWAG forces was to determine which personnel ride in vehicles during the ship-to-shore movement. These personnel generate shipping space requirements, but they do not generate volumetric requirements in landing craft. They do, however, generate weight-carrying capacity requirements in landing craft. Accordingly, the weight of these personnel was added to the weights of the vehicle systems that carry them and they were subtracted from the personnel totals of their serials.

Trucks Available for Beach Clearing. The final extension of the NAVWAG data was to determine which trucks would be available to assist in clearing nonmobile-loaded material from the beach. These trucks go ashore mobile-loaded, discharge their mobile loads at the logistic support area, and then operate between the beach and the logistic support area transporting materiel.

Data Processing

The Marine force description program was written to facilitate the task of extending the NAVWAG force data into serial data. This program provides storage for personnel, vehicle, and equipment characteristics and performs many of the mechanical manipulations required in serial construction. The thinking underlying serial construction could not be mechanized, and serials were constructed individually on an ad hoc basis.

The computer program assembles input data and file data into serials comprising one or more of the mutually exclusive components below. In Table 2, the components are described in terms of the requirements they generate for landing craft capacity; certain other descriptions are also presented to facilitate embarkation planning. The components are:

1. Personnel who neither ride in vehicles nor are members of crews of major equipment items. These personnel generate space requirements in ships and space and weight-carrying requirements in craft. A serial may not contain more than one personnel system.

2. Vehicle systems. A serial may contain up to 99 vehicle systems. Each vehicle system may consist of any of the following:

   a. Tracked self-propelled vehicle with trailer
   b. Tracked self-propelled vehicle without trailer
   c. Wheeled self-propelled vehicle with trailer
   d. Wheeled self-propelled vehicle without trailer
   e. Untowed trailer (this situation was avoided wherever possible)

   Self-propelled vehicles with trailers are considered single units for ship-to-shore movement, but separable for embarkation. Vehicles may contain personnel or mobile-loaded equipment or supplies or both. The method of determining capacity requirements are customarily stated in terms of square feet, all linear dimensions, including height, are given for vehicle systems. This is done to enable detailed sizing analysis for craft design and for

Table 2

VEHICLE SYSTEM CAPACITY REQUIREMENTS

Type of Requirement	Amphibious Shipping Requirement*	Landing Craft Requirement†
Personnel space	Number of personnel attached to system	None. Personnel ride in vehicle. For example, in case of howitzer crews, personnel not riding can be accommodated within the square envelope of the howitzer.
Weight	Vehicle weight plus mobile-loaded cargo weight	Vehicle weight, plus mobile-loaded cargo weight, plus weight of attached personnel; all for both vehicles.
Length	Length of vehicle, plus length added by protruding mobile-loaded cargo or any length added by attached equipment (e.g., length added to truck by winch)	Added shipping lengths of self-propelled vehicle and trailer (computed in middle column); then subtract from each any length that overhangs the other (e.g., for tractor-semitrailer system, subtract portion of tractor behind pin and portion of semi-trailer ahead of pin).
Width	Width of vehicle, plus width added by overhanging mobile load or attached equipment	Greater of the widths of the individual vehicles, computed as in middle column.
Height	Height of vehicle, plus height added by upward protrusion of mobile load or attached equipment	Greater of the heights of the individual vehicles, computed as in middle column.

* With reference to individual self-propelled vehicle or trailer.
† With reference to self-propelled vehicle or trailer taken as an inseparable unit.

other purposes such as checking overhead clearances aboard ships.

3. Cargo systems. These systems include only nonmobile-loaded cargo. The following types of cargo system are distinguished:

   a. Standard pallets 48 inches long by 54 inches wide by 40 inches high. Because of differing types of shipping space requirements, the following types of standard pallets are distinguished:

      (1) Ammunition pallets, weighing 3600 lbs
      (2) Packaged POL pallets, weighing 2100 lbs
      (3) General cargo pallets, weighing 1500 lbs

      Weights of these pallets are considered representative of the type.

   b. SATS matting pallets 12.3 feet long by 2.4 feet wide by 2.1 feet high. This size was chosen because of the large number of such pallets (3,750) in the MEF. There are many other SATS airfield items with approximately the same dimensions; therefore, this type does not consist solely of pallets of SATS matting, but includes the other items. Although a pallet of SATS matting weighs 2,011 lbs, any weight may be assigned to the pallet.

   c. Special cargo. This class includes those items that do not fall into any of the other classes. Dimensions and weights are specified for each individual piece of cargo of this type.

The results of the program are a deck of punched cards that are used in the SELECT, PREBOAT, and EMBARK models. The data on these cards are written on magnetic tape for use by the STS-2 program. The principal advantage to the FORCE program is its ability to change large tactical units, individual pieces of equipment, or serial composition and quickly produce a complete modified force deck. By this means, the assault force can be modified rapidly to reflect different assault conditions, different operating doctrines, or different craft requirements.

Landing Craft Mix Selection (SELECT)

The proportions of each craft type in the landing craft mix is chosen by the SELECT model with manual modifications based on operating cycle analysis. The SELECT model combines the craft selection routine (CSR) and craft fitting routines (FIT) to produce the set of craft that can most efficiently carry each serial of the force. These two routines are described in detail below. In the aggregate, these craft represent the mix that would be used if each craft made only one trip to the beach. For example, if all of the vehicles of the assault phase were moved ashore in LCU 1466 class, LCM-8 (aluminum hull), and LCM-6 craft, the most efficient movement would take place in 185 large craft loads, 426 medium craft loads, and 399 small craft loads. Although these craft have about the same nominal operating speeds through the water, their operating cycles are different because of the different times required to load and unload the craft. If, for a particular amphibious environment, the mean cycle times for these craft were: LCU, 4.45 hours; LCM-8, 4.3 hours; and LCM-6, 4.0 hours, including an allowance for craft attrition, the preferred mix would be as tabulated below:

Craft Size	Craft Loads (%)	Percent Craft Loads X Craft Cycle Time	Preferred Mix (%)
LCU	18.3%	81.4%	19.3%
LCM-8	42.2	181.3	43.1
LCM-6	39.5	158.0	37.6

Thus the relative numbers of LCU and LCM-8 craft are increased to reflect their longer mean operating cycles.

Mean cycle times are calculated using a typical set of landing craft loads. They include maneuvering, travel, beaching, retracting, loading, and unloading times plus an allowance for queues. Because of similar craft operating characteristics, cycle times are about the same for all base system craft. Differences among advanced craft are more pronounced.

Craft Selection Routine

The CSR operates in conjunction with FIT to provide logic for assigning landing craft to carry ashore the vehicles and cargo of a Marine Corps serial. The CSR selects a trial landing craft for a serial, and transfers control to the FIT. FIT loads the serial (or elements of it) on the selected landing craft, and transfers control back to the CSR. The CSR evaluates the load in terms of utilized craft cargo space. The space utilization for a particular load is the ratio of total area of the loaded cargo to area of the craft's cargo space; this ratio is compared with the utilization target for the craft. If the utilization of space is larger than the utilization target, the CSR accepts the load. Otherwise, the CSR codes it as feasible but undesirable. In the latter case, the routine tries smaller craft for better utilization of craft cargo space, returning to the original craft only if an element of the load will not fit into the smaller craft.

For each type of landing craft to be used, input data to the CSR include the cargo space dimensions, external dimensions, weight capacity, cutoff weight, and utilization target. All these variables except external craft dimensions and utilization target in turn become input parameters to the FIT. For each vehicle in the serial to be loaded, the inputs to the CSR include the vehicle weight, overall vehicle dimensions, and vehicle information relating to Marine Corps loading practices, e.g., whether they are wheeled or tracked or whether they are prime movers or trailers. All these variables are passed to FIT as input parameters.

The CSR reads all information pertaining to a particular serial before trying to load the serial. The end of serial card signals the start of the loading process. A large craft is selected, and all the vehicles of the serial are marked "unloaded." FIT is then employed to load the vehicles on the selected craft. Control is then returned to CSR from FIT with some of the vehicles marked "just loaded." The utilization of craft cargo space is calculated. If the space utilization meets or exceeds the target, the load is accepted and the vehicles "just loaded" are marked "permanently loaded" in a large craft. If the utilization target is not met, CSR rejects the load and records that a feasible load was obtained in a large craft; the vehicles "just loaded" are then marked "unloaded" again and CSR selects a medium craft.

FIT is then called to load as many of the remaining "unloaded" vehicles as possible on the medium craft. Control is returned to CSR from FIT with some of these vehicles market "just loaded." The utilization of craft cargo space is calculated. If the space utilization meets or exceeds the target, CSR accepts the load and marks the "just loaded" vehicles as "permanently loaded" in a medium craft; if the utilization target is not met, CSR rejects the load and records that a feasible load was obtained in a medium craft; the vehicles "just loaded" are then marked "unloaded" again, and CSR selects a small craft.

FIT is called to load as many of the remaining "unloaded" vehicles as possible on the small craft. In this case, if FIT loads some of these vehicles, the load is accepted regardless of utilization and the vehicles "just loaded" are marked "permanently loaded" in a small craft. However, if FIT returns control to CSR with no vehicles "just loaded," CSR selects the smallest size craft in which a feasible load was recorded during the most recent pass through the craft sizes. If there was no such feasible load, CSR outputs a message that the serial could not be loaded (i.e., there was at least one vehicle too large for all craft sizes); otherwise, FIT is called to load as many of the "unloaded" vehicles as possible in the selected craft. When control is returned to CSR, the load is accepted regardless of utilization, and the vehicles "just loaded" are marked "permanently loaded" in a craft of the selected size.

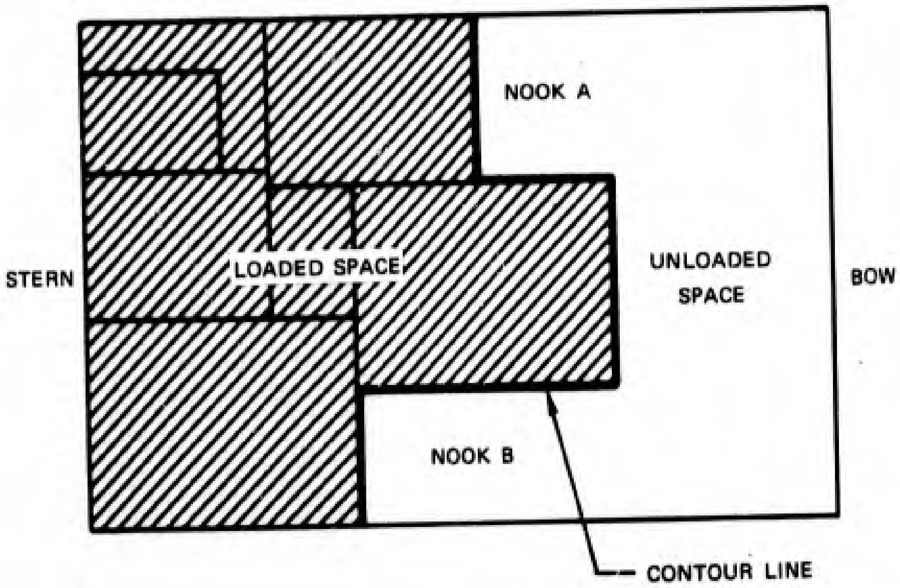
Whenever a load is accepted, CSR gives as output the names of the vehicles loaded, the craft size in which they were loaded, and the utilization of cargo space achieved; CSR then checks to see if any "unloaded" vehicles remain in the serial. If so, a large craft is selected and the logic is repeated, if not, CSR reads the information for the next serial and attempts to load it. In no case are vehicles from more than one serial loaded in a single craft.

Craft Loading Routine

FIT loads vehicles or cargo into landing craft. For a given landing craft and Marine Corps serial, the routine attempts to load as many vehicles as possible into the craft in accordance with some loading rules that are intended to produce the sort of loading efficiency that an experienced loadmaster could achieve. FIT does not attempt to optimize the load or use sophisticated mathematical techniques. Rather, a simple intuitive loading maxim is employed with modest look-ahead features to prevent major inefficiencies in craft cargo space utilization, and some checks are made to ensure compliance with certain Marine Corps loading practices.

The inputs to FIT are transmitted as parameters from the CSR. The CSR selects a craft to be loaded and passes information about that craft to FIT. This information includes cargo space dimensions, weight capacity, and weight cutoff of the craft. The CSR also passes information about vehicles remaining to be loaded, including number and types of vehicles to be loaded, and vehicle weights, dimensions, and information relating to Marine Corps loading practices (e.g., whether they are wheeled or tracked, and whether they are prime movers or trailers).

Loading Maxim. The loading maxim is essentially the following: load larger vehicles before smaller ones, but always try to fill up small remaining spaces (nooks). Loading proceeds from stern to bow. At any stage in the loading process, the craft is divided into loaded space and unloaded space. Because of the nature of the algorithm, the loaded space at any stage will always be toward the stern of the craft. Thus, there will be a line across the craft from one side to the other dividing loaded from unloaded space, consisting essentially of the fronts of the loaded vehicles closest to the bow. This is called the forward load contour line or simply, contour line, and is illustrated below.



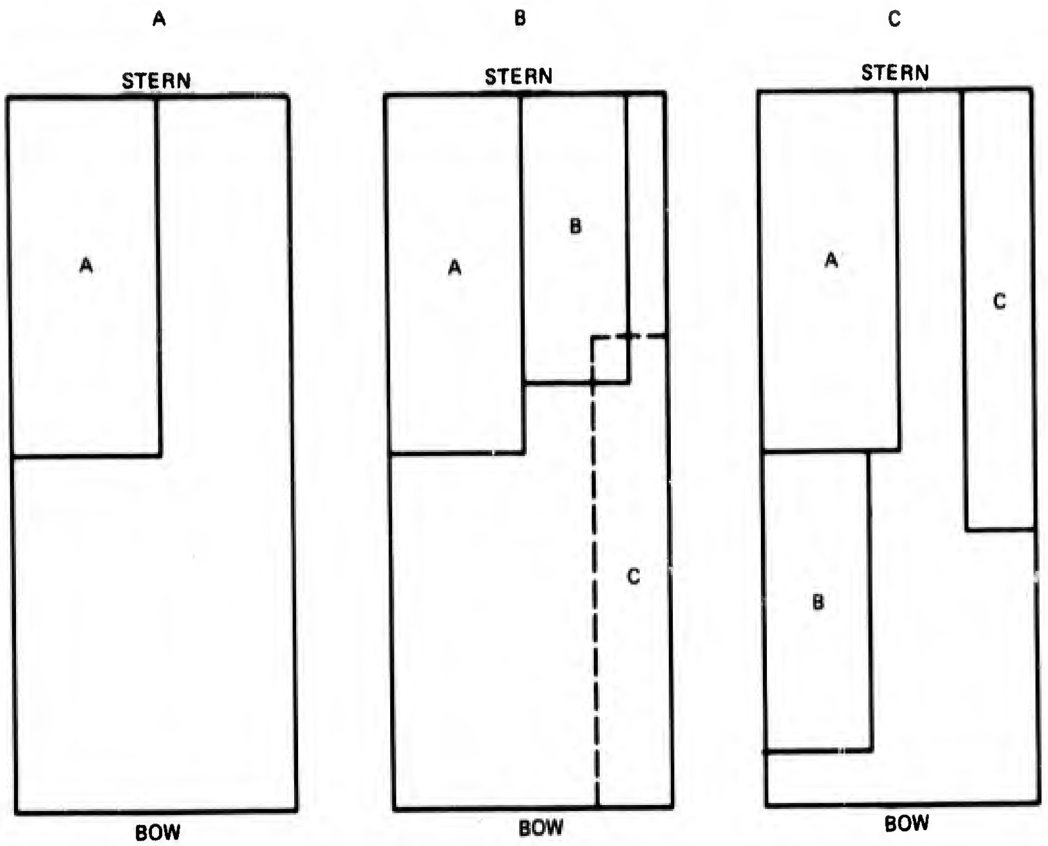
The craft is loaded by successively identifying and loading nooks. A nook is any area of unloaded space enclosed on three sides by the contour line. At the start of the algorithm, when no vehicle has yet been loaded, the contour line consists of the two sides and the stern edge of the craft cargo area; therefore, the entire cargo area is the nook under consideration. The largest vehicle available for loading is placed in the craft, establishing a new contour line. This new contour line is then scanned for the nook closest to the stern of the craft (arrow). The largest remaining unloaded vehicle that will fit in this nook is loaded there, and another new contour line is formed. If no remaining vehicle will fit, the nook is eliminated by recording it as filled in. This process is repeated until all vehicles are loaded or all nooks have been filled in, leaving the craft with no remaining unloaded space.

The loading maxim dictates that at any step in the loading process, we must look for the nook closest to the stern of the craft and place in it the largest remaining unloaded vehicle that will fit there. The effect of this maxim is to load large vehicles first, but at the same time to maintain an even "forward contour" of the loaded vehicles and not block off small spaces that could be used by small vehicles.

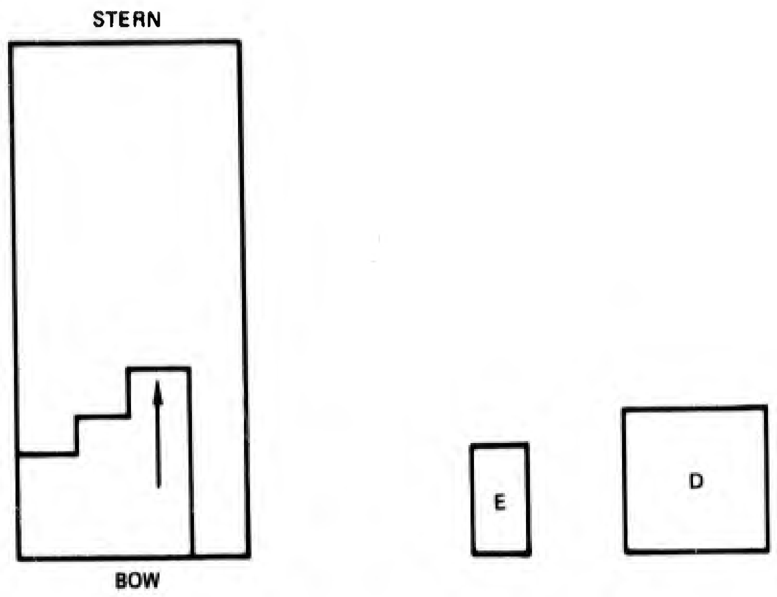
Load Size Criterion. For purposes of this routine, a vehicle's "largeness" is determined by its perimeter. Thus, the vehicle's perimeter is the primary loading priority criterion. We selected perimeter rather than length, width, area, or weight, because it is the single measure that reflects the premium on loading "outsized" or odd-shaped objects in a confining space. A long, thin vehicle will often be more of a loading problem than a more nearly square vehicle with a larger area; therefore, we would like to load the long vehicle before its more reasonably shaped companion. If, for example, the size criterion were area, the loading procedure would tend to pass over such "difficult loaders" until it was too late to fit them into the craft.

Special Features. Applied blindly, the loading maxim can sometimes produce load configurations that do not make efficient use of the cargo space in a craft. The most important problems concern long and thin vehicles and the handling of shallow nooks.

Using perimeter as a loading-priority criterion by itself will produce inefficient loads, but these can be avoided by a simple look-ahead procedure. Suppose, in accordance with the loading maxim, we have loaded vehicle A (the largest, by perimeter) into the landing craft as shown in "a" below. The largest remaining vehicle, B, is short and wide; the next largest, C, is long and thin. Following the loading maximum, the next step is to load vehicle B in the nook alongside vehicle A, but then vehicle C will not fit anywhere in the unloaded space in the craft (see "b"). However, if we load vehicle C rather than B in the nook next to A, vehicle B will fit in the remaining space (see "c"); thus, by looking ahead and juggling vehicle priorities a little, we can load all three vehicles rather than just two of them. In this illustration, the increase in loading efficiency (measured by the ratio of total area of vehicles loaded to total area of craft cargo space) is substantial.



By concentrating on nooks, it is possible, particularly in the case of shallow nooks, to load a small vehicle in the nook and thereby preclude the largest remaining vehicle. Suppose a contour line has the form shown below with the nook under consideration indicated by the arrow. The largest remaining vehicle is vehicle D, and the largest remaining vehicle that will fit in the nook is vehicle E. If vehicle E is loaded in the nook, however, vehicle D will not fit anywhere in the unloaded space of the craft. The nook will have been loaded at the expense of drastically obstructing the unloaded space of the craft. Undesirable results such as these can also be avoided by a look-ahead feature. If loading a vehicle in a nook will preclude loading the largest remaining vehicle at all, the second largest vehicle that fits in the nook is checked, then the third largest and so forth. If no vehicle can be loaded in the nook without precluding the largest remaining vehicle, the nook is assumed to be filled in.



To maintain the trim of the craft, vehicles are divided into two classes by a weight cutoff parameter (which can be varied). All vehicles heavier than the value of this parameter are considered first and loaded into the stern of the craft before any lighter vehicles are loaded. This device is intended to approximate the requirements for balancing the load in present-day craft. More sophisticated trimming rules may have to be programmed specifically for advanced craft when their trim requirements become known.

Marine Corps practice imposes two additional special features for the loading rules. First, wherever possible, trailers should be loaded behind their prime movers. Second, wheeled vehicles should not be loaded in front of tracked vehicles. Both of these rules are intended to avoid bottlenecks in unloading at the beach. Our loading procedure has incorporated these rules. The first rule is incorporated by combining trailers with their prime movers into a single "supervehicle" for loading purposes. The second rule is applied by loading wheeled vehicles in the stern before considering tracked vehicles and by considering the space in front of tracked vehicles off-limits for wheeled vehicles.

PREBOAT

The PREBOAT program is a combination of the CSR and FIT routines with the added constraint that only a specified number of craft of each type may be loaded. It was written by SRI to load the preboated serials of the Marine force realistically onto landing craft and to provide information about these loads that can be used directly as input to the STS-2 model.

The input to PREBOAT consists of the pertinent characteristics of the craft types in the mix, the number of each craft type that are available, the serialized force to be loaded on craft, and acceptable utilization factors for each craft type. The program works on one serial at a time in the order in which they are introduced, and for each serial it generates a set of landing craft that are loaded with the components of that serial. This process continues until there are no more serials to be loaded or the specified mix of craft has been exhausted.

Selection of a craft for a particular load proceeds as follows. The set of vehicles available for the load consists of those vehicles in the serial that have not yet been loaded. The first test is to check whether there are any craft remaining to be loaded. If there are none, the program summarizes and provides as output all previous information and then terminates itself. Otherwise, it checks to see if any large craft are available for loading. If the answer is no, it will ask the same question about medium craft. If there are large craft available, the dimensional fitting routine (FIT) is used to select a large craft load from among the remaining vehicles in the serial.

When the load is complete, the area utilization of the craft (e.g., the percentage of the available area in the craft occupied by the load) is checked against the desired utilization factor. If the load utilization of the craft area equals or exceeds the desired utilization factor, it is accepted, and all vehicles in the load are marked as unavailable for future loading. The vehicle load is written on a disk file, and the number of large craft available is decreased by one. A summary of the craft load is also printed. The process is then repeated by trying to form another large craft load using the unloaded vehicles in the serial. If all vehicles in the serial have been loaded, a serial data entry is written on the disk, and the program selects the next serial to repeat the process. When all craft have been loaded, the summary and output routine is used and processing is terminated.

If no large craft are available or if the desired utilization is not achieved with a large craft load, the routine checks to see if there are any medium craft available. If there are, the program will try to find an acceptable load for the medium craft. If an acceptable load is found, the acceptance procedure is executed. If an acceptable load cannot be found for a medium craft, a small craft load is tested. For all PREBOAT runs, the small craft utilization factor is set at 1 percent so that a serial cannot be rejected from all craft types. However, if the largest remaining vehicle or piece of equipment cannot fit in a small craft, the program will accept the best available medium craft load. Similarly, if it will not fit into a medium craft, the best large craft load will be accepted.

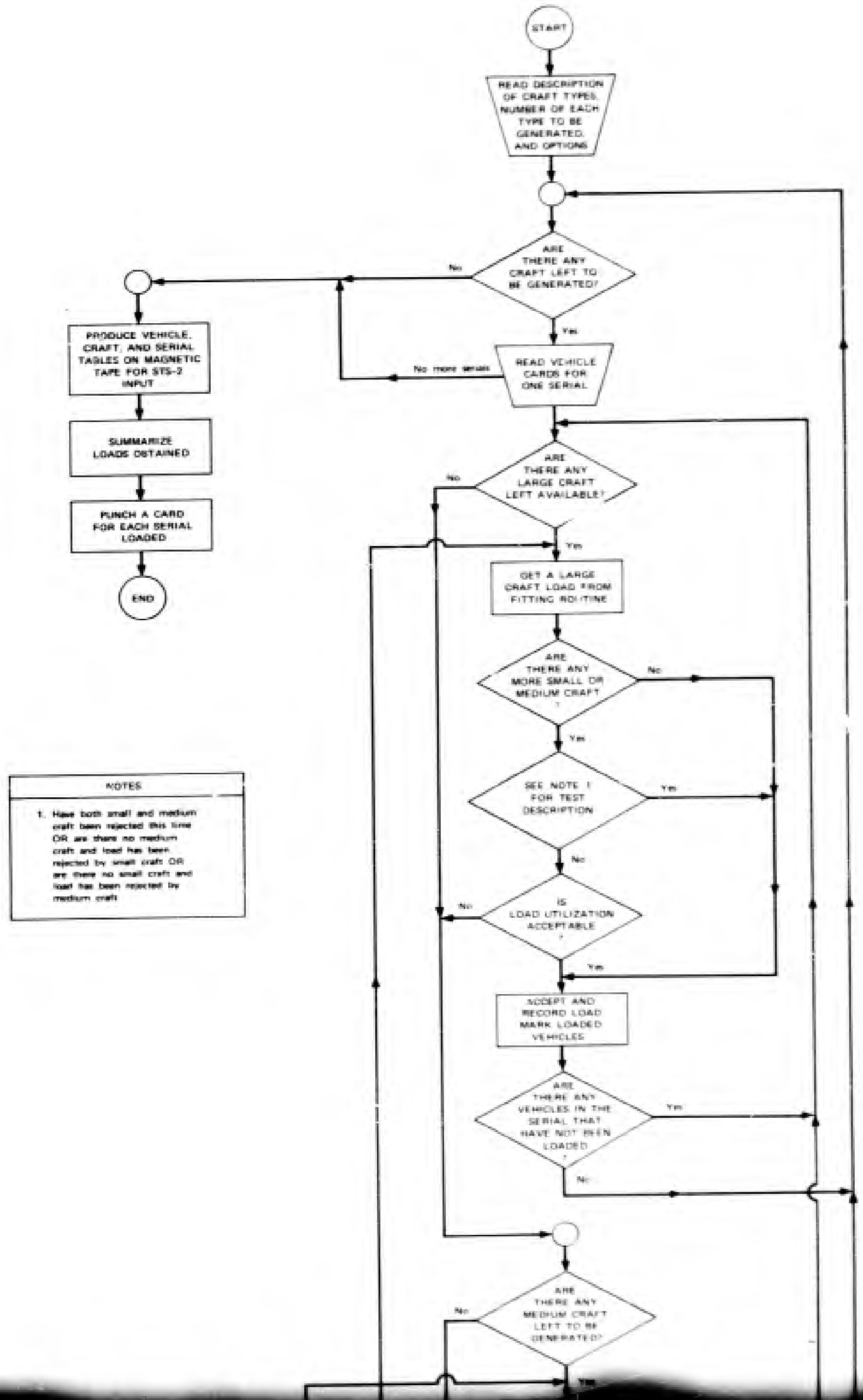
When the program is terminated, a final summary is prepared by reading the information from the disk files (on craft, vehicles, and serials) and converting each of these files into a table of data on magnetic tape. This tape is a set of STS-2 tables which must be combined with other STS-2 input. The printout of craft loads is also available.

An abbreviated flow chart of the PREBOAT model is shown in Figure 5.

EMBARK

The EMBARK program loads all of the nonpreboated serials in the Marine force into the amphibious ships. It maintains serial and tactical unit integrity by loading all vehicles and equipment of a serial or tactical unit into the same ship. Preferences for ship type and hull number are satisfied where specified for individual tactical units. Restrictions as to height, weight, and cargo type are also recognized for each cargo space where specified. For example, heavy loads are excluded from the mezzanine and superdecks of LSDs. Height restricts the vehicles that can be placed in an LPD's lower vehicle storage area, and only palletized cargo can be placed in an LPD's cargo storage areas. In LKAs, separate storage areas are designated for ammunition and POL. Individual ships are loaded to their volume or weight limitation, whichever is reached first. Marine force serials are assigned to ships in the order in which they are to be off-loading. Sequential serials are assigned to different ships to spread the load among the ships of the fleet to avoid concentrating high priority serials on one or a few ships and to provide as many simultaneous loading stations for landing craft as possible.

The program selects the ship type and particular ship number specified on the serial header card. If no ship type is specified, EMBARK selects the ship type on a rotational basis trying all ships of one type before continuing to the next type. Within ship types the ship with the largest unfilled cargo area is tried first.



NOTES

1. Have both small and medium craft been rejected this time OR are there no medium craft and load has been rejected by small craft OR are there no small craft and load has been rejected by medium craft

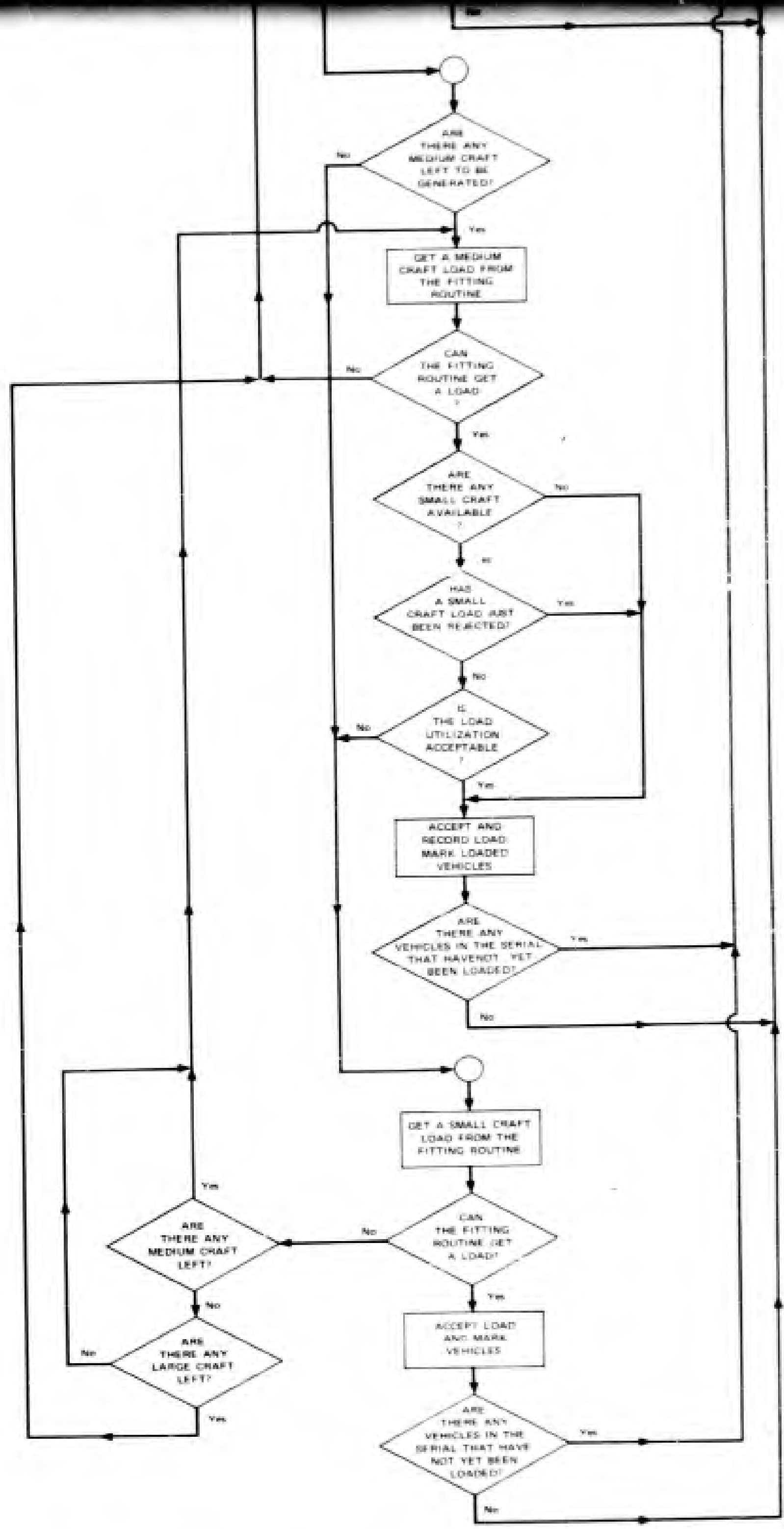


Figure 5 PREBOAT FLOW CHART

2

The vehicles of the serial are loaded in the order in which they appear, one vehicle at a time. If the vehicle can be loaded, the available area and weight is reduced by the area and weight of that vehicle and the next vehicle is tried. If the entire serial can be accommodated, the load is accepted and the next serial is considered. If the entire serial cannot be accepted on the basis of area or weight, another ship type is tried. All cargo is treated as palletized. Pallets are normally stacked two high in cargo spaces. Because of the requirements of the STS-2 model, cargo in the general unloading phase of the assault is given the special treatment described below.

EMBARK does not assign vehicles to specific locations in cargo spaces, nor does it dimensionally fit vehicles into those spaces. Such detail would unduly complicate the model and it would add little information of consequence to landing craft operations. Rather, EMBARK reduces the area of each cargo space by a broken stowage factor that reflects the size and shape of the cargo space and the number and arrangement of obstructions. The broken stowage factors also reflect the requirements for issue loading.* Vehicles are assumed able to move into position for craft loading except on LKAs where their movements are severely restricted.

Different embarkation schemes are used for well type (e.g., LPD, LSD) and hold type (e.g., LKA, LPA) ships. In well type ships, landing craft loading takes place in the well.† The number of craft that can be loaded simultaneously depends on the number that can enter the well abreast. Landing craft enter the well either wholly or partly or they may ground out against the ship's stern gate. Vehicles are driven from storage spaces directly into the landing craft. Cargo is loaded into craft from overhead by shipborne handling equipment.

In hold-type ships, vehicles and cargo are loaded over the side into craft that are alongside. However, the convention used, as dictated by the logical structure of STS-2, does not recognize the fact that large

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* By issue loading, we mean that a ship must be so loaded that it can issue its cargo in any order requested, not necessarily in the reverse order of loading.

† Side port loading from LPD and other well-type craft has not been used in the simulations because it is restricted to pallets; it is inefficient and it degrades simultaneous loading of craft in the well.

craft like LCUs can be simultaneously loaded from two holds. Consistent with normal operating practices, craft are not shifted from hold to hold. Thus, two goals are introduced. First, it is desirable to put an integral number of a serial's craft loads into each hold, and second, it is desirable to make as many loading stations available as there are craft loads. These two goals are incompatible, particularly when the craft sizes to be loaded at each station are not specified. The EMBARK procedure is a compromise between the goals. An algorithm in the program establishes a procedure for concentrating enough vehicles in a single hold for at least one efficient landing craft load and distribution of the vehicles of a large serial among the holds. Palletized cargo is not a problem because each hold is filled with palletized cargo after the vehicles are loaded and all of the cargo in the hold is treated as a single serial.

The input data requirements for EMBARK are listed in Table 3. Note that many of the input data are not used in EMBARK but are passed from the Marine Force Description Model through EMBARK to the STS-2 model. The output data are listed in Table 4. A more detailed description of the program procedures follows.

Table 3

EMBARK INPUT REQUIREMENTS

General Information Cards

1. Number of preboated serial cards to be read.
2. Preboated serial numbers.
3. Time to initiate game (in our runs "1" is used).
4. Number of vehicles required to be in a serial or tactical unit for loading in one, two, three, or four holds of an LKA.

Case Card

1. Case name.
2. Indicator specifying if preboat optional serials are to be preboated or loaded in vessels. (In our runs, all preboat optional serials are loaded into vessels if not preboated in the preboat run).

Ship Card

1. Ship type (LPD, LSD-S, LSD, LKA, LPH, LHA, LST).
2. Ship description.
3. Maximum vehicle height (restricted area), in feet.
4. Maximum vehicle weight (restricted area), in feet.
5. Square feet of cargo space available and utilization factors for six spaces as follows:

	Ship Type						
Space	LPD	LSD-S*	LSD-C†	LKA	LPH	LST	LHA
1		Super	Super	Veh & GC	Veh	-	-
2	LV	-	Mezz.	-	-	Main	LV
3	UV	-	Well	-	-	Tank	UV
4	GC	-	-	-	GC	-	GC
5	Ammo	-	-	Ammo	Ammo	-	Ammo
6	POL	-	-	POL	POL	-	POL

* LSD without mezzanine deck.
† LSD with mezzanine deck.
GC - General Cargo.

6. Number of ships of this type (more than one card for a given ship type with different characteristics can be read in.)

Wave Header Card

This card is placed in front of the serials in assault or scheduled waves.

1. Wave number.
2. Critical time (time at which assault or scheduled waves are to hit the beach).
3. Beach number.

Landing Sequence Table Card

This card is placed in front of the nonscheduled and on-call serials:

1. Time interval between nonscheduled and on-call serials.
2. Peach number.

On-Call Locator Card

This card is placed in front of each on-call serial and identifies the serial as such.

1. Beach number.

Serial Header Card

This card is placed in front of the components comprising a serial.

1. Serial number.
2. Type of serial (vehicle only, personnel, cargo, and vehicle and personnel).
3. How loaded (preboat definite, preboat optional, load on assault shipping, air unit [load on LPH, LHA or otherwise LPD], surface unit [load on LHA, LPD, LSD, or LKA in that order; can only go on a LST if it is made a tactical unit and preferred ship type is specified as LST]).
4. Element name.
5. Tactical unit number (if 0 load serial independently; if greater than 0, load serial as part of tactical unit.)

Table 3 (concluded)

6. Preferred ship type (use only for tactical units).
7. Preferred hull number (use only for tactical units).

Vehicle Serial Card

1. Serial number.
2. Vehicle number.
3. Vehicle type (wheeled prime mover, no trailer; tracked prime mover, no trailer; wheeled prime mover with trailer; tracked prime mover with trailer; towed trailer; untowed trailer).
4. Vehicle description.
5. Length, width, and height in feet.
6. Weight in pounds.
7. Availability of vehicle for supply runs ashore.

Cargo Serial Card

1. Serial number.
2. Category of cargo (palletized ammo, palletized general cargo, palletized POL, special cargo).
3. Special cargo flag (stow SATS matting 2-pallets high; all other special cargo is treated as and loaded as an untowed trailer).
4. Number of pallets or items of cargo.
5. Unit length, width, and height in feet.
6. Unit weight in pounds.
7. Description (optional).

Personnel Serial Card

1. Serial number.
2. Number of personnel.

General Unloading Card

This card indicates that all nonscheduled or on-call serials have been loaded and that the serials following are general unloading serials.

End Special Cargo

This card indicates that all special cargo general unloading serials have been loaded and that only ammo, POL, and general cargo general unloading serials remain to be loaded.

Table 4

EMBARK OUTPUTS*

Printed Output

The following information is printed out:

1. The serial numbers of preboated serials.
2. A table showing the ships used and pertinent characteristics such as maximum vehicle heights and weights in restricted areas, and the square footage and utilization factors by area.
3. For each numbered serial or special cargo serial:
   a. The serial number.
   b. The tactical unit number.
   c. The ship type and hull number in which loaded.
   d. The wave number.
   e. The beach number.
   f. The scheduled loading and beaching time.
   g. The loading category (scheduled, on-call, nonscheduled, or general unloading).
   h. A list and description of the items contained in the serial.
4. For ammunition, POL, and general cargo in general unloading, the ship type and hull number, and the number of pallets loaded.
5. A table showing the square foot utilization of each area for each ship in the force.
6. A listing of the magnetic tape output.

Magnetic Tape Output

A magnetic tape is produced for input to program REVISER, which produces the following tables for input to the STS-2 model:

1. Serial table
2. Mobile logistics table
3. Vehicle table
4. Serial composition table

Punched Card Output

The area and weights remaining after the completion of a run are punched on cards for each vessel in the force. This permits running part of the force through the program and restarting the program when it is desired to process the rest of the force.

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* EMBARK prepares three kinds of output: printed, magnetic tape, and punched card output.

Program Procedures

1. The program first reads the general information case card. The data contained in these cards are simply stored in memory.

2. The ship cards are read in, and the actual area (in square feet) available for stowing vehicles, general cargo, ammunition, and POL in each hull number of each ship type is computed by multiplying the total area available for each area type by the appropriate utilization factor.

3. The next card is a landing sequence table card that precedes all the nonscheduled and on-call serials. The purpose of this card is to signify the end of the processing of serials in scheduled waves and to indicate the beginning of serials that are in nonscheduled waves. The time interval between nonscheduled waves is also set by this card.

4. A serial header card is read, and a single serial or tactical unit composed of one or more serials is read into memory. A tactical unit or a serial must be loaded onto the same ship. As far as the program is concerned a tactical unit can be regarded as a large serial. However, a preferred ship type must be specified for a tactical unit. Optionally, a hull number of the preferred ship type may also be specified.

5. Loading nonscheduled serials

   a. Vehicle serials

      An internal counter records the number of vehicles in a serial as the serial components are read into memory. This counter is used as an index for vehicle characteristics. If a tactical unit is being loaded, the number of serials in the tactical unit is calculated and each serial in the tactical unit is treated independently.

      i. Tactical unit

         - Hull number specified--The program first tries to load the tactical unit on the specified hull number. If it cannot do this, it then tries the hull number of the preferred ship type having the largest area available for loading vehicles. If the tactical unit cannot be loaded on this second ship, it is rejected.

- Only preferred ship type specified--the program attempts to load the tactical unit on the hull number of the preferred ship type having the largest area available. If the program cannot do this, the tactical unit is rejected.

ii. Ordinary vehicle serial

The program attempts to load the serial on the hull number of the ship having the largest area available for loading vehicles in the following order: LSD-S, LSD-C,* LPD, LHA, LST, and LKA. If the serial cannot be loaded aboard any of these ships, it is rejected. If the serial is an air unit, the program uses the following sequence of ships: LPH, LHA, and LPD. If the air unit cannot be loaded in any of these ships, it is rejected.

- In attempting to load a serial or tactical unit, the procedure used for all ship types except hold types is: For ships other than LST and the LSD-S,* the vehicle is checked to see if it is towing a trailer. If so, the areas and weights of the two are summed, and the governing height (the maximum of the towing or towed vehicles) is determined. For the LST and the LSD-S, the weight and height of each vehicle are considered separately because the weight restrictions on these ships are based on maximum deck loads rather than ramp loads. If the weight and height of the vehicle (or vehicle and towed trailer) are less than the maximum permitted for loading in the restricted space of the ship, the spaces selected to load the vehicle are:

Ship	Space
LPD	Lower vehicle storage
LSD-S	--
LSD-C	Mezzanine deck
LPH	--
LST	Main deck
LHA	Lower vehicle storage

* By our designation, an LSD-S is an LSD without a mezzanine deck; an LSD-C is an LSD with a mezzanine deck.

- As vehicles are loaded, the area and weight remaining in each space is recomputed. If insufficient area or weight remains to load a vehicle or the height or weight restrictions are not met, the spaces selected to load the vehicle are:

Ship	Space
LPD	Upper vehicle storage
LSD-S	Superdeck
LSD-C	Superdeck then the well deck
LPH	Vehicle storage
LST	Tank deck
LHA	Upper vehicle storage

- If a serial cannot be loaded in a given vessel type because of lack of available area, the program attempts to load it in the next vessel type as previously described. If the serial cannot be loaded on any of the vessel types, it is rejected.

● In the case of hold type ships, no height or weight restrictions are applied. The program computes the total area of the vehicles in the serial, and if this area is not greater than the area available, the serial is loaded; if not, it is rejected.

If a serial is loaded, the hold in which each vehicle is stowed is recorded. A serial will normally be assigned to one or more holds in accordance with the following:

- If a serial contains 100 or fewer vehicles or special cargo items, it is assumed to be loaded into one hold; for 101 to 200 into two holds; for 201 to 300 into three holds, for 301 to 400 into four holds, and for more than 400 into five holds. Approximately the same number of vehicles in a serial are loaded into each hold used.

- The program "remembers" the last hold used so that the next time a specific hull type ship is being loaded, the next hold is assumed to be used (if the last hold loaded was hold No. 5, the program cycles back to Hold No. 1).

b. Cargo serials

A cargo serial is made up of one or more types of cargo--ammunition, POL, general cargo, or special cargo. In most ship types, separate spaces are designated for ammunition and POL. The model recognizes these limitations and will not mix cargo. Where excessive space is available for ammunition or POL, the space is redesignated before the run to permit its use for general cargo.

Cargo serials may be mixed with vehicle or personnel serials to form tactical units, but two or more cargo serials cannot constitute a tactical unit by themselves. Tactical units are permitted it is is desired to specify a preferred vessel type, but the tactical unit can contain only one cargo serial made up of only one type of cargo (ammunition, POL, general cargo, or special cargo).

i. Tactical unit

- Hull number specified--The program first tries to load the tactical unit on the specified hull numbers. If it cannot do this, it then tries the hull number of the preferred ship type with the largest area available for the type of cargo being loaded. If the tactical unit cannot be loaded on this hull number, it is rejected.

- Only preferred ship type specified--The program attempts to load the tactical unit on the hull number of the preferred ship type with the largest area available for the type of cargo being loaded. If the tactical unit cannot be loaded, it is rejected.

ii. Ordinary cargo serials

- Ammunition, POL, or general cargo--The program attempts to load the serial on the hull number of the ship with the largest area available for the type of cargo being loaded in the following order: LPD, LHA, and AKA. If the serial cannot be loaded aboard any of these ship types, it is rejected. If the serial is an air unit, the program uses the following sequence of ships: LPH, LHA, and LPD. If the air unit cannot be loaded in any of these ship types, it is rejected.

  In loading ammunition, POL, or general cargo in the assault phase, the following procedure is used:

  - The area required to stow the palletized cargo two high is calculated and compared with the area available in the ship.

  - If a serial cannot be loaded in any of the ship types, it is rejected. An area of 18 square feet per pallet is assumed (4.5 feet x 4.0 feet, allowing for overhang). If a serial is loaded, the spaces in which the cargo is stowed are recorded. One space for ammunition, one space for POL, and one space for general cargo are allocated for stowage on the LPD, LHA, and LPH. In addition, general cargo can be loaded into the lower vehicle storage area on an LPD. No ammunition, general cargo, or POL can be stowed on LSD-Ss, the LSD-Cs, or LSTs. On LKAs, ammunition and POL can be stowed in up to two locations (Holds numbers 1 and 2) and general cargo into up to four locations (Holds numbers 1, 2, 3, and 4).

- Special cargo--The program first attempts to load special cargo on the LST with the largest area available for special cargo and, if it cannot, it attempts to load the serial aboard the LKA with the largest area available for special cargo. If the special cargo serial cannot be loaded on an LKA, it is rejected.

In loading special cargo in the assault phase on an LST, the following procedure is used:

- Depending on the type of special cargo, it is determined whether it can be stowed in two tiers. Then the area required to stow the special cargo (either one tier or two tiers high) is computed. Each special cargo item is checked to see whether it meets the maximum weight and height restrictions associated with loading the item on the main deck. If this test is passed, a check is made to see if sufficient area and weight capacity remain on the main deck in which case it is stowed there. If the maximum weight and height restrictions are not met or if sufficient area or weight capacity do not exist on the main deck, an attempt is made to load the special cargo item on the tank deck. If sufficient area and weight capacity do not exist, an attempt is made to load the special cargo serial on an LKA.

- In loading special cargo on an LKA during the assault phase, the procedure employed is to check to see if it can be stowed in two tiers, and then compute the area required to stow all the special cargo items in the serial. No weight or height restrictions are applied. If the area required to stow the special cargo serial is less than the area available on the LKA with the maximum available area, it is loaded. If not, it is rejected. If it is loaded, the area in which the special cargo is stowed is recorded. The stowage location may be in one or more of the Holds Numbers 1, 2, 3, 4, or 5 in the same manner as for vehicles.

c. Personnel serials

Personnel may be treated as part of a vehicle serial in the assault phase. In this case, the personnel are placed aboard the same vessel as the serial. However, a serial may be composed solely of personnel in which case the serial is loaded aboard either an LHA or LPD. Personnel serials that are air units are always loaded aboard an LPH.

6. General unloading

The general unloading portion of the assault is made up almost entirely of nonserialized special cargo, ammunition, POL, and general cargo. Special cargo is loaded in the same manner used for the assault phase. However, ammunition, general cargo, and POL are loaded in a different manner. The program simply fills up the ammunition space, POL space, and general cargo spaces of the LPD, LHA, and LKA in that order and records the area in each ship in which cargo is stowed. For the LPD and LHA, one area is allotted for stowing ammunition, POL, and general cargo. For an LKA, general cargo may be stowed in one or more of Holds Numbers 1, 2, 3, and 4.

Run Procedures

Several trials are generally needed to produce an EMBARK run that does not reject any serials. Ship preferences must be balanced; and the number of ships in the fleet must be sufficient to hold the force without leaving large amounts of unused space. The stowage of LVTs for the scheduled waves must be compatible with the overall requirements of the embarkation scheme. Finally, the appropriate serials must have been removed for preloading into landing craft. After some experience, we find that minor changes can generally be accommodated with a single additional EMBARK run. Major changes typically require three runs before all of the inconsistencies can be eliminated.

REVISER

As originally conceived, the output from EMBARK would be introduced directly into the STS-2 program. However, as EMBARK was developed and STS-2 was modified, an increasing number of gaps occurred between the two. In addition, we found that the running time for STS-2 was substantially longer than originally expected--two hours for an assault phase and six to eight hours for a general unloading phase. Therefore, to eliminate time-consuming hand input preparation and to ensure successful STS-2 runs, the REVISER program was prepared at SRI. This program adds no new information to the simulations and thus it will not be described in detail. The output of REVISER is a single magnetic tape that contains all of the EMBARK information needed for an STS-2 run.

MERGER

After EMBARK, REVISER, and PREBOAT have been run and the hand input has been prepared, the input for STS-2 consists of two magnetic tapes and a deck of cards. To simplify the processing at NWL Dahlgren and also to reduce the amount of physical material transmitted by mail, MERGER was constructed at SRI to combine all of the input and write it on one reel of magnetic tape. This tape includes the control cards required to run on the IBM 7030 and therefore can be used without modification by the 7030 to run STS-2.

Ship-to-Shore Simulation (STS-2)

The conventional form of the STS-2 model has been described in two technical memoranda* and will be repeated here only as necessary to understand the structure of the modified version. The principal modifications to STS-2 for the landing craft program include introducing the CSR and FIT routines to select craft and load each individual serial and expanding the simulation to include movement of vehicles and cargo across the beach and to the first inland destination.

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* O. F. Braxton, "The Ship-to-Shore Model (STS-2) Users Guide," TMK-26164, NWL Dahlgren, Virginia, June 1964, and O. F. Braxton, "The Ship-to-Shore Model," NWL Report 1904 (U), Dahlgren, Virginia.

STS-2 is programmed in STRAP, the machine language for NWL's IBM 7030 STRECH digital computer. The program is a discrete time interval, next event type of digital simulation. All input, output, and internally produced data is organized in the form of tables. The model uses a set of events, each of which is a collection of computer instructions, and this set of tables, which contain the data necessary to define the state of the simulated landing. As simulated time advances, the events change the information stored in the tables to reflect changes in the amphibious operation.

The mechanism by which changes are made in the state of the simulation variables is with the use of a future events table. This table is a list of events that are scheduled to change the status of one or more system components. Each entry in the table contains data for one event. The entries are ordered so that the next event to occur is always first on the list. Thus, when the program completes one event, it looks for the first entry in the future events table, removes it from the table, and starts to operate according to the information about the event to be processed. Each entry carries a code to indicate the type of action required by the proper event and the data necessary to execute that action. During the processing of the event, one or more other events may be generated to occur at some future time or to occur subsequent to the current event at the same simulated time. New entries are made for these events at the appropriate location in the future events table, and processing of the current event continues. In this manner, the computer always has another event to work on as long as there are entries in the future events table.

STS-2 can be terminated in three ways. If the future events table is empty, the simulation terminates; however, this situation does not normally occur. More often the simulation is terminated by storing an entry for a termination event at the beginning of the program. The function of this entry is to terminate the program at the simulated time it is processed or by arranging to create a termination event when a certain condition occurs.

If, for example, the next event calls for a craft to depart the ship with a load and head for the beach, the routine executed for this event will store the craft utilization in the craft table. It will set an event that when processed indicates the craft has arrived at the LOD and it will compute the time that this event is to be processed by calculating the travel time based on distance to be traveled and the speed of the craft. An entry for this event is then made in the appropriate location in the future events table, and execution of the current event continues until complete.

All of the information required by the event subprograms to make computations, execute logical decisions, and update historical data is organized into tables. Physical entities such as ships, craft, vehicles, groups of personnel, and groups of palletized cargo are defined by entries in the appropriate tables. Tables also contain information on craft loading and unloading rates, the characteristics of each type of craft, attrition probabilities as a function of craft type and location, craft queueing rules, contents of beach dumps, and other information. A description of all tables used by STS-2 is provided in Appendix A.

In succeeding paragraphs, we describe the major events that relate to craft movements. The relationships among these events are shown schematically in Figure 6. There are also events that allow ship movements to simulate sea echelon unloading; however, these will not be described here. In the event descriptions, we attempt to explain how the program executes some events, the interrelationship among events, the contents of some of the tables, and some of the more important assumptions implicit in the operation of the STS-2 program. We do not provide complete flow charts of each event or complete descriptions of each table and its entries.

Serial Request Event

The serial request event selects the appropriate group of serials and enters them into the requested serial list. Serials become available in groups at intervals of 15 minutes. These serials are ordered by time of availability in the serial table. The serials already made available and not yet completely assigned constitute the list of available serials. On-call serials are given a priority and hence are actually at the top of the list as soon as they are called. The serial request event also performs some bookkeeping duties concerned with craft and serial history recorded for analytical purposes. The output of this event is a craft selection event for the purpose of assigning craft to land the serial.

Craft Selection Event

The craft selection event selects and assigns available craft to serials requiring movement to the beach. It can be initiated by the arrival of a craft from the beach or a newly available serial--i.e., one generated by the serial request event. A general flow diagram for this event is shown in **Figure 7.**

Some explanation of the terms used in the flow diagrams is included here for clarity. The selection of a craft type for part or all of a

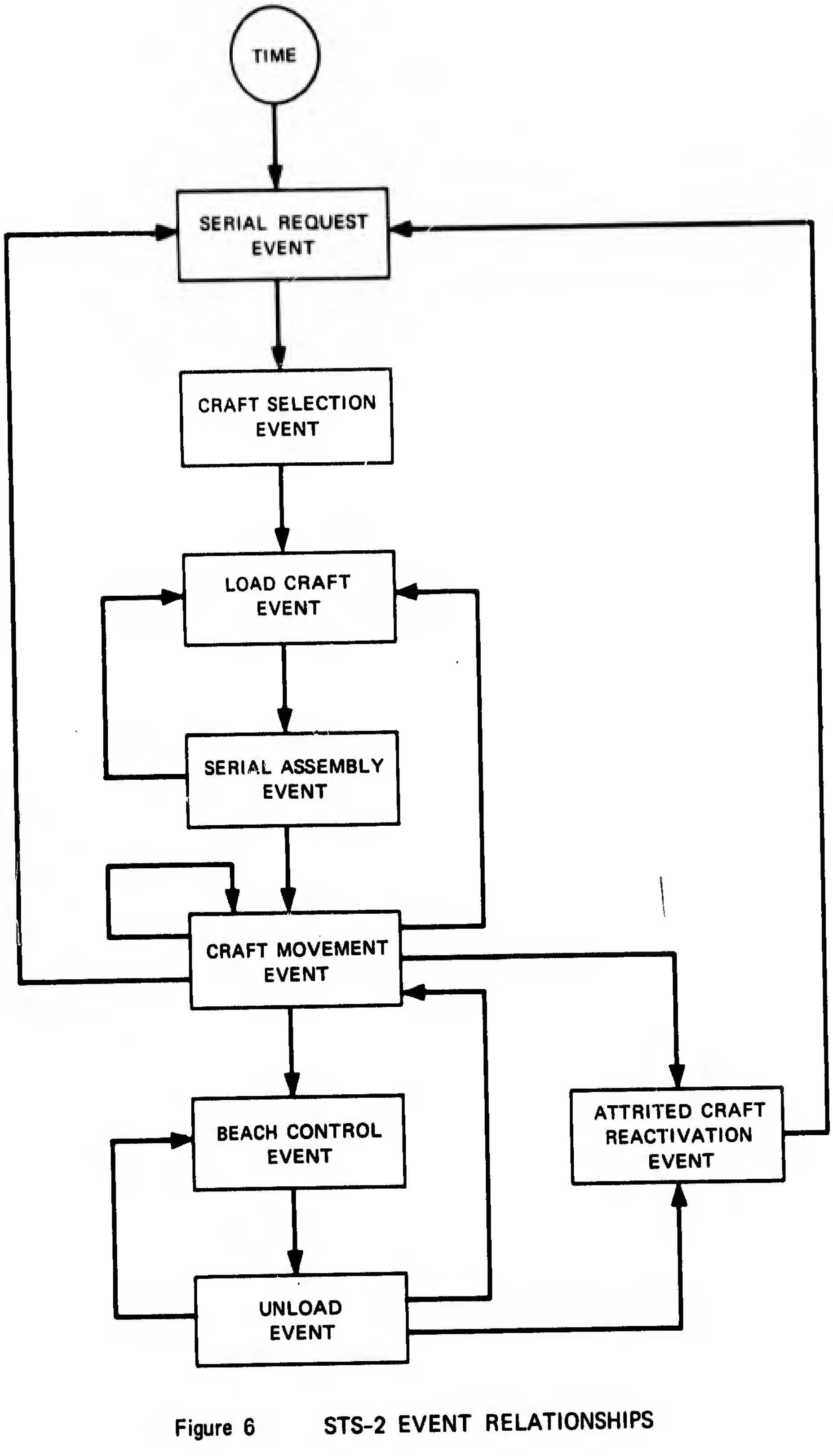

Figure 6 STS-2 EVENT RELATIONSHIPS

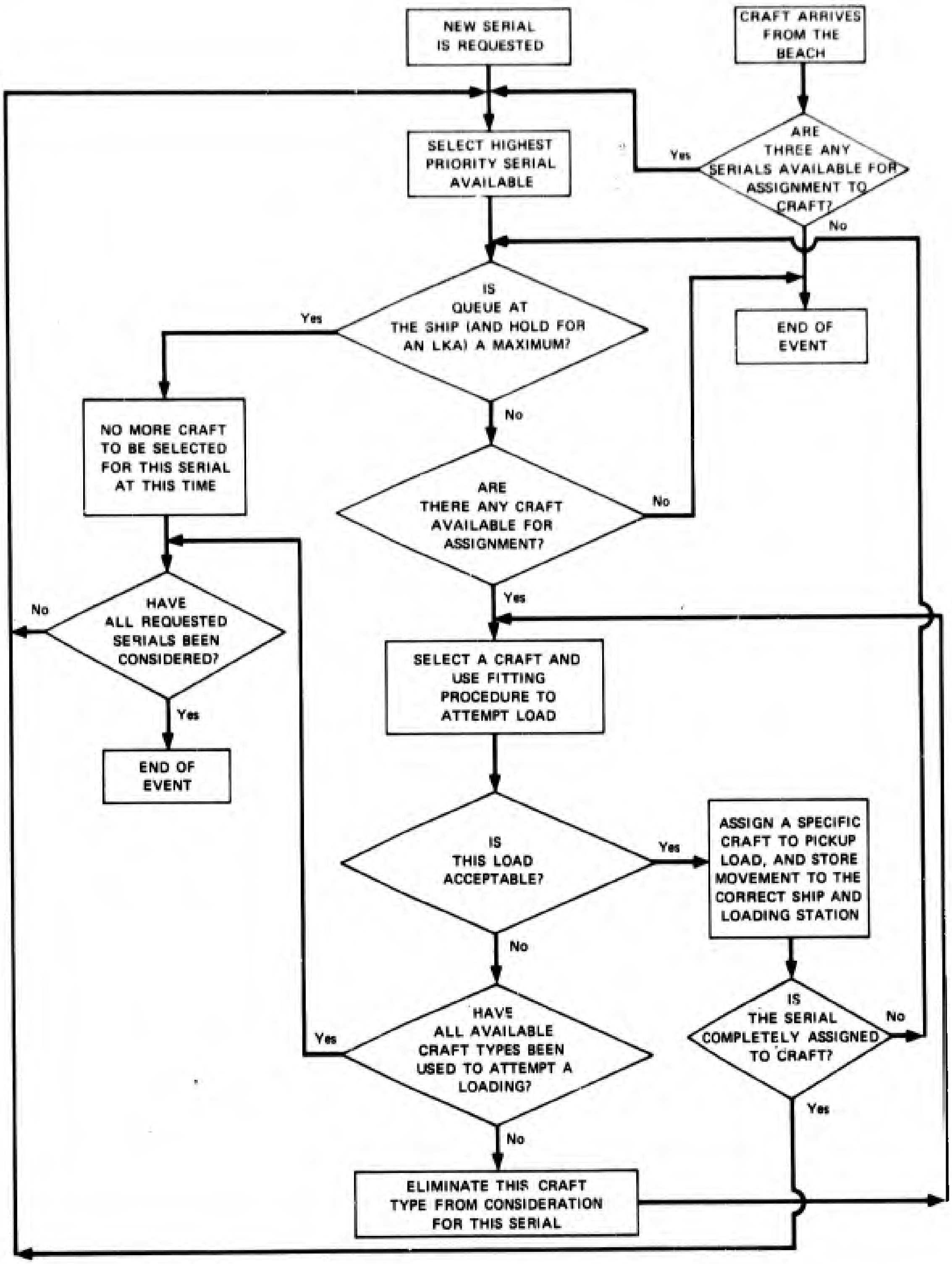

Figure 7 CRAFT SELECTION

particular serial is performed by an algorithm that considers serial priority; serial composition; serial embarkation; queue at the ship; craft characteristics such as speed, size, and amphibious capabilities; and unloading queue at the beach. The process is similar to the selection procedure outlined in the flow diagram of the PREBOAT computer program, except that no modification is made of the desired utilization for each craft. For palletized cargo, the dimensional fitting routine is bypassed and the desired craft is chosen on the basis of a ranking of preferred craft types for carrying cargo, a simplified fitting scheme is used to determine utilization, and the highest ranking craft meeting minimum utilization criteria is chosen. The ranking is an input to STS-2.

The craft selection event is similar to the CSR described earlier. However, it is modified to reflect the STS-2 operating environment in which the available craft are strictly limited in number and type. The term serial as used here also includes artificially constructed serials of general cargo. These artificial serials consist of all cargo of a type carried by a well-type ship and all cargo of a type in a single hold of a hold-type ship. Palletized cargo is not dimensionally fitted into craft as are vehicles, but rather each craft loads palletized cargo up to a specified maximum number of pallets of each type. The output of this event is a craft movement event which subsequently stores a load craft event.

Load Craft Event

The load craft event determines whether the desired hold at the ship is in use. If the hold is busy, the craft is placed in a queue. If the hold is available, the craft is assigned and the loading time is computed depending on the ship type, craft type, and size and type of load. For example, in a well deck ship, the loading time for a vehicular load is based on the craft type, the time required for this craft type to enter and leave the well, the size of the individual vehicles, whether there are trailers, and whether the craft is a drive through type. For hold-type ships, the loading time depends primarily on boom rates.

The output of this event is a serial assembly event.

Serial Assembly Event

The serial assembly event assigns the next craft in a queue to the load craft event when the preceding craft is completely loaded and the loaded craft is dispatched to the beach. On completion of loading by a craft at a ship, this event searches the list of craft waiting to load to determine if craft are waiting to load at the hold vacated and, if craft are waiting, selects the craft with the longest waiting time to begin loading. A load craft event is placed into the future events table at the same game time as the serial assembly event.

Craft containing a scheduled or on-call serial are dispatched to the beach to arrive no earlier than the desired landing time. Craft with a nonscheduled serial are sent directly to the beach when loading is completed. These craft movements are accomplished by storing a craft movement event in the future events table at the appropriate time.

Craft Movement Event

The functions of this event are to compute the point-to-point movement time for each craft and to place the next sequential event in the ship-to-shore movement process into the future event table at the appropriate future time. The travel time depends on the travel distance and the speed of the particular craft type being considered.

The next event in the sequence is based on where the craft is going. After assignment to a particular serial and ship, the craft moves to the ship, and the movement event stores a craft load event. On completion of the loading, a craft movement event is stored to move the craft from the ship to the LOD, and this event then stores a craft movement event to move the craft to the beach. The movement to the beach stores the beach control event. On completion of unloading at the beach, a craft movement event is stored to move the craft back to the LOD and this event then stores a craft assignment event to send the craft to a ship or to the boat pool. If attrition has occured an attrition assessment event is called to compute out-of-action time.

Attrition is assessed on the craft for the boat pool-to-ship and ship-to LOD legs of the trip and also for the LOD-to-beach and beach-to-LOD legs of the trip. The attrition assessment is accomplished by comparing the expected attrition probability of the particular craft type with a random number. A test is then made in the same manner using the probability of destruction given that attrition has occured.

Possible output events are craft movement, load craft, beach control, craft selection, and attrited craft reactivation.

Beach Control Event

The function of the beach control event is twofold. It operates in the first mode for craft arriving at the beach and in the second mode for craft that have completed unloading and are leaving the beach.

For craft arriving at the beach, the event first searches for a landing slot of the type appropriate to the load type aboard the craft. If no slot is available, the craft is entered into a list of craft waiting to unload and its time of arrival is recorded. If a slot of the desired type is available, the slot is marked as in use, the craft is marked as unloading, and an unload craft event is stored to perform the unloading process.

For craft leaving the beach, the event marks the vacated slot as available and searches the list of waiting craft for the next on-call serial. If no craft carrying an on-call serial is waiting, the craft with the maximum waiting time desiring this type of slot is selected. The event then records the cargo of the craft as landed, marks the craft as available, and stores a craft movement event to move the craft back into the available boat pool located at the LOD.

The output of this event is an unloaded event or a craft movement event.

Unload Craft Event

The unload craft event initiates craft unloading at or on the beach; it computes the time spent by the craft at the beach, and it decides whether there has been any damage to the craft while it is on the beach.

There are two different modes of operation for craft at the beach. Amphibious craft transit the waterline and travel to an unloading area at the rear of the beach. Their time at the beach begins when they first cross the waterline and ends when they recross it after unloading. For nonamphibious craft, time at the beach includes only the time to beach, unload, and retract.

The time spent unloading depends on the type of craft being unloaded and the composition of the craft load. For example, vehicles can be unloaded faster from an air cushion vehicle onto hard ground than from a beached craft into four feet of water followed by a ride over soft sand. The unload craft event accounts for these differences. It also provides different unloading rates for nonamphibious craft with different drafts such that they discharge their loads into different depths of water. Cargo vehicles and personnel are also unloaded at specified rates per item. For vehicles and personnel unloaded from the same craft, the unloading time of each is computed, the times are compared, and the longer of the two times is used as the unloading time of the craft. Cargo is unloaded directly into transport vehicles if there are any available; otherwise, it is placed on the beach to be picked up later. The cargo unloading time depends on the numbers of pallets unloaded by the different methods. Total unloading time is the sum of the individual unloading times for vehicles, cargo, and personnel and the time spent by the craft maneuvering at the beach before arriving and on departing.

The unload craft event considers whether a craft is damaged or destroyed at the beach and if damaged, the length of time it is out of action. To accomplish this, the event uses the input probability that each particular craft type will be damaged at the beach and a random number generator to decide which craft are damaged. If a craft is damaged, another random number is generated and then compared with the input probability of destruction or long term damage given that the craft has been damaged to decide if the craft is destroyed. If a craft is only temporarily out of action, an out-of-action time is computed using a uniform distribution whose maximum and minimum time are also input. When a nonamphibious craft is permanently out of action, its beached position is considered occupied long enough to remove the disabled craft from the unloading area. This time also is based on a uniform distribution whose maximum and minimum lengths are again input.

The events generated by this event are beach control, vehicle movement, and attrited craft reactivation.

STSTAPE

The STSTAPE program checks the output tapes from the STS-2 program for parity errors, determines the number of files on each tape, rearranges the data into a form convenient for editing and compresses the data by blocking to reduce tape length by a factor of six. The compression process reduces the likelihood of future parity errors and the number of tapes to be stored. The output tape becomes the permanent record of the run and will be stored through the end of the assault craft development program; thus if changes are made in the method of comparing craft mixes, all of the original output from the STS-2 model is available for use. The cost of holding these data in tape storage is very low when compared with the cost of repeating a single run.

STSEDIT

The STSEDIT program edits the data on the tape(s) produced by STSTAPE. The editing function consists of two types of operations on the data. Some data are merely copied onto printed output with only the addition of titles; other data are combined, summarized, used to create frequency distributions, and compiled into time histories.

It was our original intention to perform all editing on the IBM 7030 (STRETCH) as part of the STS-2 runs. However, the memory requirements for data manipulation when superimposed on the very large memory requirements for the STS-2 model exceeded the central memory capacity of the STRETCH machine. It then became necessary to fall back on use of the output tape as a source of STS-2 data. The resulting STSEDIT program has a longer running time than desired, but it represents the best alternative.

The necessity of handling STS-2 output with another computer rather than manually can best be illustrated by some sample STS-2 output (see Figure 8). Each line of STS-2 output represents one card image that consists of one physical record on magnetic tape. The card images appearing here are each one entry in the craft table. and each has information about a particular craft in the form of values for each of the 19 variables. Some 291 of these card images contain data on all of the landing craft in the base system run. These data are continuously updated by STS-2 as the simulation progresses. For the purpose of constructing a time history of the amphibious assault, this table is written onto tape at fixed time (simulated time) intervals. A typical assault phase STS-2 run has 30 complete craft tables written on the output tape, which means that there are 8,730 cards to examine, each of which has perhaps 10 significant variables. Thus, 87,300 pieces of data must be digested and summarized before any conclusions can be reached. In addition to the craft table, there are other tables to be analyzed, some longer than the craft table, but none more complicated to manipulate.

The output of STSEDIT is in two forms: printed output and punched card output. The punched cards duplicate some of the information in the printed output, but they are used by the PLOT program to prepare graphical presentations of the output.

PLOT

The PLOT program uses the punched cards produced by STSEDIT to prepare graphical displays of the STS-2 data on a CALCOMP 720 plotter. Cards are combined in a variety of ways to produce different graphs such as those presented in Chapter V. These graphs provide a basis for computation of some measures of effectiveness and also allow greater insight into what happened during the simulation.

```
12228 0 04747   504  760000000 11      0  0 0  0  0  0            C
12229 0 04747   496 1740300000 41      0  0 0  0  0  0            C
12230 0134047   614 1390000001 41      0  0 0  0  0  1            C
12231 0 04747   505  600000000 21      0  0 0  0  0  0            C
12232 0 04747   416 2770000000 51      0  0 0  0  0  0            C
12233 0134047   722 1060000001 31      0  0 0  0  0  0            C
12234 0 04747   423 2820000000 71      0  0 0  0  0  2            C
1223519 04545     0   00       2 01    0  0 0  0  0  0            C
12236 0 04747   435 2060000000 41      0  0 0  0  0  2            C
12237 0 04747   550 1720000000 51      0  0 0  0  0  1            C
12238 0 04747   405 1680000000 41      0  0 0  0  0  0            C
12239 0 04747   426 3070000000 61      0  0 0  0  0  0            C
12240 0 04747   313 2020000002 51      0  0 0  0  0  1            C
1224143 6 245    50  352 50702 01      0 52 2  0 65  0            C
12242 0 64047    90  750000002 11      0  0 0  0  0  0            C
        1         0                                              CA
1  0 43 17 14  0  0  0  0  0  0                                  CA
        1         0                                              BS
1  3197 40  0                                                    BS
        1         0                                              SC
1142973090   0    0    0    0    0    0    0    0    0    0      SC
   0    0    0    0    0    0    0    0    0    0    0         0SC
  0    0    0    0    0    0    0    0    0   0   0   0   0     0SC
 0   0   0   0   0    0    0    0    0    0    0    0    0      0SC
  0    0    0    0    0    0    0    0    0    0    0            SC
        1         0                                              CDT
  625    0  6533     0     0     0     0    0 17702    0  6712  CDT
   0 19169        0     0     0                                  CDT
        2         0                                              VP
1  10   0100002000030000400009999999999  540873     0.0      0.0VP
   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0 VP
   0.0   00                                                      VP
1  21  50100002000030000400009999999999    0  0     0.0      0.0VP
   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0 VP
   0.0   00                                                      TD
        1         0                                              TD
  0.00  0 2    0  -.0   0    0  0100 10
```

Figure 8 SAMPLE STS-2 OUTPUT

V BASELINE SYSTEM ANALYSIS

Background

The baseline system is defined as present-day craft operating in future amphibious assault environments. The present craft of interest include all of the craft listed in Table 5. Present-day craft do not include experimental craft that have not seen operational service or modifications to craft that have not been adopted, regardless of why they have not been adopted. Thus, LCVP(K), SKMR-1, LVHX 1 & 2, LVWX-2, and similar craft are not included in the analysis.

Three present-day craft, LARC-15, LARC-60, and LCA were set aside for future study. Both LARCs are wheeled amphibious craft developed by the Army for ship-to-shore movement in noncombat environments. Because their vulnerability is greater than that of landing craft, examination of them was deferred until more detailed information on relative craft attrition rates is available. Consideration of the LCA was also deferred until more information on vulnerability is available. Of the remaining present-day craft listed in Table 5, only the LCU 1610 class, the LCM-8 (steel hull), and the LCM-6 were used in the simulations. Other craft were excluded for reasons given in the table.

The simulations did not directly consider administrative and service functions that do not contribute to the ship-to-shore movement of men and materiel, but are essential to the conduct of an amphibious assault. These include wave guides, traffic control boats, salvage boats, marker boats, medical boats, causeway tenders and other boats for naval use. These functions, now performed by LCPL, LCVP, and LCM-6, and specialized craft, will have to be performed in future environments and may require the development of new small craft with high performance capability. However, it is not reasonable to speculate on the characteristics of these auxiliary craft at this time since their employment will depend heavily on the characteristics of the "work horse" logistic craft that are selected. For purposes of the baseline system analysis, space was provided aboard the amphibious ships to carry the auxiliary craft, and their use is assumed although not specifically simulated.

Table 5

PRESENT-DAY CRAFT

Designation	Pay-load (tons)	Water Speed (knots)	Amphibian	Selected for Simulation	Reason
LCVP	4	9.0	No	Naval use	
LCM-3	30	9.5	No	No	Superseded by LCM-6
LCM-6	34	9.0	No	Yes	
LCM-8 (steel)	60	9.0	No	Yes	
LCM-8 (aluminum)	60	9.0	No	No	Insufficient fleet units
LCU 501	180	5.0	No	No	Superseded by newer classes, too slow
LCU 1466	168	6.8	No	No	Too slow, superseded by newer classes
LCU 1610	180	11.0	No	Yes	
LCPL	2	17.0	No	Naval use	
PACV (SK-5)	1.5	60.0	Yes	No	Payload too small
DUKW	2.5	5.0	Yes	No	No vehicle carrying capability
LARC-5	5	7.0	Yes	Naval use	
LARC-15	15	8.0	Yes	No	Reserved for future analysis
LARC-60	60	6.0	Yes	No	Reserved for future analysis

Source: NSRDC Prior Craft Review.

The future environments are made up of 1975 era MEFs (as described in Chapter IV), 1975 shipping,* and a series of estimated threats and landing plans. In the ship-to-shore movement, present-day landing craft are supported by LVTs and CH46 and CH53 helicopters. The LVTs carry all of the initial surface assault personnel for those landing plans where only one RLT is delivered over the beach and about half of the surface assault personnel when two RLTs are delivered over the beach. Helicopters carry all of the vertical assault troops, vehicles, and cargo and assist in the general unloading of cargo.

The individual amphibious assaults are divided into assault and general unloading phases. During the assault phase, for all practical purposes, only vehicles and personnel are landed on the beach. All cargo coming ashore during this phase is mobile loaded in vehicles and does not need to be handled or unloaded at the beach. The assault phase ends when all of the serialized cargo has been unloaded. However, for efficient use of landing craft, it is expedient to begin general unloading while some serialized cargo remains to be unloaded. In the baseline system analysis, we arbitrarily specified that general unloading begins when half of the landing craft are idle because there are no assault serials available for their assignment. When general unloading begins, all of the palletized cargo loaded on the ships of amphibious fleet is available for transfer to landing craft. However, assault vehicle and personnel serials are given priority over general cargo at all times. Because of its long running time (6 to 8 hours on the IBM 7030 computer) general unloading was not simulated for runs where differences between runs were slight and the additional information appeared to be marginal.

The baseline system analysis had two objectives: (1) to determine those critical amphibious assault parameters that have the greatest impact on the measures of landing effectiveness and (2) to establish a reference performance for use in evaluating advanced craft. The critical assault parameters are used to design sets of runs for comparing advanced craft designs (see Chapter VI). In one instance--stand-off distance--we found that the number of runs could be reduced by developing an analytical technique for estimating the results of changes. The results for different stand-off distances vary almost linearly with distance.

Seven amphibious assault parameters were selected for investigation: force composition, embarkation procedures, fleet stand-off distance, landing craft order, sea state, landing craft attrition rates, and assault

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* The composition of the 1975 fleet is not discussed in this report. See SRI Memorandum "Amphibious Ships for 1975 Era Amphibious Assaults (U)," SECRET, Menlo Park, January 1969.

beach operations. Variations were measured from a reference run with the following characteristics:

1. The base Marine Force.

2. Spread loading among the ships of the fleet; all LSDs have the LSD-S configuration (no mezzanine decks); and LVTs are loaded in upper vehicle storage in all LPDs and in the wells of 2 LSDs.

3. Close-in launch (nominal five-mile, fleet stand-off distance).

4. The landing craft mix chosen by the selection procedure.

5. Sea state 1.

6. No craft attrition.

7. Normal beach operations with 27 craft unloading slots for wheeled vehicles and cargo and 10 unloading slots for tracked vehicles; unlimited area for beach dump and two hard surface beach exits.

Fourteen additional runs were made, one for each of the conditions listed in Table 6. The first run in each set is the reference run.

Reference Run

The results of the simulation process will be illustrated in terms of the reference run. The outline of the surface assault landing plan is given in Appendix B. The two vertical assault RLTs are delivered by helicopter to objective areas within 50 miles of the main assault beach. The Marine Force was embarked in the 73 logistic ships of the amphibious fleet for maximum spread loading, while serial and tactical unit integrity was maintained. All landing craft in the wells of LPD and LSD type ships were loaded with vehicular serials. All tanks were loaded on LSTs. As indicated in Appendix B, the assault is launched from a nominal stand-off distance. On arriving in the objective area, most of the ships of the amphibious fleet anchor in their assigned anchorages for off-loading operations. The LPHs continue to steam about the sea echelon point 10 miles offshore. The LPDs carrying the 228 LVTs discharge their landing craft and then move into the LVT launch line 1,000 yards outside the LOD where the scheduled waves of LVTs are launched. LKAs occupy the first two rows of anchorages beginning at the 10 fathom curve, 5,000 yards offshore. LPDs and LSDs occupy the third and fourth rows of anchorages. LSTs are anchored 6-1/2 miles offshore, awaiting the securing of the four causeways.

Table 6

SIMULATION RUNS FOR BASE SYSTEM ANALYSIS

Variable Parameter	Run Number	Description
Marine Force composition	R	Reference run: MEF with 1 RLT over the beach and 2 RLT vertical assault.
	A1	MEF with two RLTs over the beach and one RLT vertical assault, and with additional tank and artillery units.
	A2	MEF with additional engineer support and one RLT vertical assault.
Embarkation procedures	R	Reference run: All ships spread loaded by EMBARK. Also LSDs without mezzanine decks installed; no vehicles carried in the well. All LVTs are carried in upper vehicle storage of the LPDs except for two waves carried in the wells of two LSDs.
	B1	All but four LSDs have mezzanine decks installed. When a mezzanine deck is installed, vehicles are carried in part of the well deck.
	B2	All LVTs on LPDs are carried in the well instead of in upper vehicle storage.
	B3	The distribution of the vehicles in a serial among LKA holds was modified. Thus loading from LKAs to craft was improved.
Fleet stand-off distance	R	Reference run: Five nautical miles nominal stand-off distance.
	C1	15 nautical miles.
	C2	25 nautical miles.
	C3	35 nautical miles.

Table 6 (concluded)

Variability Parameter	Run Number	Description
Landing craft order	R	Reference run: Craft arranged by craft type.
	D1	Craft ordered as loaded by the PREBOAT program.
Sea state	R	Reference run: Sea state 1 (smooth, waves less than one foot). No attrition because of broaching.
	E1	Sea state 2 (slight, waves 1 to 3 feet). Lower loading and unloading rates for craft. 15 percent of LCM-6s and 10 percent of LCM-8s broach each trip.
Landing craft attrition	R	Reference run: No attrition.
	F1	10 percent attrition per trip for all craft; all attrition at the beach.
	F2	20 percent attrition per trip for all craft; all attrition at the beach.
Assault beach operations	R	Reference run: 27 slots for wheeled vehicles and cargo; 10 slots for tracked vehicles.
	G1	Increase number of slots for wheeled vehicles and cargo to 37.
	G2	Increase distance from beach to logistics support area, thus increasing truck travel time between the two points.

The surface assault takes place over two adjacent colored beaches 1,000 yards wide. The LOD is 2,500 yards offshore. The first scheduled wave hits the beach at H-hour and the eighth wave at H+33 minutes. The two vertical assault RLTs are delivered to inland objective areas between H hour and H+90 minutes.

Assault Phase

Assault serials are landed at the beach beginning immediately after the last scheduled wave has crossed the beach. The assault phase continues for approximately seven hours. The landing craft fleet includes 15 LCUs, 102 LCM-8s, and 174 LCM-6s. All craft except the 117 LCM-6s carried aboard the LKAs are preloaded with assault serials. At time H+435 minutes, the assault phase terminates because half of the landing craft are available to carry general cargo. The general unloading phase starts at H+435 minutes and is essentially complete at H+45 hours.

Table 7 and Figures 9, 10, and 11 show how the different landing craft types spend their time during the assault phase. In the aggregate, the craft spend about 60 percent of their time under way, 16 percent of their time loading, 7 percent of their time unloading, and 18 percent of their time nonproductively, waiting to load, waiting to unload, or waiting in the boat pool. Loading time includes time waiting in queues at the ships, which amounts to about one-third of the 16 percent. Individual craft types experience only slightly different time distributions.

Table 7

REFERENCE RUN - BREAKOUT OF PERCENT OF TIME SPENT BY CRAFT DURING THE ASSAULT PHASE (to 7 hrs)

	Moving	Waiting To Load	Loading	Waiting To Unload	Unloading	Boat Pool	Percent of Nonproductive Time
All craft	59.0	4.8	15.9	6.2	6.7	7.4	18.4%
LCM-6	61.0	5.2	14.7	6.1	5.1	7.9	19.2
LCM-8	57.3	4.0	16.9	7.4	8.0	6.4	17.8
LCU	46.9	6.2	22.9	0	16.4	7.6	13.8

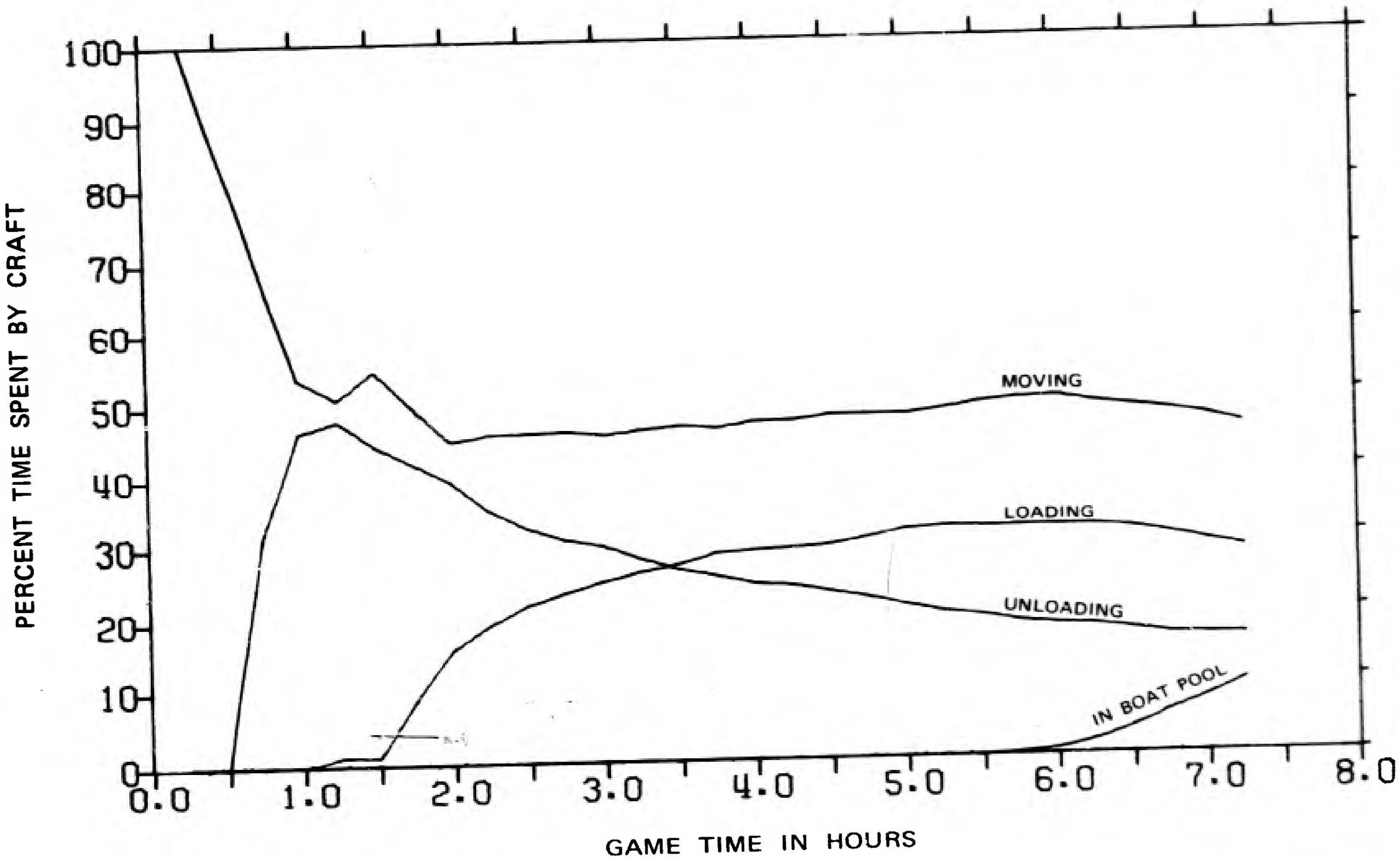

Figure 9 LARGE CRAFT ASSAULT PHASE ACTIVITY — REFERENCE RUN

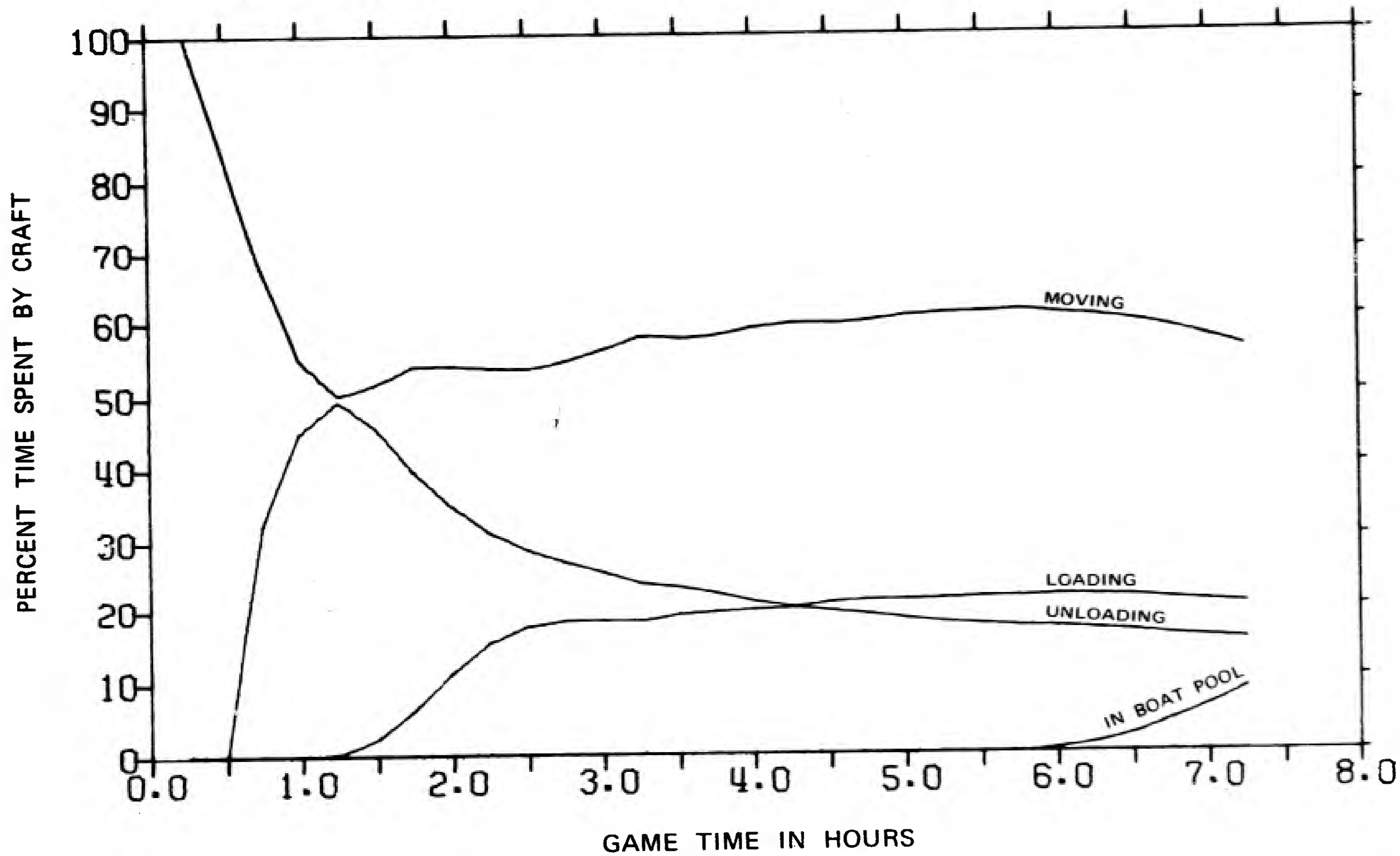

Figure 10 MEDIUM CRAFT ASSAULT PHASE ACTIVITY – REFERENCE RUN

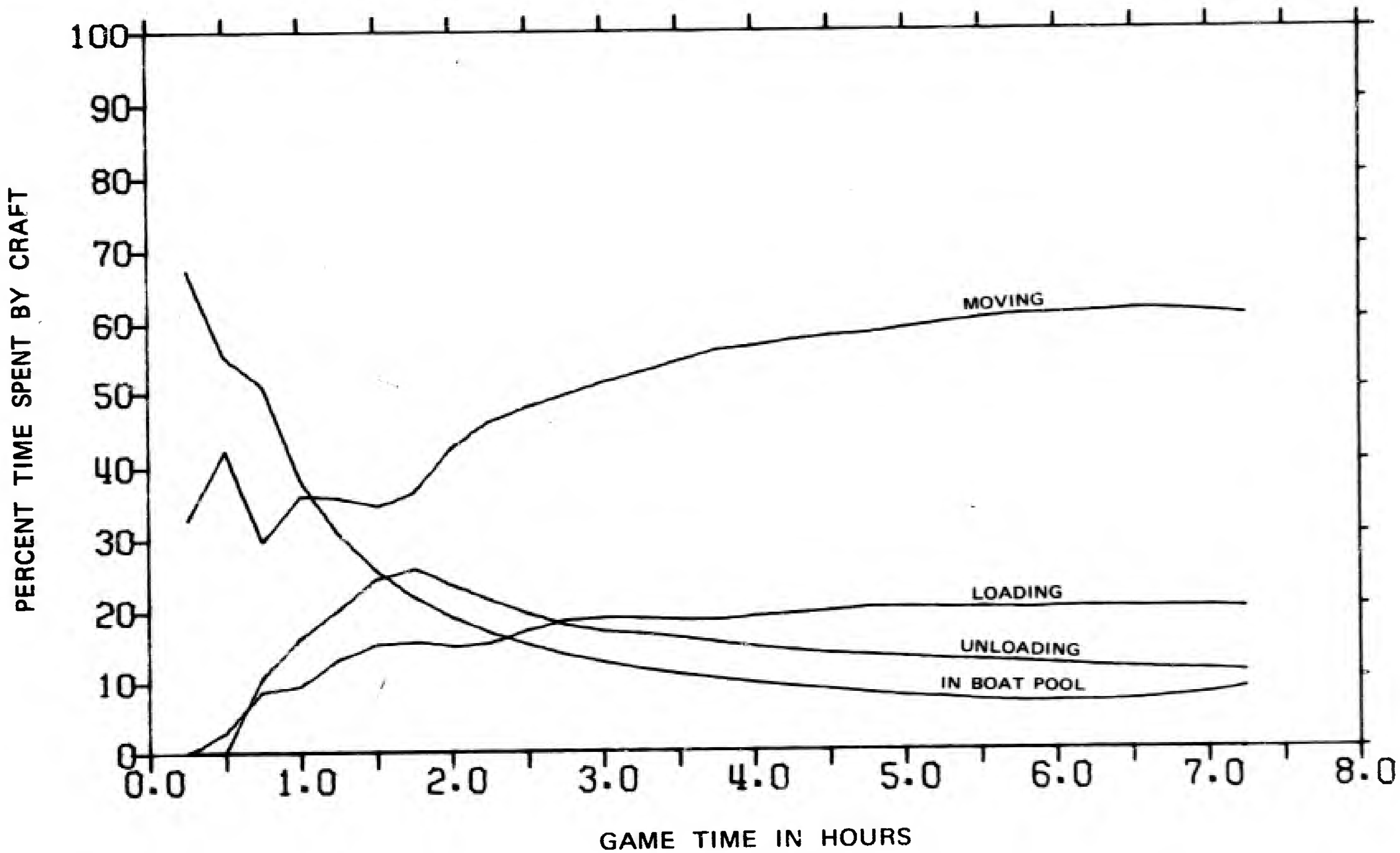

Figure 11 SMALL CRAFT ASSAULT PHASE ACTIVITY – REFERENCE RUN

Figures 9, 10, and 11 give considerably more information than the average data recited above. Initially, the preloaded large (LCU) and medium (LCM-8) craft can move toward the beach. However, not all of the craft can be simultaneously accommodated at the beach, and some must wait to unload. Unloading begins at about H+40 minutes and dominates craft activity for a time. Only after H+5 hours does the craft activity level off for all craft types. For example, LCM-8 activity levels off to 60 percent moving, 22 percent loading, and 18 percent unloading--numbers considerably different from the averages for the entire assault phase.

Times spent loading and unloading are different in part because of different cargo handling techniques but also because the STS-2 model treats queues of craft waiting to load differently from queues of craft waiting to unload. When all loading stations have been filled, additional craft seeking loads are assigned to waiting stations; however, to avoid congestion around the ships, no more than one craft is allowed to wait for each loading station. Two craft are allowed to wait at well-type ships. Other craft seeking loads are assigned to the boat pool. Once loaded, all craft proceed toward the beach. If no beach slots are available, craft are held outside the LOD. This queue is unrestricted in length. Thus typically more craft time is spent in the unrestricted queue waiting to unload than in the strictly limited queues waiting to load, because the boat pool absorbs craft not able to be assigned to ships because of restricted queues.

Small craft (LCM-6) activities are somewhat different (Figure 11) because the majority of the small craft are deck loaded (empty) on LKAs and do not carry preboated loads. Initially, most small craft are considered to be in the boat pool because they are awaiting assignment. As loading stations become available, the craft move in to receive loads, load, and proceed toward the beach where they are held up by the large queue of LCU and LCM-8 craft.

Figure 12 and Table 8 show the situation at the beach. At H+33 minutes, when the last scheduled wave has crossed the beach, all of the slots are available to receive craft. By H+1 hours, all slots are filled, and none is left unfilled until H+2 hours. As successive groups of craft arrive with assault serials, the number of available slots varies widely, with none available at H+3.5 hours and thirteen available at H+4 hours. Part of the wide fluctuation at the beach is a direct result of queueing at the ships. Most of the rest results from the tendency of the craft to move in echelons beginning with the preloaded craft that move together toward the beach. The tendency of craft to arrive in groups is gradually dissipated as individual craft encounter different delays. There is little activity at the tracked vehicle unloading stations because all but a

Table 8

BEACH STATUS TABLE

GAME TIME	BEACH	***** NUMBER OF UNLOADING SPACES AVAILABLE FOR: ***** WHEELED VEH. AND CARGO	TRACKED VEHICLES	LST S	PERSONNEL
30	1	27	13	4	0
60	1	0	13	4	0
90	1	0	9	4	0
120	1	13	13	0	0
150	1	15	13	0	0
180	1	1	13	0	0
210	1	0	11	0	0
240	1	13	13	0	0
270	1	5	13	0	0
300	1	9	13	0	0
330	1	1	13	0	0
360	1	4	13	0	0
390	1	12	13	0	0
420	1	8	13	0	0

Table 9

CRAFT AVAILABILITY TABLE

	**** **** NUMBER OF CRAFT IN BOAT POOL **** ****			
GAME TIME	LCM - 6	LCM - 8	LCU	TOTAL
15	117	0	0	117
30	74	0	0	74
45	74	0	0	74
60	0	0	0	0
75	0	0	0	0
90	0	0	0	0
105	0	0	0	0
120	0	0	0	0
135	0	0	0	0
150	0	0	0	0
165	0	0	0	0
180	0	0	0	0
195	0	0	0	0
210	0	0	0	0
225	0	0	0	0
240	0	0	0	0
255	0	0	0	0
270	0	0	0	0
285	0	0	0	0
300	0	0	0	0
315	0	0	0	0
330	0	0	0	0
345	3	0	1	4
360	14	14	2	30
375	15	20	4	39
390	20	36	7	63
405	31	50	9	90
420	37	64	9	110
435	57	73	11	141
AVERAGE NO.	15.2	8.9	1.5	25.6

Table 10

CUMULATIVE DELAY TIME TABLE

ASSAULT SERIALS

	********* TOTAL DELAYS BECAUSE OF:		*********	********* TOTAL TIME SPENT:		*********
TIME	CRAFT WAITING TO LOAD	NO LANDING SLOTS AVAIL.	NO VEH. AVAIL. TO UNLOAD CRAFT	LOADING CRAFT	UNLOADING CRAFT	MOVING SERIALS BY CRAFT
15	0.0	0.0	0.0	0.0	0.0	81.2
30	0.0	0.0	0.0	1.8	0.0	123.4
45	0.2	0.4	0.0	5.0	15.0	123.7
60	4.1	4.3	0.0	10.1	17.0	166.2
75	4.1	15.5	0.0	20.8	21.7	180.3
90	8.9	49.5	0.0	31.5	26.7	198.5
105	14.8	105.3	0.0	46.4	32.4	240.2
120	18.6	124.6	0.0	65.7	37.5	281.6
135	22.8	124.6	0.0	80.1	39.9	336.1
150	26.9	124.6	0.1	94.0	42.6	365.1
165	36.0	124.6	0.1	113.8	46.8	405.8
180	40.3	124.6	0.1	125.0	51.7	456.3
195	43.9	124.6	0.3	136.5	57.1	499.8
210	45.9	124.7	0.3	152.0	63.6	538.2
225	49.2	125.5	0.3	167.1	69.7	586.0
240	52.4	125.5	0.3	181.2	73.5	631.8
255	56.5	125.5	0.3	192.8	77.8	670.0
270	60.4	125.5	0.3	213.4	83.1	706.0
285	66.9	125.6	0.3	229.3	87.9	749.3
300	70.8	125.6	0.3	242.8	92.0	804.0
315	72.8	125.6	0.3	254.7	97.1	847.4
330	75.5	125.6	0.3	265.8	103.7	885.8
345	80.9	125.6	0.3	279.6	108.6	926.8
360	82.3	125.6	0.3	291.9	114.1	962.9
375	85.2	125.6	0.3	302.4	118.7	1000.8
390	88.3	125.6	0.3	312.6	122.6	1029.1
405	90.3	125.6	0.3	321.3	126.4	1052.4
420	93.6	125.6	0.3	328.1	130.7	1074.2
435	95.9	125.6	0.3	335.2	133.8	1094.8

LAST ASSAULT CRAFT LANDING TIME 457

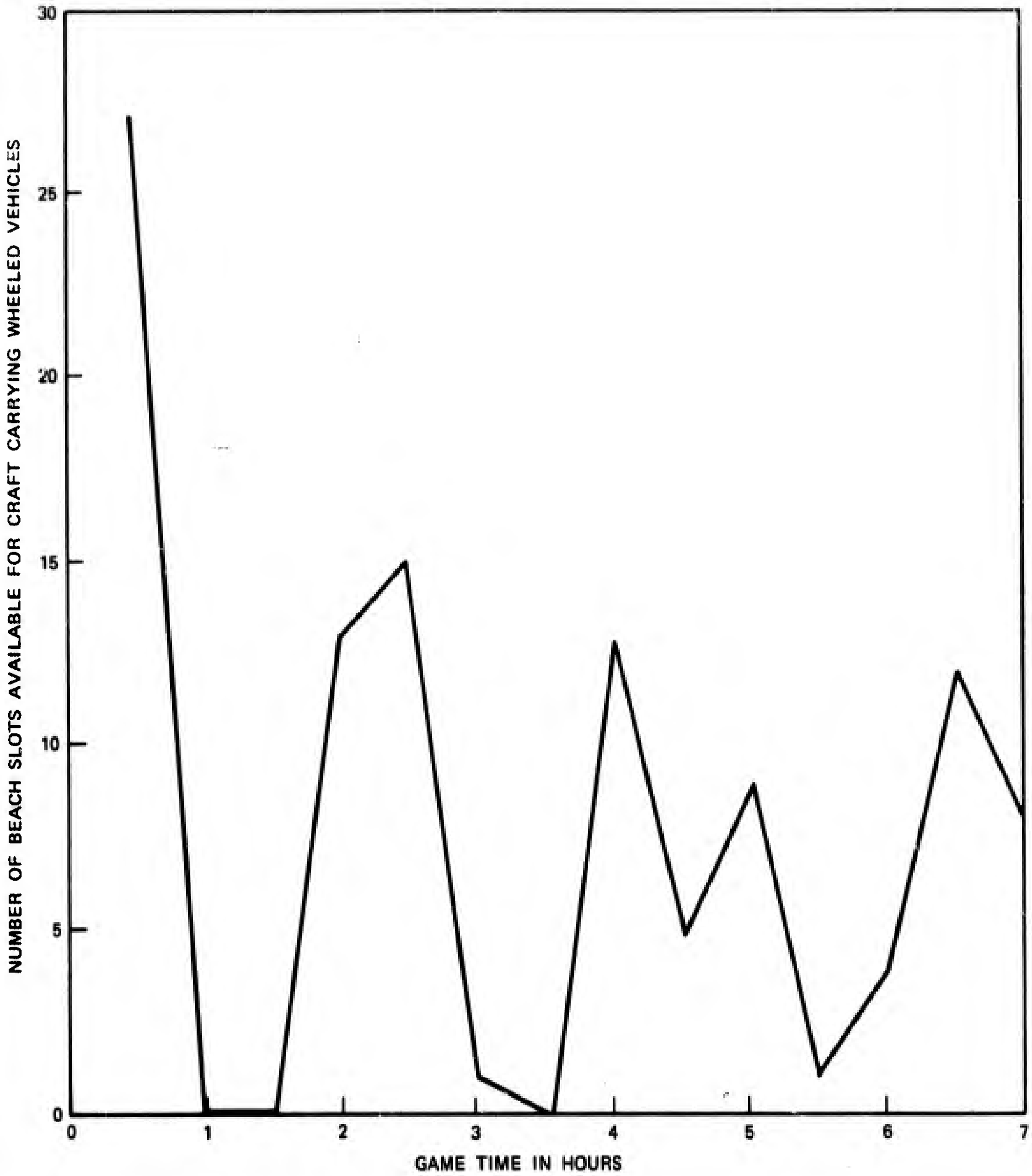

Figure 12 AVAILABLE BEACH SLOTS FOR RUN A1

few tracked vehicles are carried by LSTs. The LST causeways are fully occupied from the time that they are secured (H+120 minutes).

Figure 13 illustrates the aggregate time spent in queues by all craft. The amount of time that landing craft spend waiting in queues at ships increases steadily throughout the assault phase, confirming the fact that ship loading is a bottleneck although not a severe one for the baseline system. Virtually all queueing time at the beach occurs between times H+1 and H+2 hours, confirming the congestion suggested by Figure 12.

Table 9 shows the situation in the boat pool. At times H+15, H+30, and H+45 minutes, there are a large number of unassigned LCM-6s. These are the nonpreloaded LCM-6s that were carried on LKAs. Thereafter, no craft are assigned to the boat pool until H+345 minutes, when the available serials are becoming depleted. Table 10 gives the breakdown of craft time at 15-minute increments throughout the assault phase. These are the simulation data from which Figures 9, 10, and 11 were prepared.

General Unloading Phase

During the general unloading phase, the pattern of craft usage is distinctly different. Table 11 shows that during general unloading,

Table 11

REFERENCE RUN - PERCENT TIME SPENT BY CRAFT
DURING GENERAL UNLOADING PHASE

	Moving	Waiting To Load	Loading	Waiting To Unload	Unloading	Boat Pool	Percent of Nonproductive Time
All craft	10.2	5.3	9.3	30.7	10.6	33.9	69.9
LCM-6	12.4	5.0	8.3	32.4	10.2	21.7	69.1
LCM-8	7.1	5.5	10.9	28.0	11.4	37.1	70.6
LCU	6.1	6.9	10.3	28.5	10.0	38.2	73.6

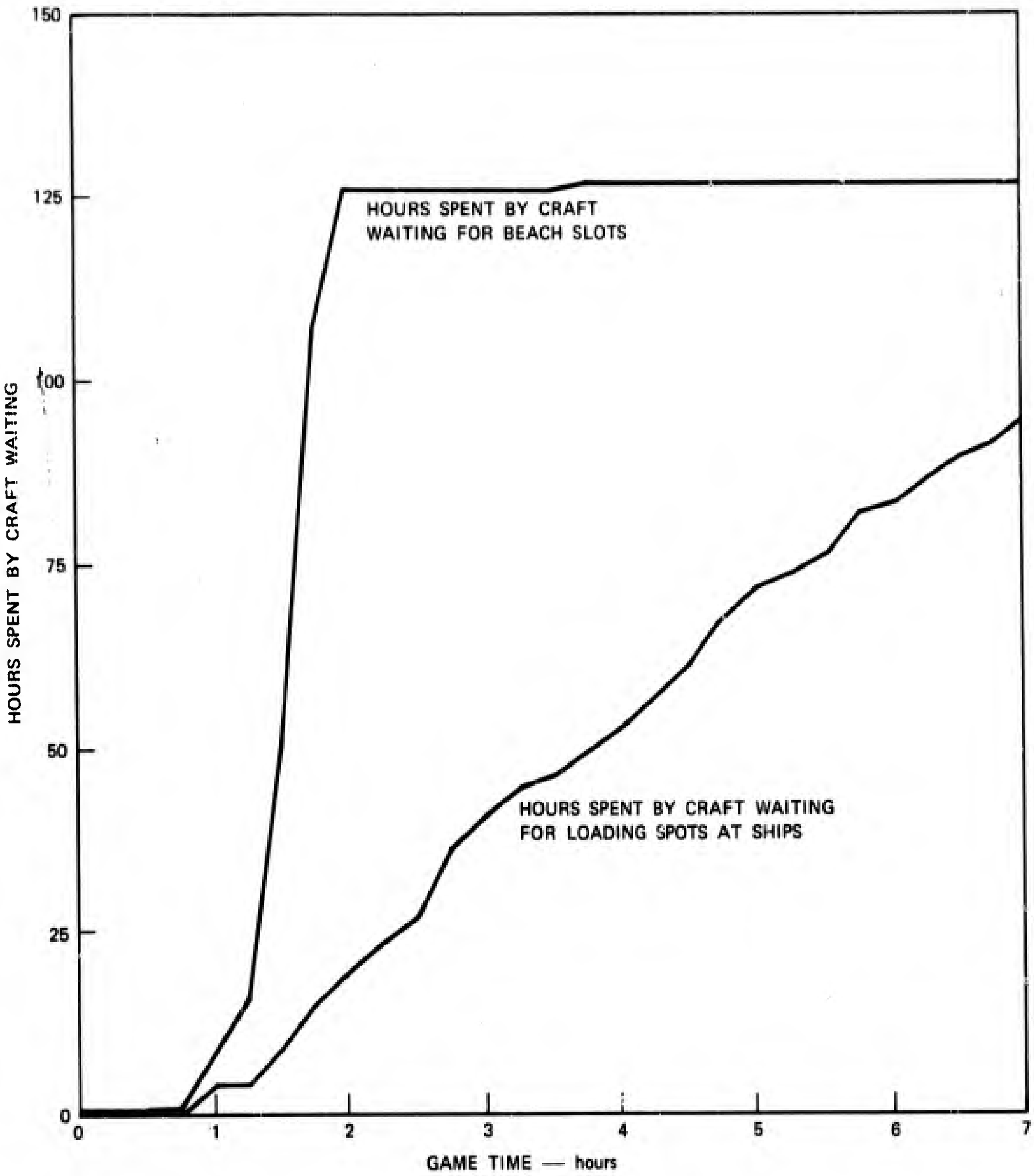

Figure 13 TIME SPENT BY CRAFT IN QUEUES – REFERENCE RUN

craft spend only 10 percent of their time moving compared with 60 percent during the assault phase. Further examination of this table in conjunction with Figures 14, 15, and 16 indicates that this drastic decrease in craft movement time is a result of queues developing at the beach and at the ships. By the time H+11.5 hours, all beach slots are filled with craft unloading cargo. Furthermore, all beach slots remain filled until H+37 hours, by which time most of the cargo has been landed as shown in Figure 17. Figure 18 shows the disparity between cumulative time spent waiting to beach and cumulative time spent waiting to load. Time spent waiting to load levels off after T+30 hours. By this time, the amount of craft time effectively employed in ship-to-shore transfer has been reduced until the ship-to-shore transfer rate is equal to the lesser of the loading rate at the ships or the unloading rate at the beach. Also, general cargo has been depleted on many ships.

Movement constraints can be identified by studying pallet flow. The general unloading cargo largely comprises two types of palletized cargo, standard (40-inch by 48-inch) pallets, and special pallets approximated by SATS matting pallets (12.3 feet by 2.4 feet). These two types of palletized cargo are accounted for separately. For both special and standard pallets, the transportation inland from the beach is performed by a truck fleet of cargo-carrying trucks. Most of these trucks have been delivered ashore by the end of the assault phase. When they arrive on the beach, transport vehicles go immediately to the LSA to discharge their initial cargo, and then they return to the beach for assignment. Initially, there are 49 designated loading areas for cargo carrying vehicles, each of which can handle only one vehicle at a time. Thirty-nine of these areas are the craft unloading slots and the other ten are located at the temporary beach dump just over the berm.

The beach dump serves as buffer storage for pallets unloaded from craft that cannot be placed directly in transport vehicles. As trucks are available, they are first assigned to support craft unloading because craft can be unloaded faster into trucks than to the beach dump and because this procedure avoids double handling. Cargo is removed from the beach dump only when surplus trucks are available. A vehicle pool is also maintained for trucks if there is no cargo-handling equipment available to load them.

Figures 19 and 20 show a reduction of the basic data on pallet flow to a graphical form. Figure 19 shows the cumulative total number of pallets that have reached three major areas of the cargo-handling systems: landing craft; the beach; and the LSA. The curves of Figure 20 represent the number of each type of pallet currently either on craft or on the beach. This should be distinguished from Figure 19 which is cumulative.

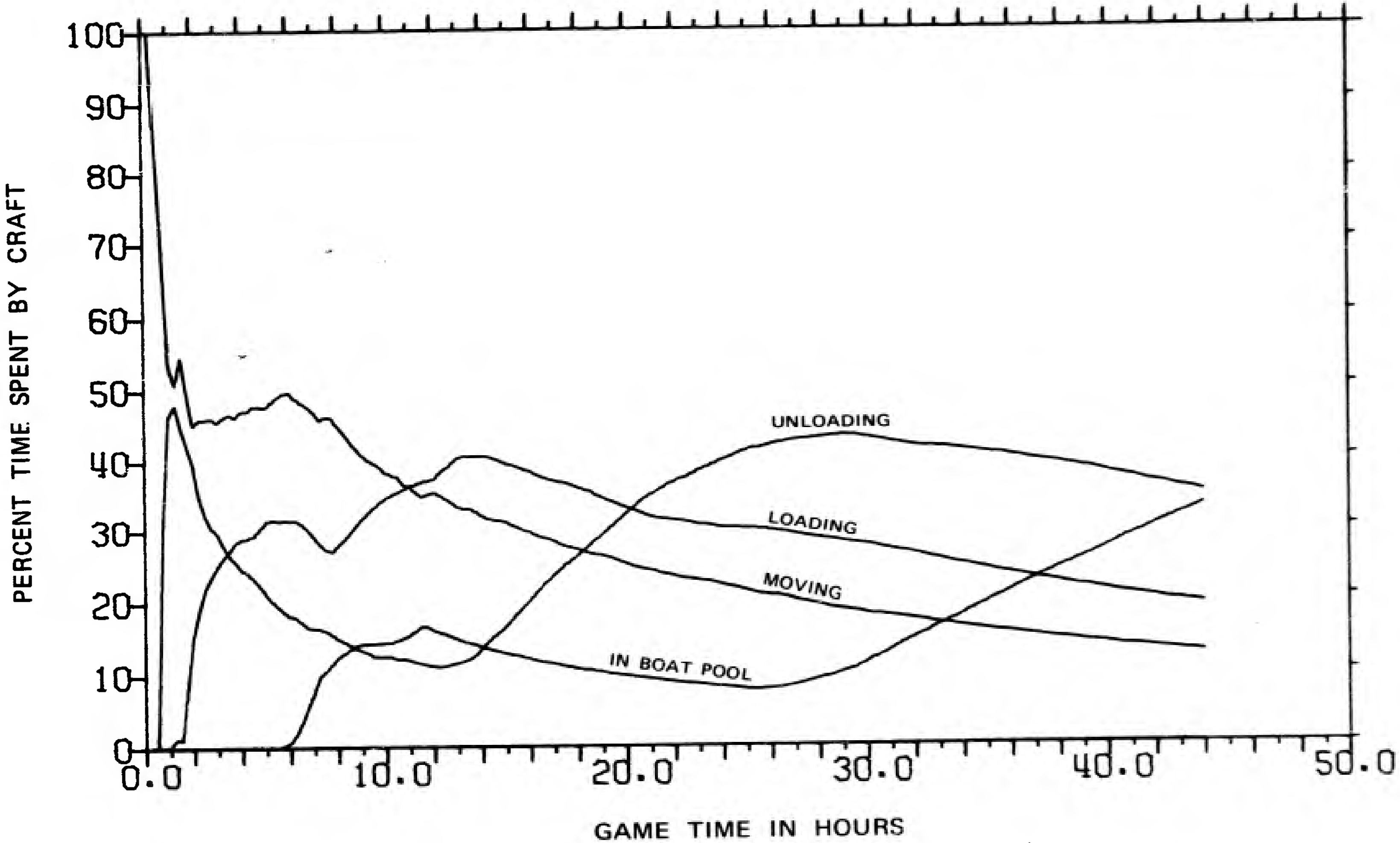

Figure 14 LARGE CRAFT GENERAL UNLOADING PHASE ACTIVITY – REFERENCE RUN

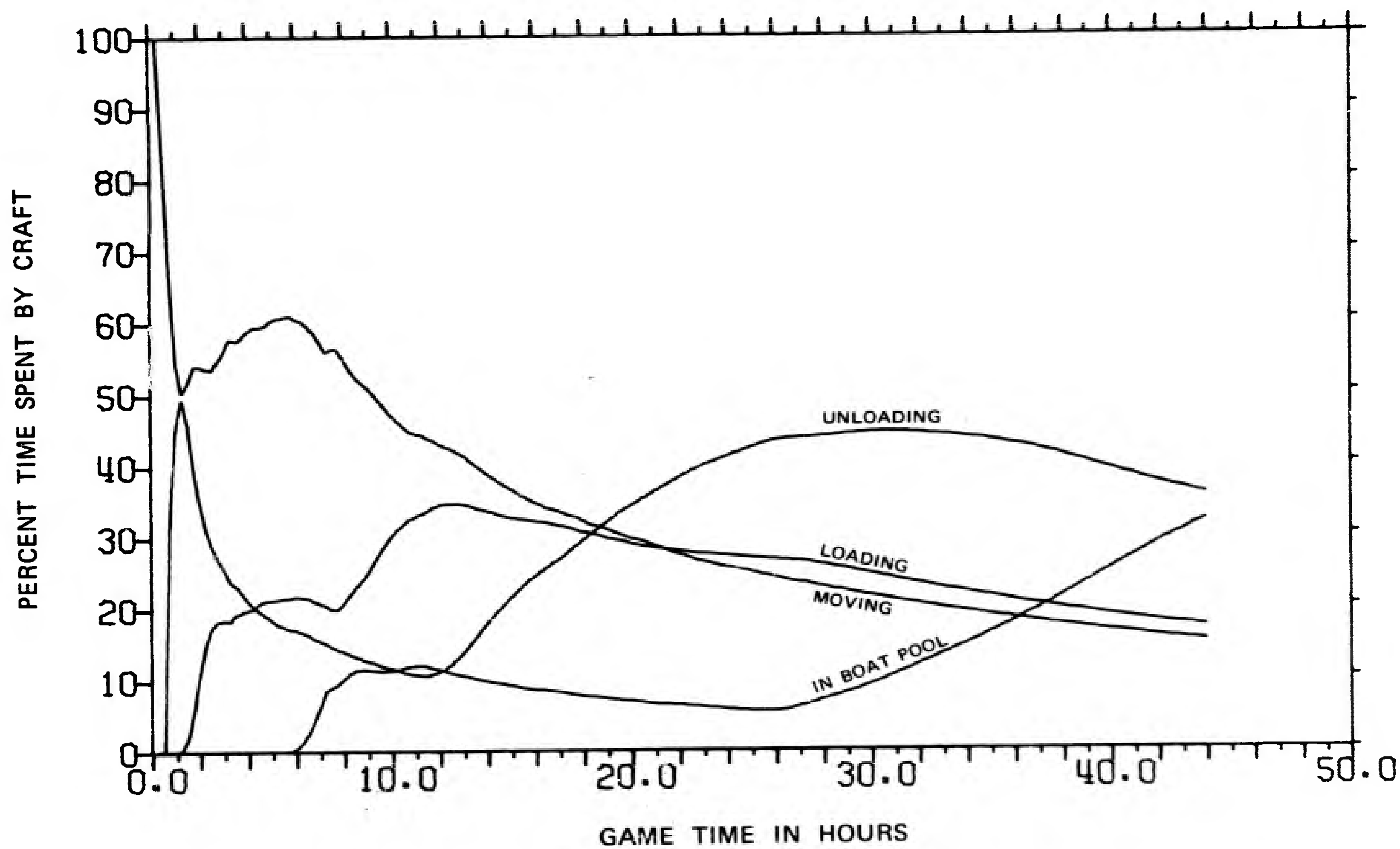

Figure 15 MEDIUM CRAFT GENERAL UNLOADING PHASE ACTIVITY – REFERENCE RUN

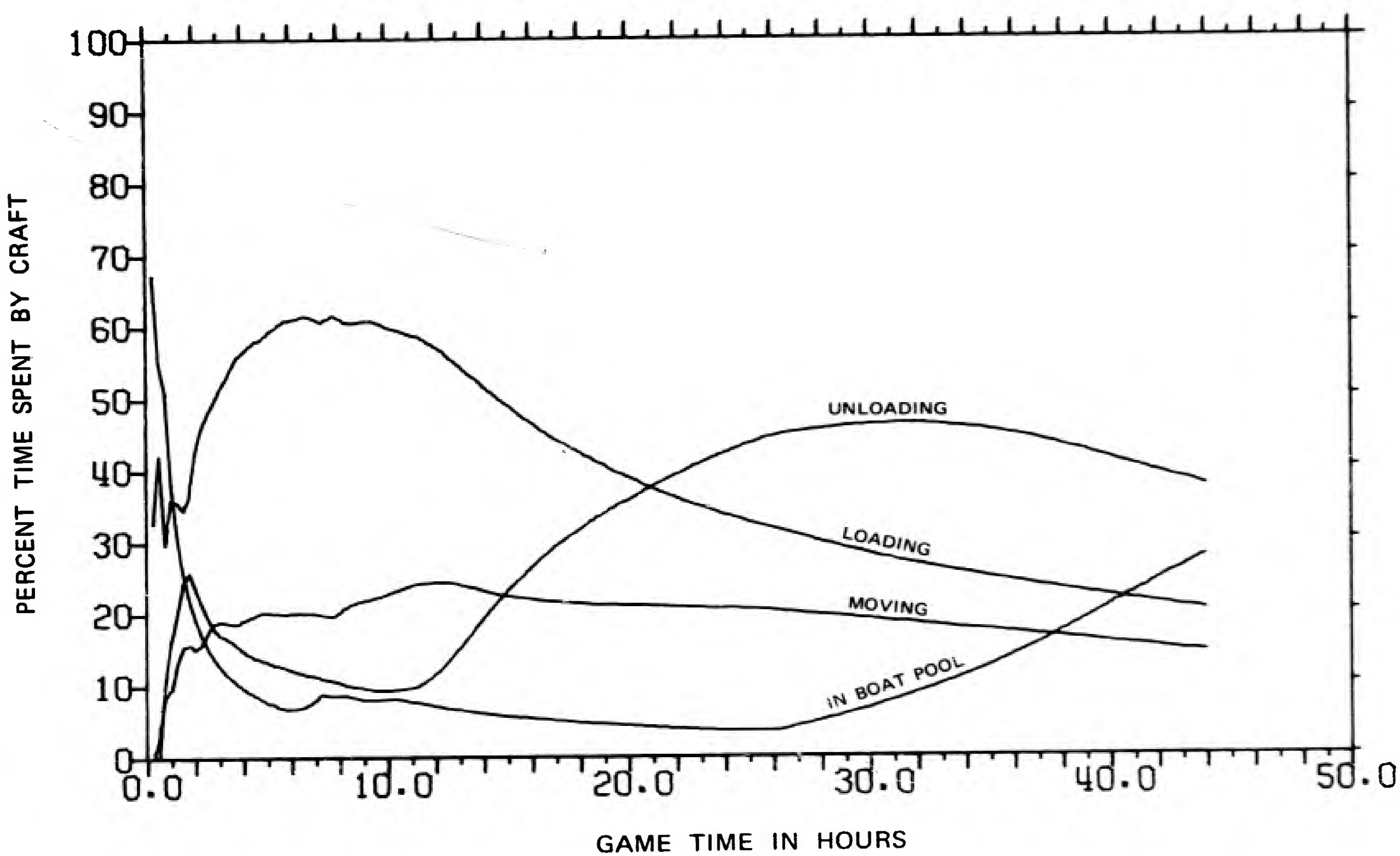

Figure 16 SMALL CRAFT GENERAL UNLOADING PHASE ACTIVITY – REFERENCE RUN

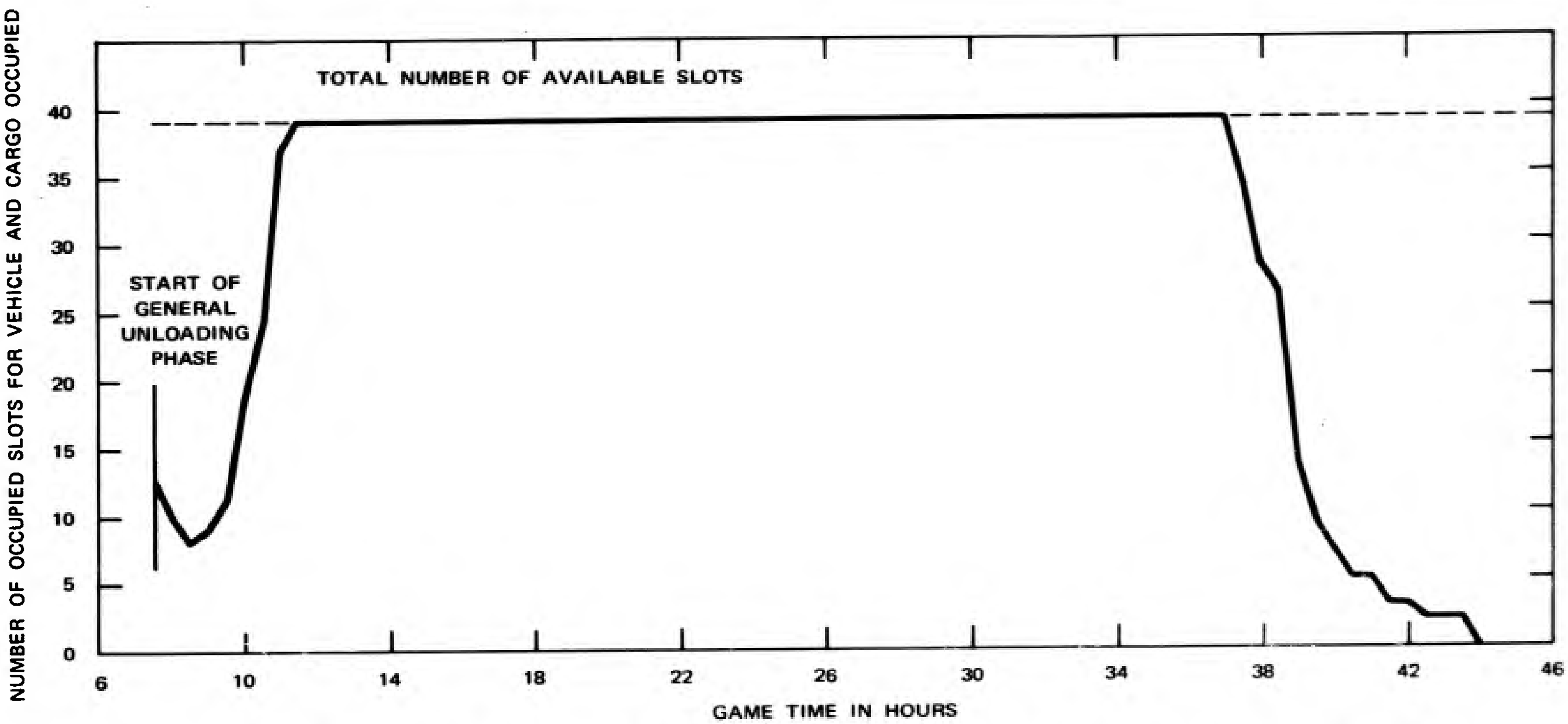

Figure 17 USE OF BEACH SLOTS DURING REFERENCE RUN – GENERAL UNLOADING PHASE

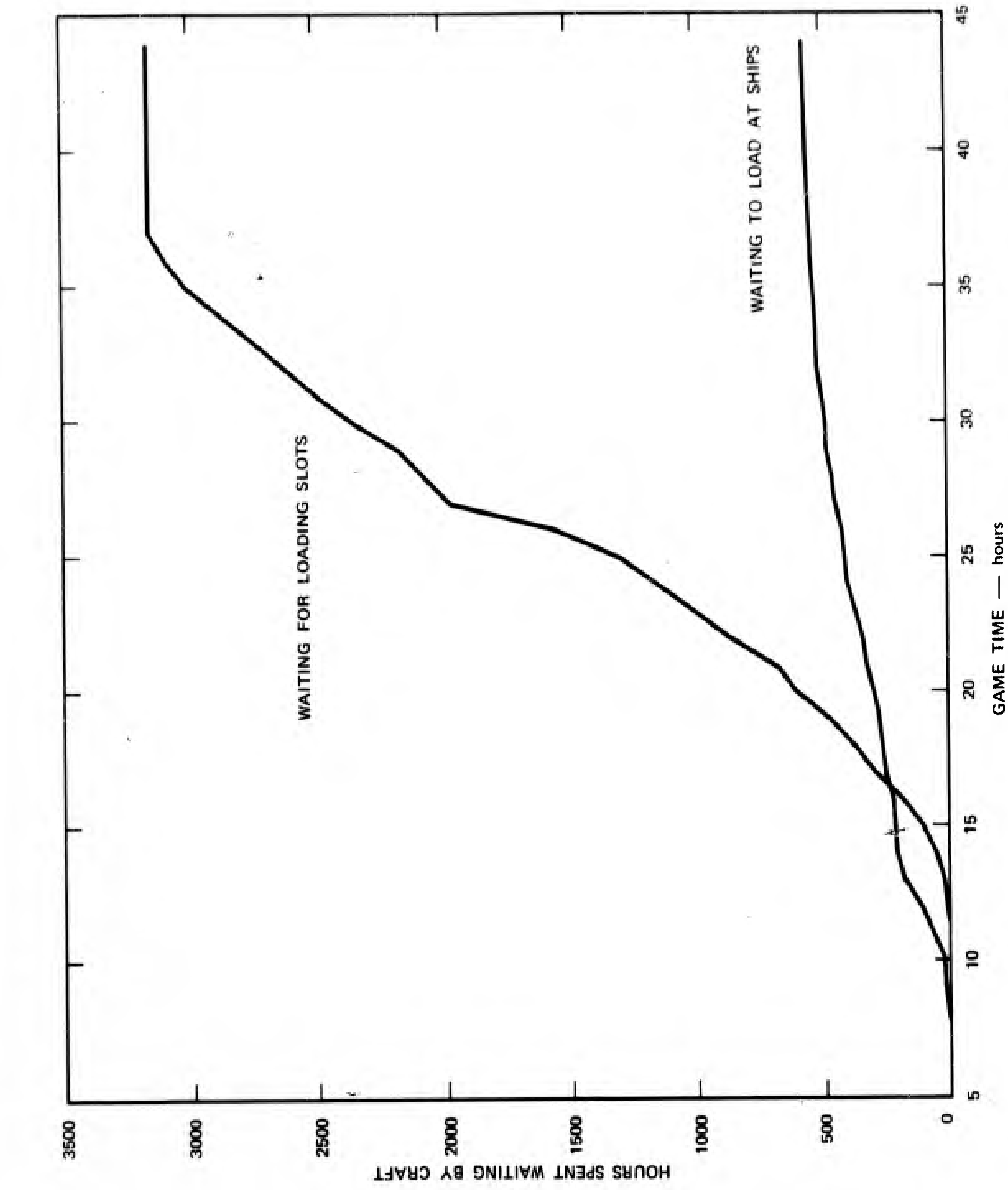

Figure 18 TIME SPENT IN QUEUES BY CRAFT DURING GENERAL UNLOADING PHASE – REFERENCE RUN

An examination of the actual curves for the reference run leads to a better understanding of the simulation results and also to greater confidence in those results. The slope of the curves in Figure 19 represents the delivery rates to the three areas. A perfectly balanced system with no bottlenecks would have equal flow rates to all areas in the system. This would be shown by parallel curves on Figure 19 that are offset in time. Neither set of curves, those for standard or special pallets, has this parallel structure, and thus there are bottlenecks in the pallet movements. The bottlenecks are evident in Figure 20 where each curve has a distinct maximum. If Figure 19 had a parallel structure, the curves in Figure 20 would increase to a constant value representing pallets in transit from ship to shore or from the beach to the LSA.

The maximum sustained flow rates (in pallets per hour) are as tabulated below.

	Loading into Craft	Unloading on Beach	Delivery to LSA
Standard pallets	1,820	480	280
Special pallets	290	330	130

The flow rate for loading standard pallets onto the craft, 1,820 pallets per hours, is the slope of the standard pallet-on-craft curve in Figure 19 taken from H+8 hours to about H+14 hours when craft loading is at its maximum. Thereafter, a gradual decrease begins because some of the loading stations at the ships have exhausted their supply of standard pallets. Initially, the flow rate to the beach is almost as great as the craft loading rate. This rate is sustained for only a short time (H+9 to H+11 hours) and then decreases to 480 pallets per hour. The higher rate was transient because it did not reflect the time required for empty craft to depart from the beach and new craft to take their places. The first craft to arrive at the beach with palletized cargo experienced no delay. However, when these craft had been unloaded, a significant delay in unloading occurred while they were retracting and while other craft were landing. Another factor is the initial availability of all cargo-carrying trucks. Thus, the first craft were unloaded directly into trucks, a faster procedure than unloading at the beach dump. The rate of 480 pallets per hour was sustained until the number of loaded craft arriving at the beach was not sufficient to occupy available beach slots fully.

The flow rate of standard pallets to the LSA (280 pallets per hour) is quite uniform throughout general unloading. This rate depends directly

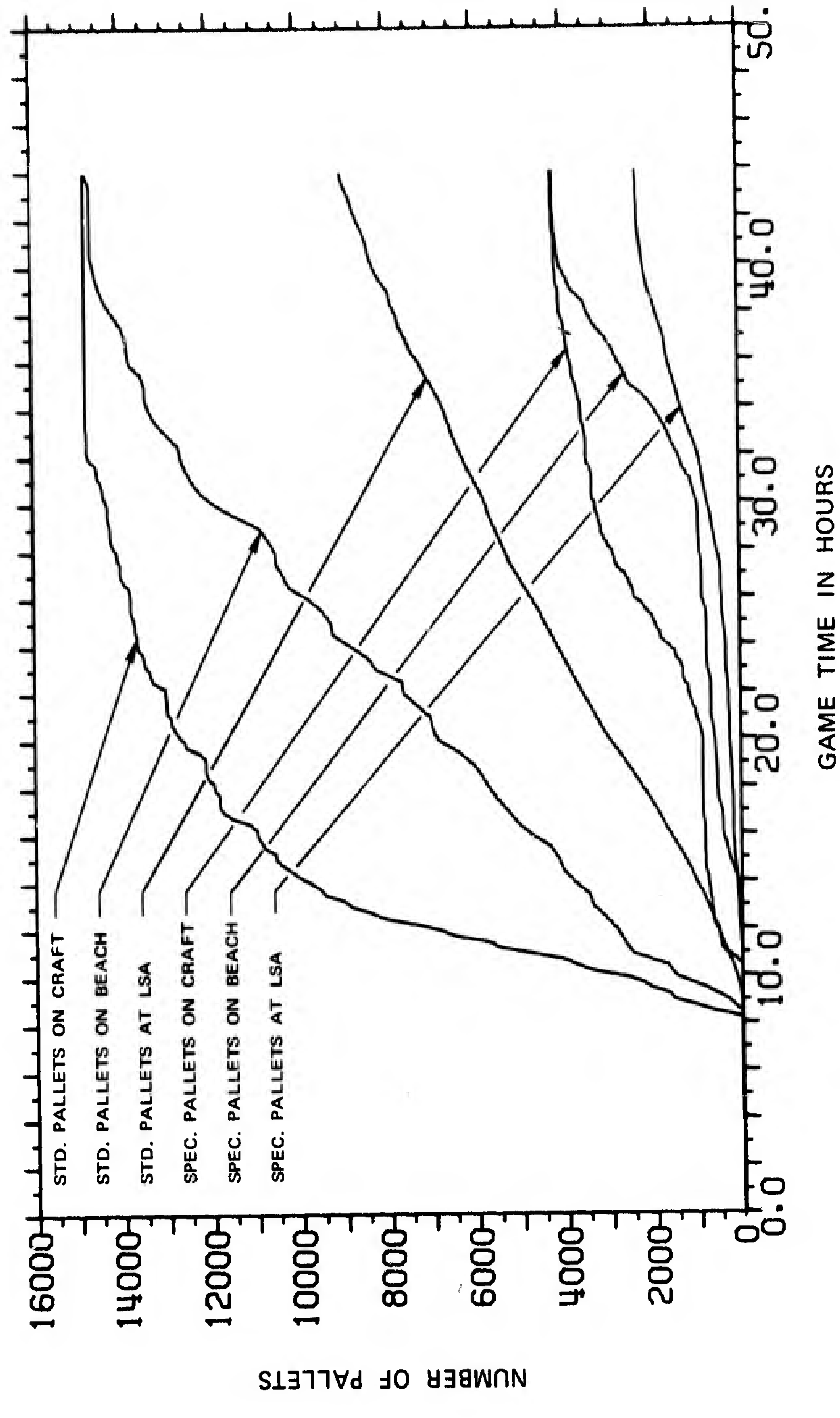

Figure 19 FLOW OF PALLETS – RUN A1

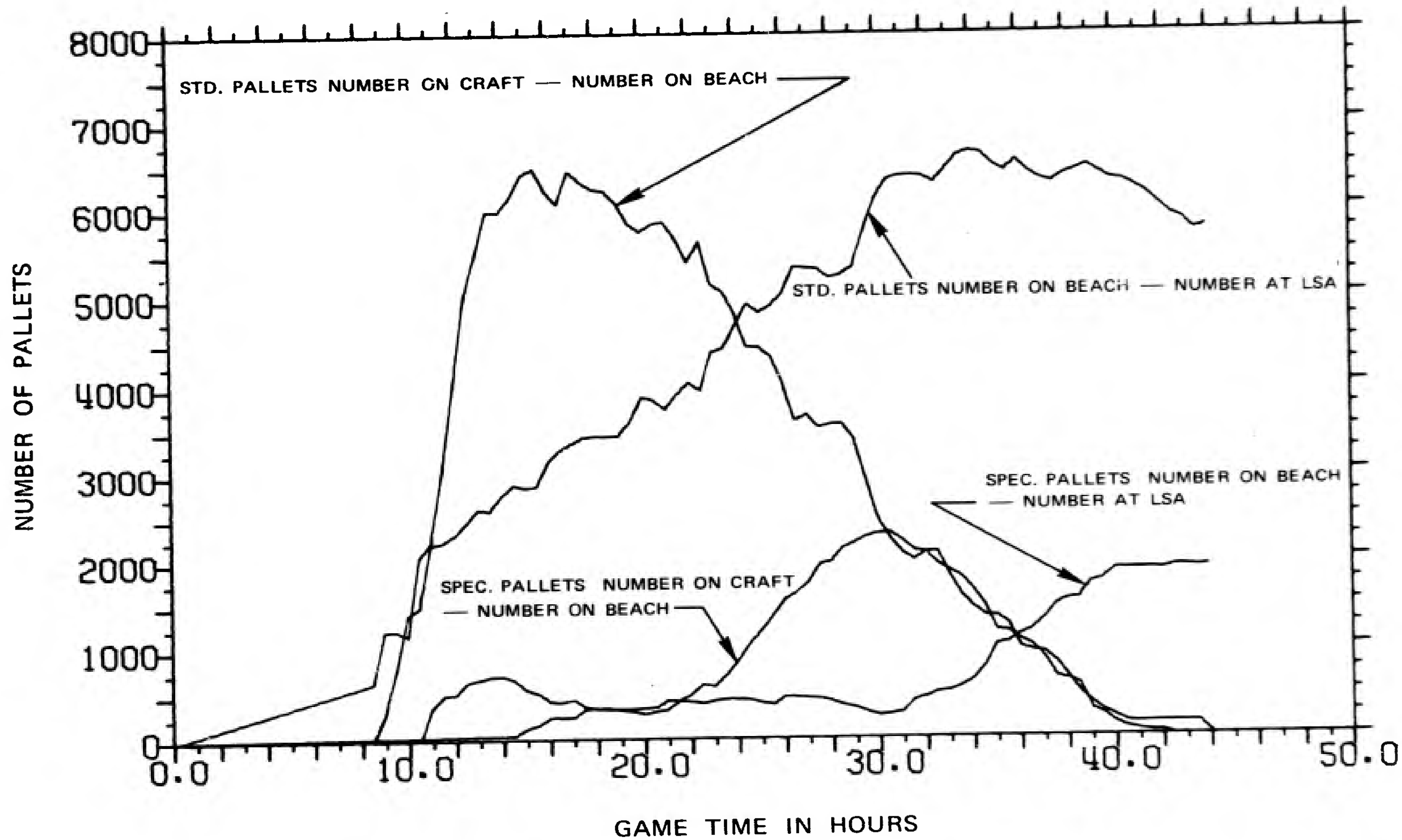

Figure 20 PALLET ACCUMULATION – REFERENCE RUN

on the number of cargo-carrying trucks, the distance to the LSA, and the speed achieved by the trucks. The simulation was terminated before all pallets arrived at the LSA. However, projecting the movement of cargo to the LSA suggests that general unloading will be complete by time H+70 hours.

The curves of Figure 19 confirm that the beach cannot receive standard pallets at the rate at which they can be loaded onto craft, and moreover the pallets reaching the beach cannot be removed as fast as they accumulate.

Figure 20 shows the accumulation of standard pallets first in landing craft, then at the beach, and finally at the LSA. The number of pallets on craft increases sharply until about H+14 hours, when the rate of unloading pallets at the beach equals and then surpasses the rate of loading pallets into craft. A similar situation occurs at the beach. In this case, the build-up at the beach continues until about H+35 hours when the flow of pallets to the beach finally slows down.

The movement of special pallets shown in Figures 19 and 20 is more erratic and more difficult to interpret than the movement of standard pallets. This erratic behavior resulted from the relatively smaller number of special pallets than standard pallets (less than one-third) and the handling procedure for special pallets used in the STS-2 model. For the appropriate functioning of STS-2, serials of general unloading cargo are artificially created by the EMBARK program. As constructed by EMBARK, a general unloading serial consists of all of one type of cargo (ammunition, general cargo, POL, or special cargo) able to be off-loaded using a particular loading station. The first three categories are all standard pallet size but have different weights and cannot be mixed in a craft load. These general unloading serials are entered in the STS-2 serial table in the order that they are formed, which places all of the special cargo serials at the end of the table. Since serial preferences are assigned in the order of listing in the serial table, the special cargo is last type of cargo to be unloaded at any particular ship loading station.*

The curve in Figure 19 representing special pallet loading onto craft shows two distinct spurts. The first spurt represents off-loading special pallets from loading stations with no standard pallets. It occurs at H+10 hours, lasts for only about 1/2 hour, and has a rate of 750

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* Because of the loading procedure used in EMBARK, some holds will have special pallets but not standard pallets. Thus, special pallets will be off-loaded from these holds as soon as general unloading begins.

pallets per hour. The second spurt starts at H+22 hours when a reasonable number of special pallets become available for off-loading. This spurt lasts for about 8 hours and has a rate of 290 pallets per hour.

Delivery of pallets to the beach shows a similar bimodal character, lagging off-loading into craft by about 2-1/2 hours for the first spurt and by about 9 hours for the second spurt. The long time lag at the second spurt is a direct result of the long queue at the LOD. Flow rates for delivery to the beach in the first and second spurts are about 115 pallets per hour and 330 pallets per hour, respectively. The second rate is higher because the rate of arrival of standard pallets has tapered off.

Special pallets arrive at the LSA at the very low rate of 20 pallets per hour for 16 hours starting at H+12 hours. As more special pallets are delivered to the beach, the flow rate to the LSA increases to about 130 pallets per hour. This increase is accompanied by a decrease in the delivery rate for standard pallets because of the limited number of transport trucks. If the rate of 130 pallets per hour were maintained, all special pallets would reach the LSA by about H+60 hours. Since all standard pallets would not arrive at the LSA until H+70 hours, no further increase in the special pallet delivery rate to the LSA can be predicted until the standard pallets on the beach are exhausted.

Figure 19 shows that the flow rate of special pallets to the LSA declines markedly at about H+41 hours. Figure 17 indicates that only five unloading slots are in use at this time and that the number of unloading slots in use reaches zero at H+44 hours. When all cargo has been delivered to the beach, completion of the ship-to-shore movement artificially limits the number of loading areas available for cargo carrying vehicles to the 10 loading areas available for cargo carrying vehicles at the beach dump. The STS-2 model does not allow cargo-handling equipment to transfer from the craft slots to the temporary dump after all cargo has arrived on the beach. Therefore, the flow of cargo to the LSA is considerably reduced. Manual adjustments were made to correct this situation.

Sensitivity Analysis

The purpose of the sensitivity analysis was to determine those amphibious operation parameters that have the greatest impact on the measures of landing craft effectiveness. The seven parameters given in the Background section of this chapter were investigated. The basic characteristics of each of the different simulation runs are listed in Table 16.

In each instance, the reference run is the point of departure for the sensitivity investigation. The results of these sensitivity runs are discussed below for each of the seven parameters.

Marine Force Composition

Three different Marine Forces were simulated to test the sensitivity of Marine Force composition to landing craft performance. The first force is that used in the reference run; the other two are modificiations of the basic MEF and are closely related to the CNA force modifications.*

In Run A-1, two of the three RLTs are transported ashore by landing craft. The third, together with light equipment and some palletized cargo, is transported by helicopter. This force is also augmented with more tanks and artillery units. In Run A-2, two RLTs are transported by landing craft and one by helicopter. This force is augmented with additional engineer support equipment and personnel. In Run A-2, the length of the assault beach has also been doubled to better accommodate the larger surface assault force. In both Runs A-1 and A-2, equipment formerly loaded in LPHs was loaded in LKAs for off-loading to landing craft. The additional tank, artillery, and engineer equipment was also loaded into LKAs. As a result, the total number of LKAs in the fleet was increased. With more personnel landing over the beach, it was necessary to use landing craft in scheduled waves 4, 5, and 6. Eleven LCM-8s and 30 LCM-6s were used in the scheduled waves.

The changes in the composition of the force had only minor effects on landing craft performance. An MEF-size force is so large and includes such a tremendous variety of different types and numbers of vehicles and equipment that the perturbations introduced by fairly major force modifications do not greatly influence either craft operation or the efficiency with which craft can carry the loads of the force ashore. The change in this set of runs that had the most pronounced effect on landing craft performance was the lengthening of the assault beach for Run A-2. Beach length had only a very minor effect on the assault phase but it was of major importance in the general unloading phase. The long beach in Run A-2 eased congestion during the short period from H+1 hour to H+2 hours when a substantial queue of preloaded craft was waiting to unload. During the general unloading phase, the larger number of beach slots allowed more craft to be unloaded simultaneously with an increase in the unloading rate. This virtually eliminated the queue of craft waiting to unload and

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* **CNA Naval Warfare Analysis Group Study 44, "Amphibious Assault Shipping in the Mid-Range Period (U)", 15 February 1966 CONFIDENTIAL**

placed the ship-to-shore burden squarely on craft loading at the ships. The pallet delivery rate to the LSA was not appreciably affected even though there were 10 percent more cargo-carrying trucks and more loading areas for them in Run A-2 than in the reference run.

The effectiveness measures for the three runs are tabulated in Table 12. The measures that reflect assault phase operations--force-time effectiveness, lost cargo, response time, time to bring 250,000 square feet of vehicles ashore, and mean productivity bv craft type are similar, reflecting the close similarity of the forces from the viewpoint of the landing craft. The longer beach in Run A-2 is reflected by the slight reduction in mean response time and the substantial reduction in the variance of response times. Craft productivity is also higher for LCM-8 and LCU types of craft, reflecting the influence of the shorter queue at the LOD. The difference between the cargo transfer rates of Run A-2 and the reference run are small, suggesting that the major impact of the longer beach used for Run A-2 is to reduce the queue at the beach and thus the number of pallets enroute from ships to beach. Other factors prevent the systemwide realization of this improved performance. Because of the similarity of the assault phases, general unloading was not simulated for Run A-1.

The effectiveness measures provide a convenient way to display the results of a simulation run, but they do not give the whole picture. Important insights result from detailed analysis of the plotted and edited results of the STS-2 simulation. Figure 21 shows comparative arrival times for the three runs (square feet of vehicles loaded on craft versus time). The quantity of preboated vehicles is the same for the reference run and Run A-1 but somewhat lower for Run A-2, because 30 craft were used in the scheduled waves. Thus, the initial delivery of vehicles lags in Run A-2. The curve for Run A-2 eventually crosses and exceeds those for both the reference run and Run A-1; however, the differences in performance are not very large. Figure 22 shows distribution of craft time for the three runs. Differences are small. The largest relative difference is in time spent waiting to unload. Run A-2, by virtue of the increased number of craft unloading slots and a reduced number of reloaded craft, has less of an initial queue at the LOD, and the queue is also reduced at a faster rate. Figures 23 and 24 show the pallet movement in Run A-2.

In Figure 23, the almost parallel curves of pallets on craft and pallets on the beach illustrate the elimination of the beach bottleneck by the longer beach available in this run. This is confirmed in Figure 24 which shows a modest build-up of pallets on craft between H+10 hours and H+14 hours. This build-up is essentially eliminated by about H+30 hours. Pallet transfer from the beach to the LSA is unable to take

Table 12

EFFECTIVENESS MEASURES--MARINE FORCE COMPOSITION

	Simulation Runs		
	Reference	A-1	A-2
Force-time effectiveness* (vehicle-square feet-hours)	1,100	1,080	1,080
Lost cargo (square feet)	None	None	None
Response time (minutes)			
Mean	92	98	80
Variance	347	428	190
Time to deliver 250,000 square feet of vehicles ashore (hours)	6.15	6.20	6.10
Mean productivity (vehicle square feet/craft square feet)			
LCM-6	0.904	0.829	0.824
LCM-8	0.721	0.718	0.843
LCU	0.595	0.606	0.711
Mean cargo transfer rates (pallets/hour)			
Standard pallets			
Ships to craft	623		544
Craft to beach	459		496
Beach to LSA	247		231
Special pallets			
Ships to craft	142		139
Craft to beach	138		138
Beach to LSA	78		

* Reference time = H+7 hours.

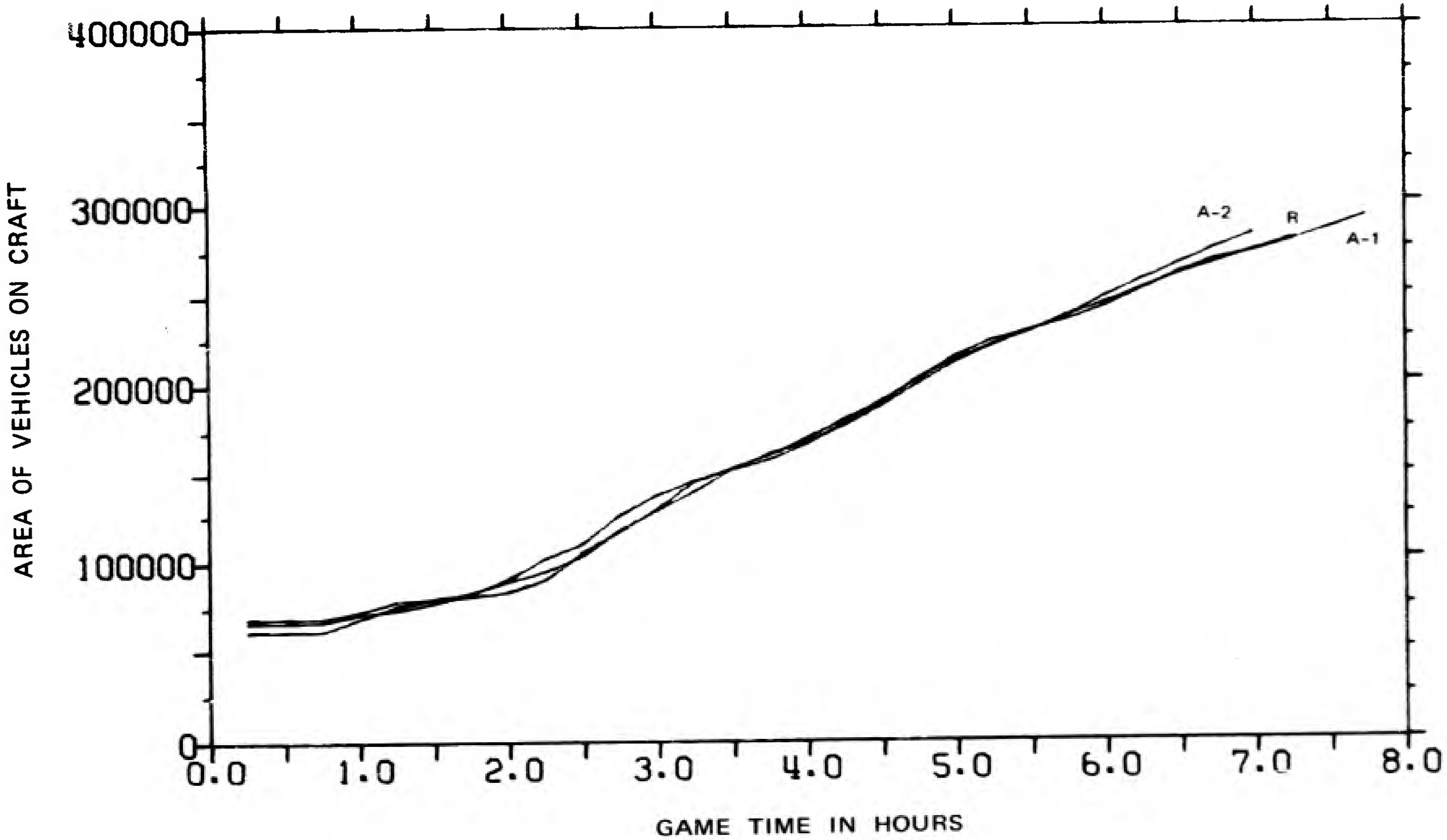

Figure 21 VEHICLES ON CRAFT – ASSAULT PHASE FOR FORCE COMPOSITION VARIATIONS

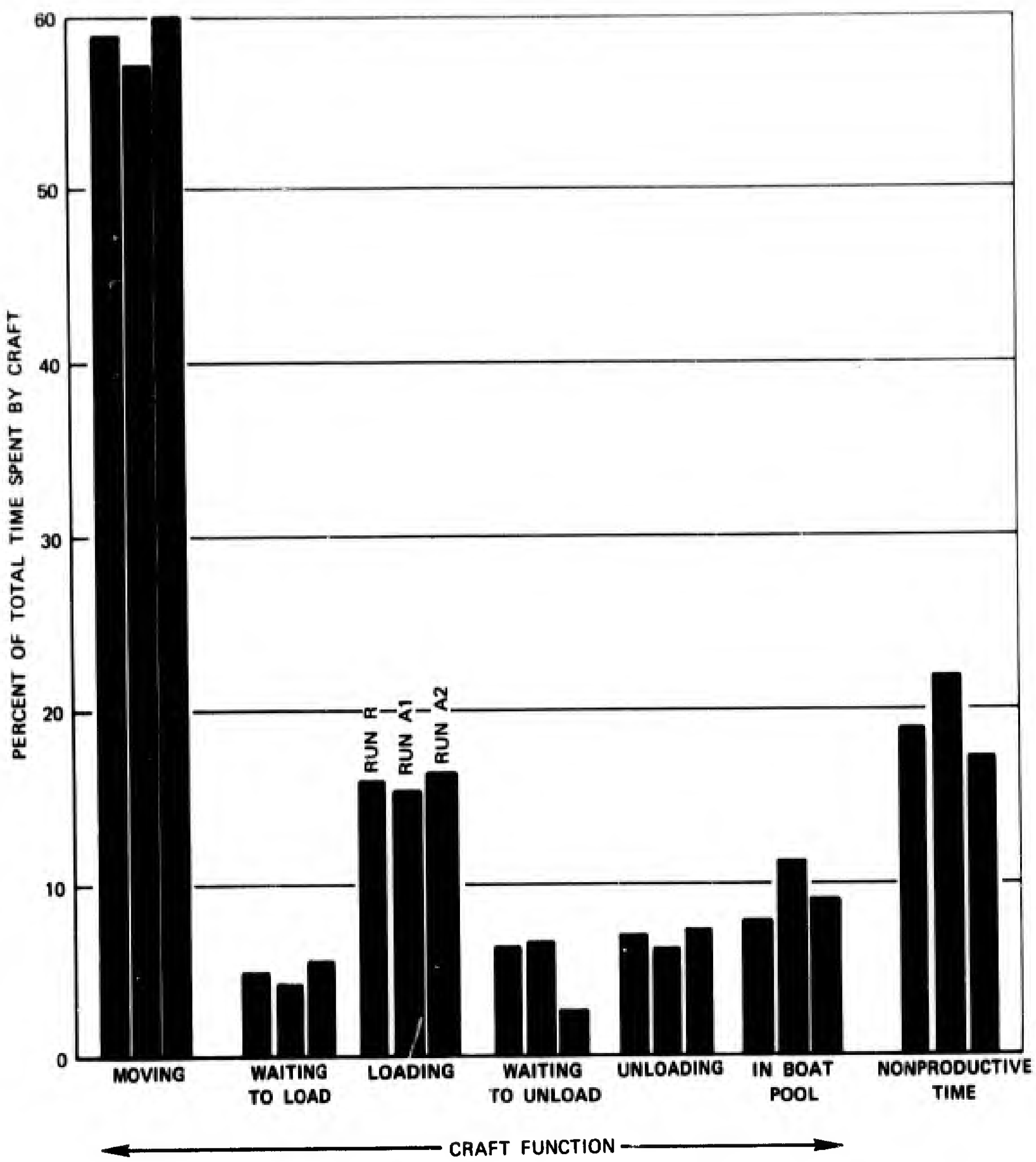

Figure 22 FORCE COMPOSITION VARIATIONS – CRAFT FUNCTION DURING ASSAULT PHASE

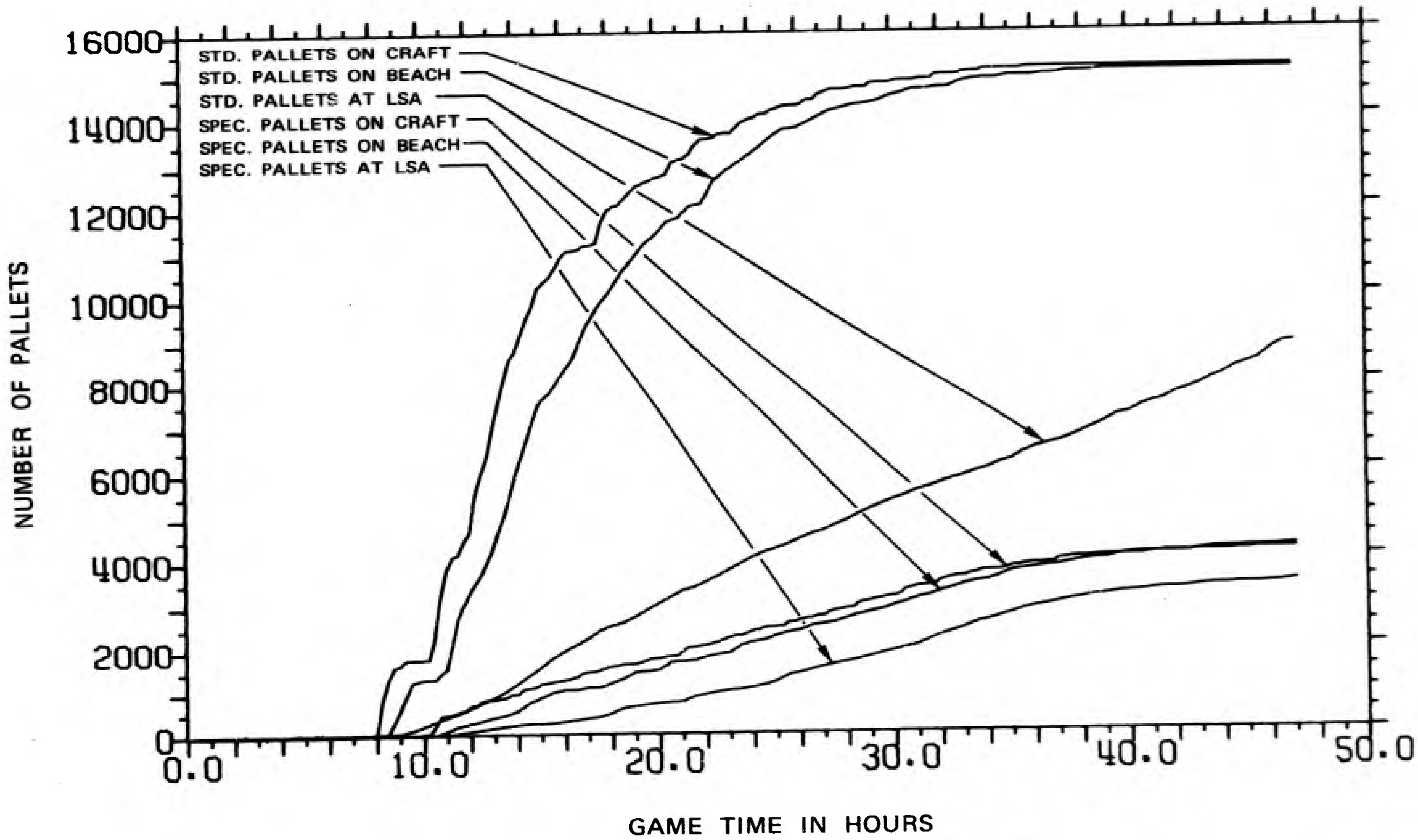

Figure 23 FLOW OF PALLETS – RUN A2

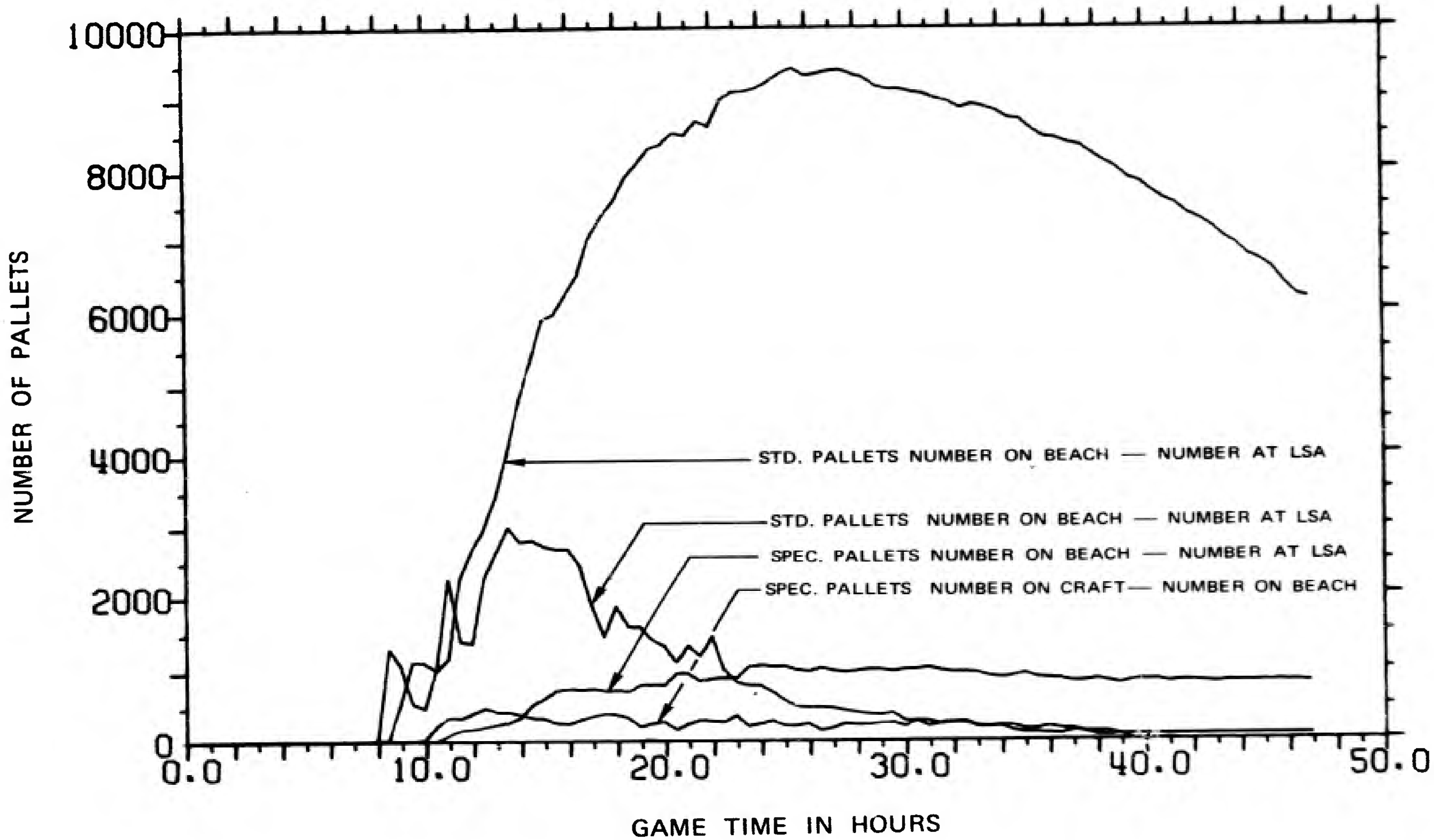

Figure 24 PALLET ACCUMULATION – RUN A2

advantage of the larger number of cargo-carrying vehicles for two reasons: first, because of slow craft loading, all of the available beach slots are not used. As a result, there are a limited number of loading positions for trucks resulting in truck queues. Second, the limited amount of handling equipment assigned to the beach dump (10 units) prevents use of more trucks. The result of these two factors combined is a slightly lower delivery rate to the LSA for Run A-2 than for the reference run. This situation could be relieved by modifying the beach dump operating procedures, but alternative procedures were not used for this analysis.

Embarkation Procedures

Before the EMBARK program is run, several decisions are made that have the potential of affecting landing craft operations. These are: (1) whether the LSDs are configured with or without mezzanine decks, (2) where the LVTs are carried, and (3) how the load is spread on the LKAs. The analysis revealed that the numbers and gross cargo-carrying capability of landing craft are critical factors in assault phase performance, but they are not critical in the general unloading phase when surplus craft are normally available. Therefore, for an effective assault phase performance, LSDs should be configured for maximum craft-carrying capability. Similarly, LVTs should not be allowed to pre-empt space that can be used to carry landing craft. Reconfiguration of LKA loads to provide more efficient landing craft loads is most beneficial.

In the reference run, no LSDs were equipped with mezzanine decks. Installation of the mezzanine itself adds to the vehicle carrying area of the ships. Included with the mezzanine decks are vehicle ramps that allow vehicles from both the superdeck and the mezzanine deck to drive to the well for ramp loading. However, the addition of the mezzanine deck limits the LSDs craft-carrying capability. LCM-6s and a limited number of LCM-8s can be maneuvered under the mezzanine, but the LSD is limited to carrying only two LCUs.

In Run B-1, we used a mixture of LSDs with and without mezzanine decks. No craft were loaded in the well behind the designated position of the LSD's water barrier. This area was used for vehicle storage. The addition of part of the well and the mezzanine decks added 18,000 square feet for vehicle storage in each LSD and allowed 12 LKAs to be dropped from the fleet. This, of course, meant that the LCM-6s carried as deck loads on the LKAs were also lost to the assault together with the craft lost from the LSDs. The number of craft was reduced from 291 in the references run to 149 for Run B-1.

In the reference run, the LVTs were loaded in the upper vehicle storage area of the LPDs. In these areas, the LVTs did not usurp valuable craft-carrying space, but they did seriously affect the serials that were assigned to the LPDs. Because of the size restrictions on vehicles that can be placed in lower vehicle storage, many serials that included one or more large vehicles were prevented from being loaded on LPDs. As a result, full advantage was not taken of the ramp loading capabilities of these ships. Alternative locations for the LVTs are LSDs, LSTs, and in the wells of the LPDs. Because LSDs do not have appreciable troop accommodations, and pre-H-hour personnel transfers are not desirable, this choice was not simulated except to supplement LVTs carried in LPDs. LSTs were also omitted at this time because of uncertainties as to the place and method of launching the LVTs. In Run B-2, 182 LVTs were loaded in the well decks of the LPDs, and the remaining 44 in the wells of the two LSDs. There was a net reduction of 31 (11 percent) in the number of craft carried. The added vehicle storage space allowed a major reorientation of the force embarkation but did not allow any of the LKAs to be dropped from the fleet.

In spreading the load on the LKAs, we sought to minimize loading time for each serial. To accomplish this, the vehicles of a serial were assigned in groups of four to successive holds. Thus, serials of five to eight vehicles would be loaded into two holds so that the serial could be loaded aboard two craft simultaneously. Larger serials would be spread among more holds. In this fashion, we hoped to avoid loading two craft in sequence at the same hold. This objective was achieved but at considerable cost because all LCUs and some LCM-8s loaded at LKAs received small, inefficient loads. To correct this situation, the load spreading procedure was modified. In Run B-3, serials containing 9 or fewer vehicles are loaded in a single hold, those containing 9 to 19 vehicles are loaded in two holds, and those containing 20 to 29, three holds and so forth. The transition points were selected by analyzing past runs but they can be modified if desirable.

The effectiveness measures for the four embarkation procedure runs are listed in Table 13. Almost cutting in half the number of landing craft from the reference run to Run B-1 did not cut the force-time effectiveness in half but reduced it by one-quarter. This improved relative performance can be accounted for by (1) faster vehicle loading on LSDs than on LKAs in combination with increased vehicle storage space on LSDs, and (2) the reduced time lost in the craft queues at the ships and at the LOD. Note that craft productivity for run B-1 is higher than that for the reference run. The effect on the time to deliver 250,000 square feet of vehicles is more pronounced. This time increased 2.3 hours or 37 percent. The changes in productivity between the reference run and Run B-2

Table 13

EFFECTIVENESS MEASURES--EMBARKATION PROCEDURES

	Simulation Run			
	Reference	B-1	B-2	B-3
Force-time Effectiveness* (vehicle-square feet-hours)	1,100	820	990	1,135
Lost cargo (square feet)	None	None	None	None
Response time (minutes)				
Mean	92	95	96	80
Variance	357	368	433	407
Time to deliver 250,000 square feet of vehicles ashore (hours)	6.15	8.45	6.60	5.95
Mean productivity (vehicle square feet/craft square feet)				
LCM-6	0.904	0.924	0.960	0.952
LCM-8	0.721	0.801	0.798	0.750
LCU	0.395	0.716	0.622	0.657
Mean cargo transfer rates (pallets/hour)				
Standard pallets				
Ships to craft	623	564		
Craft to beach	459	442		
Beach to LSA	257	250		
Special pallets				
Ships to craft	142	124		
Craft to beach	138	123		
Beach to LSA	78	80		

* Reference time = H+7 hours.

relate directly to the reduction in numbers of landing craft. The modified LKA loading procedure gives a modest improvement in performance suggesting that it should be incorporated in future runs.

Figure 25 shows the delivery of vehicles ashore versus time for each of the runs. Their relative shapes closely follow the explanations given above. Similarly, the shapes of the force-time effectiveness curves shown in Figure 26 are as expected. The distribution of craft time is illustrated in Figure 27. In Run B-1, craft spend a greater percentage of their time moving and smaller percentage loading (which includes time spent waiting at the ships) and waiting than in other runs.

General unloading was not simulated in runs B-2 and B-3. Run B-2 would be only slightly different than the reference run except for the 11 percent reduction in landing craft. Inasmuch as surplus craft are available during general unloading, it is not likely to be different from the reference run. Run B-3 would be no different from the reference run because there was no change in the method of handling general cargo.

The general unloading phase was simulated for Run B-1 to determine the effect on pallet delivery rates of drastic reductions in the number of landing craft. As one might expect, the result was a large decrease in queues at the ships but no marked decrease in the rate of delivering pallets to the beach. Because the assault phases for Run R ended at time H+7.25 hours and the assault phase for Run B-1 ended at H+9 hours, it is necessary to adjust the time scale by 1.75 hours so that the general unloading phases will begin at the same time. This has been done in Figure 28 . The difference in the number of pallets loaded on craft for the two runs is negligible because all loading stations are occupied by free craft at the start of general unloading. After a short time, the smaller number of craft available in Run B-1 causes some unoccupied loading stations with a decrease in the flow of standard pallets onto the craft. However, as loading stations are depleted of pallets, the smaller number of craft is sufficient to occupy the remaining stations. In the reference run, which has maintained a higher off-loading rate into craft, the loading stations aboard some ships are exhausted early, and the flow rate decreases so that by the end of the general unloading the performances of Run B-2 and the reference run are about the same.

The pallet flow rate onto the beach is constrained by the number of available craft unloading slots--the same for both runs. A queue develops at the LOD for the reference run soon after the start of general unloading; this queue has craft in it almost to the end of the general unloading phase. Therefore, the flow of pallets onto the beach is very close to a maximum for the type of craft and number of unloading slots used. Reduction of

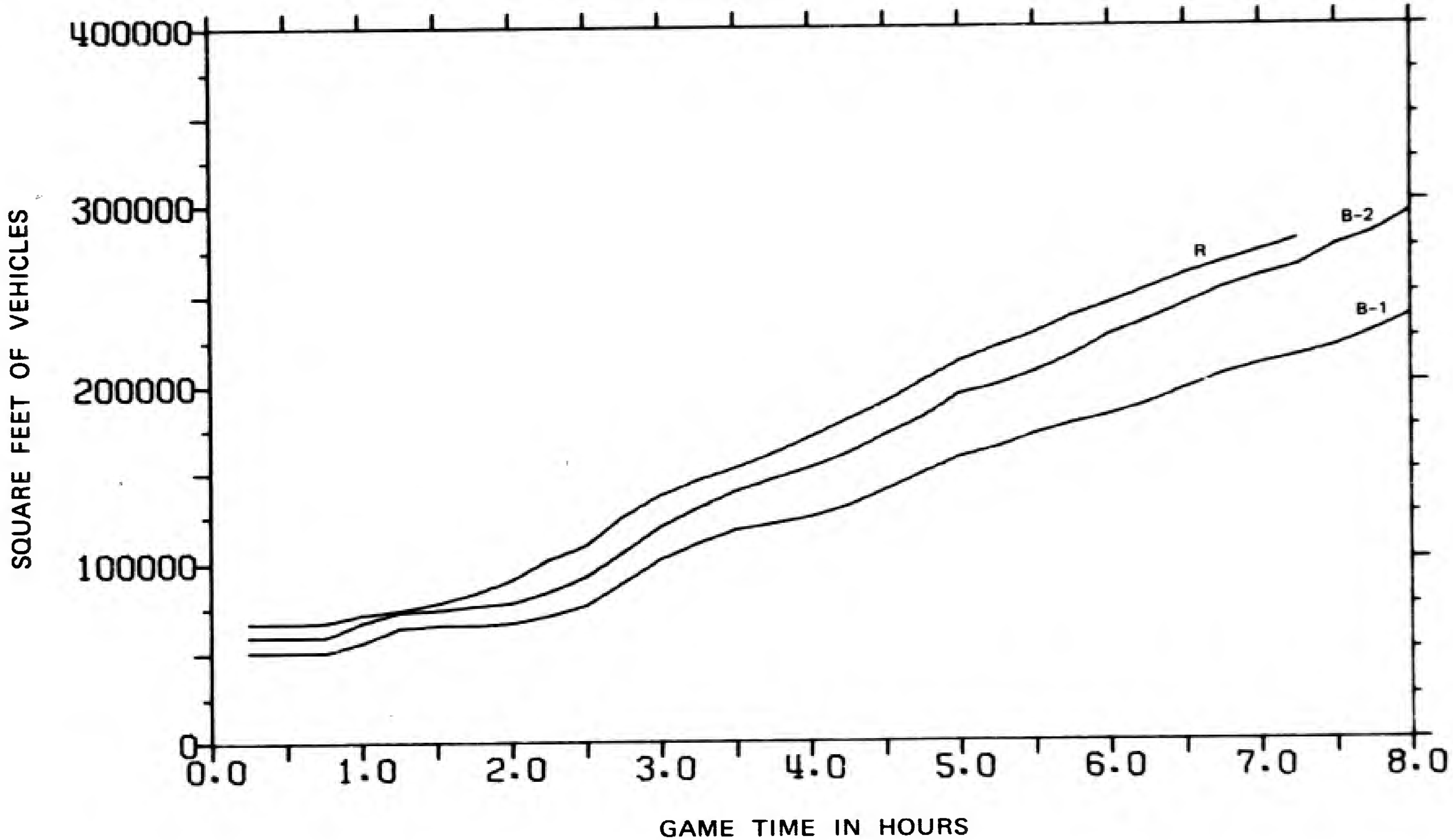

Figure 25 VEHICLES ON CRAFT – ASSAULT PHASE FOR EMBARKATION PROCEDURE VARIATIONS

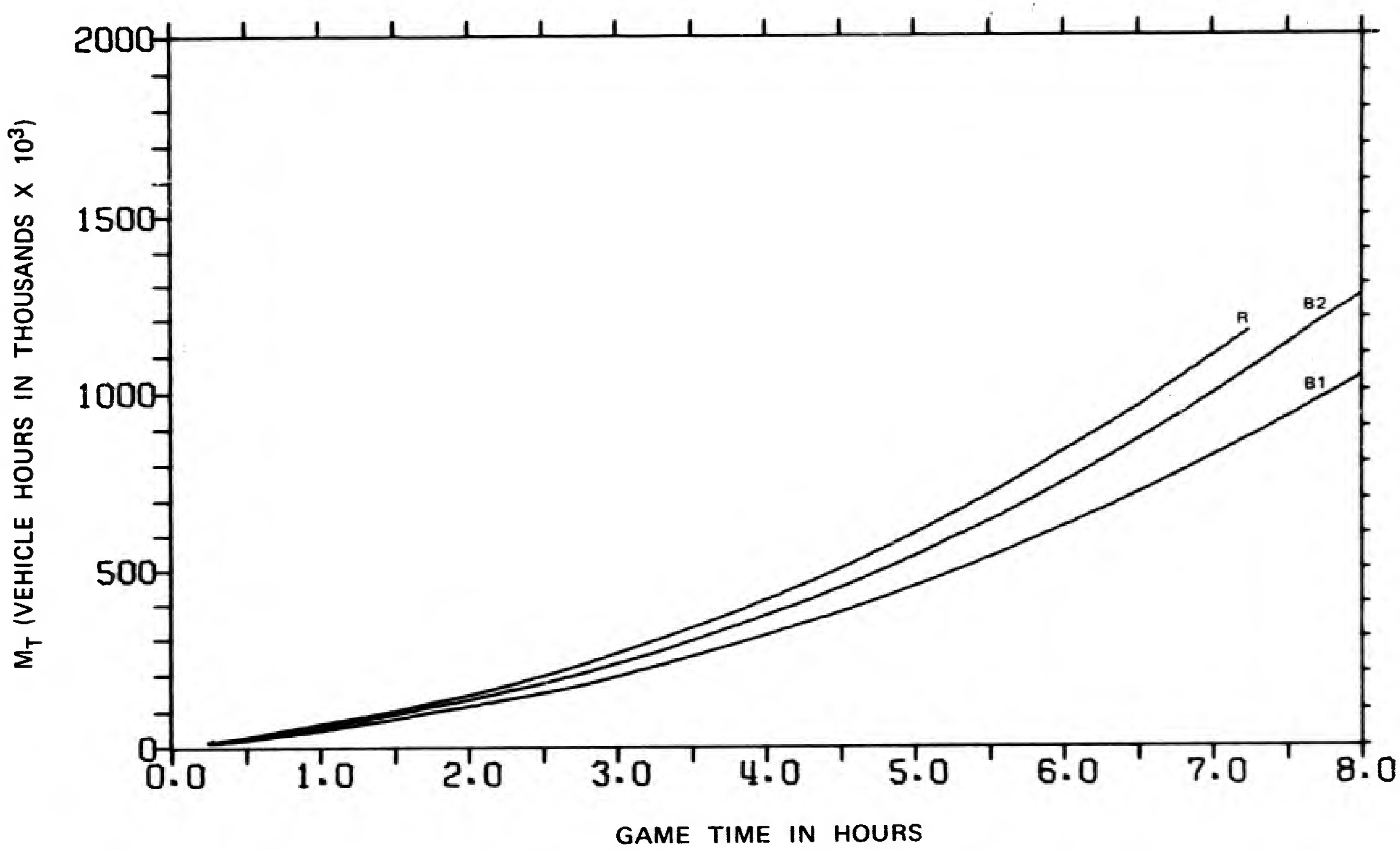

Figure 26 EMBARKATION VARIATIONS – FORCE TIME EFFECTIVENESS

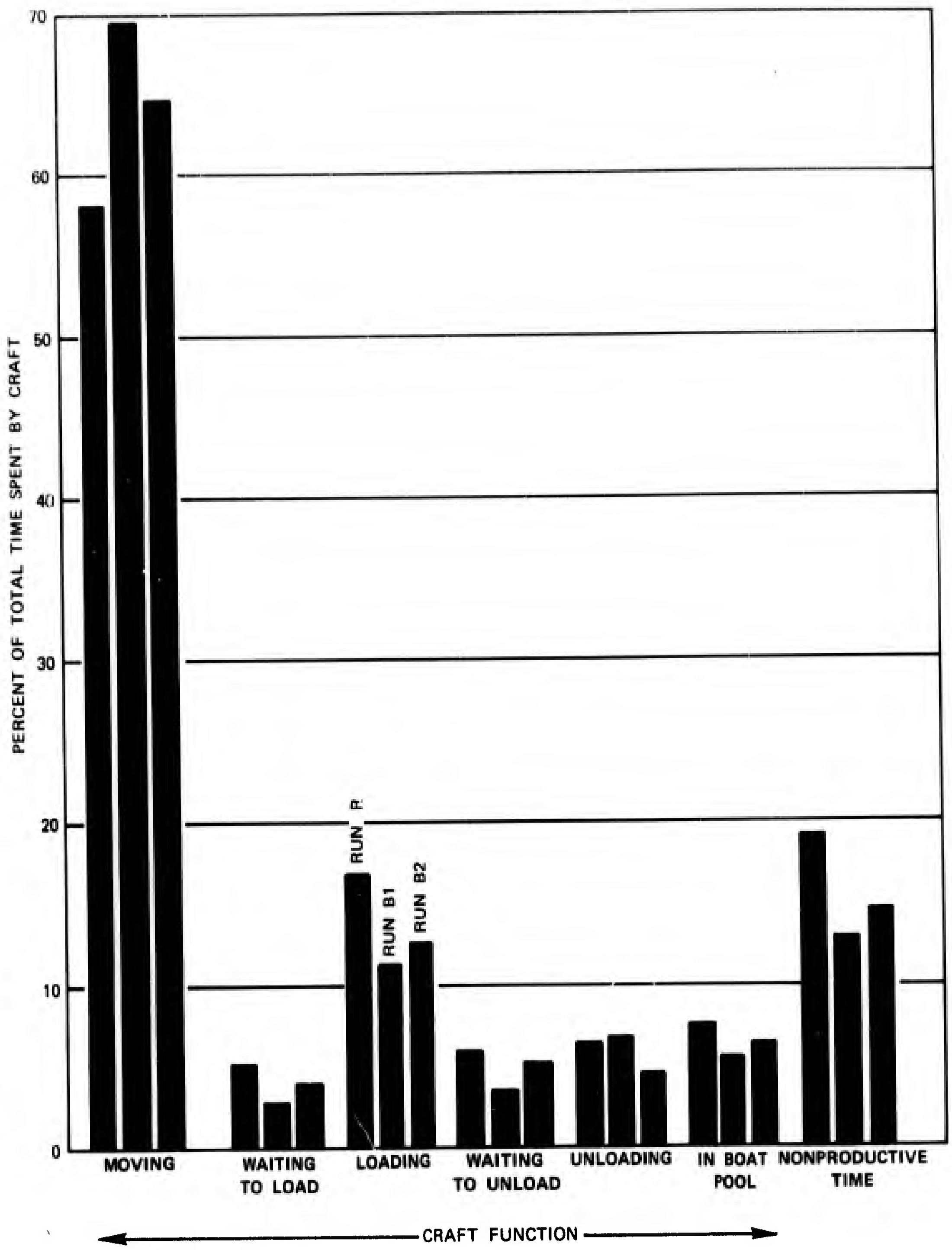

Figure 27 EMBARKATION VARIATIONS – CRAFT FUNCTIONS DURING ASSAULT PHASE

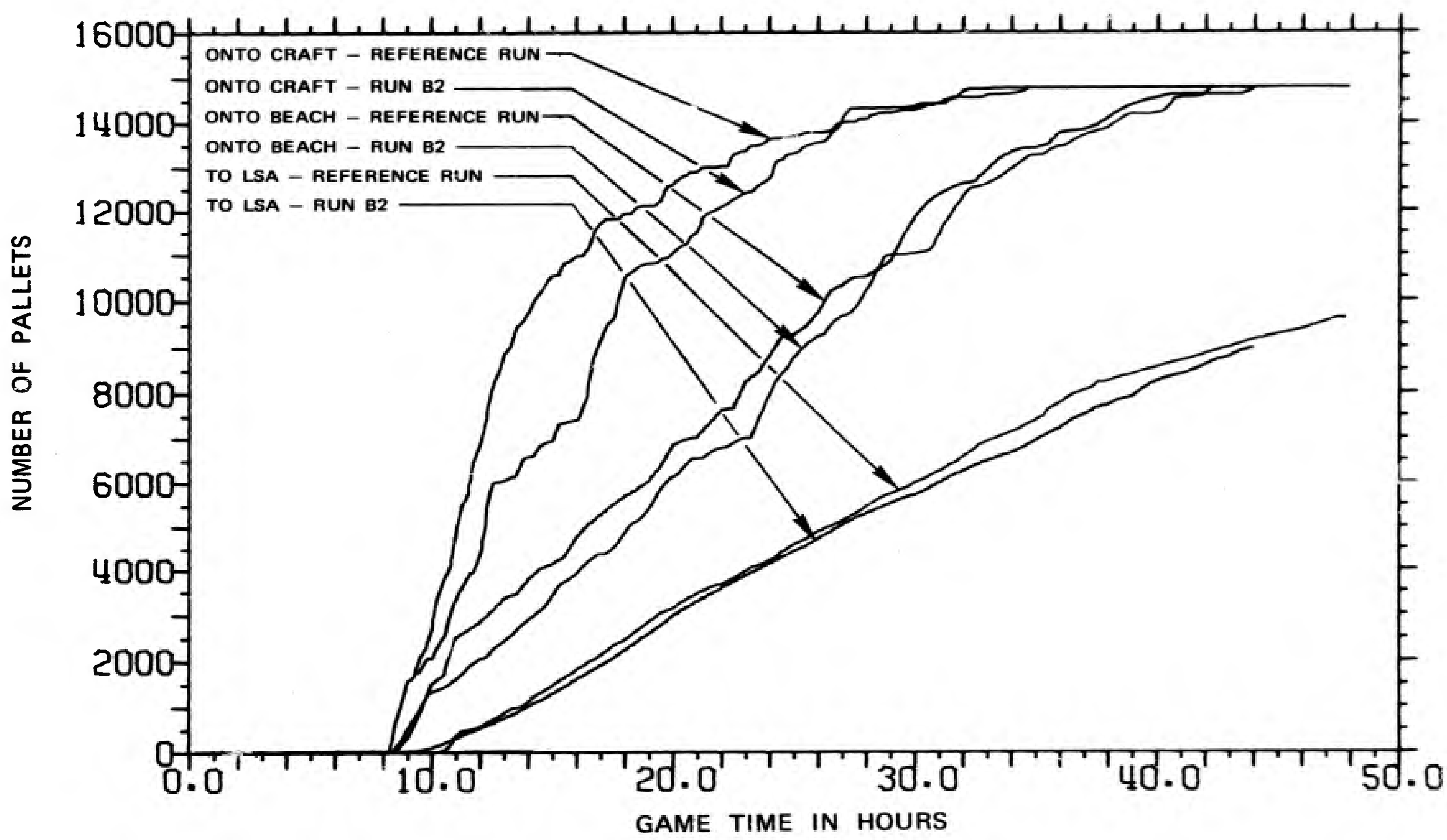

Figure 28 FLOW OF PALLETS – REFERENCE RUN VERSUS RUN B2

the number of craft arriving on the beach for Run B-3, although significant, is not enough to reduce the use of the unloading slots. As a consequence, the pallet flow onto the beach is almost the same as that in the reference run.

The flow of pallets inland to the LSA is virtually unaffected by the change in the number of available craft because the delivery rate to the beach constrains the maximum attainable flow rate.

The flows of special pallets are more uniform for Run B-1 than for the reference run because standard pallets are depleted more slowly. Allowing for the 1.75-hour time difference in the start of the two general unloading phases, there is an additional three-hour lag in getting all of the special pallets ashore for Run B-1.

Fleet Stand-Off Distance

Fleet stand-off distance is a major determinant of landing craft performance and will play a major role in the analysis of advanced landing craft. Several stand-off distances were investigated for base system craft, and an analytical technique was developed and tested for predicting craft performance at long stand-off distances.

For convenience, the landing force configuration used in the reference run (see Appendix B) has been assigned a nominal stand-off distance of five miles.* Longer fleet stand-off distances were simulated by merely increasing the distances in the STS-2 geographic location table by the amount of the desired increase in distance. Thus, the relative locations of the different ships of the fleet were not changed. In practice, we would expect increases in stand-off distance to be accompanied by rather drastic changes in operational procedures. At the very least, a sea echelon procedure would be adopted as water depths become too great for anchoring. However, operational schemes for long stand-off amphibious assaults are still in the formation stage. Furthermore, new procedures are not likely to change the distances traveled by landing craft drastically. Therefore, the simplified procedure followed is considered appropriate for the present analysis.

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* The mean distance from the beach to the centers of the LPD, LSD, and LKA anchorages is four miles. The mean distance that craft travel from ship-to-shore is about 6-1/2 miles.

Three stand-off distances were simulated in addition to that of the reference run: (1) C-1, 15 nautical miles, (2) C-2, 25 nautical miles, and (3) C-3, 35 nautical miles; additions of 10, 20, and 30 nautical miles, respectively, to the stand-off distance of the reference run.

The effectiveness measures for Runs C-1, C-2, and C-3 are listed in Table 14. In the assault phase of the reference run, landing craft

Table 14

EFFECTIVENESS MEASURES--FLEET STAND-OFF DISTANCE

	Simulation Runs			
	Reference	C-1	C-2	C-3
Stand-off distance (nautical miles)	5	15	25	35
Force-time effectiveness* (thousands of vehicle-square feet-hours)	1,100	664	558	545
Lost cargo (square feet)	None	None	None	None
Response time (minutes)				
Mean	92	171	249	323
Variance	357	290	309	313
Time to deliver 250,000 square feet of vehicles ashore (hours)	6.5	14.1	21.9	29.6
Mean productivity (vehicle square feet/craft square feet)				
LCM-6	0.904	0.397	0.233	0.192
LCM-8	0.721	0.405	0.240	0.224
LCU	0.595	0.452	0.342	0.332

* Reference time = H+7 hours.

spend approximately 60 percent of their time moving and almost one-quarter of their time waiting. As the stand-off distance increases, one would expect the longer movement times to reduce the effective number of craft available for loading and unloading. As a result, one would also expect craft congestion to be reduced. The results of the simulation are not so favorable. In all runs, the preloaded craft approach the beach behind the scheduled waves for early delivery of the critical serials. At time H+7 hours, the reference for force-time effectiveness, landing craft in the reference run have made three to five trips to the beach. Those in C-1 (15 miles) have made one to two trips, a few craft in C-2 (25 miles) have made a second trip, and no craft in C-3 (35 miles) have made a second trip. Thus, the differences in force-time effectiveness for the latter three runs are very small. The situation is illustrated in Figure 29. The curve for the reference run is smooth because distances are short, and the small groups of landing craft carrying individual serials tend to act more or less independently. At the other extreme, in Run C-3, because of the continued dominance of long moving time and because craft speeds are essentially the same, the landing craft move in echelons that perpetuate delays at the beach and at the ships. These delays cause some smoothing of the curve with the passage of time. The results of Runs C-1 and C-2 are intermediate between the extremes. Figure 30 illustrates force-time effectiveness over time. Differences among Runs C-1, C-2, and C-3 become more pronounced after H+10 hours.

As stand-off distance increases, the mean productivity of the LCM-8 and LCU craft is higher than that of the LCM-6s because of their greater load-carrying capability. In fact, the order of relative productivity is inverted between the 5- and 15-mile stand-off distances.

General unloading was not simulated for any of the long stand-off distances. We presumed that, by the end of the assault phase, the reasons for the long stand-off assault (e.g., tactical surprise and reduced ship vulnerability) would have been eliminated, and the fleet could come in close to shore to discharge general cargo.

A careful examination of the simulation results revealed a technique for estimating simulation results for different stand-off distances. This technique depends on the following assumptions:

1. Time spent in queues does not change

2. Craft loads are similar so that loading and unloading times do not change

3. Time spent in the boat pool is the same.

This, in turn, suggests that the echelon effect described above will continue through the assault phase. Accepting these assumptions, the

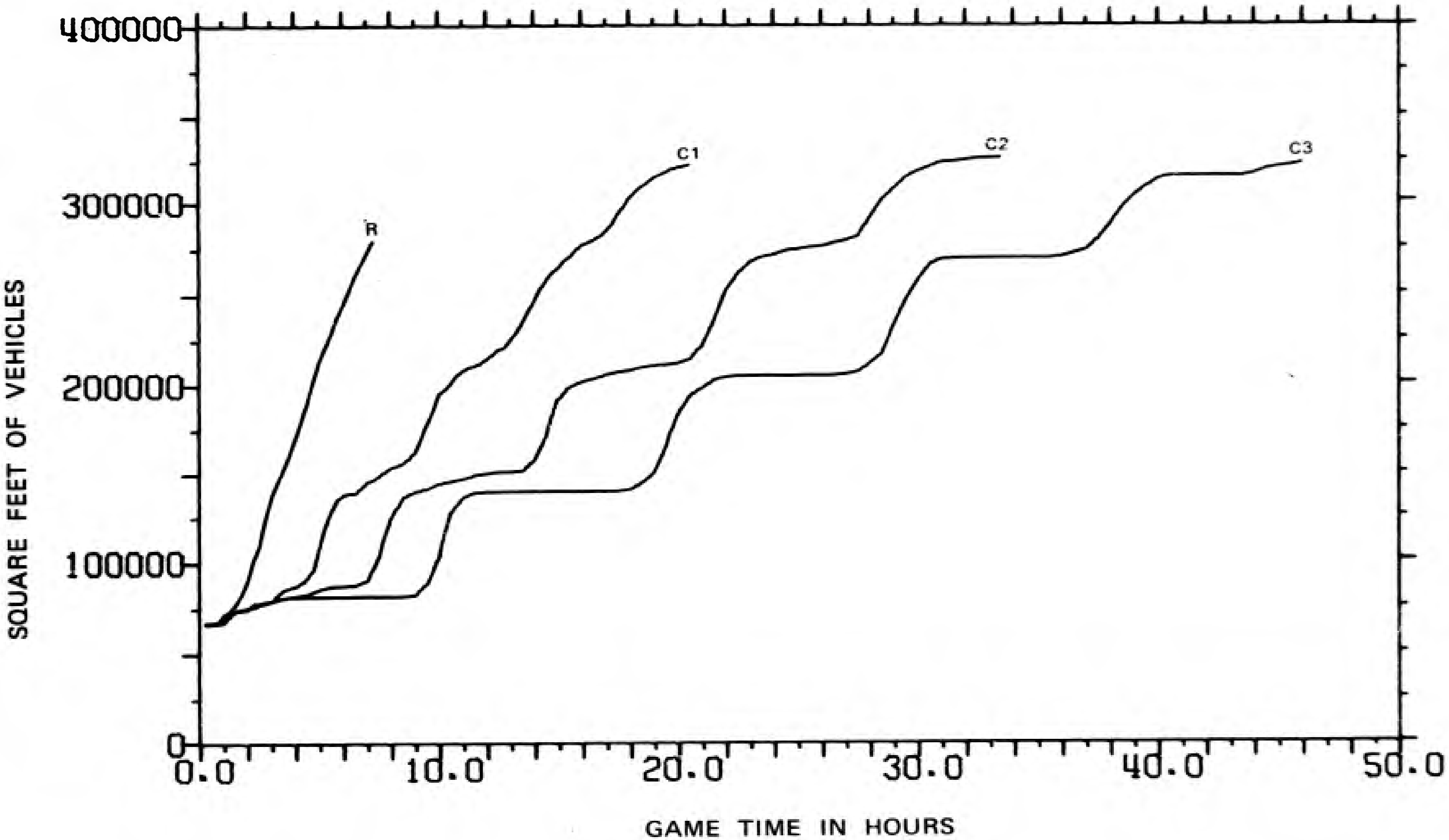

Figure 29 VEHICLES ON CRAFT – ASSAULT PHASE FOR DIFFERENT STAND-OFF DISTANCES

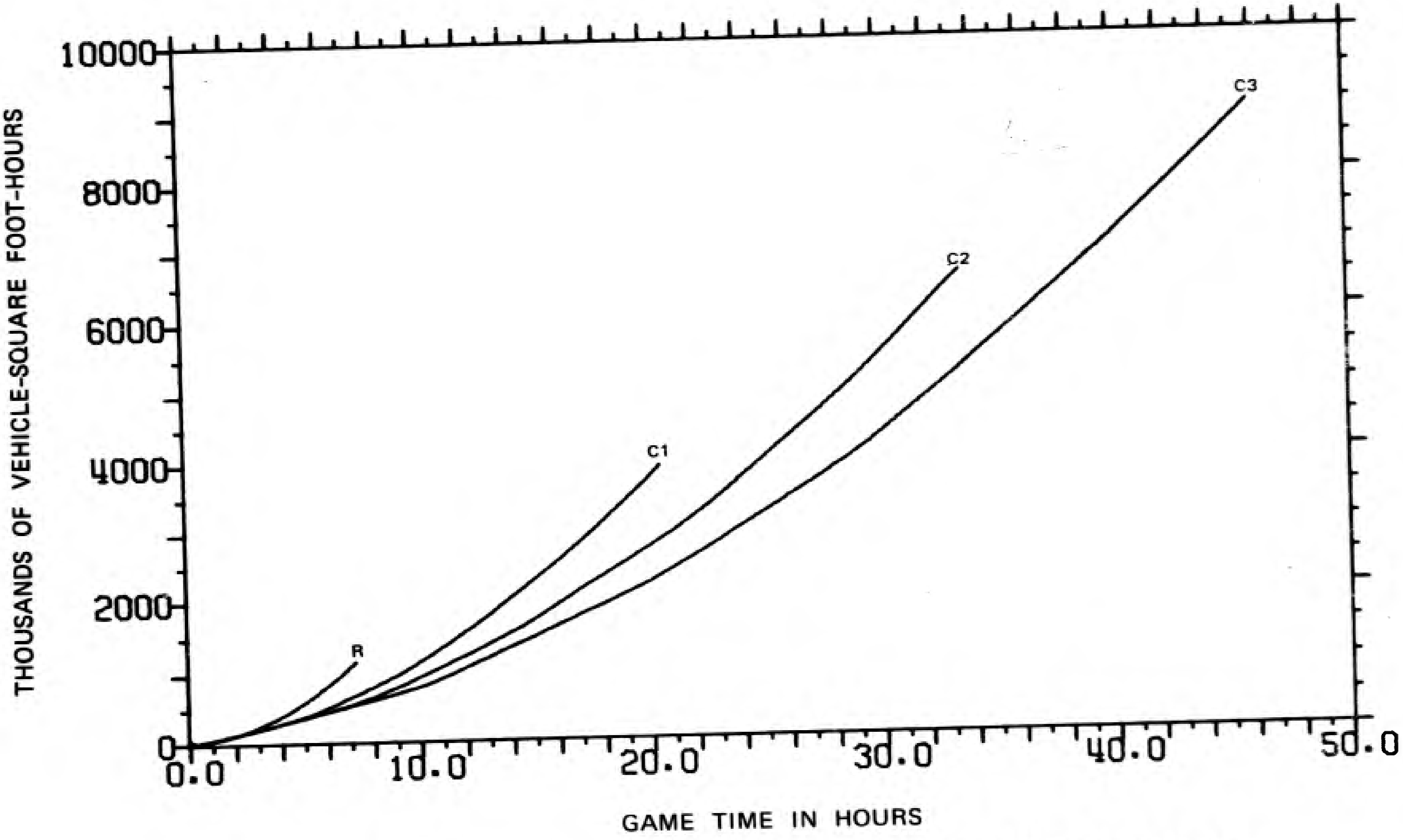

Figure 30 FORCE-TIME EFFECTIVENESS FOR DIFFERENT STAND-OFF DISTANCES

relationship between the percent time spent moving (P), in hours, and stand-off distance (D), in nautical miles, can be expressed as follows:

$$P = \frac{\frac{D}{d} \times P_m}{\frac{D}{d} \times P_m + (100-P_m)}$$

where d = reference stand-off distance

P_m = percent movement time for craft at the reference stand-off distance, d

In terms of the reference run with a nominal stand-off distance of 5 n. mi. (d), and 59 percent movement time experience (P_m), the equation can be reduced to:

$$P = \frac{11.8D}{11.8D + 41}$$

This equation is plotted in Figure 31, together with the actual results of the four simulations. The difference between the theoretical curve and the simulation results is slight except at the 35-mile distance. Furthermore, the shape of the theoretical curve fits the data, suggesting that the form of the derived equation is correct.

In Figure 32 the times to load 250,000 square feet of vehicles onto the craft are plotted for each of the four stand-off distances. These points have been fitted by a linear approximation using a least squares fit (labeled "actual"). The line labeled "theoretical" is derived from the results of the reference run only, on the assumption that time spent not moving (t_{nm}) is constant. Since P(D) is the percent of time spent moving, 1-P(D) is the percent of time not moving, and the actual time spent not moving for any stand-off distance is:

$$t_{nm}(D) = T(1-P(D))$$

where $P(D) = \frac{11.8D}{11.8D + 41}$

hence $T = \frac{t_{nm}(5)}{1 - P(D)} = \frac{2.54}{1-P(D)}$

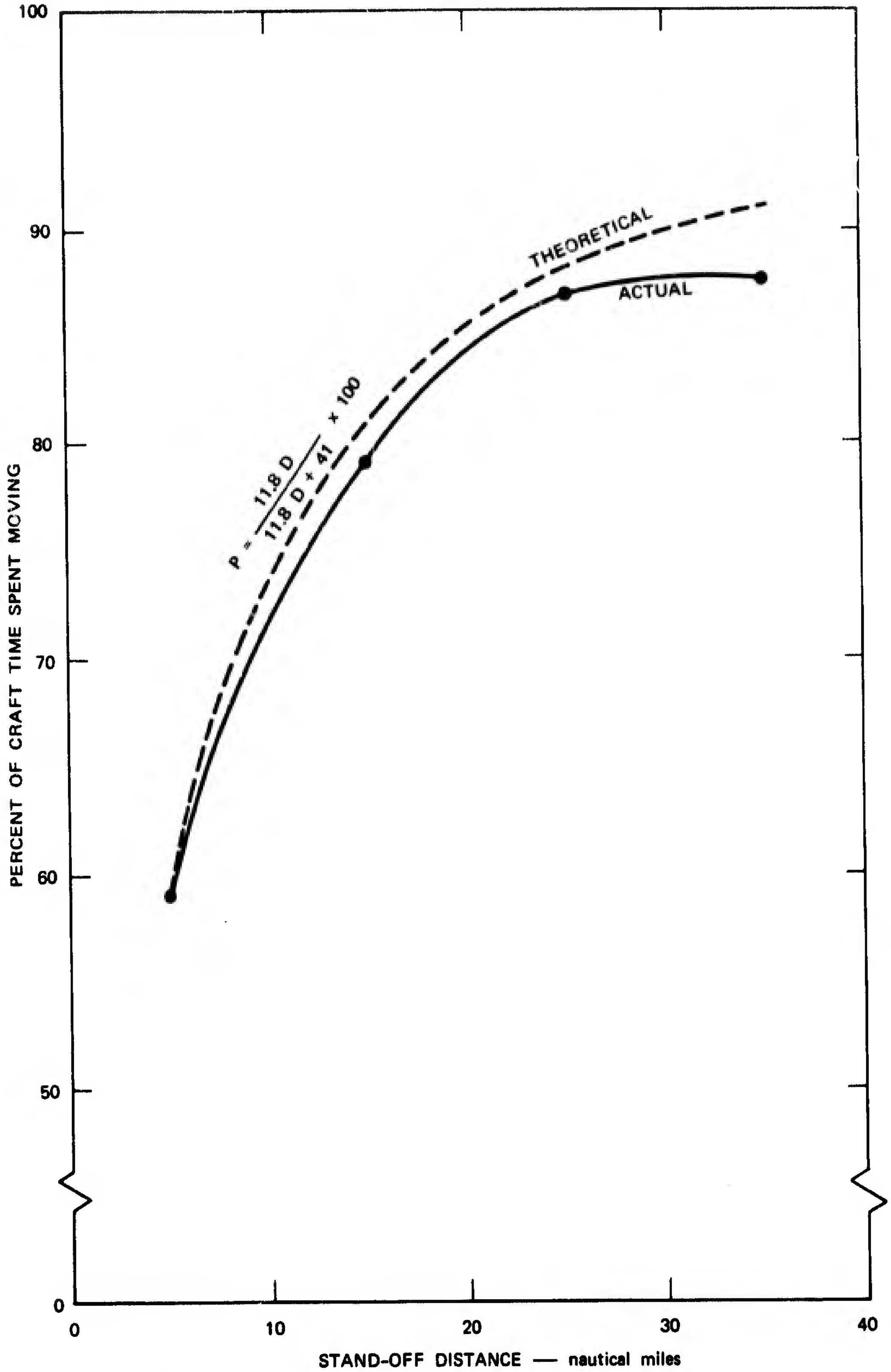

Figure 31 CRAFT FUNCTION VERSUS STAND-OFF DISTANCE

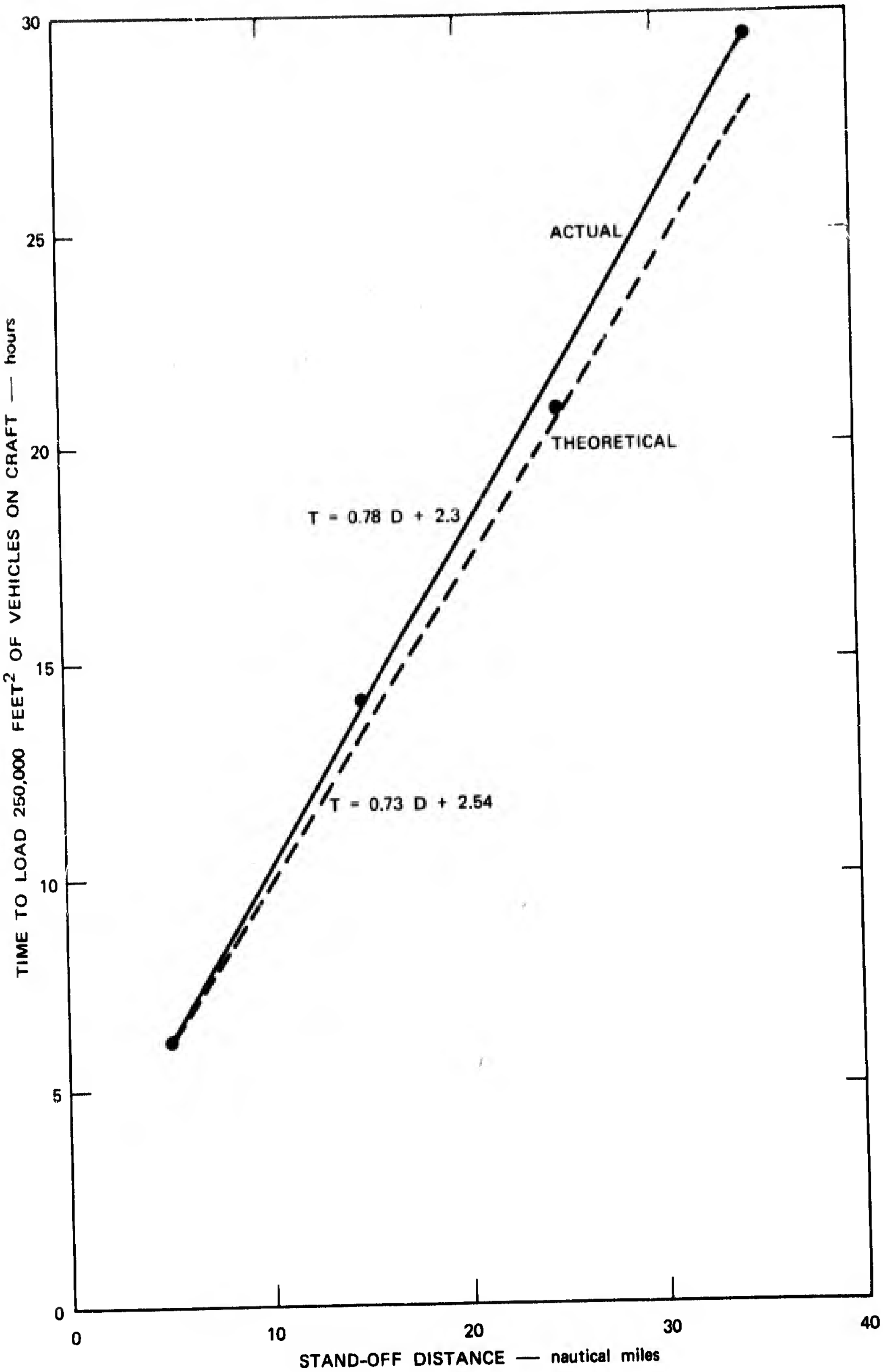

Figure 32 VEHICLE FLOW ONTO CRAFT AS A FUNCTION OF STAND-OFF DISTANCE

which yields the equation

$$T = 0.73\ D + 2.54$$

using $t_{nm} = 0.41 \times 6.2$, which are the values for $D = 5$ n. mi.

This curve agrees quite well with the "actual" curve for the stand-off distances of interest.

Landing Craft Order

When the craft carrying several serials arrive simultaneously at the LOD, the STS-2 model assigns them to unloading slots in the order of their landing craft numbers. In the reference run, craft numbers were assigned by craft type: LCUs first, then LCM-8s, and finally LCM-6s. Thus, when the preboated loads arrived at the LOD, beach slots were first assigned to LCUs and then to LCM-8s. Most of the LCM-8s and all of the preloaded LCM-6s had to wait until the LCUs were unloaded before they could proceed to the beach. This wait amounted to one hour or in a few instances more. As a result, LCUs and a few LCM-8s were the first to return to the ships for second loads, thus tending to have maximum productivity during both assault and general unloading phases.

In Run D-1, we learned that the results of the simulations are not sensitive to this arbitrary procedure. Landing craft order does not have a major impact on total craft performance, but the revised procedure developed for this run is preferable to that used in the reference run.

In Run D-1, numbers were assigned to landing craft in the order in which they were selected to carry preboated serials. Thus, when the preloaded craft arrive at the LOD, the first slots are assigned to the mix of craft carrying the first serial, the next to the second, and so forth. This revised procedure more nearly reflects actual operating procedures.

Table 15 lists the assault phase effectiveness measures for the reference run and for Run D-1. Run D-1 is slightly preferable to the reference run by all measures except response time variance. Changes in mean productivity by craft type reflect the ordering scheme in use. The productivity of LCU and LCM-8 craft declined slightly, and that of LCM-6 craft increased slightly.

The general unloading phase was not simulated for Run D-1.

Table 15

EFFECTIVENESS MEASURES--LANDING CRAFT ORDER

	Simulation Runs	
	Reference	D-1
Force-time effectiveness* (thousands of vehicle-square feet-hours)	1,100	1,130
Lost cargo (square feet)	None	None
Response time (minutes)		
Mean	92	70
Variance	357	505
Time to deliver 250,000 square feet of vehicles ashore (hours)	6.15	5.87
Mean productivity (vehicle square feet/ craft square feet)		
LCM-6	0.904	0.947
LCM-8	0.721	0.723
LCU	0.595	0.582

* Reference time = H+7 hours.

Sea State

The sea state has played important roles in all past amphibious assaults and promises to be an important parameter in evaluating advanced landing craft. Two simulation runs were based on sea states other than sea state 1 used for the reference run: sea state 2 (Run E-1) and sea state 3 (Run E-2). A change in sea state affects craft speed, craft loading and unloading times, and the number of craft lost or delayed by broaching at the beach. Table 16 lists the values of all of the parameters that were changed as a result of sea state. These rates reflect the best data available at the time the runs were made, as well as the opinions of

Table 16

THE EFFECTS OF SEA STATE ON LANDING CRAFT CHARACTERISTICS

	Simulation Runs		
	Reference	E-1	E-2
Craft speed (knots)			
LCU	8	8	7
LCM-8	8	7	6
LCM-6	8	7	6
Craft loading time (minutes)			
LPD or LSD			
100 personnel	10	10	10
1 vehicle	3	3	4
LKA			
100 personnel	20	20	20
1 vehicle	10	15	30
Craft unloading time (minutes)			
100 personnel	5	5	5
1 vehicle	2.5	2.5	2.5
Probability of broaching	0	0	0
LCU	0	0	0
LCM-8	0	0.05	0.10
LCM-6	0	0.10	0.15

Navy and Marine Corps operating personnel. However, they do not take into account the results of recent testing.*

The loading rate from well-type ships is not judged to be as sensitive to sea state as the alongside loading rate from an LKA. The well of the LPD or LSD provides some protection for the craft. Wave action in the

* Since these runs were made, the STS-2 has been modified to compute loading and unloading times as a function of ship type, vehicle type, vehicle size, and vehicle weight. See Nielsen, Michael J., "Systems Analysis of Amphibious Assault Craft: Vehicle Loading Test Results", Stanford Research Institute, Menlo Park, California, April 1969

well can be supressed by closing the ship's stern gate if necessary, and craft can be securely gounded by deballasting. Loading alongside is very sensitive to sea state. The pendulum effect of vehicles on hooks becomes significant. It becomes more difficult to keep the craft alongside, and absolute motion of craft and ship increase relative motion between the two making it more difficult and time-consuming to set cargo in the craft without damage to either. Unloading rates are not listed by craft type because LCUs, LCM-8s, and LCM-6s are similar craft (displacement hull, diesel powered, propeller driven), and they have about the same draft. Data were not available for ascertaining differences.

Table 17 lists the effectiveness measures for the three simulation runs with different sea states. Force-time effectiveness is reduced

Table 17

EFFECTIVENESS MEASURES--SEA STATE

	Simulation Runs		
	Reference	E-1	E-2
Force-time effectiveness* (thousands of vehicle-square feet-hours)	1,100	854	790
Lost cargo (square feet)	None	None	None
Response time (minutes)			
Mean	92	96	
Variance	357	294	
Time to deliver 250,000 square feet of vehicles ashore (hours)	6.15	7.97	>12.0
Mean productivity (vehicle square feet/ craft square feet)			
LCM-6	0.904	0.709	0.503
LCM-8	0.721	0.622	0.490
LCU	0.595	0.617	0.528

* Reference time = H+7 hours.

13 percent when the sea state changes from sea state 1 to sea state 2, and it is reduced 28 percent when the sea state changes from 2 to 3. The influence of the preloaded craft on force-time effectiveness is evident in Figure 33. Figure 34 shows force-time effectiveness plotted throughout the assault phase. The time to deliver 250,000 square feet of vehicles ashore is heavily influenced by the increased broaching and longer craft turnaround times. This time increased almost 30 percent from sea state 1 to sea state 2. Run E-2 was terminated at H+12 hours before 250,000 square feet of vehicles had been brought ashore. The changes in productivity of the different craft types reflect their relative sensitivity to sea state. LCM-6 performance declines sharply as the sea rises. LCM-8 performance also declines but less sharply because it is a larger, more stable craft. LCU productivity actually rises from sea state 1 to 2 because its performance is not degraded and it suffers less interference from other craft. At sea state 3, the LCUs are definitely the most productive craft.

Table 18 illustrates the increase in loading time that results from heavier seas for Runs E-1 and E-2. The proportion of time spent loading

Table 18

PERCENT OF TIME SPENT BY ALL CRAFT DURING THE ASSAULT PHASE

Run	Moving	Waiting To Load	Loading	Waiting To Unload	Un-loading	In Boat Pool	Attrited	Percent of Nonproductive Time
A-1	59.0%	4.8%	15.9%	6.2%	6.7%	7.4%	0 %	18.4%
E-2	51.0	5.4	16.2	4.7	4.7	15.5	2.5	28.1
E-3	39.7	10.6	19.3	2.8	3.6	20.2	3.8	37.4

does not change dramatically, but the time spent waiting to load and in the boat pool increases substantially. Both of these increases are a result of queues at the ships. The boat pool absorbs the craft not able to enter the limited queues. Time spent moving decreases relatively even though it has increased absolutely because of the craft speed reductions shown in Table 16.

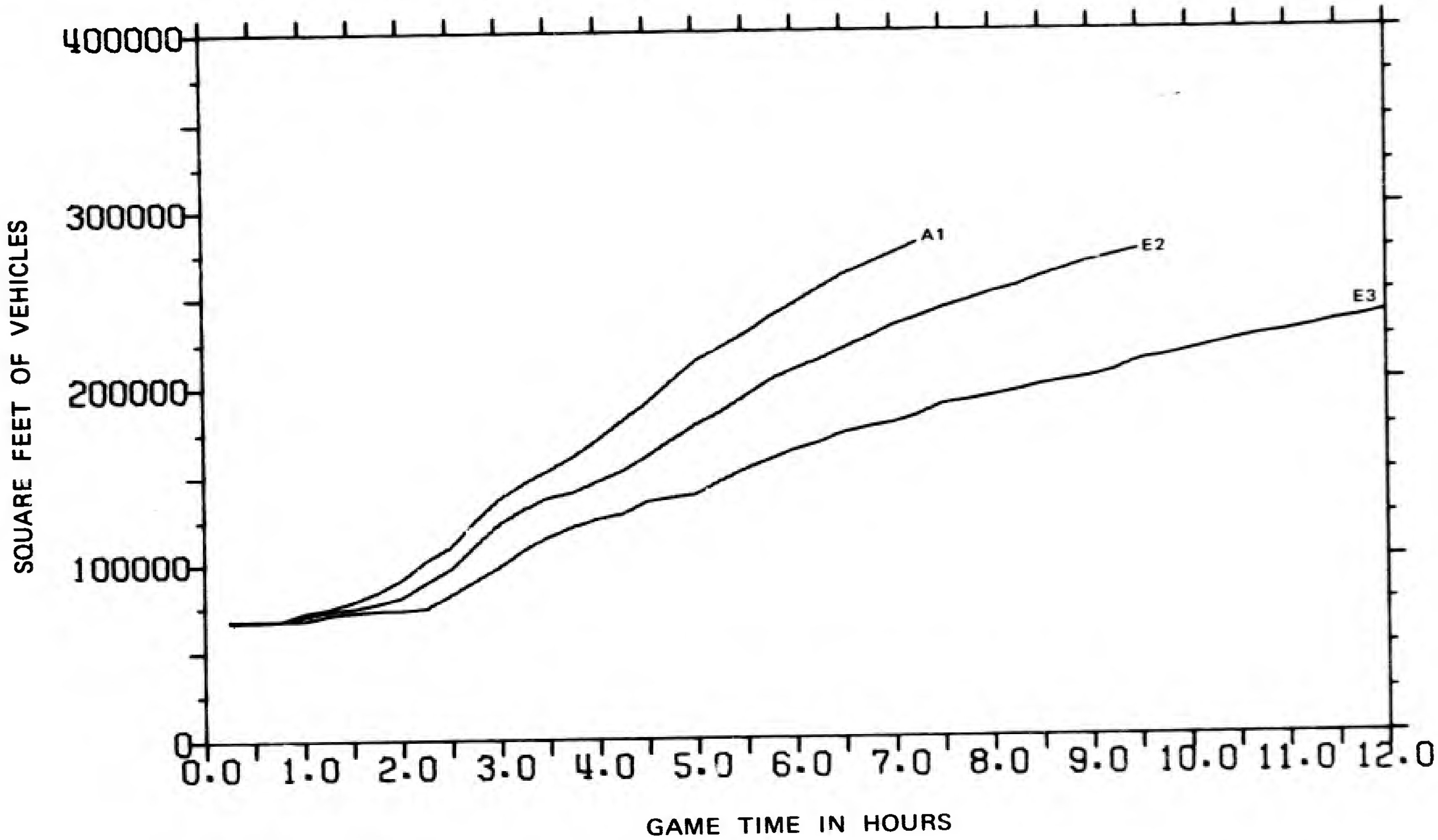

Figure 33 VEHICLES ON CRAFT – ASSAULT PHASE FOR DIFFERENT SEA STATES

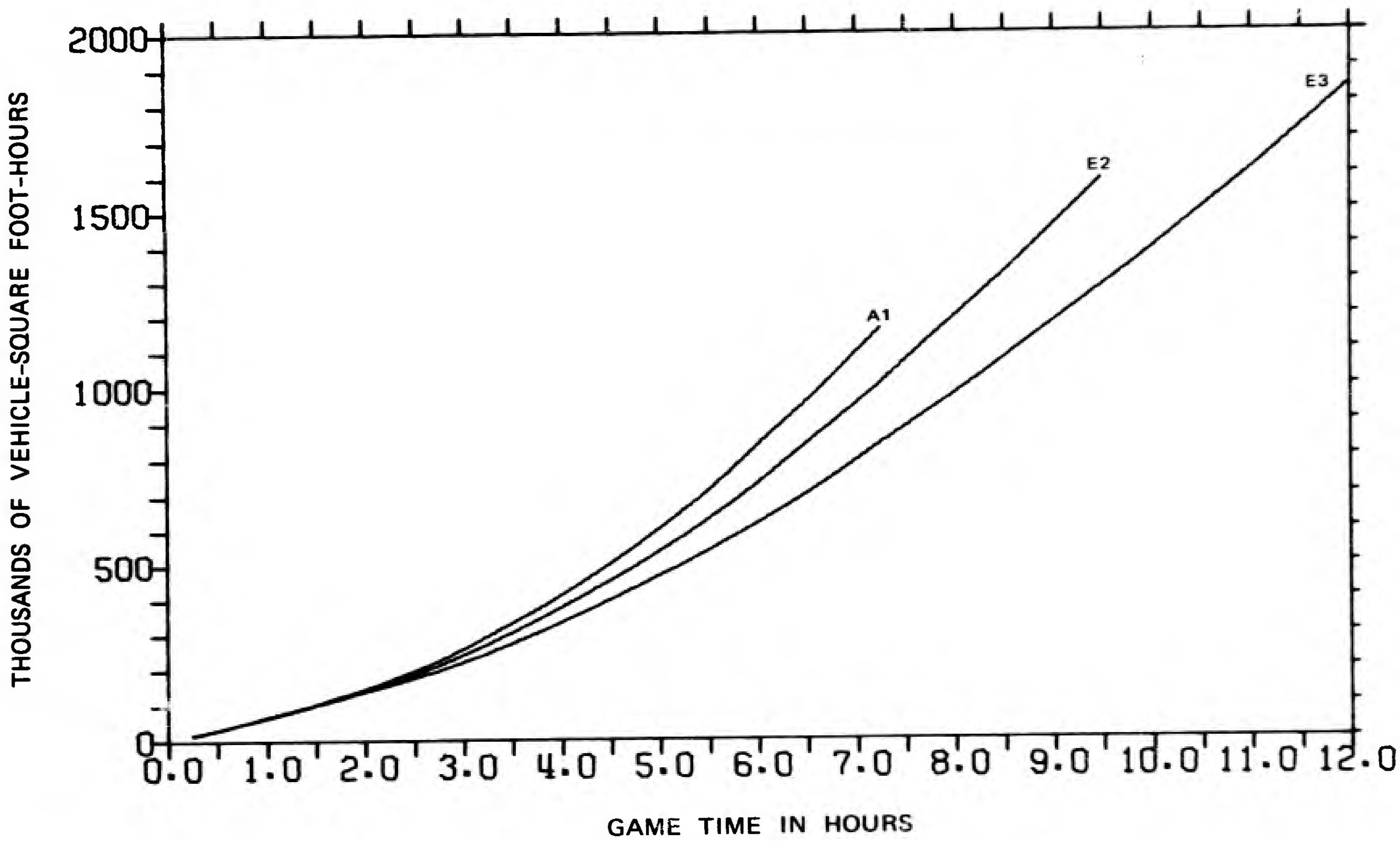

Figure 34 FORCE-TIME EFFECTIVENESS FOR DIFFERENT SEA STATES

The general unloading phase was not simulated in these runs because of the uncertain data on heavy weather performance. However, the impact of sea state on general unloading is likely to be even greater than its impact on the assault phase.

Landing Craft Attrition

The two runs listed in Table 6 as Runs F-1 and F-2 were made using arbitrarily selected attrition rates for the baseline system craft. Further analysis of attrition for baseline system and advance craft revealed that these attrition rates are completely inappropriate. They do not adequately reflect differences in vulnerability at different locations, nor are the selected numbers consistent among the three craft types. Therefore, a discussion of the results of the two runs would have little value.

The importance of craft attrition must not be overlooked. It will be a major factor in all of the advanced craft comparisons. Using procedures developed for this purpose,* attrition factors are being computed for each craft type. The appropriate figures will be used for each craft in each simulated mix.

Beach Operations

Changes in beach operating procedures will be important in the analysis of advanced landing craft, particularly those craft that can cross the beach line and unload away from the water. However, the modifications in beach operations that were investigated for base system landing craft had a relatively minor effect on assault phase performance.

In the reference run, the ten beach slots reserved for tracked vehicles had relatively little use, and the 27 reserved for wheeled vehicles were overtaxed at different times. To relieve this situation, all 37 slots were made available for wheeled vehicles in Run G-1. The measures of effectiveness, as shown in Table 19, indicate that this change produced only modest improvement in overall performance. This result was entirely predictable in the light of results of Run A-2 in which the beach length was doubled.

In Run G-2, the distance from the beach to the LSA was increased. The average round trip time for cargo-carrying vehicles was also increased.

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* A. Grant, op. cit.

Table 19

EFFECTIVENESS MEASURES--BEACH OPERATIONS

	Simulation Runs		
	Reference	G-1	G-2
Force-time effectiveness* (thousands of vehicle-square feet-hours)	1,100	1,125	1,100
Lost cargo (square feet)	None	None	None
Response time (minutes)			
Mean	92	81	92
Variance	357	225	357
Time to deliver 250,000 square feet of vehicles ashore (hours)	6.15	5.00	6.15
Mean productivity (vehicle square feet/ craft square feet)			
LCM-6	0.904	0.907	0.904
LCM-8	0.721	0.741	0.721
LCU	0.595	0.608	0.595

* Reference time = H+7 hours.

This change had no perceptible effect on craft unloading at the beach. It greatly increased the size of the beach dump by reducing the rate at which pallets were removed to the LSA.

Summary

The sensitivity analyses revealed that landing craft performance is particularly sensitive to fleet stand-off distance, sea state, and craft attrition or vulnerability. For the most effective craft performance during the assault phase, embarkation procedures should stress maximum numbers of craft by configuring LSDs without mezzanine decks and by not allowing LVTs to be stored in areas where craft could be carried. Landing craft performance is relatively insensitive to the precise composition of the force carried, the order in which craft are introduced into the simulation, and minor changes in beach operations. Useful insights and revised operating procedures were developed as a result of the sensitivity analyses. These changes will substantially improve the comparison of advanced craft.

The general unloading phase is very sensitive to cargo handling rates, both at the ships and at the beach. Increasing beach width provided improved beach handling capability, but because of a constraint elsewhere there was little overall improvement in performance.

VI PROCEDURES FOR THE ANALYSIS OF ADVANCED LANDING CRAFT

Background

The Naval Ship Systems Command, through Gibbs and Cox, Inc., invited 11 firms to submit preliminary designs of landing craft based on advanced technology familiar to them. The guidance given these designers was deliberately constructed to encourage imaginative work. Each was provided with a tabulation of speed ranges, payload sizes, and craft types. The speed ranges were 20, 35, and 50 knots. There were six payload sizes including both present craft sizes and sizes judged to be attractive based on early analytical work* as tabulated below.

Payload (pounds)	Minimum Cargo Well Dimensions (feet)		
	Length	Width	Ramp Width
10,400	28.5	8.0	8.0
30,000	37.5	9.0	9.0
70,000	45.5	17.0	14.5
125,000	45.5	17.0	14.5
150,000	66.0	26.0	14.5
320,000	100.0	26.0	15.0

The designers were also given the dimensional limitations of the wells in LPD and LSD types of ships.† Six hull types were suggested: displacement, planing, air cushion, air lubricated, hydrofoil, and hydroski. The designers were requested to propose preliminary designs, including outline drawing, machinery arrangements, power train and control drawings, design calculations sufficient to support the feasibility of their designs, and estimated operating characteristics.

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* S. Stidham, op. cit.

† LHA characteristics were not available at that time.

The 11 design firms submitted a total of 32 designs, which are summarized in Table 20. These included 14 planing hulls, 4 hydrofoil hulls, and 14 air cushion hulls. None of the other hull forms were considered sufficiently promising to interest the designers. The 32 designs were subjected to critical review by a 44-man committee made up of representatives from a wide range of technical and operating activities, as listed below.

- Office of Chief of Naval Operations
- Commander Amphibious Forces, Pacific Fleet
- Commander Amphibious Training Command, Atlantic Fleet
- Office of Chief of Naval Material
- Naval Ship Systems Command
- Naval Ship Engineering Center
- Office of Naval Research
- Naval Research Laboratory
- Personnel Research Laboratory
- Naval Ship Research and Development Center
- Headquarters, U.S. Marine Corps
- USMC Landing Force Development Center
- U.S. Army Combat Development Command
- U.S. Army LARC Project Field Office
- Gibbs and Cox, Inc.

The committee members reviewed the craft designs from technical and operational points of view and submitted their comments to Gibbs and Cox for compilation. The Gibbs and Cox team, under the direction of Mr. Malcolm Dick, assembled and summarized all of the comments and, together with NavShips representatives, decided which designs were sufficiently sound to be approved for analysis. Those designs that were not approved were set aside for a variety of reasons, but none was permanently rejected. In some instances, the reviewers believed that a designer had not adequately demonstrated his competence, either through experience or through his development and test program. This criticism was particularly frequent for the air cushion designs. Some craft were judged to be underpowered. In other instances, the reviewers felt that the designer had not provided sufficient information to warrant approval.

In all, twelve planing hulls, two hydrofoil hulls, and four air cushion hulls were approved for analysis. These cover the full range of payload sizes, but there is a design for each size only among the planing hulls.

Even though the technical review eliminated 14 of the 32 preliminary designs, an exhaustive analysis of the 18 craft that were approved represents

Table 20

ADVANCED CRAFT CHARACTERISTICS

	Hull Type*	Nominal Payload (thousands of pounds)	Nominal Speed (knots)	Approved for Analysis
Aerojet-General Corporation	ACV	30	35	No
	ACV	125	50	No
	ACV	150	50	No
	ACV	320	35	No
Atlantic Hydrofoils, Inc.	HF	70	35	No
	HF	125	35	No
Bell Aerosystems Company	ACV	30	50	Yes
	ACV	125	35	Yes
	ACV	150	50	Yes
	ACV	320	50	Yes
J. E. Bowker Associates, Inc.	P	320	20	Yes
	P	320	35	Yes
Control Data Corporation, TRG Division	P	125	20	Yes
	P	320	20	Yes
General Dynamics Corporation, Electric Boat Division	ACV	10.4	50	No
	ACV	30	50	No
	ACV	70	50	No
	ACV	125	50	No
	ACV	150	50	No
	ACV	320	50	No
General Dynamics Corporation, Quincy Division	HF	70	35	Yes
	HF	125	35	Yes
Hydronautics, Inc.	P	10.4	35	No
MacLear & Harris	P	30	35	Yes
	P	125	20	Yes
Sparkman & Stephens, Inc.	P	10.4	20	Yes
	P	10.4	20	Yes
	P	125	20	Yes
	P	125	35	No
United Aircraft Corporation	P	70	20	Yes
	P	70	35	Yes
	P	150	20	Yes

* ACV = air cushion hull, HF = hydrofoil hull, P = planing hull.

a formidable task. The performance of each of the approved craft could be simulated by itself in the surface ship-to-shore movement or it could be combined with one or two (or perhaps more) of the other craft. There are more than 1,000 possible combinations. Some of the possible combinations can easily be eliminated for valid reasons, but the simulation burden would still be enormous.

After considering a number of alternative approaches, we chose to analyze the craft in two steps:

1. Simulate the use of typical representatives of each craft size to determine whether any of the sizes can be eliminated.

2. Compare individual craft or craft characteristics for each size to determine relative effectiveness and cost. These comparisons will use both simulation and nonsimulation techniques.

By this means, we hope to reduce the number of simulations to 25 or fewer and to provide a basis for doing much of the craft-by-craft comparison outside of the simulations. Three major problems remained in executing the first step: selecting the typical craft, designing the initial set of simulation runs, and developing the necessary operating characteristics for the selected craft.

Selection of Typical Craft Designs

In selecting typical craft designs for each payload size, it was necessary to identify the differences among craft types and weigh these differences in the light of base system experience. The 18 approved designs are listed in Table 21 by hull type and payload.

Two features--speed and drive-through capability--were considered sufficiently important to play major roles in the selection process. The base system analysis did not yield any specific information about the speed ranges of interest. However, we did learn that moving time is very important for long fleet stand-off distances and is significant throughout the assault phase of the landing. A craft with drive-through capability is one that has bow and stern ramps or that has bow and stern access to its cargo hold. This allows vehicles to be driven forward into the cargo well instead of having to back in. Significant savings in loading time can be realized if craft have drive-through capability. Large vehicles with trailers can be driven into a craft in one-eighth to one-tenth the time needed to back them aboard. The full impact of improved loading times on system performance has not yet been measured. The value of drive-through

Table 21

APPROVED ADVANCED CRAFT DESIGNS

Payload (pounds)	Planing Hulls	Hydrofoil Hulls	Air Cushion Hulls
10,400	Sparkman & Stephens P 10-20K Gas turbine Diesel engine		
30,000	MacLear & Harris P30-35K		Bell C 30-35K
70,000	United Aircraft P 70-20K P 70-35K	GD Quincy F 70-35K	
125,000	MacLear & Harris P 125-20K	GD Quincy F 125-35K	Bell C 125-35K
	Sparkman & Stephens P 125-20K		
	TRG P 125-20K		
150,000	United Aircraft P 150-20K		Bell C 150-50K
320,000	Bowker P 320-20K P 320-35K		Bell C 320-50K
	TRG P 320-20K		

capability was tentatively measured in the vehicle loading tests conducted by the Marine Corps at Camp Pendleton in May 1968.*

We decided to initiate the analysis using the highest speeds available--20 knots for the smallest planing hull, 35 knots for other planing and hydrofoil hulls, and 50 knots for air cushion hulls. There were two reasons for this decision. First, we wanted to establish, as nearly as possible, an upper bound for advanced craft effectiveness. This bound will show the range of improvement now considered attainable and it will make it easier to relate performance differences of pairs of craft. Second, we want, insofar as possible, to eliminate the influence of speed on the relative performance of different craft sizes. This dictated the selection of the higher (35 knot) speed for planing hulls to be compatible with speeds of hydrofoil and air cushion hulls.

The joint features of high speed and drive-through capability were not available in all of the designs. As indicated in Table 21, approved 35-knot planing hull designs were available in only three of the craft sizes. Also, most of the planing hull designs and neither of the hydrofoil designs had either stern ramps or stern gates. Rather than make comparisons predestined to favor craft with these desirable features, we decided to synthesize the designs to the extent necessary to be able to simulate comparable craft. In some instances, this required only minor modifications to existing designs; in other instances, our typical craft were based on designs that were not approved for analysis. Nonetheless, we believe that this first step is valid because it will provide the structure in which more detailed comparisons can be made in the future. Corrections from this rather optimistic first look will be made in the second step when the favored craft sizes are explored in more detail. The principle characteristics of the selected craft are listed in Table 22.

The operational shortcomings of the approved craft designs have been transmitted to NavShips where they have been added to the technical shortcomings identified in the technical review. These have then been used as a basis for redesign of the craft. The redesign work is underway at the time of this writing. Redesigns will be evaluated in future comparisons.

10,400-Pound Payload

For the 10,400-pound payload LCVP replacement, we selected the Sparkman & Stephens diesel engine design. This craft has a design speed of only

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* Nielsen, op. cit.

Table 22

CRAFT CHARACTERISTICS FOR STEP 1 ANALYSIS

	Payload (pounds)				
	10,400	30,000	125,000	150,000	320,000
Hull type	Planing	Air Cushion	Planing	Air Cushion	Planing
External dimensions (feet					
Length	46.1	50.0*	73.8	104.0	140.0
Width	12.8	24.0*	24.0	44.0	32.0
Height	14.5	18.0/ 21.5†	21.5	23.0/ 27.1†	21.0‡
Cargo well dimensions (feet)					
Length	29.0	37.0*	46.0	66.0	115.0
Width	8.0	12.0*	17.0	26.0	26.0
Drive-through capability	No	Yes	Yes*	Yes	Yes*
Ramp width (feet)					
Bow	8.0	12.0*	17.5	26.0	15.0
Stern	--	9.0	Gate only	13.0	Gate only
Draft (feet)					
Maximum	4.0	1.1	4.6	1.5	6.8
Bow, loaded	1.8	1.1	3.8	1.5	3.6
Weight (thousands of pounds)					
Light	21.8	34.0	81.0	127.6	386.0
Payload	10.4	30.0	125.0	150.0	320.0
Fuel	2.7	12.0	39.5	34.5	78.4
Gross	35.3	77.0	246.3	312.1	674.0

* Modified for analysis.

† Height on cushion/off cushion.

‡ Mast down.

20 knots, suggesting that the higher speed (and technically rejected) Hydronautics, Inc. design would be preferable for the first round of analyses. However, we used the 20-knot design primarily to obtain information on the relative merits of 20-knot versus 35-knot speeds. If, at 20 knots, this craft size appears unattractive, we will retest it in the second step using a higher speed. The diesel engine design was selected because of its lower cost, lower fuel consumption, less complex maintenance, and apparently superior mechanical reliability.

The Sparkman & Stephens craft does not have stern access for drive-through capability. However, this is not a significant disadvantage because the light vehicles that fall within the craft's weight and dimensional limits are relatively easily backed onboard, even with trailers.

Use of present Welland davits has been discussed extensively in connection with an LCVP replacement. The Sparkman & Stephens craft is 10 feet longer, 2 feet wider, and 8,000 pounds heavier than the present LCVP. San Francisco Bay Naval Shipyard personnel suggest that Welland davits can be modified to accept the Sparkman & Stephens craft. However, we have assumed that the Welland davits will be used exclusively for LCPL and other small craft assigned to naval uses and not specifically simulated. All of the 10,400-pound craft used in the simulation are either deck loaded on LKAs or carried in wells.

30,000-Pound Payload

We selected a hybrid air cushion craft for the 30,000-pound payload size. An air cushion design was selected because the mean hull loadings fall well within present air cushion technology. The similarity between the approved air cushion and planing craft will permit a meaningful comparison between these two hull forms in the second step investigation.

On the advice of several of the technical reviewers, the design speed of the air cushion craft was increased from 35 to 50 knots. It was their opinion that an air cushion craft powered for 35 knots could be designed for 50 knots without an appreciable increase in power requirements.

To provide drive-through capability, several design modifications to the Bell craft were examined. As these were studied, we found that we were considering changes that are probably infeasible without complete redesign of the craft. For this reason, we ultimately abandoned the Bell design in favor of a revised Aerojet-General design that included both bow and stern access. The specific differences between the selected craft and the Bell design will be compared during the second step.

Craft width is also an important consideration in this size. The Bell air cushion craft is 25 feet wide when on its cushion--too wide to be able to place two abreast in a 50-foot well. The alternatives of filling out the wells with small craft or leaving them empty are not attractive. Thus, we need a 30,000-pound air cushion design that can fit two abreast in a 50-foot well. The Aerojet-General design is marginal in this respect (24 feet wide), but we will base the number of craft carried by the fleet on two abreast loading. A more realistic width constraint is being imposed on the firms engaged in the current craft redesign effort.

This selected 30,000-pound craft is light enough and short enough to be deck-loaded aboard LKAs. However, we are uncertain about the vertical clearance, because of its height--20.8 feet off the cushion--and the danger to the air screws and pylons. Nonetheless, in the first step where the 30,000-pound craft are the smallest of the craft types in use, they are loaded aboard LKAs. Where the 10,400-pound planing craft are the smallest craft, the 30,000-pound craft are carried in wells.

70,000-Pound Payload

The 70,000-pound payload craft was dropped from the analysis. These craft were required to have cargo wells as large as the 125,000-pound payload craft and as a result have dimensional and performance characteristics very similar to those of the larger craft. None of the 70,000-pound craft is small enough to be deck-loaded on LKAs as is the 70,000-pound LCM-6. As a result, 70,000-pound and 125,000-pound craft will be competing for the same limited well space in the amphibious ships. Therefore, it is attractive to carry 70,000-pound craft only if they are significantly smaller than the 125,000-pound craft. The comparative dimensions and weights of the 70,000-pound and 125,000-pound craft are tabulated on the following page.

Both the TRG and Sparkman & Stephens 125,000-pound craft are dimensionally smaller than all of the approved 70,000-pound craft designs. General Dynamics, Quincy used the same hull size for both craft. Only the United Aircraft and MacLear & Harris 125,000-pound designs are significantly larger than the 70,000-pound designs. It thus appears that the 70,000-pound craft is not attractive from a design standpoint and can appropriately be dismissed without further consideration.

Design	70,000-Pound Craft Length (feet)	Width (feet)	Full Load Displacement (pounds)	125,000-Pound Craft Length (feet)	Width (feet)	Full Load Displacement (pounds)
United Aircraft	93	20	184	117	32	334
United Aircraft	93	20	205			
General Dynamics, Quincy	97	23	366	97	23	437
TRG				81	22	260
Sparkman & Stephens				74	24	246
MacLear & Harris				103	30	316

125,00C-Pound Payload

The 125,000-pound replacement for the LCM-8 is designed to carry either a single main battle tank or a larger number of lighter motor vehicles. We selected a planing hull design so as to have a craft that could fit two abreast in a 50-foot well. This criterion immediately eliminated the Maclear & Harris and United Aircraft designs. Of those remaining, only the General Dynamics hydrofoil is capable of 35 knots. However, this is by far the heaviest of all of the 125,000-pound craft, and it is substantially longer than the other two designs under consideration. We ultimately elected the Sparkman & Stephens 35-knot design, even though this was not an approved design.

Two versions of the 125,000-pound craft will be simulated. The first will be a craft without drive-through capability, such as the craft designed by Sparkman & Stephens. The second will be modified to provide a stern gate and a ramp to the cargo well so that vehicles can be loaded over the craft's stern.

Both selected craft are dimensionally small enough to be deck loaded on LKAs, but because of their weight (190,000 pounds with fuel) we have not considered them capable of being loaded aboard LKAs. Present LKAs can lift no more than 134,000 pounds--and this with great difficulty. The question of carrying these craft aboard LKAs will be considered in the second step analysis when we know more about the most favorable craft mixes.

150,000-Pound Payload

The Bell air cushion design was selected for the 150,000-pound size. The air cushion design was selected in preference to the United Aircraft planing hull design because this size, with a large cargo well and low payload capacity, is particularly well suited to wheeled vehicle loads. Wheeled vehicles can benefit materially from the beach transit capability of the air cushion craft. This capability largely eliminates vehicle maneuvering in soft sand, freeing bulldozers and other engineer equipment for other assignments. A considerable amount of the beach matting now carried ashore can be omitted. Also, the Bell and United Aircraft craft are the same length and are both too wide to fit two abreast in a 50-foot well.

320,000-Pound Payload

The Bowker 35-knot craft was selected for the 320,000-pound payload size. The Bell air cushion craft was eliminated because it is too wide (50 feet), too high (27.5 feet), and too long (188 feet) to enter an LPD well. It might be squeezed in as far as width and height are concerned, but there is no question about length. The choice between the Bowker and TRG designs was based entirely on speed;* both are about the same size.

To accommodate the proposed LHA well dimensions, it was necessary to assume a reduction in craft width. We arbitrarily reduced the craft width to 32 feet with the understanding that an exact width cannot be selected until the merits of this craft and the requirements of the LHA are more fully established

Simulation Runs

Fourteen simulation runs were selected to test what appear to be the most favorable combinations of the five craft selected for Step 1 analysis. Base system craft will be used in three of these runs to determine the change in effectiveness resulting from the introduction of one or two new craft types to be used in conjunction with present-day craft. The craft mixes used in each of the runs are listed in Table 23. The new base run will be made using present-day craft and the environment selected for the Step 1 analyses.

The criteria used to develop the set of runs are directed toward obtaining the most favorable results from mixes of the advanced craft, from

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* The TRG design speed is 20 knots.

Table 23

CRAFT MIXES FOR STEP 1 SIMULATIONS

	Large Craft		Medium Craft		Small Craft	
Run Number	Payload (thousands of pounds)	Type	Payload (thousands of pounds)	Type	Payload (thousands of pounds)	Type
1	320	P	150	AC	30	AC
2	150	AC	125	P*	30	AC
3	150	AC	125	P†	30	AC
4	380	LCU	150	AC	70	LCM-6
5	380	LCU	125	LCM-8	30	AC
6	150	AC	125	LCM-8	30	AC
7	125	P*	30	AC	10.4	P
8	320	P	125	P*	30	AC
9	320	P	150	AC	125	P*
10	150	AC	125	P*	10.4	P
11	150	AC	30	AC	10.4	P
12	320	P	30	AC	10.4	P
13	320	P	125	P*	10.4	P
14	380	LCU	125	LCM-8	70	LCM-6

* Drive-through capability.

† No drive-through capability.

the viewpoints of both ships of the fleet and Marine Corps cargoes. In each mix, the following requirements were met:

1. One craft type is suitable for deck loading aboard LKAs.

2. At least one craft is capable of carrying a tank retriever (perhaps under overload conditions).

3. Three craft sizes are used to provide some degree of flexibility in handling Marine Corps cargoes.

The first requirement was violated only in Run 9. In this run, we are seeking to assess the importance of LKA carried craft. All runs have at least one air cushion craft except Run 13 and the base run. All runs have at least one planing hull or displacement craft. Runs 2 and 3 are identical except that in Run 3, the medium size planing craft will not have drive-through capability, and in Run 2 it will.

The amphibious fleet includes LHA-type ships. Run 1 will be repeated, first without LHAs in the fleet and then with LHAs to assess the impact that this new ship type will have on amphibious assault operations.

All of the Step 1 simulations will use the same amphibious environment. The fleet will be close in (nominally five miles from the beach) to test whether operational advantages can be realized in present-day operational configurations. Sea State 2 will be used to give some advantage to the more seaworthy craft. The landing plan will be as described in Appendix B, and the force will be as described for the reference run. Variations in stand-off distance can be investigated analytically using the procedures outlined in Chapter V. These results will be confirmed through additional simulation in Step 2. At that time, additional deviations from the Step 1 conditions will be investigated. At the time of this writing, the Step 1 simulations are almost complete.

Operating Characteristics

Many of the operating procedures used for present-day landing craft cannot be used for advanced craft. For example, it will probably not be acceptable to bring air cushion craft with air screws operating either alongside LKAs or into wells.

The proximity of the air screws to rigging, appendages, and personnel is an unacceptable risk. To circumvent this problem, procedures need to be developed to bring air cushion craft alongside and into wells after their air screws have been secured. Shipboard winches, towing devices, and other techniques need to be investigated. In other instances, new procedures need to be developed to take advantage of advanced craft capabilities. For example, to use the drive-through capabilities of advanced planing craft, it will be necessary to back the craft into ships' wells so that the vehicles can drive forward over the bow ramps when the craft reach the beach. Not only must the craft be backed into the well, but the ship must also provide access for vehicles to the craft's stern gates. This access might be provided with a portable ramp that is part of the ship's equipment. It will also be necessary to develop operating procedures for directing air cushion craft across the beach line and for handling their unloading.

Before amphibious operations using advanced craft can be simulated, it is necessary to establish concepts for their use and develop procedures to the extent that estimates can be made of performance data. This work is under way as part of Step 1 in the advanced craft simulation. All procedures are being discussed with cognizant operational commands and will be described in considerable detail in the report describing the advanced craft comparisons.

Step 2 Comparisons

The Step 2 comparisons will not be planned in detail until Step 1 has been completed. Some of the comparisons that will be made are already known. These include:

1. Speed comparisons such as described for the 10,400-pound payload craft.

2. Comparisons between drive-through and nondrive-through craft.

3. Comparison between different craft types of the same size, such as between planing and air cushion craft for the 150,000-pound size and between planing and hydrofoil craft for the 125,000-pound size.

4. Different stand-off distances.

5. Different sea states.

Technical comparisons will also be made of craft of the same size and type. Attrition factors comprising mechanical reliability, personnel reliability, and vulnerability will be compared either directly or through simulation. Costs will be compared using cost modeling procedures reported elsewhere.* Performance standards will be evaluated and compared to the extent possible. The results of this analysis will be a complete benefit/cost analysis of the advanced craft designs, toegther with sufficient evidence to support a decision on the next step in landing craft development.

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* Jorgensen, David G., "Systems Analysis of Amphibious Assault Craft: Cost Model and Cost Estimates", Stanford Research Institute, Menlo Park, California March 1969, unpublished draft

Appendix A

DESCRIPTION OF STS-2 VARIABLES

Appendix A

DESCRIPTION OF STS-2 VARIABLES

This appendix consists of detailed descriptions of the important tables in the STS-2 simulation program. All information (variables) that is input to, output from, or generated by the program is organized into these tables. The table descriptions are intended to familiarize the reader with the level of detail at which the simulation operates by providing a list of the information internally available to the program during a run.

Each table is described in terms of the format and information content of a typical entry. Some tables have only one such entry while others have thousands. For instance, the Vehicle Table has one entry for each vehicle included in the Marine force.

The numbers assigned to each table are those used by the Naval Weapons Laboratory to designate these tables in the STS-2. All of the tables described are used in the surface version of the STS-2; the helicopter version uses some additional tables that are similar to the tables described in this appendix but are somewhat less detailed.

SERIAL TABLE - TABLE 2

NWL Variable Name	Card #	Columns	Format	Description
S1	1	2	X	Beach destination (= 1 for our runs)
S2	1	3	X	Landing category 0 - Serials in Scheduled Waves 1 - On call Serials 2 - Nonscheduled Serials 3 - General unloading
S3	1	4-8	XXXXX	Serial number, alpha-numeric
S4	1	9-10	XX	Number of ship on which serial was embarked. (See variable SS2 in Ship Table, Table 4.)
S13	1	19	X	Hold stowage 1 - Serial contains personnel only (i.e., is type 2), so hold stowage is not used. 0 - All other serials, hold stowage is used.
S14	1	20-24	XXXXX	Time in minutes from start of game at which the serial is made available for loading. Leave blank for preloaded serials.

Table 2 (continued)

NWL Variable Name	Card #	Columns	Format	Description
S15	1	25-29	XXXXX	Time in minutes from start of game at which the serial is scheduled to arrive at the beach. For the base system runs this was set five minutes later than S14 so the first craft carrying the serial can arrive at the beach as soon as possible.
S16	1	30-32	XXX	Number of personnel to be offloaded. The number of personnel already offloaded is subtracted until S16 = 0 when entire serial has been offloaded.
S17	1	33-34	XX	Number of vehicles in the serial (trailers are counted as separate vehicles). Offloaded vehicles are subtracted from this number until S17 = 0 at which point the entire serial has been offloaded.
S18	1	35	X	Palletized cargo indicator 0 - No palletized cargo in the serial. 1 - Palletized cargo is included in the serial.
S19	1	36-40	XXXXX	Game time in minutes at which craft carrying the serial arrive at the beach. Leave blank for input. During running of the program this variable is updated as each craft carrying part of the serial arrives, so that after the entire serial has been delivered to the beach S19 = time at which the last craft carrying the serial arrived at the beach.

Table 2 (continued)

NWL Variable Name	Card #	Columns	Format	Description
S20	1	41	X	Loading status of serial. Leave blank for input unless the serial is preloaded or to be unloaded at the beach from an LST (Codes 3 and 4). 0 - Not assigned to craft. 1 - Requested (Game time is $\geq$ S14). 2 - Assigned to craft. 3 - Preloaded on craft. 4 - To be unloaded at beach from LST.
S25	1	46-47	XX	Number of tracked vehicles in serial, including trailers towed by tracked vehicles counted as separate vehicles.
S26	1	48-49	XX	Number of vehicles of first type in serial that are available for transporting cargo across the beach. The four types of vehicle used in our runs that are available for transporting cargo across the beach were the M35, M36, M52, and M54. These are counted in the totals shown in S26, S28, S30, and S32 only if the indicator of availability, V22 in Vehicle Table 42, is set = 2. The four types of vehicle may be input in any order.
S27	1	50-51	XXX	Code for first type of vehicle for beach transport of cargo. Codes used were the two digits of the model numbers, "35," "36," "52," or "54."
S28	1	52-53	XX	Number of vehicles of second type in the serial that are available for transporting cargo across the beach. See description of S26.

Table 2 (concluded)

NWL Variable Name	Card #	Columns	Format	Description
S29	1	54-55	XX	Code for second type of vehicle for beach transport of cargo. See description of S27.
S30	1	56-57	XX	Number of vehicles of third type in the serial that are available for transporting cargo across the beach. See description of S26.
S31	1	58-59	XX	Code for third type of vehicle for beach transport of cargo. See description of S27.
S32	1	60-61	XX	Number of vehicles of fourth type in the serial that are available for transporting cargo across the beach. See description of S26.
S33	1	62-63	XX	Code for fourth type of vehicle for beach transport of cargo. See description of S27.
S34	1	64	X	Indicator of type of special cargo attached to the serial (used only if the serial contains special cargo). 0 - Special cargo other than SATS matting pallets, such as a generator on a skid or other non-palletized item. 1 - The special cargo consists of pallets of SATS matting.
--	1	67	X	= S

SHIP TABLE - TABLE 4

NWL Variable Name	Card #	Columns	Format	Description
SS1	1	2	X	Beach Number (= 1 for our runs)
SS2	1	3-4	XX	Ship Number - each ship in the amphibious fleet is given a number. The numbering for each ship type starts at a specified initial value for the first ship and is increased by 1 for each succeeding ship of that type. The range of numbers for each ship type are as follows: LPD - 1 to 10 LHA - 11-20 LSD - 21-40 LKA - 41-60 LPH - Not used in craft section of STS-2 LST - 61-99
SS3	1	5	X	Ship Type Code for each ship type is: 0 - LPD 1 - LSD 4 - LHA 2 - LKA 3 - LPH B - LST
SS4	1	6-7	XX	Code for present location of ship. This variable corresponds to a code used in the GL (Geographic Location) Table which is Table 18. The variable in the GL Table containing the location code is GL2. Coordinates of location GL2 are GL3 and GL4.

Table 4 (continued)

NWL Variable Name	Card #	Columns	Format	Description
SS6	1	10-12	X.X	Set = 1.0 for input (operating scale factor)
SS9	1	16	X	Status of load station number 1 for ship number SS2. The code is: 0 - available 1 - busy 2 - not used For input on an LKA with 5 holds set SS9 thru SS13 equal to 0 initially. For well deck ships there is only one "hold" therefore set SS9 = 0 and SS10 thru SS13 = 2.
SS10	1	17	X	See description of SS9
SS11	1	18	X	See description of SS9
SS12	1	19	X	See description of SS9
SS13	1	20	X	See description of SS9
SS14	1	21	X	Set = 2 since there are no ships presently in the fleet with more than 5 holds. (See SS9 description).
SS15	1	22	X	See SS14 description.
SS16	1	23	X	See SS14 description.

Table 4 (continued)

NWL Variable Name	Card #	Columns	Format	Description
SS17	1	24	X	Unloading status 0 - Ready to be unloaded at present ship position. 1 - All logistics assigned to craft. 2 - Ship has been completely off-loaded. 3 - Waiting to move into berth to be unloaded. 4 - To be unloaded at the beach. Set SS17 = 4 for LST only.
SS18	1	25	X	Always = 1
SS19	1	26	X	Always = 1
SS20	1	27	X	Always = 1
SS21	1	28	X	Always = 1
SS22	1	29	X	Always = 1
SS23	1	30	X	Always = 1
SS24	1	31	X	Always = 1
SS25	1	32	X	Always = 1
SS27	1	35	X	Indicator of ship type: 0 - Hold type ship 1 - Well deck type ship

Table 4 (concluded)

NWL Variable Name	Card #	Columns	Format	Description
SS28	1	36-39	XXXX	Width of well deck. Leave blank if ship has no well deck.
SS29	1	40-43	XXXX	Remaining width of well deck. Leave blank if ship has no well deck. For input, set = SS28. During running of the program, the exterior width of craft (CC16 in Craft Characteristics Table 13) is added to or subtracted from this variable as craft move in or out of the well.
SS30	1	44-45	XX	Total number of landing craft in well deck. (Used only if ship has a well deck).
SS31	1	46-50	XXXXX	Weight in pounds for a vehicle with trailer that determines whether the program uses loading time LT5 or LT7 in Loading Time Table 9a. A vehicle with trailer weighing less than this amount is classified as small, whereas if it weighs more than this amount it is classified as large.
SS32	1	51-54	XXXXX	Weight in pounds for a vehicle without trailer that determines whether the program uses loading time LT4 or LT6 in Loading Time Table 9a. A vehicle weighing less than this amount is classified as small, whereas if it weighs more than this it is classified as large.
--	1	67-68	XX	= SS

MOBIL LOGISTICS - TABLE 6

NWL Variable Name	Card #	Columns	Format	Description
ML1	1	2-6	XXXXX	Serial number for palletized cargo not initially assigned to a serial. A separate number is assigned, starting at 10000 and incremented by 1, for each hold used.
ML2	1	7-8	XX	Category of palletized cargo: 1 - Ammunition 2 - General cargo 3 - Petroleum, oil, and lubricants (POL) 4 - Special cargo (SATS matting) More than one category may be assigned to each hold, but the program will not load categories numbered 3 or lower with category 4. Since ammunition and POL cannot be combined in practice, do not combine categories 1 and 3 in the same hold.
ML3	1	9-12	XXXX	Number of pallets
ML4	1	13	X	Hold number of ship designated in ML6
ML6	1	15-16	XX	Ship number on which the palletized cargo was embarked. (See SS2 in Ship Table 4.)
--	1	67-68	XX	= ML

LOADING TIME TABLE - TABLE 9a

(For well deck ships use 9a, for LKAs use Table 9b)

NWL Variable Name	Card #	Columns	Format	Description
LT1	1	2	X	Ship Type Code: 0 - LPD 1 - LSD 4 - LHA
LT2	1	3-4	XX	Craft Type Code: 2 - Small Craft 3 - Medium Craft 4 - Large Craft
LT3	1	5-6	XX	Time in minutes to transfer 100 personnel from ship to craft (see LT1 & LT2)
LT4	1	7-8	XX	Time in minutes to load 5 small wheeled vehicles on craft.
LT5	1	9-10	XX	Time in minutes to load 5 small wheeled vehicles towing trailers on craft.
LT6	1	11-12	XX	Time in minutes to load 5 large wheeled vehicles on craft.
LT7	1	13-14	XX	Time in minutes to load 5 large wheeled vehicles towing trailers on craft.
LT8	1	15-16	XX	Time in minutes to load 5 tracked vehicles on craft. (If the tracked vehicle is pulling a trailer this time is multiplied by a factor F inside the STS-2 program).

Table 9a (concluded)

NWL Variable Name	Card #	Columns	Format	Description
LT9	1	17-18	XX	Time to load one pallet on the craft (minutes)
LT10	1	19-20	XX	Time in minutes for craft of type specified in LT2 to enter the well of ship type LT1, be ready to load and to depart the well after loading the last vehicle or pallet.
--	1	67-68	XX	= LT

LOADING TIME TABLE - TABLE 9b

(For nonwell deck ships; for LPDs, LSDs, and LHAs use Table 9a)

NWL Variable Name	Card #	Columns	Format	Description
LT1	1	2	X	Ship Type Code: 2 - LKA 3 - LPH B - LST
LT2	1	3-4	XX	Craft Type Code: 2 - Small Craft 3 - Medium Craft 4 - Large Craft
LT3	1	5-6	XX	Time, in minutes, to transfer 100 personnel from ship to craft.
LT6	1	11-12	XX	Time, in minutes, to load one vehicle (any size) on the craft. This is doubled for a vehicle towing a trailer.
LT9	1	17-18	XX	Time, in minutes, to load one pallet on a craft.
LT10	1	19-20	XX	Time, in minutes, for craft of type specified in LT2 to come alongside of ship type LT1 and be ready to load. Also includes the time to depart after the last vehicle or pallet is loaded.
--	1	67-68	XX	= LT

CRAFT QUEUE TABLE - TABLE 10

(Generated by Program)

NWL Variable Name	Card #	Columns	Format	Description
CQ1	1	2	X	Beach number (= 1 for our runs)
CQ2	1	3-4	XX	Ship number where this queue is located. (See SS2, Ship Table, Table 4).
CQ3	1	5	X	Hold number of ship specified by CQ2 at which queue is located.
CQ4	1	6-7	XX	Number of craft in queue waiting to load at ship and hold specified by CQ2 and CQ3. Generated by program for each hold of each ship.
--	1	67-68	XX	= CQ

CRAFT TABLE - TABLE 11

NWL Variable Name	Card #	Columns	Format	Description
C1	1	2	X	Beach served (= 1 for our runs)
C2	1	3	X	Craft type: 2 - Small 3 - Medium 4 - Large
C3	1	4-6	XXX	Craft number. Starting with 1, craft are assigned numbers by the program by incrementing the last craft number by 1.
C4	1	7-8	XX	Number of foster ship. For the base system runs the input prepared by the PREBOAT Program assigned all preboated craft to a dummy foster ship located at the LOD. Craft carried on decks of LKAs were assigned to a dummy foster ship at the boat pool.
C5	1	9-10	XX	Number of event in progress for this particular craft; assigned and updated during running of the program.
C6	1	11-12	XX	Present location of craft, coded to correspond to a value given for GL2 in the Geographic Location Table, Table 18, and for which the coordinates are given in the corresponding values for GL3 and GL4. For input of preloaded craft, set C6 = location code of foster ship C4. Craft location is updated by the program as a craft moves from one location to another.

Table 11 (continued)

NWL Variable Name	Card #	Columns	Format	Description
C7	1	13-14	XX	Future location of craft, coded to correspond to a value given for GL2 in Table 18. (See description of C6). For input of preloaded craft, set C7 = location code of LOD.
C8	1	15-19	XXXXX	Completion time of the event in which this particular craft has been engaged. What occurs at completion time depends on which event has just been completed.
C9	1	20-23	XXXX	Total utilization time in minutes, generated by the program. Includes any time assigned for loading or unloading, including waiting at the beach and at the ship and movement time, but does not include time in the boat pool waiting for assignment or time out of action.
C10	1	24	X	Craft availability status: 0 - Available for assignment 1 - Serial assigned 2 - Loaded 3 - Preloaded 4 - Waiting for load station 5 - Waiting for unloading point 6 - Loading 7 - Unloading 8 - Out of game

Table 11 (continued)

NWL Variable Name	Card #	Columns	Format	Description
C11	1	25-29	XXXXX	Serial number (alpha-numeric) of serial assigned to craft.
C12	1	30	X	Attrition status: 0 - No damage 1 - Damaged (Temporarily out of action) 2 - Sunk (Permanently out of action)
C13	1	31-32	XX	Number of trips made by this craft; incremented each time the craft completes a round trip.
C14	1	33	X	Craft category: 0 - Regular craft 1 - Navy amphibian (Returns to ships for more loads) 2 - Marine amphibian (Traverses beach once and does not return.)
C15	1	34-38	XXXXX	Time craft was generated
C16	1	39-41	XXX	Number of personnel on craft. Each time a craft gets a load, the number of personnel is recalculated. For preboated craft this number is input.
C17	1	42-43	XX	Number of vehicles on craft, including trailers counted as separate vehicles.

Table 11 (continued)

NWL Variable Name	Card #	Columns	Format	Description
C18	1	44-46	XXX	Craft generation status: 0 - Craft was input 1 - Craft was generated but has not yet been used 2 - Craft was generated and has previously been used
C19	1	47-49	XXX	Percent of craft load-carrying capacity (referred to as utilization factor) used by the specific load generated by the program or the load input in the case of preloaded craft. Craft load-carrying capacity and percent utilization of this capacity are defined for different types of loads as follows:

Type of Serial	Definition of Craft Load-Carrying Capacity and Percent Utilization of This Capacity
Vehicle or Mixed Vehicle and Personnel	Capacity is the available cargo-carrying area in the craft. This is calculated using the craft interior dimensions in CC14 and CC15 of the Craft Characteristics Table 13 and assuming the craft has a rectangular well. The utilization is the total area of the vehicles in the craft load divided by the craft capacity defined above. Then multiply by 100 to get percent utilization.

Table 11 (concluded)

NWL Variable Name	Card #	Columns	Format	Description	
				Personnel Only	Capacity is again the available cargo-carrying area as defined above.
					Utilization is computed by multiplying the area occupied by one Marine (as specified in M8 of the Miscellaneous Table 27) times the number of Marines in the craft load and dividing this by the area capacity of the craft. This is multiplied by 100 to get percent utilization.
				Cargo Only	Capacity is the maximum number of standard or special pallets the craft can carry. (Standard pallets are never combined with special pallets in the same craft load.) These numbers are specified in CC19 and CC20 of the Craft Characteristics Table 13.
					Utilization is the ratio of the number of pallets actually carried to the capacity as defined above. Percent utilization is the number multiplied by 100.

CRAFT AVAILABILITY TABLE - TABLE 12

NWL Variable Name	Card #	Columns	Format	Description
CA1	1	2	X	Beach served (= 1 for our runs)
CA2	1	3-5	XXX	Number of Type 1 craft in boat pool. Types are those coded as C2 in Craft Table, Table 11. For input, CA2 through CA10 = 0. Since type 1 and types 5 through 9 were not used in our runs, CA2 and CA6 through CA10 were always = 0.
CA3	1	6-8	XXX	Number of Type 2 craft (small) in boat pool. See description of CA2.
CA4	1	9-11	XXX	Number of Type 3 craft (medium size) in boat pool. See description of CA2.
CA5	1	12-14	XXX	Number of Type 4 craft (large) in boat pool. See description of CA2.
CA6	1	15-17	XXX	Number of Type 5 craft in boat pool. See description of CA2.
CA7	1	18-20	XXX	Number of Type 6 craft in boat pool. See description of CA2.
CA8	1	21-23	XXX	Number of Type 7 craft in boat pool. See description of CA2.
CA9	1	24-26	XXX	Number of Type 8 craft in boat pool. See description of CA6.
CA10	1	27-29	XXX	Number of Type 9 craft in boat pool. See description of CA6.
--	1	67-68	XX	= CA

CRAFT CHARACTERISTICS TABLE - TABLE 13

NWL Variable Name	Card #	Columns	Format	Description
CC1	1	2	XX	Craft Type Code: 2 - Small Craft 3 - Medium Craft 4 - Large Craft
CC2	1	3-4	XX	Cruising speed of craft in knots
CC3	1	5-7	XXX	Cargo capacity of craft in short tons
CC7	1	14-16	X.X	= 1.0 (loading time scale factor)
CC8	1	17-18	XX	Maximum speed of craft in knots
CC9	1	19-21	X.X	= 1.0 (Unloading time scale factor)
CC10	1	23	X	Over the waterline capability indicator: 0 - stops at waterline 1 - can unload on beach (past waterline)
CC11	1	25	X	Indicates whether or not STS-2 may create more craft of this type than were input in the Craft Table. 0 - may create 1 - no creation Set = 1 for normal runs

Table 13 (continued)

NWL Variable Name	Card #	Columns	Format	Description
CC12	1	26-27	XX	Indicates which craft types are preferred for palletized cargo loads by assigning a priority to each craft type. The priorities run from 0 to 9 in steps of 1, with 0 being the highest (preferred) priority and 9 being the lowest (last choice).
CC13	1	28-29	XX	Maneuver time at the beach in minutes for craft of type CC1. This includes all time used over and above the time that would be used if the craft reached its unloading point at normal speed, was instantaneously ready to unload, and also departed at normal speed at the same moment the last vehicle or pallet was unloaded. For over-the-waterline craft, CC13 is the time required in addition to the delay time computed by the program for amphibious craft to make the transition from over-water to over-beach travel. This delay time is computed by using the speed specified by the variable VC7 in the Vehicle Characteristics Table 49 for the entry in which VC1 = CC1. The distance used is twice the distance (go and return) specified by the variable VP4 in the Vehicle Point Location Table 54 for the entry in which VP3 = 1. Any movement or maneuvering time on the beach above this computed value should be included in the value input for CC13.
CC14	1	30-33	XXXX	Length of cargo well in tenths of feet
CC15	1	34-36	XXX	Width of cargo well in tenths of feet

Table 13 (concluded)

NWL Variable Name	Card #	Columns	Format	Description
CC16	1	37-40	XXXX	Exterior width of landing craft in feet (round up actual width to next high integer). Used to fit craft into wells of well deck ships for loading cargo and vehicles on the craft.
CC17	1	41-42	XX	Desired utilization factor for this craft type in percent. Usually, the following values are used: 00 - Small Craft (CC1 = 2) 50 - Medium Craft (CC1 = 3) 65 - Large Craft (CC1 = 4)
CC19	1	44-48	XXXXX	Maximum number of standard pallets this craft can hold.
CC20	1	49-51	XXX	Maximum number of special pallets this craft can hold.
--	1	67-68	XX	= CC

ATTRITION PROBABILITY TABLE - TABLE 14

NWL Variable Name	Card #	Columns	Format	Description
AP1	1	2	X	Beach Number (= 1 for our runs)
AP2	1	3	X	Craft Type Code: 2 - Small Craft 3 - Medium Craft 4 - Large Craft
AP3	1	4-6	XXX	Probability of craft type AP2 being attrited seaward of the Line of Departure (LOD) times 1000 (e.g. if the prob. of attrition is 0.80 then AP3 = 080).
AP4	1	7-9	XXX	Probability that the craft is permanently out of action (x 1000) given that attrition has occurred seaward of the LOD:
AP5	1	10-12	XXX	Probability of craft being attrited between the LOD and the beach (x 1000)
AP6	1	13-15	XXX	Probability that the craft is permanently out of action (x 1000) given that attrition has occurred between the LOD and the beach.
AP7	1	16-18	XXX	Probability that the craft is attrited while unloading at (or on) the beach (x 1000)
AP8	1	19-21	XXX	Probability that the craft is permanently out of action (x 1000) given that attrition has occurred at (or on) the beach.
--	1	67-68	XX	= AP

CRAFT WAITING TABLE - TABLE 15

NWL Variable Name	Card #	Columns	Format	Description
CW1		2	X	Beach served by craft (= 1 for our runs)
CW2		3-4	XX	Number of ship where craft is waiting.
CW3		5	X	Hold number of ship specified in CW2 at which the craft is waiting to load or the code for the unloading point at beach where craft is waiting to unload (see CW6). Codes for beach unloading points: 3 - Wheeled vehicles and palletized cargo (see BS3 in Beach Status Table) 4 - Tracked vehicles (see BS4, Beach Status Table)
CW4		6-8	XXX	Craft number for this craft which is now in a queue. (See C3 in Craft Table 11.)
CW5		9-13	XXXXX	Time when craft started waiting.
CW6		14	X	Queue location indicator: 0 - Queue at ship 1 - Queue at beach
		67-68	XX	= CW

BEACH STATUS TABLE - TABLE 16

NWL Variable Name	Card #	Columns	Format	Description
BS1	1	2	X	Beach number (= 1 for our runs)
BS3	1	6-8	XXX	Number of unloading spaces available for craft carrying wheeled vehicles and personnel, or personnel only, or palletized cargo only.
BS4	1	9-11	XXX	Number of unloading spaces available for craft carrying tracked vehicles.
BS5	1	12-14	XXX	Number of unloading spaces (causeways for the base system) available for LSTs.
--	1	67-68	XX	= BS

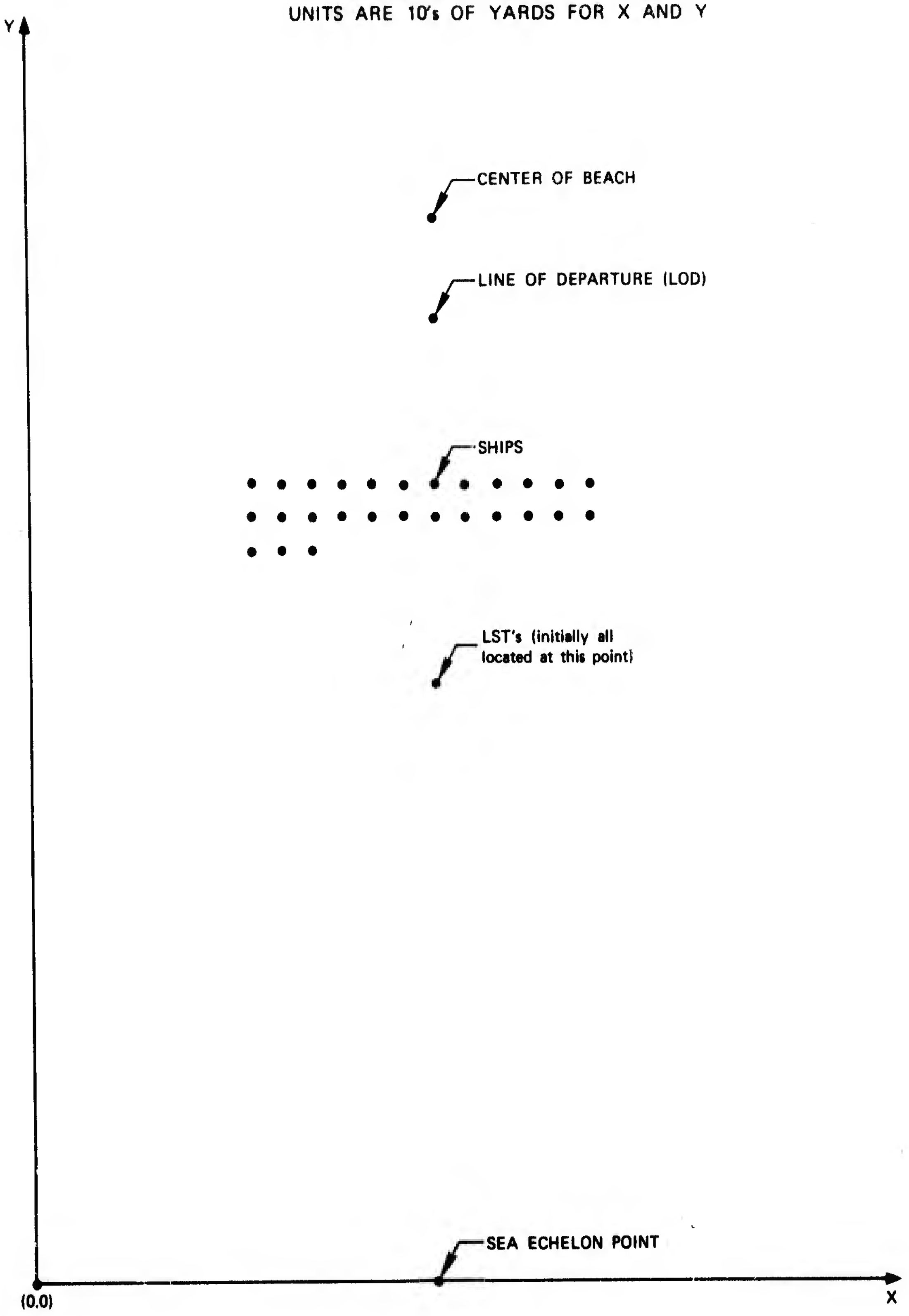
UNLOADING TIME TABLE - TABLE 17

NWL Variable Name	Card #	Columns	Format	Description
UT1	1	2	X	Beach Number (= 1 for our runs)
UT2	1	3-4	XX	Craft Type: 02 - Small Craft 03 - Medium Craft 04 - Large Craft
UT3	1	5-6	XX	Time in minutes to discharge 100 personnel from the craft
UT6	1	11-12	XX	Time in minutes to discharge 10 vehicles from the craft
UT9	1	17-18	XX	Time in minutes to discharge 10 pallets from the craft
--	1	67-68	XX	= UT

GEOGRAPHIC LOCATION TABLE - TABLE 18

NWL Variable Name	Card #	Columns	Format	Description
GL1	1	2	X	Beach Number (= 1 for our runs)
GL2	1	3-4	XX	An arbitrary two digit number greater than zero which refers to the location specified in GL3 and GL4. This number is used in the Ship Table (Table 4) as the variable SS4 to assign ships to locations. In addition, location codes are assigned to the sea echelon point, the LOD, and the beach.
GL3	1	5-9	XXXXX	X coordinate of point whose number is in GL2 in tens of yards (see diagram).
GL4	1	10-14	XXXXX	Y coordinate of point whose number is in GL2 in tens of yards (see diagram).
GL5	1	15	X	Type of point described: 0 - Beach (Center of beach in GL3 & GL4) 1 - LOD 2 - Ship Berth 3 - Sea Echelon Point
--	1	67-68	XX	= GL

GEOGRAPHIC LOCATION TABLE LAYOUT
SAMPLE LAYOUT NOT TO SCALE
UNITS ARE 10's OF YARDS FOR X AND Y



SHORE COMPILER TABLE - TABLE 19

NWL Variable Name	Card #	Columns	Format	Description
SC1	1	2	X	Beach Number (= 1 for our runs)
SC2	1	3-7	XXXXX	Number of personnel landed, generated by program. Input = 0.
SC3	1	8-11	XXXX	Number of vehicles landed, including those from LSTs. Generated by program. Input = 0.
SC4	1	12-16	XXXXX	Short tons of category 1 cargo (ammunition) landed. Generated by program. Input = 0.
SC5	1	17-21	XXXXX	Short tons of category 2 cargo (general cargo) landed. Generated by program. Input = 0.
SC6	1	22-26	XXXXX	Short tons of category 3 cargo (POL) landed. Generated by program. Input = 0.
SC7	1	27-31	XXXXX	Short tons of category 4 cargo (SATS matting) landed. Generated by program. Input = 0.
--	1	67-68	XX	= SC
SC14	2	2-7	XXXXXX	Current level in short tons of category 1 cargo that has been landed and has not yet been moved from the beach slot to the temporary dump. Generated by program.
SC15	2	8-13	XXXXXX	Current level in short tons of category 2 cargo (see description of SC14).

(Table 19 (concluded)

NWL Variable Name	Card #	Columns	Format	Description
SC16	2	14-19	XXXXXX	Current level in short tons of category 3 cargo (see description of SC14).
SC17	2	20-25	XXXXXX	Current level in short tons of category 4 cargo (see description of SC14).
--	2	67-68	XX	= SC
--	3	67-68	XX	= SC
--	4	67-68	XX	= SC
--	5	67-68	XX	= SC

LIFT CONVERSION TABLE - TABLE 25

NWL Variable Name	Card #	Columns	Format	Description
LC1	1	2-4	X.X	Weight in tons of one ammunition pallet
LC2	1	5-7	X.X	Weight in tons of one pallet of general cargo
LC3	1	8-10	X.X	Weight in tons of one POL pallet
LC4	1	11-13	X.X	Weight in tons of one pallet of special cargo (SATS matting)
--	1	67-68	XX	= LC

ATTRITION RECORD TABLE - TABLE 26

NWL Variable Name	Card #	Columns	Format	Description
AR1	1	2	X	Beach destination (= 1 for our runs)
AR2	1	3-5	XXX	Craft number (C3 in Craft Table 11)
AR3	1	6	X	Craft type: 2 - Small 3 - Medium 4 - Large
AR4	1	7-11	XXXXX	Game time at which craft is attrited (in minutes).
AR5	1	12-15	XXXX	Length of time, in minutes, that craft is out of action. If craft is permanently out of action, this is recorded as 9999 minutes.
AR6	1	16-20	XXXXX	Serial number of craft load at time of attrition.
AR7	1	21-23	XXX	Quantity of pallets, in short tons, being carried at time of attrition.
AR8	1	24	X	Craft position at time of attrition 0 - Moving from LOD to ship 1 - Moving from ship to LOD 2 - Moving from LOD to beach 3 - Moving from beach to LOD 4 - Unloading at beach
--	1	67-68	XX	= AR

MISCELLANEOUS TABLE - TABLE 27

NWL Variable Name	Card #	Columns	Format	Description
M2	1	4-6	XXX	Lower bound for uniform distribution function used to generate the repair time for damaged craft (all types), in minutes.
M3	1	7-10	XXXX	Upper bound for distribution described above, in minutes.
M4	1	11	X	Indicates whether the assault phase or general unloading phase is being simulated. 0 - assault phase 1 - general unloading phase
M5	1	12-13	XX	Lower bound for uniform distribution function used to generate the time for which a beach slot with a permanently damaged craft is not available for use by other craft, in minutes. Note that over-the-waterline craft do not use beach slots since the slots are at the waterline.
M6	1	14-16	XXX	Upper bound for distribution described above (in M5), in minutes.
M7	1	17-19	XXX	The time used by an LST to come in, hook up to a causeway and get ready to start unloading, in minutes. Valve used currently is 30 minutes.
M8	1	20	X	The number of square feet occupied by one Marine in a landing craft. This is used to fit personnel serials into craft that can carry them. Value currently used is 3 square feet.

Table 27 (continued)

NWL Variable Name	Card #	Columns	Format	Description
M9	1	21-22	XX	Maximum number of craft waiting to load or loading at any loading position of an LKA. Using 2 currently.
M10	1	23-25	XXX	If an LST tries to find a free causeway and none are available, it will try again in M10 minutes. Currently using 10 minutes.
M13	1	30	X	= 1 always
M14	1	31-33	XXX	The maximum number of craft which STS-2 may create (sum of all types) when it is used in the craft generation mode (e.g. when M20 = 1)
M15	1	34-36	XXX	When in the craft generation made if the program needs a certain craft type it will create a craft if no craft of this type will be available in time M15, in minutes. Currently using 10 minutes.
M17	1	40-44	XXXXX	When using the fitting routine to get a craft load, any vehicle which weighs more than M17 pounds must be loaded flush to the rear wall of the cargo box. Currently using 35000 pounds.
M20	1	55	X	Indicator to tell STS-2 whether or not it may create craft. 0 - no craft creation 1 - craft creation allowed.

Table 27 (concluded)

NWL Variable Name	Card #	Columns	Format	Description
M21	1	56	X	Maximum queue at well deck ships. Currently using 4.
M22	1	57	X	Special Editing Indicator 0 - Don't do special editing 1 - Do special editing Special editing involves producing the Selected Serial History Table, the Selected Craft History Table, and the Cumulative Delay Time Table. Always use 1.
--	1	67	X	= M

VEHICLE TABLE - TABLE 42

NWL Variable Name	Card #	Columns	Format	Description
V1	1	2-6	XXXXX	Vehicle number, assigned by numbering the first vehicle in the force 1001 and incrementing by 1 for each vehicle without trailer, incrementing by 2 for each vehicle with trailer. There is an entry in this table for amphibious craft with V1 = C3, the craft number in Craft Table 11. (Craft numbers are less than 1000.
V2	1	7	X	= 1
V3	1	8-12	XXXXX	Serial number of serial to which this vehicle is attached.
V4	1	13-14	XX	Ship number of ship on which this vehicle is embarked.
V5	1	15	X	Hold number of ship designated in V4 in which this vehicle is loaded.
V6	1	16	X	Hold level, always = 1
V7	1	17-18	XX	Code for vehicle type. For amphibious craft, the craft type code was used as the value for this variable. The code used: 02 - Small amphibian 03 - Medium amphibian 04 - Large amphibian 35 - M35 truck 36 - M36 truck 52 - M52 truck tractor 54 - M54 truck 99 - Other vehicles

Table 42 (continued)

NWL Variable Name	Card #	Columns	Format	Description
V8	1	19	X	Indicator of status of the vehicle prior to its use on the beach. For input, set V8 = 0 unless the vehicle is preloaded on a craft, in which case set V8 = 2. 0 - Embarked on ship 1 - Tentatively assigned to craft 2 - Loaded on craft 3 - Landed on beach
V9	1	20	X	Vehicle description indicator: 0 - wheeled vehicle 1 - tracked vehicle 2 - wheeled vehicle, trailer to follow 3 - tracked vehicle, trailer to follow 4 - towed trailer 5 - untowed trailer
V10	1	21-22	XX	Indicator of status of the vehicle for transporting cargo on the beach. For input, if the vehicle will not be available for transporting cargo across the beach, set V10 = 3 (unavailable). In addition, for the vehicle that will not be available for moving cargo on the beach, V22 must be set = 0. If the vehicle will be available for beach transport of cargo, set V10 = 12 (mobile loaded vehicle) for input, and V22 must be set = 2. The only types of vehicle which could be used in our runs for carrying cargo across the beach were of the types 35, 36, 52, or 54 (see V7). The code for beach status is:

Table 42 (continued)

NWL Variable Name	Card #	Columns	Format	Description
				0 - available for loading 1 - assigned 2 - attrited 3 - destroyed and/or unavailable 4 - loading 5 - unloading 6 - waiting to load 7 - waiting to unload 8 - waiting at beach exit 9 - waiting at beach entrance 10 - moving from beach to LSA (logistics support area) 11 - moving from LSA to beach 12 - mobile loaded vehicle
V11	1	23-27	XXXXX	Descriptive code for each vehicle type
V12	1	28-30	XXX	Craft number of craft onto which vehicle is loaded. For input, leave blank except for vehicles pre-loaded on craft.
V15	1	38-40	XXX	Present location of vehicle, either the beach number or the LSA number corresponding to VP1 or VP2 in the Vehicle Point Location Table 54. Variables V15 through V21 apply only to vehicles carrying cargo across the beach. Leave blank for input.
V16	1	41-43	XXX	Future location of vehicle, either beach number or LSA number. See description of V15.

Table 42 (continued)

NWL Variable Name	Card #	Columns	Format	Description
V18	1	47-49	XXX	Number of trips made across the beach by this vehicle. See description of V15.
V19	1	50-54	XXXXX	Cumulative operating time of vehicle on the beach. See description of V15.
V20	1	55-56	XX	Event in progress for vehicle carrying cargo across the beach. See list of events in STS Users Guide for description of event variables.
V21	1	57-61	XXXXX	Completion time of event being executed by this vehicle. Applicable only to vehicles carrying cargo across the beach.
V22	1	62	X	Indicator of availability of vehicle for moving cargo after it arrives on the beach. V22 is used by the program in conjunction with V10 to control the movement of vehicles after they arrive on the beach. See description of V10.
--	1	67	X	= V
V23	2	2-6	XXX.X	Gross weight, in short tons, of the vehicle including a trailer if attached.
V24	2	7-10	XXXX	Perimeter of vehicle to nearest tenth of a foot; The perimeter used is the perimeter of the smallest box that would enclose the vehicle or, if it has a trailer attached, would enclose the vehicle together with its trailer. In other words, V24 is equal to twice the sum of V25 and V26.

Table 42 (concluded)

NWL Variable Name	Card #	Columns	Format	Description
V25	2	11-14	XXXX	Length of vehicle together with its trailer, if any, to nearest tenth of a foot.
V26	2	15-18	XXXX	Width of vehicle (or if it has an attached trailer that is wider than the vehicle, the width of the trailer) to the nearest tenth of a foot.
--	2	67	X	= V

SERIAL COMPOSITION TABLE - TABLE 43

NWL Variable Name	Card #	Columns	Format	Description
SCT1	1	2	X	Beach destination number (= 1 for our runs) as in S1 of Serial Table 2.
SCT2	1	3-7	XXXXX	Serial number, alpha-numeric, as in S2 of Serial Table 2.
SCT3	1	8-9	XX	Number of ship on which serial was embarked, as in S4 of Serial Table 2.
SCT4	1	10-12	XXX	Total number of personnel in serial = S16 in the Serial Table.
SCT5	1	13-14	XX	Number of vehicles in hold number 1. Trailer plus accompanying prime mover count as two vehicles. The total of variables SCT5 through SCT9 should equal S17 in the Serial Table. For well deck ships, SCT5 = S17 and SCT6 through 9 = 0.
SCT6	1	15-16	XX	Number of vehicles in hold number 2. See description of SCT5.
SCT7	1	17-18	XX	Number of vehicles in hold number 3. See description of SCT5.
SCT8	1	19-20	XX	Number of vehicles in hold number 4. See description of SCT5.
SCT9	1	21-22	XX	Number of vehicles in hold number 5. See description of SCT5.

Table 43 (concluded)

NWL Variable Name	Card #	Columns	Format	Description
SCT10	1	23-24	XX	Leave blank since there are no ships presently in the fleet with more than 5 holds.
SCT11	1	25-26	XX	See description of SCT10.
SCT12	1	27-28	XX	See description of SCT10.
--	1	67-69	XXX	"SCT"

CUMULATIVE DELAY TIME TABLE - TABLE 50

(Generated by Program)

NWL Variable Name	Card #	Columns	Format	Description
CDT1	1	2-6	XXXXX	Landing time of last assault craft, in minutes.
CDT2	1	7-11	XXXXX	Landing time of last craft, in minutes (same as CDT1 if there is no general unloading phase).
CDT3	1	12-17	XXXXXX	Total delay time in minutes for craft waiting to load assault serials.
CDT4	1	18-23	XXXXXX	Total delay time in minutes for craft waiting to load during general unloading.
CDT5	1	24-29	XXXXXX	Total delay time in minutes for craft waiting for landing slots at the beach for assault serials.
CDT6	1	30-35	XXXXXX	Total delay time in minutes for craft waiting for landing slots at the beach during general unloading.
CDT7	1	36-41	XXXXXX	Total delay time in minutes due to lack of available vehicles for offloading craft carrying assault serials.
CDT8	1	42-47	XXXXXX	Total delay time in minutes due to lack of available vehicles for offloading craft during general unloading.
CDT9	1	48-53	XXXXXX	Total time in minutes spent loading assault serials onto craft.

Table 50 (concluded)

NWL Variable Name	Card #	Columns	Format	Description
CDT10	1	54-59	XXXXXX	Total time in minutes spent loading craft during general unloading.
CDT11	1	60-65	XXXXXX	Total time in minutes spent unloading assault serials from craft, including delay time due to lack of vehicles (CDT7).
--	1	67-69	XXX	= CDT
CDT12	2	2-7	XXXXXX	Total time in minutes spent unloading craft during general unloading, including delay time due to lack of vehicles (CDT8).
CDT13	2	8-13	XXXXXX	Total time in minutes spent moving assault serials by craft.
CDT14	2	14-19	XXXXXX	Total time in minutes spent moving by craft during general unloading.
--	2	67-69	XXX	= CDT

SELECTED CRAFT HISTORY TABLE - TABLE 52

NWL Variable Name	Card #	Columns	Format	Description
SCH1	1	2-4	XXX	Craft number (C3 in Craft Table).
SCH2	1	5-9	XXXXX	Number of serial (S3 in Serial Table) to which craft is assigned.
SCH3	1	10-14	XXXXX	Time craft was assigned to serial.
SCH4	1	15-19	XXXXX	Time craft arrived at ship.
SCH5	1	20-24	XXXXX	Time craft loading started.
SCH6	1	25-29	XXXXX	Time craft loading was completed.
SCH7	1	30-34	XXXXX	Time craft departed the ship.
SCH8	1	35-39	XXXXX	Time craft arrived at the LOD.
SCH9	1	40-44	XXXXX	Time craft departed the LOD.
SCH10	1	45-49	XXXXX	Time craft arrived at the beach.
SCH11	1	50-54	XXXXX	Time craft started unloading.
SCH12	1	55-59	XXXXX	Time craft completed unloading.
SCH13	1	60-62	XXX	Number of personnel aboard craft.

Table 52 (concluded)

NWL Variable Name	Card #	Columns	Format	Description
SCH14	1	63-64	XX	Number of vehicles, aboard craft including trailers as separate vehicles.
--	1	67-69	XXX	= SCH
SCH15	2	2-5	XXXX	Number of pallets (either standard or special) aboard craft.
SCH16	2	6-8	XXX	Percent utilization obtained as calculated for C19 in the Craft Table.

VEHICLE POINT LOCATION TABLE - TABLE 54

NWL Variable Name	Card #	Columns	Format	Description
VP1	1	2	X	Beach number (= 1 for our runs)
VP2	1	3-5	XXX	Logistics supply area (LSA) number. LSA's are not assigned grid locations in the Geographic Location Table 18 but are identified only by LSA number. An LSA number must also be assigned to the beach.
VP3	1	6	X	Indicator 0 - VP2 applies to beach 1 - VP2 applies to LSA
VP4	1	7-10	XXXX	Distance from VP2 to beach in tens of yards. VP4 = 0 when VP3 = 0.
VP5	1	11-15	XXXXX	End of first time period in minutes, set = 10000 for our runs.
VP6	1	16-20	XXXXX	End of second time period in minutes, set = 20000 for our runs.
VP7	1	21-25	XXXXX	End of third time period in minutes, set = 30000 for our runs.
VP8	1	26-30	XXXXX	End of fourth time period in minutes, set = 40000 for our runs.
VP9	1	31-33	XXX	Number of vehicles per hour allowed to enter or leave beach during first time period.

Table 54 (continued)

NWL Variable Name	Card #	Columns	Format	Description
VP10	1	34-36	XXX	Number of vehicles per hour allowed to enter or leave beach during second time period.
VP11	1	37-39	XXX	Number of vehicles per hour allowed to enter or leave beach during third time period.
VP12	1	40-42	XXX	Number of vehicles per hour allowed to enter or leave beach during fourth time period.
VP13	1	43-47	XXXXX	Time at which traffic rate was last updated. After the end of first time period, VP13 = 10000 for example. For input VP13 = 0.
VP14	1	48-50	XXX	Remaining number of vehicles allowed to enter or leave beach during current time period. This is calculated by the program by subtracting each vehicle entering or leaving during the time period from the appropriate parameter, i.e., from V9, V10, V11, or V12. For input VP14 = 0.
VP15	1	51-58	XXXXXX.X	Quantity of cargo category 1 (ammunition) in short tons that has already arrived at either the beach or the LSA (see VP3). This is cumulative. For input VP15 through VP18 = 0.0.
VP16	1	59-66	XXXXXX.X	Quantity of cargo category 2 (general cargo) in short tons that has already arrived at the beach or LSA. See description of VP15.
--	1	67-68	XX	= VP

Table 54 (concluded)

NWL Variable Name	Card #	Columns	Format	Description
VP17	2	2-9	XXXXXX.X	Quantity of cargo category 3 (POL) in short tons that has already arrived at either the beach or the LSA. See description of VP15.
VP18	2	10-17	XXXXXX.X	Quantity of cargo category 4 (special cargo SATS matting pallets) in short tons that has already arrived at the beach of LSA. See description of VP15.
--	2	67-68	XX	= VP
VP27	3	13-14	XX	= 00
--	3	67-68	XX	= VP

SELECTED SERIAL HISTORY TABLE - TABLE 55 (Generated by Program)

NWL Variable Name	Card #	Columns	Format	Description
SSH1	1	2-6	XXXXX	Serial number, alpha-numeric, of on-call serial. (For on-call serials, S2 = 1 in Serial Table 2).
SSH2	1	7-11	XXXXX	Call time of serial.
SSH3	1	12-16	XXXXX	Time last craft used for carrying the serial was assigned to the serial.
SSH4	1	17-21	XXXXX	Time last craft used for carrying the serial arrived at ship.
SSH5	1	22-26	XXXXX	Time first craft used for carrying the serial started loading.
SSH6	1	27-31	XXXXX	Time last craft used for carrying the serial completed loading.
SSH8	1	37-41	XXXXX	Time last craft used for carrying the serial arrived at beach.
SSH9	1	42-46	XXXXX	Time first craft used for carrying the serial started unloading.
SSH10	1	47-51	XXXXX	Time last craft used for carrying the serial completed unloading.
SSH11	1	52-54	XXX	Craft number of first craft assigned to serial.

Table 55 (continued)

NWL Variable Name	Card #	Columns	Format	Description
SSH12	1	55	X	Craft type of first craft assigned to serial. 2 - Small 3 - Medium 4 - Large
SSH13	1	56-58	XXX	Craft number of second craft assigned to serial.
SSH14	1	59	X	Craft type of second craft assigned to serial.
SSH15	1	60-62	XXX	Craft number of third craft assigned to serial.
SSH16	1	63	X	Craft type of third craft assigned to serial.
SSH17	1	64-66	XXX	Craft number of fourth craft assigned to serial.
--	1	67-69	XXX	= SSH
SSH18	2	2	X	Craft type of fourth craft assigned to serial.
SSH19	2	3-5	XXX	Craft number of fifth craft assigned to serial.
SSH20	2	6	X	Craft type of fifth craft assigned to serial.
SSH21	2	7-9	XXX	Craft number of sixth craft assigned to serial.
SSH22	2	10	X	Craft type of sixth craft assigned to serial.
SSH23	2	11-13	XXX	Craft number of seventh craft assigned to serial.

Table 55 (continued)

NWL Variable Name	Card #	Columns	Format	Description
SSH24	2	14	X	Craft type of seventh craft assigned to serial.
SSH25	2	15-17	XXX	Craft number of eighth craft assigned to serial.
SSH26	2	18	X	Craft type of eighth craft assigned to serial.
SSH27	2	19-21	XXX	Craft number of ninth craft assigned to serial.
SSH28	2	22	X	Craft type of ninth craft assigned to serial.
SSH29	2	23-25	XXX	Craft number of tenth craft assigned to serial.
SSH30	2	26	X	Craft type of tenth craft assigned to serial.
SSH31	2	27-29	XXX	Craft number of eleventh craft assigned to serial.
SSH32	2	30	X	Craft type of eleventh craft assigned to serial.
SSH33	2	31-33	XXX	Craft number of twelfth craft assigned to serial.
SSH34	2	34	X	Craft type of twelfth craft assigned to serial.
SSH35	2	35-37	XXX	Craft number of thirteenth craft assigned to serial.
SSH36	2	38	X	Craft type of thirteenth craft assigned to serial.
SSH37	2	39-41	XXX	Craft number of fourteenth craft assigned to serial.
SSH38	2	42	X	Craft type of fourteenth craft assigned to serial.

Table 55 (concluded)

NWL Variable Name	Card #	Columns	Format	Description
SSH39	2	43-45	XXX	Craft number of fifteenth craft assigned to serial.
SSH40	2	46	X	Craft type of fifteenth craft assigned to serial.
SSH41	2	47-49	XXX	Craft number of sixteenth craft assigned to serial.
SSH42	2	50	X	Craft type of sixteenth craft assigned to serial.
SSH43	2	51-53	XXX	Craft number of seventeenth craft assigned to serial.
SSH44	2	54	X	Craft type of seventeenth craft assigned to serial.
SSH45	2	55-57	XXX	Craft number of eighteenth craft assigned to serial.
SSH46	2	58	X	Craft type of eighteenth craft assigned to serial.
SSH47	2	59-61	XXX	Craft number of nineteenth craft assigned to serial.
SSH48	2	62	X	Craft type of nineteenth craft assigned to serial.
--	2	67-69	XXX	= SSH

TEMPORARY DUMP TABLE - TABLE 58

NWL Variable Name	Card #	Columns	Format	Description
TD1	1	2-9	XXXXX.XX	Current dump level in short tons, generated by program. Input TD1 = 0.00
TD3	1	13-14	XX	Time in minutes required for each pallet to be moved from craft in beach slot to temporary dump if no vehicle is available. Input TD = 2 for our runs.
TD9	1	36-38	XXX	Number of vehicles waiting for assignment, generated by program.
TD10	1	39-41	XXX	Number of vehicle loading slots currently available for cargo-carrying vehicles to use. Total number of slots is input, this number was 10 for the base system runs.
--	1	67-68	XX	= TD

Appendix B

REPRESENTATIVE LANDING PLAN

Appendix B

REPRESENTATIVE LANDING PLAN

The following pages show applicable portions of a representative Amphibious Task Force Operation Plan (Annex I to an Amphibious Operation Plan). This plan was used for testing the various analytical models developed at Stanford Research Institute and at the Naval Weapons Laboratory, Dahlgren, Virginia. Since it is a test plan, changes will probably be required before actual analytical runs are made; however, changes should be relatively minor.

AMPHIBIOUS TASK FORCE OPERATION PLAN

Annex I

Ship-to-Shore Movement

Task Organization (Detailed Task Organization in Annex I)

_____ First Attack Group		RADM _____________ (COMPHIB GRU ____)
a.	_______ First Landing Group	MAJGEN _____________ (CG MEF)
b.	_______ First Transport Unit	COMO _____________ (COMPHIBRON _____)
c.	_______ Helicopter Transport Element	CAPT _____________ (COMLPHDIV ______)
d.	_______ First Control Unit	CAPT _____________ ( )

1. General Situation

As in basic order.

This Annex provides for the ship-to-shore movement of the First Landing Group in the _________ area.

2. This force will land the First Landing Group in assault over RED Beach and in helicopter landing zones (to be designated) in the __________ area, employing landing ships, landing craft, amphibious vehicles, and helicopters,

in order to

seize, occupy, and defend a beachhead at ________ and firmly establish the First Landing Group ashore.

3. a. First Landing Group

(1) On the order "Land the Landing Force," provide boat teams and equipment in accordance with the Commander, First Landing Group Consolidated Landing Plan.

(2) Provide and operate amphibious vehicles in accordance with the Amphibious Vehicle Availability Table, Tab B to Appendix III; the Consolidated Landing and Approach Plan, Appendix VI; and the Assault Wave Diagram, Appendix VII to this Annex.

(3) Provide units and personnel for control of the ship-to-shore movement in accordance with Control Plan, Appendix IV to this Annex.

b. First Transport Unit

(1) When directed by Commander, First Attack Group, take stations in accordance with Assault Area Diagram, Appendix I to this Annex.

(2) On the order "Land the Landing Force," conduct pre-H-Hour transfers and load and dispatch boats and amphibious vehicles as necessary to meet the schedules set forth in the Consolidated Landing and Approach Plan, Appendix VI to this Annex.

(3) Provide landing craft for the ship-to-shore movement in accordance with Landing Craft Availability Table, Tab A to Appendix III to this Annex.

(4) Provide personnel for control of the ship-to-shore movement in accordance with Control Plan, Appendix IV to this Annex.

(5) When the assault waves have landed and when directed by the Commander, First Attack Group, conduct ship-to-shore movement of remainder of First Landing Group (less helicopterborne units) in accordance with this Annex.

(6) When directed by Commander, First Attack Group, commence general unloading.

c. First Helicopter Transport Element

(1) When directed by Commander, First Attack Group, land the helicopter borne units in landing zones to be designated in accordance with Appendix V to this Annex.

d. First Control Unit

(1) Control the ship-to-shore movement of landing ships, landing craft, and amphibious vehicles in accordance with Control Plan, Appendix IV to this Annex.

(2) Control evacuation of casualties in accordance with Annex M.

4. a. Logistics in accordance with Annex L.

b. Medical Services in accordance with Annex M.

5. a. Communications in accordance with Annex N.

APPENDICES:

I - Transport Area Diagrams

Tab A - Assault Area Diagram
B - Transport Area Diagram

II - Beach Approach Diagram

III - Landing Craft and Amphibious Vehicle Availability

Tab A - Landing Craft Availability Table
B - Amphibious Vehicle Availability Table

IV - Control Plan (not developed for this study)

V - Helicopter Ship-to-Shore Movement (Not developed in this example)

VI - Consolidated Landing and Approach Plan

VII - Assault Wave Diagram

Tab A - Assault Wave Diagram for RED Beach.

VIII - Ship-to-Shore Nuclear Defense Plan (Not developed in this example)

IX - Anchorage Diagram

X - Landing Craft and Amphibious Vehicle Employment

Tab A - Landing Craft Employment Plan

B - Amphibious Vehicle Employment Plan

XI - Causeway Plan

Tab A - Pontoon Causeway Operation

B - Tabular Summary of Pontoon Components (Omitted)

XII - Unloading Plan (Serials to be landed by helicopters not included)

Tab A - Serial Assignment Table

B - Landing Sequence Table

C - Landing Sequence Table for Landing Ships

XIII - Personnel Transfer Plan (Not developed for this study)

XIV - Service and Salvage Plan (Not developed for this study)

Appendix I to Annex I

TRANSPORT AREA DIAGRAMS

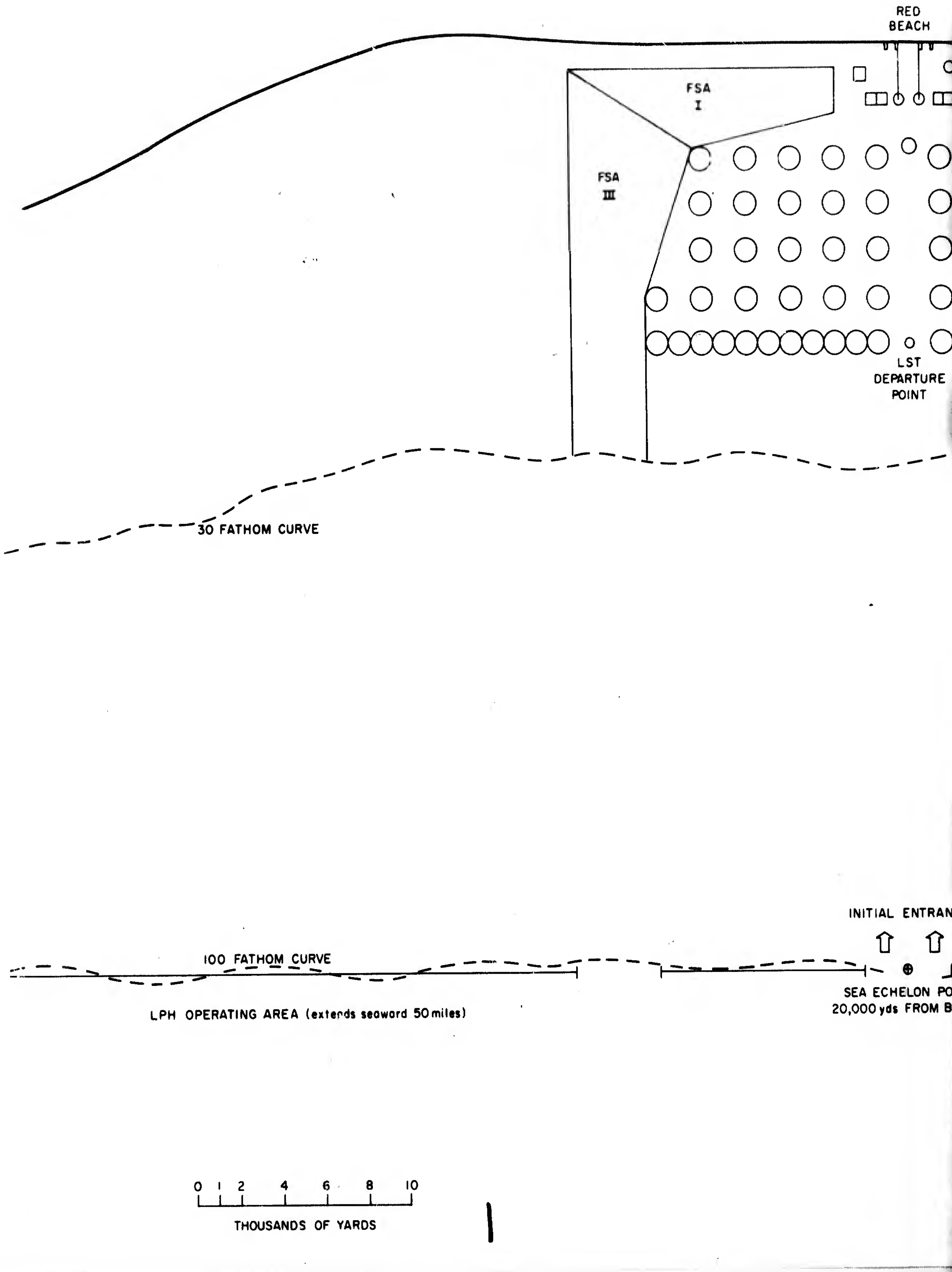
1. The assault area diagram is set forth in Tab A.

2. The transport area diagram is set forth in Tab B.

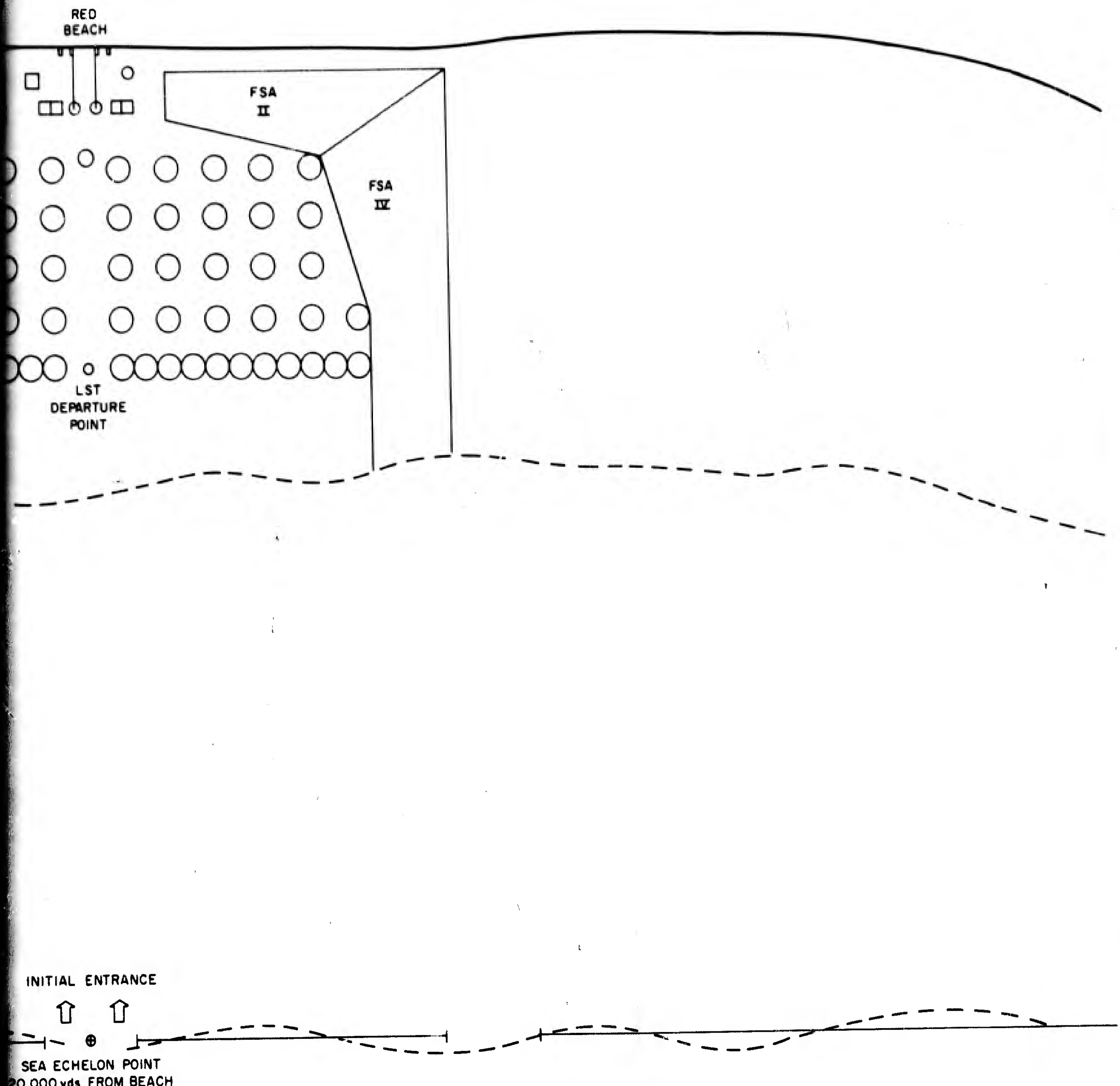
TABS:

A - Assault Area Diagram

B - Transport Area Diagram

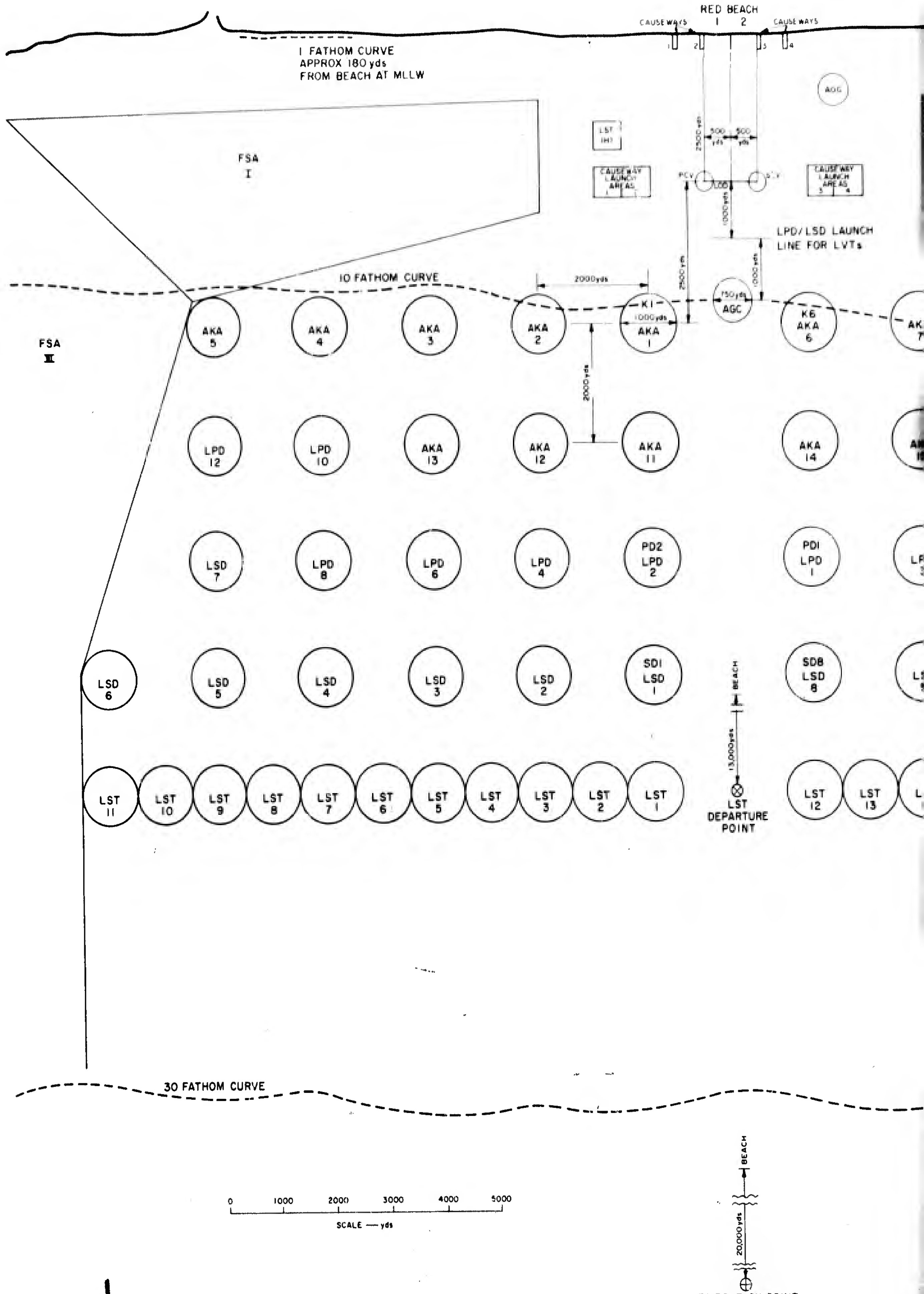

RED BEACH
FSA I
FSA III
LST DEPARTURE POINT
30 FATHOM CURVE
INITIAL ENTRANC
100 FATHOM CURVE
SEA ECHELON POI
20,000 yds FROM BE
LPH OPERATING AREA (extends seaword 50 miles)
0 1 2 4 6 8 10
THOUSANDS OF YARDS

A TO APPENDIX I TO ANNEX I
ASSAULT AREA DIAGRAM

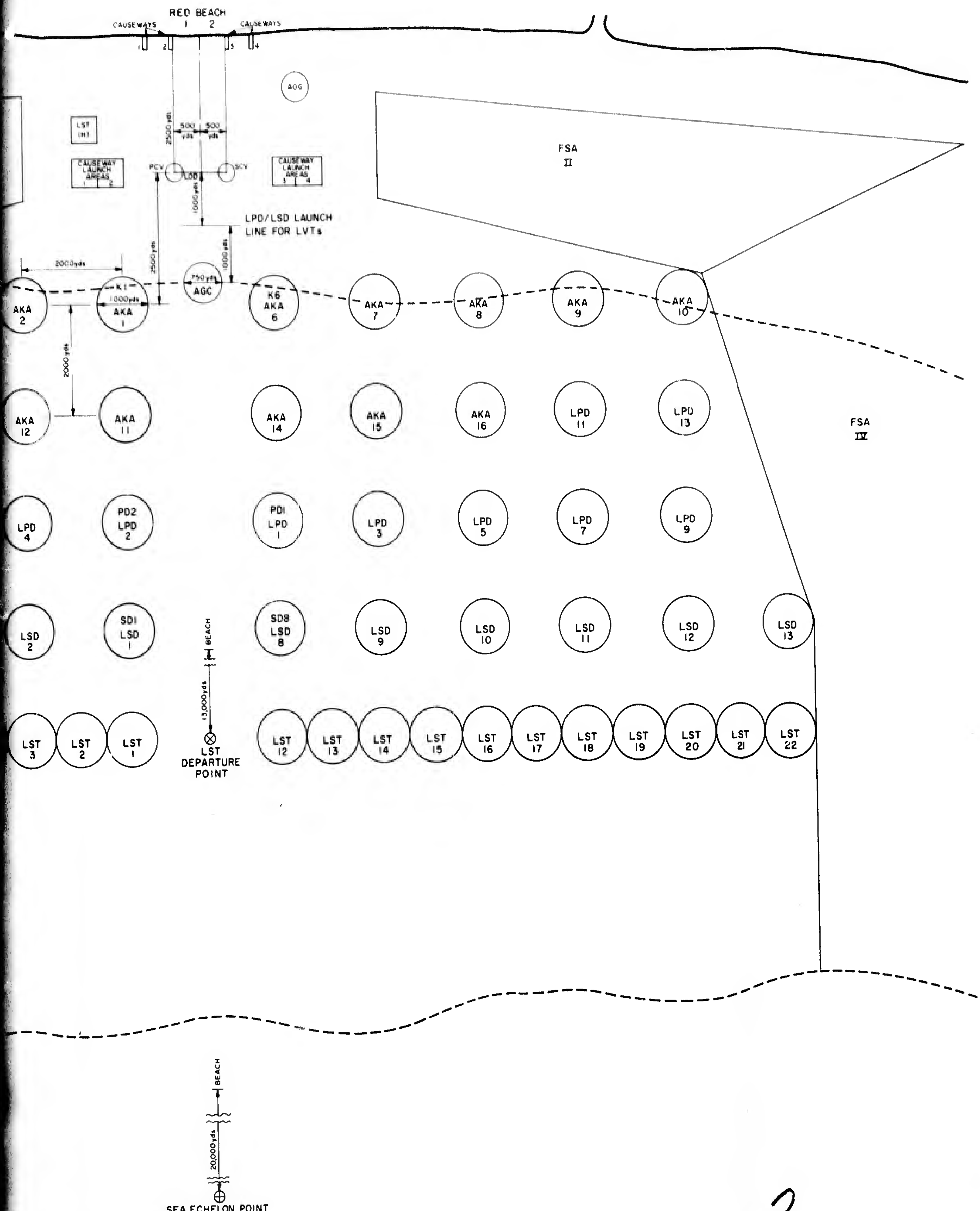


2

TAB B TO APPENDIX I TO ANNEX I
TRANSPORT AREA DIAGRAM



TAB B TO APPENDIX I TO ANNEX I
TRANSPORT AREA DIAGRAM



Appendix II to Annex I

BEACH APPROACH

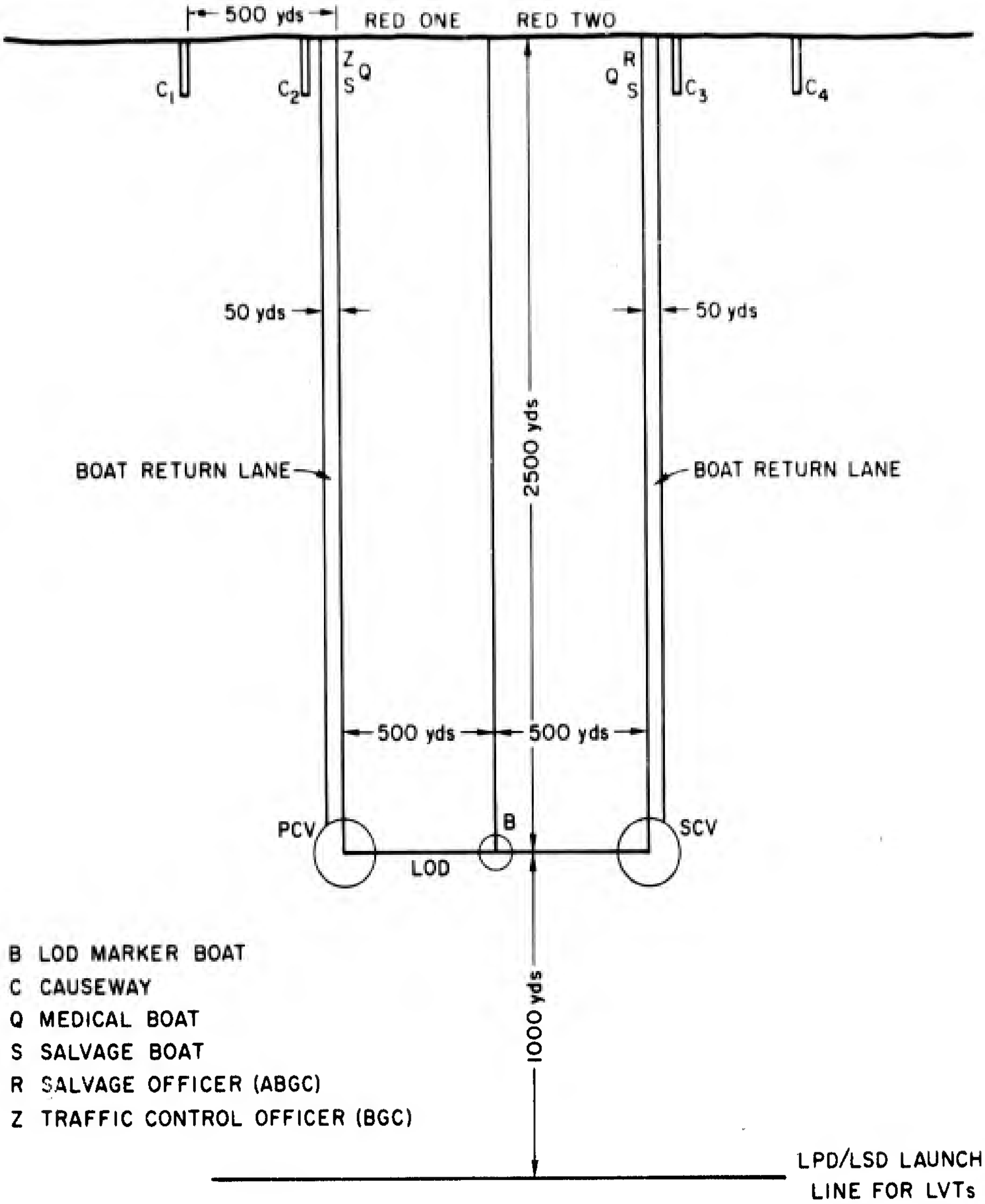
1. RED Beach approach diagram as prescribed in Tab A to this appendix.

TABS:

A - RED Beach Approach Diagram

TAB A TO APPENDIX II TO ANNEX I

BEACH APPROACH DIAGRAM



Appendix III to Annex I

LANDING CRAFT AND AMPHIBIOUS VEHICLE AVAILABILITY

1. Landing craft availability is shown in Tab A to this Annex. The landing craft available to the landing force will be updated as the various phases of this study are run.

2. Amphibian vehicle availability is shown in Tab B to this Annex. The characteristics of the two vehicles shown in LSD-1 are not known at this time.

TABS:

A - Landing Craft Availability Table

B - Amphibian Vehicle Availability Table

TAB A to Appendix III to Annex I

LANDING CRAFT AVAILABILITY TABLE

Ship		LCM (6)	LCM (8)	LCU (1610)	LCPL MKV				
AKA	1	9			3				
	2	9			3				
	3	9			3				
	4	9			3				
	5	9			3				
	6	9			3				
	7	9			3				
	8	9			2				
	9	9			3				
	10	9			3				
	11	9			3				
	12	9			3				
	13	9			3				
	14	9			3				
	15	9			3				
	16	9			3				
LPD	1	5		1	2				
	2	5		1	2				
	3	5		1	2				
	4	5		1	2				
	5	4	4		2				
	6	4	4		2				
	7	4	4		2				
	8	4	4		2				
	9	4	4		2				
	10	4	4		2				
	11	4	4		2				
	12	4	4		2				
	13	4	4		2				

LANDING CRAFT AVAILABILITY TABLE (Continued)

Ship		LCM (6)	LCM (8)	LCU (1610)	LCPL MKV				
LSD	1	5	3	2	2				
	2	5	3	2	2				
	3	5	3	2	2				
	4	5	3	2	2				
	5	5	3	2	2				
	6	5	3	2	2				
	7	5	3	2	2				
	8	1	9		2				
	9	1	9		2				
	10	1	9		2				
	11	1	9		2				
	12	1	9		2				
	13	1	9		2				
LST	1				2				
	2				2				
	3				2				
	4				2				
	5				2				
	6				2				
	7				2				
	8				2				
	9				2				
	10				2				
	11				2				
	12				2				
	13				2				
	14				2				
	15				2				
	16				2				

LANDING CRAFT AVAILABILITY TABLE (Concluded)

Ship	LCM (6)	LCM (8)	LCU (1610)	LCPL MKV				
LST 17				2				
18				2				
19				2				
20				2				
21				2				
22				2				
Total Less 10% for Spares	251 25	111 11	18 2	96 10				
Total Available for Employment	226	100	16	86				
Boats for Naval Use								
Amphibious Vehicle Wave Guides				16				
Asst Amphibious Vehicle Wave Guides				4				
Traffic Control Boats				2				
Causeway Tender Boats	8							
Salvage Boats	4							
Medical Boats	4							
Total for Naval Use	16			22				
Total Available for Landing Force Use	210	100	16					

TAB B to Appendix III to Annex I

AMPHIBIAN VEHICLE AVAILABILITY TABLE

Ship	Number and Type Amphibian Vehicle					Remarks
	LVTP	LVTE	LVTR	LVTH	Vehicle	
LPD-1		5		10		Wave 1
LPD-2		4		8		Wave 1
LPD-3	16					Wave 2
LPD-4	16					Wave 2
LPD-5	11	2	2			Wave 3
LPD-6	11	1	2			Wave 3
LPD-7	14					Wave 4
LPD-8	14					Wave 4
LPD-9	15		1			Wave 5
LPD-10	15		1			Wave 5
LPD-11	17					Wave 6
LPD-12	17					Wave 6
LSD-1	12					Wave 7
	10				1	Wave 8
LSD-2	12					Wave 7
	10				1	Wave 8
	190	12	6	18	2	

Appendix IV to Annex I

CONTROL PLAN

Task Organization

(Detailed Organization normally shown in Annex A not required for study; therefore not developed).

1. General Situation

As in basic plan.

This Annex provides for the control of the ship-to-shore movement of the First Landing Group.

2. This Group will control the movement of all landing ships, landing craft, amphibious vehicles, and helicopters in the ship-to-shore movement.

in order to

land elements of the First Landing Group at the prescribed time on the specified beaches and with the required logistic support for the capture, occupation, and defense of the ________________ area.

3. a. First Landing Group

Provide Tactical Logistical Parties to the Central Control (AGC-1) and the Primary Control Vessel.

b. First Transport Unit

(1) Provide Control Liaison Parties to First Control Unit.

(2) Provide personnel to First Control Unit for control and salvage operations.

c. First Helicopter Transport Element

(Not developed for this study)

d. First Control Unit

(1) On signal "Land the Landing Force," stations control and marker ships in accordance with Transport Area Diagrams, Appendix I.

(2) Report to Commander, First Attack Group, prior to H-90 minutes, estimated set and drift of current at LOD.

(3) Advise Commander, First Attack Group, prior to H-60 minutes, whether H-hour can be met.

(4) Dispatch scheduled waves across the line of departure in accordance with the Consolidated Landing and Approach Plan, Appendix VI.

(5) Track and vector all scheduled waves and ensure their arrival on this prescribed beach at the specified time.

(6) Dispatch "on call" waves when requested (the request time will be generated by the simulator).

x.

4. ....

5. Central Control is in AGC-1

Appendix V to Annex I

HELICOPTER SHIP-TO-SHORE MOVEMENT

This appendix is not used in this example and therefore is not developed.

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Appendix VI to Annex I

CONSOLIDATED LANDING AND APPROACH PLAN

1. RLT Plan for landing over RED Beach

a. Consolidated Landing and Approach Plan*

(1) Scheduled Waves

Wave No.	Composition	Source	Leave Launch Area on Ship	Leave LOD	Land	Beach
1	10 LVTH 5 LVTE	LPD-1	H-28	H-18	H-Hour	Red 1
	8 LVTH 4 LVTE	LPD-2	H-28	H-18	H-Hour	Red 2
2	16 LVTP	LPD-3	H-25	H-15	H+3	Red 1
	16 LVTP	LPD-4	H-25	H-15	H+3	Red 2
3	11 LVTP 2 LVTR 2 LVTE	LPD-5	H-20	H-10	H+8	Red 1
	11 LVTP 2 LVTR 1 LVTE	LPD-6	H-20	H-10	H+8	Red 2
4	14 LVTP	LPD-7	H-15	H-5	H+13	Red 1
	14 LVTP	LPD-8	H-15	H-5	H+13	Red 2
5	15 LVTP 1 LVTR	LPD-9	H-10	H-Hour	H+18	Red 1
	15 LVTP 1 LVTR	LPD-10	H-10	H-Hour	H+18	Red 2
6	17 LVTP	LPD-11	H-5	H+5	H+23	Red 1
	17 LVTP	LPD-12	H-5	H+5	H+23	Red 2
7	12 LVTP	LSD-1	H-Hour	H+10	H+28	Red 1
	12 LVTP	LSD-2	H-Hour	H+10	H+28	Red 2
8	10 LVTP 1 Veh	LSD-1	H+5	H+15	H+33	Red 1
	10 LVTP 1 Veh	LSD-2	H+5	H+15	H+33	Red 2

* The Unit and Remarks columns were not required for purposes of this study and consequently were omitted.

ON CALL WAVES

Serial No.	Compo-sition	Unit	Source	Report to	Time	Remarks
3031		Reserve BLT	LPD-1	PCV	H+7	
3032		Reserve BLT	LPD-2	PCV	H+9	
3033		Inf. Co.	LPD-3	PCV	H+11	
3034		Inf. Co.	LPD-4	PCV	H+13	
3035		Inf. Co.	LPD-5	PCV	H+15	
3036		Inf. Co.	LPD-6	PCV	H+17	
3037		Reserve BLT	LSD-1	PCV	H+19	
3021		D/S Antitank Co. (R)	AKA-1	PCV	H+21	
3022		D/S Antitank Co. (R)	AKA-2	PCV	H+23	
3023		D/S Antitank Co. (R)	AKA-3	PCV	H+25	
3024		Antitank Co. (R)	AKA-4	PCV	H+27	
3011		D/S Tk Co. (R)	LST-1	*	H+120	Causeway No. 1
3012		D/S Tk Co. (R)	LST-2	*	H+120	Causeway No. 3
3013		D/S Tk Co. (R)	LST-2	*	H+120	Causeway No. 3
3014		D/S Tk Co. (R)	LST-3	*	H+165	Causeway No. 2
3015		D/S Tk Co. (R)	LST-3	*	H+165	Causeway No. 4

Note: * Will be debarked over causeway.

b. Landing Craft Employment Plan

(1) Pre-H-Hour transfers will not form a part of this study.

(2) Scheduled and On Call Waves

(a) Scheduled waves are composed entirely of amphibian vehicles.

(b) On call serials will be boated in craft generated during the run of the simulator.

(3) Landing Craft for Naval Use.

No.of Craft	Type	From	To	Time of Arrival	Period Attached	Remarks
1	LCPL	AKA-1	PCV	LTLF	Until released	BGC
1	LCPL	AKA-1	SCV	LTLF	Until released	ABGC
1	LCPL	AKA-2	PCV	LTLF	Until released	WGB Lead Wave 1-Red 1
1	LCPL	AKA-2	PCV	LTLF	Until released	AWGB Follow Wave 1-Red 1
1	LCPL	AKA-6	SCV	LTLF	Until released	WGB Lead Wave 1-Red 2
1	LCPL	AKA-6	SCV	LTLF	Until released	AWGB Follow Wave 1-Red 2
1	LCPL	AKA-3	PCV	LTLF	Until released	WGB Lead Wave 2-Red 1
1	LCPL	AKA-3	PCV	LTLF	Until released	AWGB Follow Wave 2-Red 1
1	LCPL	AKA-7	SCV	LTLF	Until released	WGB Lead Wave 2-Red 2
1	LCPL	AKA-7	SCV	LTLF	Until released	AWGB Follow Wave 2-Red 2
1	LCPL	AKA-4	PCV	LTLF	Until released	WGB Lead Wave 3-Red 1
1	LCPL	AKA-8	SCV	LTLF	Until released	WGB Lead Wave 3-Red 2
1	LCPL	AKA-4	PCV	LTLF	Until released	WGB Lead Wave 4-Red 1
1	LCPL	AKA-8	SCV	LTLF	Until released	WGB Lead Wave 4-Red 2
1	LCPL	AKA-5	PCV	LTLF	Until released	WGB Lead Wave 5-Red 1
1	LCPL	AKA-9	SCV	LTLF	Until released	WGB Lead Wave 5-Red 2
1	LCPL	AKA-5	PCV	LTLF	Until released	WGB Lead Wave 6-Red 1
1	LCPL	AKA-9	SCV	LTLF	Until released	WGB Lead Wave 6-Red 2
1	LCPL	AKA-11	PCV	LTLF	Until released	WGB Lead Wave 7-Red 1
1	LCPL	AKA-10	SCV	LTLF	Until released	WGB Lead Wave 7-Red 2
1	LCPL	AKA-11	PCV	LTLF	Until released	WGB Lead Wave 8-Red 1
1	LCPL	AKA-10	SCV	LTLF	Until released	WGB Lead Wave 8-Red 2
2	LCM(6)	AKA-1	PCV	H-30	Until released	Salvage boat follow Wave 3-Red 1
2	LCM(6)	AKA-6	SCV	H-30	Until released	Salvage boat follow Wave 3-Red 2
2	LCM(6)	AKA-14	PCV	H-40	Until released	Medical Evac follow Wave 2-Red 1

No.of Craft	Type	From	To	Time of Arrival	Period Attached	Remarks
2	LCM(6)	AKA-15	SCV	H-40	Until released	Medical Evac follow Wave 2-Red 2
2	LCM 6	AKA-12	Causeway Launch Area 1	H+5	Until released	Causeway tender boats
2	LCM 6	AKA-13	Causeway Launch Area 2	H+5	Until released	Causeway tender boats
2	LCM 6	AKA-16	Causeway Launch Area 3	H+5	Until released	Causeway tender boats
2	LCM 6	AKA-7	Causeway Launch Area 4	H+5	Until released	Causeway tender boats

Appendix VII to Annex I

ASSAULT WAVE DIAGRAM

Wave	Beach	Craft	Leave LVT Launch Line	Leave LOD	Arrive Beach	Remarks
1	Red 1	10 LVTH 5 LVTE	H-28	H-18	H-Hour	
	Red 2	8 LVTH 4 LVTE	H-28	H-18	H-Hour	
2	Red 1	16 LVTP	H-25	H-15	H+2	
	Red 2	16 LVTP	H-25	H-15	H+3	
3	Red 1	11 LVTP 2 LVTE 2 LVTR	H-20	H-10	H+8	
	Red 2	11 LVTP 1 LVTE 2 LVTR	H-20	H-10	H+8	
4	Red 1	14 LVTP	H-15	H-5	H+13	
	Red 2	14 LVTP	H-15	H-5	H+13	
5	Red 1	15 LVTP 1 LVTR	H-10	H-Hour	H+18	
	Red 2	15 LVTP 1 LVTR	H-10	H-Hour	H+18	
6	Red 1	17 LVTP	H-5	H+5	H+23	
	Red 2	17 LVTP	H-5	H+5	H+23	
7	Red 1	12 LVTP	H-Hour	H+10	H+28	
	Red 2	12 LVTP	H-Hour	H+10	H+28	
8	Red 1	10 LVTP 1 Wheeled	H+5	H+15	H+33	Follow Wave 8 to Beach
	Red 2	10 LVTP 1 Wheeled	H+5	H+15	H+33	Follow Wave 8 to Beach

Serial	Craft	Report to PCV Ready for Dispatch to Beach	Remarks
3031		H+7	
3032		H+9	
3033		H+11	
3034		H+13	
3035		H+15	
3036		H+17	
3037		H+19	
3021		H+21	
3022		H+23	
3023		H+25	
3024		H+27	
3011		H+120	*
3012		H+120	*
3013		H+120	*
3014		H+165	†
3015		H+165	†

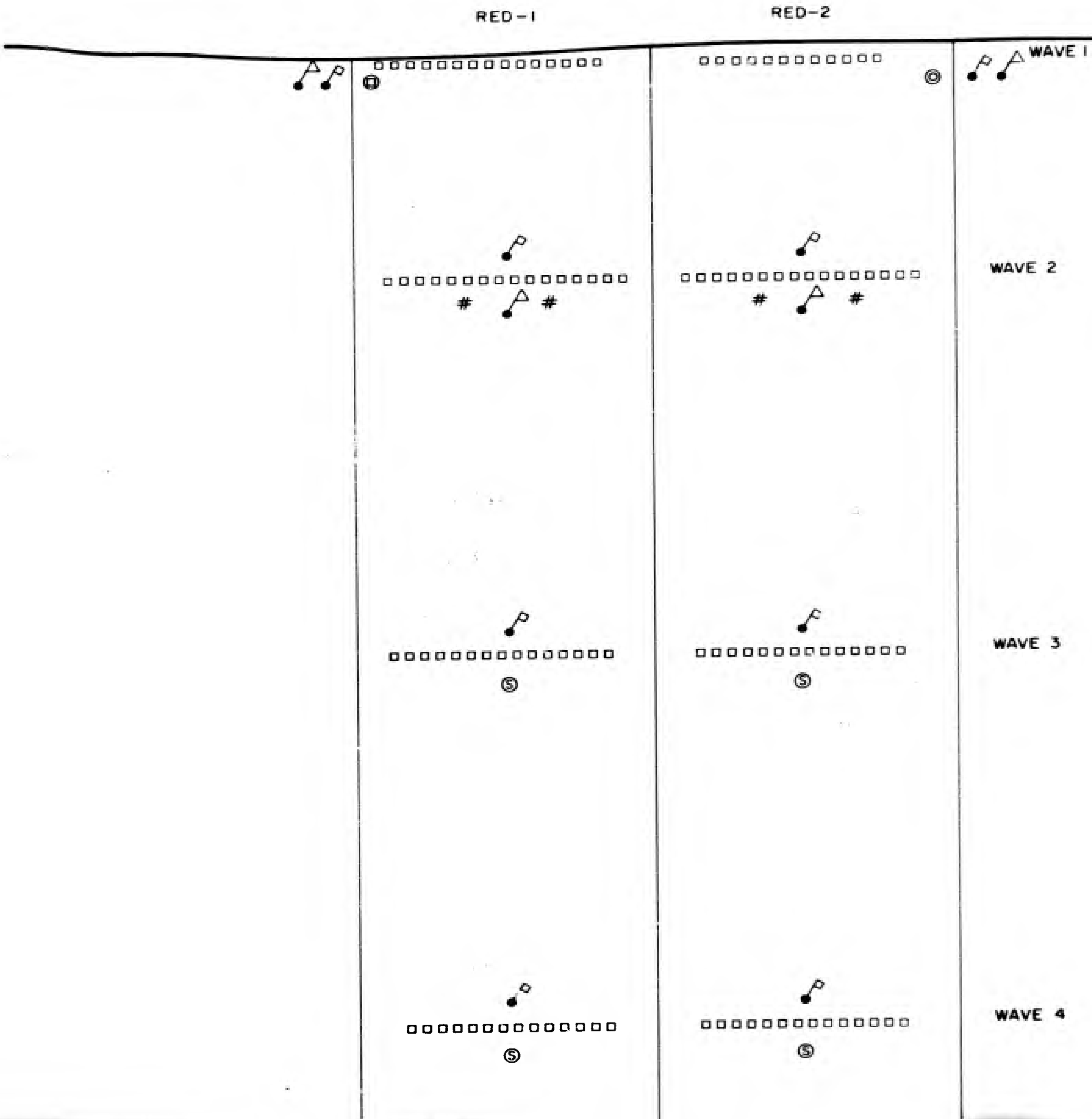
* These serials embarked in LSTs; anticipate they will be first LSTs called to causeways about H+120 minutes.

† Anticipate LSTs with these serials embarked will be called to their causeways about H+165 minutes.

TAB:

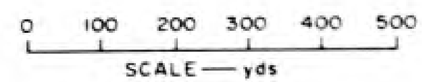
A - Assault Wave Diagram (pictorial)

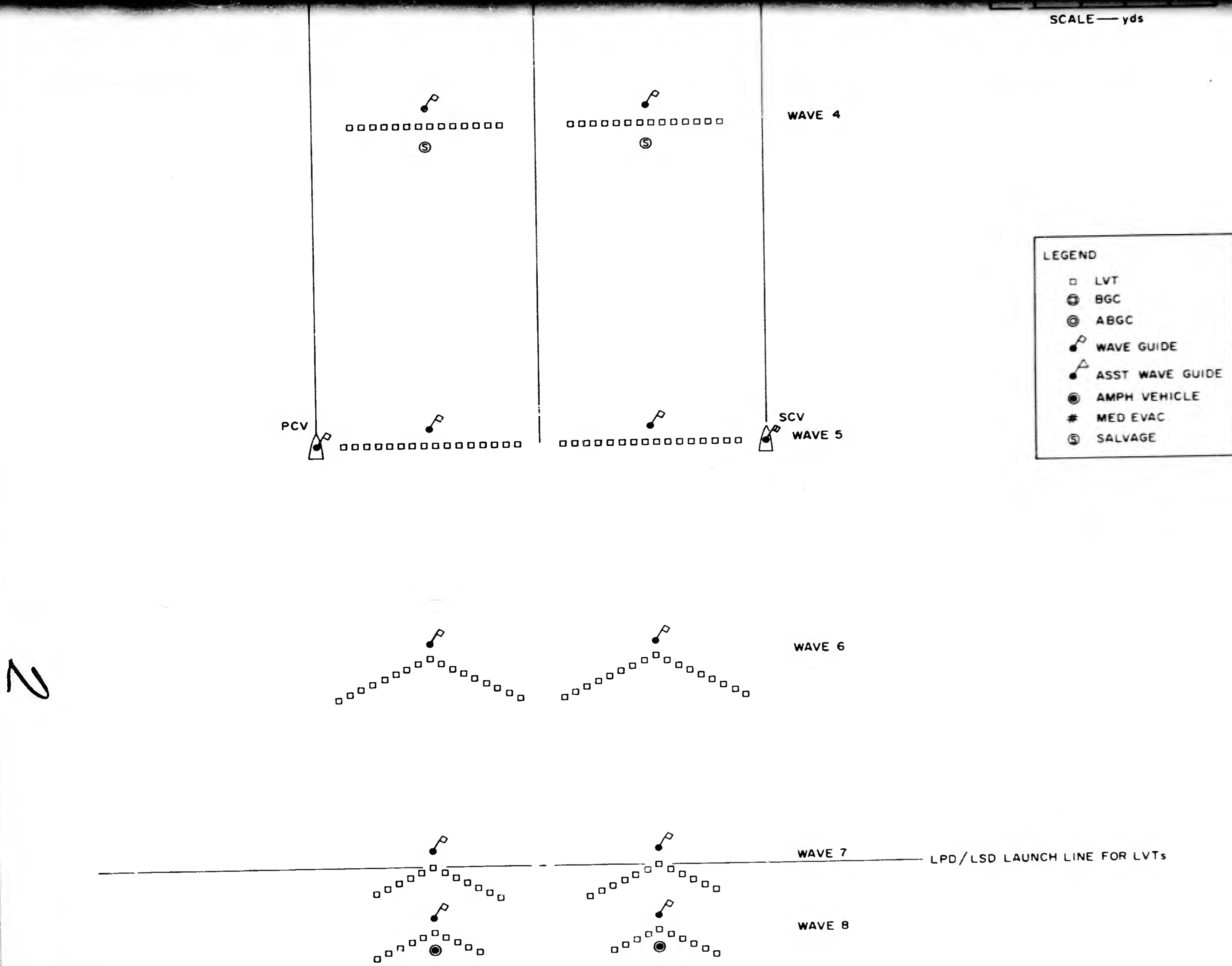
TAB A TO APPENDIX VII TO ANNEX I
ASSAULT WAVE DIAGRAM



NOTES:

1. POSITIONS OF WAVES SHOWN ARE THOSE FOR H-HOUR
2. POSITIONS OF WAVES ARE BASED ON FOLLOWING SPEEDS:
   LVT - FROM LAUNCH LINE TO LOD - 3KTs
   FROM LOD TO BEACH - 4KTs
3. ON CALL SERIAL ARE NOT SHOWN THE SIMULATOR WILL BOAT THEM AND PROGRAM THEM TO LOD AND BEACH




SCALE —— yds
WAVE 4
PCV
SCV
WAVE 5
WAVE 6
WAVE 7
LPD/LSD LAUNCH LINE FOR LVTs
WAVE 8
LEGEND
LVT
BGC
ABGC
WAVE GUIDE
ASST WAVE GUIDE
AMPH VEHICLE
MED EVAC
SALVAGE
2

Appendix VIII to Annex I

SHIP TO SHORE NUCLEAR DEFENSE PLAN

This plan not required or developed for this study.

Appendix IX to Annex I

ANCHORAGE DIAGRAM

1. Anchorage assignments are as indicated in the Transport Area Diagram (Tab B to Appendix I to Annex I).

2. LST anchorages are administrative. LSTs will not take their anchorages until after they have completed unloading of assault serials.

Appendix X to Annex I

Landing Craft and Amphibious Vehicle Employment

1. Employment of landing craft and amphibious vehicles is as prescribed in Tabs A and B to this Appendix.

TABS:

A - Landing Craft Employment Plan

B - Amphibious Vehicle Employment Plan

Tab A to Appendix X to Annex I

LANDING CRAFT EMPLOYMENT PLAN

Beach: RED

No. of Craft	Type	From	To	Time of Arrival	Period Attached	Remarks
	A. Pre-H-Hour Transfers					
	(Not required for this study; therefore, landing craft required for pre-H-Hour transfers have not been developed.)					
	B. Scheduled Waves					
	(All scheduled waves are made up entirely of amphibian tractors.)					
	C. On-Call Serials					
	(Craft required for on call and nonscheduled serials will be developed as this study progresses.)					

LANDING CRAFT EMPLOYMENT PLAN (Continued)

Beach: RED D. LANDING CRAFT FOR NAVAL USE (Cont'd.)

No. of Craft	Type	From	To	Time of Arrival	Period Attached	Remarks
1	LCPL	AKA-3	PCV	H-35	One trip	Wave Guide, Wave 3, Beach RED One
1	LCM (6)	AKA-5	PCV	H-20	Until released	Salvage boat (Beach RED One), follow Wave 3 to beach; Asst Salvage Officer embarked
1	LCPL	AKA-8	SCV	H-35	One trip	Wave Guide, Wave 3, Beach RED Two
1	LCM (6)	AKA-10	SCV	H-20	Until released	Salvage boat (Beach RED Two), follow Wave 3 to beach
1	LCPL	AKA-4	PCV	H-30	One trip	Wave Guide, Wave 4, Beach RED One
1	LCM (6)	AKA-2	PCV	H-15	Until released	Salvage boat (Beach RED One), follow Wave 4 to beach
1	LCPL	AKA-9	SCV	H-30	One trip	Wave Guide, Wave 4, Beach RED Two
1	LCM (6)	AKA-7	SCV	H-15	Until released	Salvage boat (Beach RED Two) follow Wave 4 to beach
1	LCPL	AKA-1	PCV	H-45	Until released	Traffic Control Officer boat (Boat Group Commander embarked)
1	LCPL	AKA-6	PCV	H-45	Until released	Traffic Control Officer boat (Asst Boat Group Commander embarked)
1	LCPL	AKA-6	PCV	H-60	Until released	LOD marker boat. Take station Right Flank RED one, on LOD

LANDING CRAFT EMPLOYMENT PLAN (Continued)

Beach: RED D. LANDING CRAFT FOR NAVAL USE (Cont'd.)

No. of Craft	Type	From	To	Time of Arrival	Period Attached	Remarks
1	LCPL	AKA-1	PCV	H-45	Until released	Wave Guide, Wave 1, Beach RED One
1	LCPL	AKA-2	PCV	H-45	Until released	Asst Wave Guide, Wave 1, Beach RED One
1	LCPL	AKA-7	SCV	H-45	Until released	Wave Guide, Wave 1, Beach RED Two
1	LCPL	AKA-7	SCV	H-45	Until released	Asst Wave Guide, Wave 1, Beach RED Two
1	LCFL	AKA-11	PCV	H-40	One trip	Wave Guide, Wave 2, Beach RED One
1	LCPL	AKA-11	PCV	H-40	One trip	Asst Wave Guide, Wave 2, Beach RED One
1	LCM-6	AKA-4	PCV	H-25	Until released	Medical boat (Beach RED One), follow Wave 2 to beach; parent ship provide medical team
1	LCPL	AKA-14	SCV	H-40	One trip	Wave Guide, Wave 2, Beach RED Two
1	LCM (6)	AKA-9	SCV	H-25	Until released	Medical boat (Beach RED Two), follow Wave 2 to beach; parent ship provide medical team
1	LCPL	AKA-14	SCV	H-40	One trip	Asst Wave Guide, Wave 2, Beach RED Two

LAND CRAFT EMPLOYMENT PLAN (Concluded)

Beach: RED D. LANDING CRAFT FOR NAVAL USE (Cont'd.)

No. of Craft	Type	From	To	Time of Arrival	Period Attached	Remarks
1	LCPL	AKA-4	PCV	H-25	One trip	Wave Guide, Wave 5, Beach RED One
1	LCPL	AKA-9	SCV	H-25	One trip	Wave Guide, Wave 5, Beach RED Two
1	LCPL	AKA-12	PCV	H-20	One trip	Wave Guide, Wave 6, Beach RED One
1	LCPL	AKA-15	SCV	H-20	One trip	Wave Guide, Wave 6, Beach RED Two
1	LCPL	AKA-12	PCV	H-15	One trip	Wave Guide, Wave 7, Beach RED One
1	LCPL	AKA-15	SCV	H-15	One trip	Wave Guide, Wave 7, Beach RED Two
1	LCPL	AKA-16	PCV	H-10	One trip	Wave Guide. Wave 8, Beach RED One
1	LCPL	AKA-16	SCV	H-10	One trip	Wave Guide, Wave 8, Beach RED Two
2	LCM (6)	AKA-12	LST-17 (In Causeway Launch Area 1)	H-5	Until released	Causeway tender boats
2	LCM (6)	AKA-13	LST-20 (In Causeway Launch Area 3)	H-50	Until released	Causeway tender boats
2	LCM (6)	AKA-16	LST-17 (In Causeway Launch Area 1)	H-5	Until released	Causeway tender boats
2	LCM (6)	AKA-7	LST-20 (In Causeway Launch Area 3)	H-50	Until released	Causeway tender boats

Tab B to Appendix X

AMPHIBIAN VEHICLE EMPLOYMENT PLAN

Origin	Number and Type Amphibian Vehicle					Wave	Destination
	LVTP	LVTH	LVTE	LVTR	Other		
LPD-1		10	5			1	Red One
LPD-2		8	4			1	Red Two
LPD-3	16					2	Red One
LPD-4	16					2	Red Two
LPD-5	11		2	2		3	Red One
LPD-6	11		1	2		3	Red Two
LPD-7	14					4	Red One
LPD-8	14					4	Red Two
LPD-9	15			1		5	Red One
LPD-10	15			1		5	Red Two
LPD-11	17					6	Red One
LPD-12	17					6	Red Two
LSD-1	12					7	Red One
	12				1	8	Red One
LSD-2	10					7	Red Two
	10				1	8	Red Two

Appendix XI to Annex I

CAUSEWAY PLAN

Task Organization

a. First Transport Unit	COMO ______ (COMPHIBRON ______)
b. First Transport Element ONE	
c. First Transport Element TWO	
d. First Landing Ship Element	CAPT ______ (COMLANSHIPFLOT ______)
e. First Pontoon Causeway Element	CDR ______ CEC

1. General Situation

As in basic operation order.

2. This group will conduct the causeway operation herein prescribed, in order to support the ship-to-shore movement of the First Attack Group.

3. a. First Transport Elements ONE and TWO provide LCMs for causeway tenders in accordance with Tab A to this Appendix.

b. First Landing Ship Element

(1) About H+5 minutes, commence pontoon causeway launching operations in accordance with Tab A to this Appendix.

(2) Commencing about H+90 minutes, in accordance with instructions from Commander, First Control Unit, beach pontoon causeways in accordance with Tab A to this Appendix.

c. First Pontoon Causeway Element

Commencing about H+120 minutes, as pontoon causeways become operational, direct pontoon causeway personnel to report, with tenders, to their respective beachmasters for causeway operations.

4. . . . .

5. . . . .

TAB:

A - Pontoon Causeway Operation

B - Tabulary Summary of Pontoon Components

(Not required for this study, therefore omitted)

Tab A to Appendix XI to Annex I

PONTOON CAUSEWAY OPERATION

1. Launch causeway sections in accordance with following table:

Ship	No. of 3 X 15 Causeway Sections to be Launched	In Causeway Launch Area	At Time	For Causeway No.
LST-17	4	1	H+5	1
LST-18	4	2	H+50	2
LST-19	2	1	H+5	1
LST-19	2	2	H+50	2
LST-20	4	3	H+5	3
LST-21	4	4	H+50	4
LST-22	2	3	H+5	3
LST-22	2	4	H+50	4

2. Causeway Tender (LCM) and Warping Tug Schedule

LCM transported in ships indicated are provided as causeway tenders in accordance with following table:

Ship	No. and Type Craft To Be Provided	At Causeway Launch Area	At Time
AKA-12	2 LCM (6)	1	H+5
AKA-13	2 LCM (6)	2	H+50
AKA-16	2 LCM (6)	3	H+5
AKA-7	2 LCM (6)	4	H+50
LSD-2	1 warp tug	1	H+5
LSD-2	1 warp tug	2	H+5
LSD-9	1 warp tug	3	H+5
LSD-9	1 warp tug	4	H+5

3. Causeway Beaching Schedule

Upon completion of assembly, causeway elements will beach 6 sections of 3 x 15 pontoon causeway piers at times and places shown below and be ready to receive LST 30 minutes thereafter.

From Ship	Causeway No.	Beach at Causeway Slot No.	At Time
LST-17	1	1	H+90
	2	2	H+135
	3	3	H+90
	4	4	H+135

4. Transfer of Causeway Sections

After launching from secondary LST(LST 19, LST 22) the warping tugs will transfer the two section units to the primary LSTs (LST 17, LST 18, LST 20 and LST 21).

Appendix XII to Annex I

UNLOADING PLAN

1. Scope

This plan provides for continuation of the unloading of the First Attack Group in the assault area __________ after scheduled and on-call waves have been landed.

2. Basic Plan

a. All ships (except LSTs) will unload from their assault anchorages. However, during general unloading phase some ships may be ordered to closer in anchorages as anchorages become available.

b. Unless otherwise directed, continue unloading during darkness.

c. Unless otherwise requested by Commander, First Landing Group, or his designated representative, in accordance with procedures prescribed in NWIP 22-3, unload in the sequence prescribed in Tabs B and C to this appendix.

3. General Unloading

On request by Commander, First Landing Group, and when directed by Commander, First Attack Group, commence general unloading.

4. Reports

While unloading is being conducted, Commander, First Transport Unit, make status of unloading reports to Commander, First Attack Group, as follows:

a. Submit message report every 4 hours, commencing with first even hour after general unloading has begun.

b. Include the unloading status of all major ships of the First Transport Unit in the report.

c. Use the following letter designators:

ALFA - percentage of personnel unloaded

BRAVO - percentage of vehicles unloaded

CHARLIE - percentage of cargo unloaded.

TABS:

A - Serial Assignment Table [not developed for this study; the Landing Sequence Table (Tab B) will suffice]

B - Landing Sequence Table

C - Landing Sequence Table for Landing Ships

TAB-B TO APPENDIX XII TO ANNEX I
LANDING SEQUENCE TABLE

SERIAL	UNIT		SHIP		UNLOAD PRIORITY TIME
5047	NRG001	NONSCHEDULED	LPD	13	2
5049	NRG003	NONSCHEDULED	LPD	13	4
5051	NRG005	NONSCHEDULED	LPD	5	6
5052	NRG006	NONSCHEDULED	LPD	12	8
5053	NRG007	NONSCHEDULED	LPD	11	10
3031	RESERVE RLT	ON-CALL	LPD	1	12
3032	RESERVE RLT	ON-CALL	LPD	2	14
3033	RESERVE RLT	ON-CALL	LPD	3	16
3034	RESERVE RLT	ON-CALL	LPD	4	18
3035	RESERVE RLT	ON-CALL	LPD	5	20
3036	RESERVE RLT	ON-CALL	LPD	6	22
3037	RESERVE RLT	ON-CALL	LPD	3	24
3021	D/S ANTITNKCO(R)	ON-CALL	LPD	4	26
3022	D/S ANTITNKCO(R)	ON-CALL	LPD	6	28
3023	D/S ANTITNKCO(R)	ON-CALL	LPD	7	30
3024	D/S ANTITNKCO(R)	ON-CALL	LPD	8	32
3001	D/S ARTY BN (-)	NONSCHEDULED	LPD	9	34
3002	D/S ARTY BN (-)	NONSCHEDULED	LPD	10	36
3003	D/S ARTY BN (-)	NONSCHEDULED	LPD	2	38
3008	D/S ARTY BN (-)	NONSCHEDULED	LPD	3	48
3009	D/S ARTY BN (-)	NONSCHEDULED	LPD	4	50
3042	LC3017 (ON CALL)	NONSCHEDULED	LPD	1	54
3043	S/P GP C.O.,STAF	NONSCHEDULED	LPD	2	56
3062	ELS ADV CMD PCST	NONSCHEDULED	LPD	4	58
5001	LV1016,1017	NONSCHEDULED	LPD	5	60
5002	LV2016,2017	NONSCHEDULED	LPD	6	62
5003	LC3033	NONSCHEDULED	LPD	7	64
5077	LC3001	NONSCHEDULED	LPD	8	66
5004	LC3002	NONSCHEDULED	LPD	9	68
5005	LC3015	NONSCHEDULED	LPD	10	70
5007	LC3023	NONSCHEDULED	LPD	4	74
5008	LC3024	NONSCHEDULED	LPD	5	76
5009	LC3025	NONSCHEDULED	LPD	6	78

SERIAL	UNIT		SHIP		UNLOAD PRIORITY TIME
3004	D/S ARTY BN (-)	NONSCHEDULED	AKA	1	140
3005	D/S ARTY BN (-)	NONSCHEDULED	AKA	2	142
3006	D/S ARTY BN (-)	NONSCHEDULED	AKA	3	144
3007	D/S ARTY BN (-)	NONSCHEDULED	AKA	4	146
3011	D/S TANK CO (R)	ON-CALL	LST	1	148
3012	D/S TANK CO (R)	ON-CALL	LST	2	150
3013	D/S TANK CO (R)	ON-CALL	LST	2	152
3014	D/S TANK CO (R)	ON-CALL	LST	3	154
3015	D/S TANK CO (R)	ON-CALL	LST	3	156
3041	SHP001 (ON CALL)	NONSCHEDULED	AKA	5	158
5006	ENG003	NONSCHEDULED	AKA	6	160
5010	LAAM001	NONSCHEDULED	LST	4	162
5011	LAAM02	NONSCHEDULED	LST	4	164
5012	LAAM03	NONSCHEDULED	LST	4	166
5013	LAAM05	NONSCHEDULED	LST	5	168
5014	LAAM06	NONSCHEDULED	LST	5	170
5015	LAAM07	NONSCHEDULED	LST	5	172
5016	TANK CO (R)	NONSCHEDULED	LST	6	174
5017	TANK CO (R)	NONSCHEDULED	LST	7	176
5018	TANK CO (R)	NONSCHEDULED	LST	8	178
5019	TANK CO (R)	NONSCHEDULED	LST	9	180
5020	TANK CO (R)	NONSCHEDULED	LST	10	182
5021	TKS001	NONSCHEDULED	LST	11	184
5022	TKS002	NONSCHEDULED	LST	12	186
5023	TKS003	NONSCHEDULED	LST	13	188
5024	TKS004	NONSCHEDULED	LST	14	190
5025	TKS005	NONSCHEDULED	LST	15	192
5026	TKS006	NONSCHEDULED	LST	16	194
5027	TKS007	NONSCHEDULED	LST	17	196
5028	TKS008	NONSCHEDULED	LST	18	198
5029	TKS009	NONSCHEDULED	LST	19	200
5030	TKS010	NONSCHEDULED	LST	20	202
5031	TKS011	NONSCHEDULED	LST	21	204
5032	ATB001	NONSCHEDULED	LST	1	206
5033	ATB002	NONSCHEDULED	LST	1	208
5034	ATB003	NONSCHEDULED	LST	1	210
5035	ATB004	NONSCHEDULED	LST	1	212
5036	ATB005	NONSCHEDULED	LST	1	214
5037	ATB006	NONSCHEDULED	LST	1	216
5038	ATB007	NONSCHEDULED	LST	2	218
5039	ATB008	NONSCHEDULED	LST	2	220
5040	ATB009	NONSCHEDULED	LST	2	222
5041	ATB010	NONSCHEDULED	LST	2	224
5165	SFR001	NONSCHEDULED	AKA	7	226
5042	SHP002	NONSCHEDULED	AKA	8	228
5043	SHP003	NONSCHEDULED	AKA	9	230
5044	SHP004	NONSCHEDULED	AKA	10	232
5045	SHP005	NONSCHEDULED	AKA	11	234
5046	SHP006	NONSCHEDULED	AKA	12	236
5048	NPG002	NONSCHEDULED	AKA	13	238
5050	NPG004	NONSCHEDULED	AKA	14	240
5054	FFC001	NONSCHEDULED	AKA	15	242
5055	FFC002	NONSCHEDULED	AKA	16	244
5056	FFC003	NONSCHEDULED	LPD	6	246
5057	FFC004	NONSCHEDULED	LPD	7	248

SERIAL	UNIT		SHIP		UNLOAD PRIORITY TIME
5058	ART003	NONSCHEDULED	AKA	1	250
5060	ART005	NONSCHEDULED	AKA	1	252
5059	ART004	NONSCHEDULED	AKA	1	254
5061	ART006	NONSCHEDULED	AKA	2	256
5062	ART007	NONSCHEDULED	AKA	3	258
5063	ART008	NONSCHEDULED	LST	4	260
5064	ART009	NONSCHEDULED	LST	4	262
5066	DHE001	NONSCHEDULED	AKA	2	264
5067	AGC002	NONSCHEDULED	AKA	2	266
5068	DHB002	NONSCHEDULED	AKA	4	268
5069	DHB003	NONSCHEDULED	AKA	5	270
5070	AGC001	NONSCHEDULED	AKA	3	272
5071	ART001	NONSCHEDULED	AKA	1	274
5072	ARI001	NONSCHEDULED	AKA	1	276
5073	HHG001	NONSCHEDULED	AKA	6	278
5074	HHG002	NONSCHEDULED	AKA	7	280
5075	HHG003	NONSCHEDULED	AKA	8	282
5076	LVT005	NONSCHEDULED	AKA	9	284
5078	LC3026	NONSCHEDULED	AKA	10	286
5079	LC3027	NONSCHEDULED	AKA	11	288
5080	LC3028	NONSCHEDULED	AKA	12	290
5081	FSR013(MOD)	NONSCHEDULED	AKA	13	292
5082	FSR014(MOD)	NONSCHEDULED	AKA	14	294
5083	FSR015(MOD)	NONSCHEDULED	AKA	15	296
5084	FSR007	NONSCHEDULED	LST	2	298
5085	FSR016(MOD)	NONSCHEDULED	LST	2	300
5086	FSR017	NONSCHEDULED	LST	5	302
5087	FSR018	NONSCHEDULED	LST	7	304
5088	FSR019(MOD)	NONSCHEDULED	LST	6	306
5089	FSR020(MOD)	NONSCHEDULED	LST	6	310
5090	FSR021(MOD)	NONSCHEDULED	LST	6	308
5091	FSR022(MOD)	NONSCHEDULED	LST	7	312
5092	FSR023(MOD)	NONSCHEDULED	LST	6	314
5093	LVT005(MOD)	NONSCHEDULED	AKA	16	316
5094	LVT007(MOD)	NONSCHEDULED	AKA	1	318
6001	ENG001 LESS CARG	NONSCHEDULED	AKA	2	320
6002	CARGO FOR ENG001	NONSCHEDULED	AKA	3	322
1	CARGO FOR ENG001	NONSCHEDULED	AKA	4	324
6003	ENG002 LESS CARG	NONSCHEDULED	AKA	5	326
6004	CARGO FOR ENG001	NONSCHEDULED	AKA	6	328
2	CARGO FOR ENG001	NONSCHEDULED	AKA	7	330
6005	ENG004	NONSCHEDULED	LST	10	332
6006	ENG005	NONSCHEDULED	LST	6	334
6007	ENG006	NONSCHEDULED	LST	7	336
6008	ENG007	NONSCHEDULED	LST	8	338
6009	ENG008	NONSCHEDULED	LST	9	340
6010	HFC001	NONSCHEDULED	AKA	8	342
6011	HFC002	NONSCHEDULED	AKA	9	344
6012	HFC003	NONSCHEDULED	AKA	10	346
6013	HFC004	NONSCHEDULED	AKA	11	348
6014	HANRCB	NONSCHEDULED	AKA	12	350
6015	HFTHOB	NONSCHEDULED	AKA	13	352
6016	HHG017	NONSCHEDULED	LPH	1	354
6017	HHG018	NONSCHEDULED	AKA	14	356
6018	HHG019	NONSCHEDULED	LPH	2	358

SERIAL	UNIT		SHIP		UNLOAD PRIORITY TIME
6019	WHG020	NONSCHEDULED	AKA	15	360
6020	LAAP04	NONSCHEDULED	AKA	16	362
6021	LAAP08	NONSCHEDULED	LPU	6	364
6022	SER002 (MOD)	NONSCHEDULED	LPU	9	366
6023	SER003 (MOD)	NONSCHEDULED	AKA	1	368
6024	SER004 (MOD)	NONSCHEDULED	AKA	2	370
6025	SER005 (MOD)	NONSCHEDULED	AKA	3	372
6026	SER006	NONSCHEDULED	AKA	4	374
6027	SER007	NONSCHEDULED	AKA	5	376
6028	SER008	NONSCHEDULED	AKA	6	378
6029	SER009 (MOD)	NONSCHEDULED	AKA	7	380
6030	SER010 (MOD)	NONSCHEDULED	AKA	8	382
6031	SER011 (MOD)	NONSCHEDULED	AKA	9	384
6032	SER012 (MOD)	NONSCHEDULED	AKA	10	386
6033	SER013 (MOD)	NONSCHEDULED	LST	3	388
6034	SER014	NONSCHEDULED	LST	8	390
6035	SER015 (MOD)	NONSCHEDULED	LST	5	392
6036	SER016 (MOD)	NONSCHEDULED	LST	3	394
6037	DMT001	NONSCHEDULED	LST	2	396
6038	DMT002	NONSCHEDULED	LST	7	398
6039	DMT003	NONSCHEDULED	LST	9	400
6040	DMT004	NONSCHEDULED	LST	10	402
6041	DMT005	NONSCHEDULED	LST	7	404
6042	DMT006	NONSCHEDULED	LST	10	406
6043	DMT007	NONSCHEDULED	LST	11	408
6044	BRG001 (MOD)	NONSCHEDULED	LST	12	410
6045	BRG002 (MOD)	NONSCHEDULED	LST	13	412
6046	DHB004	NONSCHEDULED	AKA	11	414
6047	DHB005(MOD)	NONSCHEDULED	AKA	12	416
6048	DHB006	NONSCHEDULED	AKA	13	418
6049	DHB007(MOD)	NONSCHEDULED	AKA	14	420
6052	FAG003	NONSCHEDULED	LST	11	422
6053	FAG004	NONSCHEDULED	LST	12	424
6050	FAG001	NONSCHEDULED	LST	13	426
6054	FAG005 (MOD)	NONSCHEDULED	LST	13	428
6051	FAG002	NONSCHEDULED	LST	16	430
6055	FAG006 (MOD)	NONSCHEDULED	LST	16	432
6056	FAG007	NONSCHEDULED	LST	17	434
6057	FAG008	NONSCHEDULED	LST	18	436
6058	HALF OF FAG009	NONSCHEDULED	LST	19	438
8058	HALF OF FAG009	NONSCHEDULED	LST	20	440
6059	FAG010	NONSCHEDULED	LST	21	442
6060	WHG009	NONSCHEDULED	AKA	15	444
6061	WHG010	NONSCHEDULED	AKA	16	446
6062	WHG011	NONSCHEDULED	AKA	1	448
6063	WHG012	NONSCHEDULED	AKA	2	450
6064	FMT001(MOD)	NONSCHEDULED	AKA	3	452
6065	FMT002(MOD)	NONSCHEDULED	AKA	4	454
6066	FMT003(MOD)	NONSCHEDULED	AKA	5	456
6067	MCE001(MOD)	NONSCHEDULED	LST	14	458
6068	HALF OF MCR002-M	NONSCHEDULED	LST	15	460
8068	HALF OF MCR002-M	NONSCHEDULED	LST	16	462
6069	MCR003(MOD)	NONSCHEDULED	LST	17	464
6070	HALF OF MCR004-M	NONSCHEDULED	LST	18	466
8070	HALF OF MCR004-M	NONSCHEDULED	LST	19	468

SERIAL	UNIT		SHIP		UNLOAD PRIORITY TIME
6071	MCH005(MOD)	NONSCHEDULED	LST	20	470
6072	HALF OF MCR006-M	NONSCHEDULED	LST	21	472
8072	HALF OF MCR006-M	NONSCHEDULED	LST	22	474
6073	MCH007(MOD)	NONSCHEDULED	LST	17	476
6074	MCH008(MOD)	NONSCHEDULED	LST	18	478
6075	HALF OF MCR009-M	NONSCHEDULED	LST	19	480
8075	HALF OF MCR009-M	NONSCHEDULED	LST	20	482
6076	HALF OF MCR010-M	NONSCHEDULED	LST	22	484
8076	HALF OF MCR010-M	NONSCHEDULED	LST	22	486
6077	COM001	NONSCHEDULED	AKA	6	488
6078	COM002	NONSCHEDULED	AKA	7	490
6079	COM003	NONSCHEDULED	AKA	8	492
6080	COM004	NONSCHEDULED	AKA	9	494
6081	COM005	NONSCHEDULED	AKA	10	496
6082	RAD001	NONSCHEDULED	AKA	11	498
6083	RAD002	NONSCHEDULED	AKA	12	500
6084	RAD003	NONSCHEDULED	AKA	13	502
6085	RAD004	NONSCHEDULED	AKA	14	504
6086	MFF001	NONSCHEDULED	AKA	15	506
6087	MFF002	NONSCHEDULED	AKA	16	508
6088	MOS001	NONSCHEDULED	LPD	7	510
6089	MOS002	NONSCHEDULED	LPD	10	512
6090	FSR001	NONSCHEDULED	AKA	1	514
6091	FSR002	NONSCHEDULED	AKA	2	516
6092	FSR003	NONSCHEDULED	AKA	3	518
6093	FSR004	NONSCHEDULED	AKA	4	520
6094	FSR005	NONSCHEDULED	AKA	5	522
6095	FSR006	NONSCHEDULED	AKA	6	524
6096	FSR008(MOD)	NONSCHEDULED	AKA	7	526
6097	FSR009(MOD)	NONSCHEDULED	AKA	8	528
6098	FSR010(MOD)	NONSCHEDULED	AKA	9	530
6099	FSR011	NONSCHEDULED	AKA	10	532
7000	FSR012	NONSCHEDULED	AKA	11	534
7001	1/5 OF REPL01	NONSCHEDULED	LPD	1	536
7002	1/5 OF REPL01	NONSCHEDULED	LPD	2	538
7003	1/5 OF REPL01	NONSCHEDULED	LPD	3	540
7004	1/5 OF REPL01	NONSCHEDULED	LPD	4	542
7005	1/5 OF REPL01	NONSCHEDULED	LPD	5	544
7006	HAN020	NONSCHEDULED	AKA	12	546
7007	HAN021	NONSCHEDULED	AKA	13	548
7008	HAN022	NONSCHEDULED	AKA	14	550
7009	HRN020	NONSCHEDULED	AKA	15	552
7010	HRN021	NONSCHEDULED	AKA	16	554
7011	HRN022	NONSCHEDULED	LSD-S	1	556
4001	HAN001	NONSCHEDULED	LSD-S	2	558
4002	HAN002	NONSCHEDULED	LSD-S	3	560
4003	HAN003	NONSCHEDULED	LSD-S	4	562
4004	HAN004	NONSCHEDULED	LSD-S	5	564
4005	HAN005	NONSCHEDULED	LPD	1	566
4006	HAN006	NONSCHEDULED	LPD	2	568
4007	HAN007	NONSCHEDULED	LPD	3	570
4008	HAN008	NONSCHEDULED	LPD	4	572
4009	HAN009	NONSCHEDULED	LSD-S	6	574
4010	HAN010	NONSCHEDULED	LSD-S	7	576
4011	HAN011	NONSCHEDULED	LSD-S	8	578

SERIAL	UNIT		SHIP		UNLOAD PRIORITY TIME
4012	HAN012	NONSCHEDULED	LSD-S	9	580
4013	HAN013	NONSCHEDULED	LSD-S	10	582
4014	HAN014	NONSCHEDULED	LSD-S	11	584
4015	HAN015	NONSCHEDULED	LSD-S	12	586
4016	HAN016	NONSCHEDULED	LSD-S	13	588
4017	HAN017	NONSCHEDULED	LPD	5	590
4018	HAN018	NONSCHEDULED	AKA	1	592
4019	HAN019	NONSCHEDULED	LPD	6	594
4101	HBN001	NONSCHEDULED	AKA	2	596
4102	HBN002	NONSCHEDULED	AKA	3	598
4103	HBN003	NONSCHEDULED	AKA	4	600
4104	HBN004	NONSCHEDULED	AKA	5	602
4105	HBN005	NONSCHEDULED	LPD	7	604
4106	HBN006	NONSCHEDULED	LPD	8	606
4107	HBN007	NONSCHEDULED	LPD	9	608
4108	HBN008	NONSCHEDULED	LPD	10	610
4109	HBN009	NONSCHEDULED	AKA	6	612
4110	HBN010	NONSCHEDULED	AKA	7	614
4111	HBN011	NONSCHEDULED	AKA	8	616
4112	HBN012	NONSCHEDULED	AKA	9	618
4113	HBN013	NONSCHEDULED	AKA	10	620
4114	HBN014	NONSCHEDULED	AKA	11	622
4115	HBN015	NONSCHEDULED	AKA	12	624
4116	HBN016	NONSCHEDULED	AKA	13	626
4117	HBN017	NONSCHEDULED	LPD	11	628
4118	HBN018	NONSCHEDULED	AKA	14	630
4119	HBN019	NONSCHEDULED	LPD	12	632
4120	HMS001	NONSCHEDULED	AKA	15	634
4121	HMS002	NONSCHEDULED	AKA	16	636
4122	HMS003	NONSCHEDULED	LPD	1	638
4123	HMS004	NONSCHEDULED	LPD	2	640
4124	MABS10	NONSCHEDULED	LPD	3	642
4125	MABS20	NONSCHEDULED	LPD	4	644
4126	VM0002	NONSCHEDULED	LPD	5	646
4127	VM0003	NONSCHEDULED	LPD	6	648
4128	VM0010	NONSCHEDULED	LPD	7	650
4129	HMH001	NONSCHEDULED	LPD	8	652
4130	HMH002	NONSCHEDULED	LPD	9	654
4131	HMM201	NONSCHEDULED	LPD	10	656
4132	HMM301	NONSCHEDULED	LPD	11	658
4133	HMM401	NONSCHEDULED	LPD	12	660
4134	HMM501	NONSCHEDULED	LPD	13	662
4135	HMM601	NONSCHEDULED	LSD-S	1	664
4136	HMM701	NONSCHEDULED	LSD-S	2	666
4137	VM0001	NONSCHEDULED	LPD	1	668
4138	VM0004	NONSCHEDULED	LPD	2	670
4139	VM0005	NONSCHEDULED	LPD	3	672
4140	VM0006	NONSCHEDULED	LPD	4	674
4141	VM0007	NONSCHEDULED	LPD	5	676
4142	VM0008	NONSCHEDULED	LPD	6	678
4143	VM0009	NONSCHEDULED	LPD	7	680
4144	HMH003	NONSCHEDULED	LPD	8	682
4145	HMH004	NONSCHEDULED	LPD	9	684
4146	HMH005	NONSCHEDULED	LPD	10	686
4147	HMH006	NONSCHEDULED	LPD	11	688

SERIAL	UNIT		SHIP		UNLOAD PRIORITY TIME
4148	HMH007	NONSCHEDULED	LPD	12	690
4149	HMH008	NONSCHEDULED	LPD	13	692
4150	HMH009	NONSCHEDULED	LPD	1	694
4151	HMM801	NONSCHEDULED	LPD	2	696
4152	HMM802	NONSCHEDULED	LPD	3	698
4153	HMM803	NONSCHEDULED	LPD	4	700
4154	HMM804	NONSCHEDULED	LPD	5	702
4155	HMM805	NONSCHEDULED	LPD	6	704
4156	HMM806	NONSCHEDULED	LPD	7	706
4157	HMM807	NONSCHEDULED	LPD	8	708
4158	MABS 40	NONSCHEDULED	LST	11	710
4159	MABS 41	NONSCHEDULED	LST	15	712
4160	MABS 51	NONSCHEDULED	LST	16	714
4161	MABS 52	NONSCHEDULED	LST	17	716
4162	VMO 011	NONSCHEDULED	AKA	1	718
4163	VMO 012	NONSCHEDULED	AKA	2	720
4164	HMM 011	NONSCHEDULED	AKA	3	722
4165	HMM 101	NONSCHEDULED	AKA	4	724
4166	HMM 102	NONSCHEDULED	AKA	5	726
4167	HMM 103	NONSCHEDULED	AKA	6	728
4168	HMM 202	NONSCHEDULED	AKA	7	730
4169	HMM 203	NONSCHEDULED	AKA	8	732
4170	HMM 302	NONSCHEDULED	AKA	9	734
4171	HMM 303	NONSCHEDULED	AKA	10	736
4172	HMM 402	NONSCHEDULED	AKA	11	738
4173	HMM 403	NONSCHEDULED	AKA	12	740
4174	HMM 502	NONSCHEDULED	AKA	13	742
4175	HMM 503	NONSCHEDULED	AKA	14	744
4176	HMM 602	NONSCHEDULED	AKA	15	746
4177	HMM 603	NONSCHEDULED	AKA	16	748
4178	HMM 702	NONSCHEDULED	LPD	6	750
4179	HMM 703	NONSCHEDULED	LPD	11	752
4180	MABS53	NONSCHEDULED	AKA	1	754
4181	HANR01	NONSCHEDULED	AKA	2	756
4182	HANR02	NONSCHEDULED	AKA	3	758
4183	HANR03	NONSCHEDULED	AKA	4	760
4184	MANR04	NONSCHEDULED	AKA	5	762
4185	HANR05	NONSCHEDULED	AKA	6	764
4186	HANR06	NONSCHEDULED	AKA	7	766
4187	HANR07	NONSCHEDULED	AKA	8	768
4188	HMS050	NONSCHEDULED	AKA	9	770
4189	HMS051	NONSCHEDULED	AKA	10	772
4190	HMS052	NONSCHEDULED	AKA	11	774
4191	MABS42	NONSCHEDULED	AKA	12	776
4192	MABS43	NONSCHEDULED	AKA	13	778
4193	MABS50	NONSCHEDULED	AKA	14	780
4194	HMH010	NONSCHEDULED	AKA	15	782
4195	FATCU1	NONSCHEDULED	AKA	16	784
4281	HPNR01	NONSCHEDULED	AKA	1	786
4282	HPNR02	NONSCHEDULED	AKA	2	788
4283	HPNR03	NONSCHEDULED	AKA	3	790
4284	HPNR04	NONSCHEDULED	AKA	4	792
4285	HPNR05	NONSCHEDULED	AKA	5	794
4286	HPNR06	NONSCHEDULED	AKA	6	796
4287	HPNR07	NONSCHEDULED	AKA	7	798

Tab C to Appendix XII to Annex I

LANDING SEQUENCE FOR LANDING SHIPS

Unit	Serial Number	Ship	Causeway Number	Est. Time Ship Completes Marriage
D/S Tank Co (R)	3011	LST-1	1	H+150 (2 hrs 30 min)
Antitank Bn (H&S Co)	5032			
Antitank Bn (H&S Co)	5033			
Anti Tk Co (Co Hq)	5034			
Anti Tk Co (At Pl)	5035			
Antitank Co (AT Plt)	5036			
Antitank Co (AT Plt)	5037			
Bulk Fuel Co (Co Hq & Pack Fuel Plt)	5085			
D/S Tank Co (R)	3012	LST-2	3	H+150 (2 hrs 30 min)
D/S Tank Co (R)	3013			
Antitank Co (Co Hq)	5038			
Antitank Co (AT Plt)	5039			
Antitank Co (AT Plt)	5040			
Antitank Co (AT Plt)	5041			
Bulk Fuel Co (1st Bulk Fuel Plt)	5086			
D/S Tank Co (R)	3014	LST-3	2	H+195 (3 hrs 15 min)
D/S Tank Co (R)	3015			
Trk Co (Co Hqs)	6042			
MCB Bn; Fld Co [2nd "C" Co (-)]	6074			
LAAM Btry (-)	5010	LST-4	4	H+195 (3 hrs 15 min)
LAAM Btry (-)	5011			
LAAM Btry (-)	5012			
G/S Arty Bn ("C" 155mm How Btry)	5063			
G/S Arty Bn ("C" 155mm How Btry)	5064			
LAAM Btry (-)	5013	LST-5	1	H+230 (3 hrs 45 min)
LAAM Btry (-)	5014			
LAAM Btry (-)	5015			
Bulk Fuel Co (1st Bulk Fuel Plt)	5087			
MCB Bn [Trans Co (-)]	6068			
Tank Co (R)	5016	LST-6	3	H+230 (3 hrs 45 min)
Bulk Fuel Co (2nd Bulk Fuel Plt)	5088			
Bulk Fuel Co (2nd Bulk Fuel Plt)	5089			
Bulk Fuel Co (3rd Bulk Fuel Plt)	5090			
Trk Co (Trk Plt)	6043			

LANDING SEQUENCE FOR LANDING SHIPS (Continued)

Unit	Serial Number	Ship	Causeway Number	Est. Time Ship Completes Marriage
Tank Co (R) Bulk Fuel Co (3rd Bulk Fuel Plt) For Brg Co (Co Hq & Serv Plt) MCB Bn; Fld Co [2nd "C" Co (-)]	5017 5091 6044 6075	LST-7	2	N+275 (4 hrs 35 min)
Tank Co (R) Bulk Fuel Co (4th Bulk Fuel Plt) For Brg Co (1st Brg Plt)	5018 5092 60[illegible]	LST-8	4	H+275 (4 hrs 35 min)
Tank Co (R) Engr Bn (Eng Spt Co) MCB Bn; Fld Co [Trans Co (-)] MCB Bn; Fld Co [2nd "C" Co (-)]	5019 6005 8068 8075	LST-9	1	H+310 (5 hrs 10 min)
Tank Co (R) Engr Bn (Eng Spt Co) MCB Bn [Trans. Co (-)] MCB Bn; Fld Co [2nd "C" Co (-)]	5020 6006 6069 6076	LST-10	3	H+310 (5 hrs 10 min)
Tank Bn (H&S Co) Eng Bn (Engr Spt Co) Fld Arty Grp (155mm Gun Btry) MCB Bn (Trans Co) MCB Bn; Fld Co [2nd "C" Co (-)]	5021 6007 6052 6070 8076	LST-11	2	H+355 (5 hrs 55 min)
Tank Bn (H&S Co) Eng Bn (Engr Spt Co) Fld Arty Grp (155mm Gun Btry) MABS (Base Serv)	5022 6008 6053 4158	LST-12	4	H+355 (5 hrs 55 min)
Tank Bn (Flame Plt) Engr Bn (Engr Spt Co) Fld Arty Grp (Hq Btry) Fld Arty Grp (8" How Btry)	5023 6009 6050 6054	LST-13	1	H+390 (6 hr 30 min)
Tank Bn (MT Plt) Serv Bn (Main. Co) (Base Serv)	5024 6033 4159	LST-14	3	H+390 (6 hrs 30 min)

LANDING SEQUENCE FOR LANDING SHIPS (Concluded)

Unit	Serial Number	Ship	Causeway Number	Est. Time Ship Completes Marriage
Tank Co (MT Plt)	5025	LST-15	2	H+435
Serv Bn (Trk Co)	6034			(7 hrs 15 min)
MCB Bn (Trans Co)	8070			
Tank Co (Maint Plt)	5026	LST-16	4	H+435
Serv Bn (Trk Co)	6035			(7 hrs 15 min)
Fld Arty Grp (Hq Btry)	6051			
Fld Arty Grp (8" How Btry)	6055			
MCB Bn; Fld Co [1st "C" Co (-)]	6071			
MABS (Base Serv)	4160			
Tank Co (Sup Plt)	5027	LST-17	1	H+470
Serv Bn (Trk Co)	6036			(7 hrs 50 min)
Fld Arty Grp (8" How Btry)	6056			
MCB Bn; Fld Co [1st "C" Co (-)]	6072			
MABS (Base Serv)	4161			
90mm Tk Co (Co Hq)	5028	LST-18	3	H+470
Mtr Trans Bn (H&S Co)	6037			(7 hrs 50 min)
Fld Arty Gp (8" How Btry)	6057			
MCB Bn; Fld Co [1st "C" Co (-)]	8072			
90mm Tk Co (Tk Plt)	5029	LST-19	2	H+515
MT Bn; Trk Co (Co Hq)	6038			(8 hrs 35 min)
Fld Arty Grp [155mm Gun Bty (-)]	6058			
90mm Tk Co (Tk Plt)	5030	LST-20	4	H+515
Trk Co (Trk Plt)	6039			(8 hrs 35 min)
Fld Arty Grp [155mm Gun Bty (-)]	8058			
90mm Tk Co (Tk Plt)	5031	LST-21	1	H+550
Trk Co (Trk Plt)	6040			(9 hrs 10 min)
Fld Arty Grp (155mm Gun Btry	6059			
FSR Det (Fuel Trans Sec.)	5084	LST-22	3	H+550
Trk Co (Co Hqs)	6041			(9 hrs 10 min)
MCB Bn (Hq Co & "B" Co)	6067			

Appendix XIII to Annex I

PERSONNEL TRANSFER PLAN

This plan not required for purposes of this study; therefore not developed.

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13. ABSTRACT

This report describes the results of an analysis of the operation of present amphibious assault landing craft when placed in various future environments. The evaluation of the craft operations was accomplished using a set of computer programs to simulate an amphibious landing. The movement of individual vehicles in the Marine Force and individual craft was considered. Included is a complete description of the methodology and computer programs used in the analysis.

The measures of effectiveness, methodology and the set of computer programs described by this report are currently being employed to evaluate preliminary designs of a large number of advanced craft.

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Ship-to-Shore Model						
Effectiveness of Landing Craft Operations						

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