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SHIP-TO-SHORE INTERFACE ANALYSIS

by

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ABSTRACT

This report's basic task, which has been successfully accomplished, is that of developing the mathematical model simulating the following cargo unloading procedure.

The cargo is to be unloaded from a ship at some distance from the shore. The final destination of the cargo is to be at point A on the beach where no port facilities are available. The transferring of cargo from the ship to the shore is to be accomplished by means of transfer vehicles, such as amphibious craft. The cargo transfer from the ship to the transfer vehicles is to be accomplished by ship-based unloading gear, such as ship-based cranes. The cargo transfer from the transfer vehicles on the shore is to be accomplished by beach-based unloading gear, such as fork lifts.

The above mentioned simulation enables the user to gain insight into the aforementioned unloading procedure and thus to derive correctly the optimal use strategy of the ship-to-shore transfer operations, which is the ultimate goal of the present analysis.

Acknowledgments

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All computations were performed at the Computation Center of the Massachusetts Institute of Technology.

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1. Introduction

The basic task of the problem posed is that of developing the methodology that will permit the overall analysis of a cargo offloading procedure. In the offloading procedure under investigation, the cargo is to be unloaded from a ship, henceforth referred to as the mother ship, which is at some distance, say x miles, from the shore. The Mother Ship is to be stationary during the entire unloading operation. The final and only destination of the cargo is to be a point A on the beach. There are to be no port facilities on the shore or beach unloading areas.

The cargo involved in this study is to be contained in

i) Containers or pallets of arbitrary size, weight and capacity that are not capable of any self-induced motion, or

ii) Vehicles of arbitrary size, weight and capacity that are capable of self-induced rolling motion only. It should be noted that in this case the vehicle itself may be the cargo.

The actual transferring from the Mother Ship to the beach is to be accomplished by means of amphibious craft, whose number and characteristics have been prespecified. These are henceforth referred to as the transfer vehicles, such as LARCs, GEMs, etc. The loading into the transfer vehicles alongside the mother ship is to be in one of the two modes: sequential or simultaneous. Similarly, but toally independent from the loading mode, the unloading from the transfer vehicles on the beach is to be in one of the two modes: sequential or simultaneous.

In order to accomplish the cargo transfer from the Mother Ship to the transfer vehicles, the Mother Ship is to be provided with all the necessary unloading facilities, for example ship-borne crane(s), ramp(s), etc. However, the transfer vehicles are not to be provided with any special unloading facilities, because some means, such as a fork lift, is to be made available on the beach to carry out the cargo unloading.

Finally, the prespecified number of transfer vehicles and beach unloading gear is to be made available at point A, and their transportation and arrival is to be independent of that of the Mother Ship, and from each other.

With the above description, the cargo offloading procedure under investigation has been fully defined. In order to complete the description of the problem posed, it remains to define the analysis objectives, which can be stated as follows: The resulting technique is to be designed to first provide a common measure of success for a number of prespecified use strategies for given ship-based loading facilities, transfer vehicles and beach-based unloading facilities distributions, for a given x and environment state, and for given breakdown considerations. The common measure of success is to depend on time and/or level of risk or uncertainty. Thus the final analysis objective is to determine the optimum strategy (minimum time and/or level of risk or uncertainty) among those examined or, if the findings of the previous calculations suggest it, to continue the analysis with new strategies until the optimal one is found.

With the above, the problem description has been completed. The solution process is to be outlined in the subsequent Sections and Appendices. We start our discussion with a general outline of the solution process.

2. Solution Process

The solution process in this study is best illustrated by the block diagram shown in Fig. 2-1. A brief discussion of each step involved in the solution process is given below.

Problem Definition. This involved the following:

i) Identification of the variables of the problem.

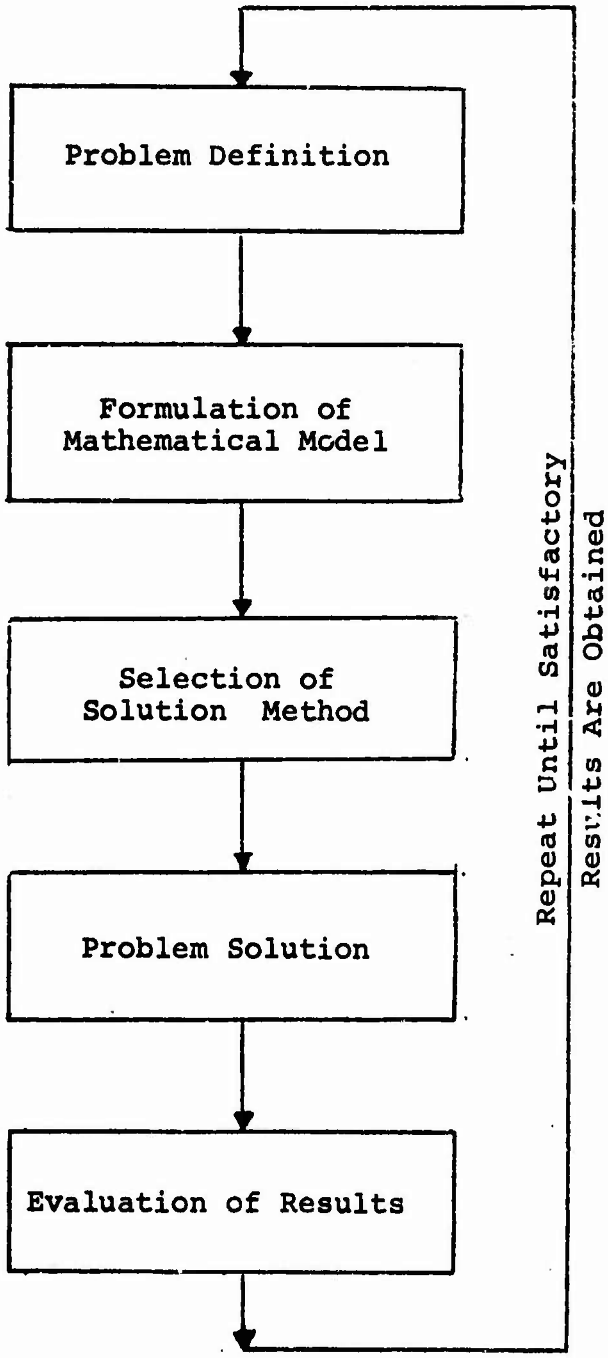
ii) Establishment of the relations among the variables.

iii) Identification of the dependent and independent variables of the problem consistent with i) and ii).

iv) Establishment of the range of variation of all problem parameters.

v) Selection of the figure of merit.

By definition, the variables of a problem are those parameters necessary to fully describe a given system to the degree of accuracy and extent desired. The process of variable identification for a new problem, such as ours, is a major and a very difficult task. In order to simplify our task of identifying our variables, it was found advantageous to first identify the subsystems involved in our study and then find the variables necessary to fully describe each subsystem to the degree of accuracy and extent desired. The subsystems involved in our study were found to be:



<u>BLOCK DIAGRAM OF SOLUTION PROCESS</u>

Fig. 2-1

1. The mother ship.
2. The payload.
3. The ship-based unloading facilities, S.U.F.
4. The shore-based unloading facilities, B.U.F.
5. The transfer vehicles, T.V.

The variable identification is deferred until the next Section where the Problem Definition will be discussed in detail. It is of importance to note in conjunction with the discussion of the variable identification that although it was recognized that the environment state as described by

1. Wind speed,
2. Sea state,
3. Current,
4. Tide,
5. Obstacles,
6. Beach configuration, and
7. Shore configuration

influences our offloading operation, it was decided to describe their effect by externally adjusting the magnitude of the appropriate parameters. For this reason, it is not necessary to identify any variables that describe the environment state. However, when assigning the magnitude of the parameters that are affected by the environment state, the user must assign the appropriate values by taking the environment state into consideration.

The establishment of the relations, if any, among the problem variables is a necessity as they form a part of the mathematical model. The reason for this is that because the mathematical model is, by definition, the replica of our system in the form of mathematical equations, any such relations must be part of it in order to permit it to be a true replica of the original. The establishment of any such relations is deferred until the next Section where the Problem Definition will be discussed in detail.

As was stated at the beginning of this section, the problem variables were so selected that when the appropriate values were assigned to them, they could serve to define a given offloading system uniquely to the degree of accuracy and extent desired. This, however, should not be taken to imply that if we assign arbitrary but logical values to these variables we will always be able to generate an offloading system because of the possible interrelations among the variables, which do not permit independent selection of values for all the interrelated variables. This fact makes it necessary to identify those variables whose values can be assigned arbitrarily and those whose value cannot. This is because our solution method involves the evaluation of different offloading systems which are generated by prespecifying the values of their variables. This is best done by classifying the variables into dependent and independent ones. The independent variables are those variables which must be prescribed to completely describe our system as desired. The dependent variables are the ones remaining in our original list of variables after the independent ones have been removed. The identification of the dependent and independent variables is deferred until the next Section where the Problem Definition will be discussed in detail.

Ideally speaking, we would like to impose no restrictions on the range of variation of our problem parameters, as this will tend to decrease the universality of our methodology, something a true engineer does not like to do voluntarily. However, there are practical considerations, common to this type of problem, which make it necessary that we impose limits on the range of variation of our problem parameters. The most common of these considerations (requiring us to compromise by imposing limits on the range of variation of our problem parameters) is that it is impossible to construct the mathematical model valid over the entire range of variation of the problem parameters. In the few times that it is possible to construct such a model, it again becomes necessary to restrict the range of variation to simplify the model and make it a useful engineering tool. Therefore, the above indicates the need for the introduction of restrictions as unavoidable. These restrictions, of course, ought to be introduced with great care. Care should be taken because we do not wish to reduce the universality of our methodology unnecessarily, as we wish to utilize it to solve most, if not all, of the problems that we are likely to encounter, but at the same time we wish to obtain this solution with relative ease and consistent but adequate precision. The introduction of these restrictions is deferred until the next Section, when the Problem Definition will be discussed in detail.

Finally, as was already mentioned in the Introduction, the figure of merit (the measure of success) is the weighted combination of time and level of risk and uncertainty. The time component of the figure of merit involves the calculation of time elapsed since the start of the mission to

1. prepare the mother ship for departure after all the payload has been transferred into the transfer vehicles, and all transfer vehicles have cleared the mother ship,

2. complete the payload transfer from the mother ship to point *A* on the beach,

3. return all transfer vehicles to their bases, and

4. return all beach-based unloading facilities to their bases.

The level of risk and uncertainty component of the figure of merit involves the calculation of the percentage of transfer vehicles that did not complete their mission because of breakdown. The factors determining the likelihood of breakdown for each transfer vehicle are

1. Reliability of the transfer vehicle's components.
2. Hazard vulnerability.
3. Control stability.
4. Operational limitations.

The establishment of the exact nature of the figure of merit is deferred until the next Section where the Problem Definition will be discussed in detail.

Formulation of the Mathematical Model.

As was stated earlier, the mathematical model is, by definition, the replica of our system, to the degree of accuracy and extent desired, in the form of mathematical equations. Because of the nature of our problem, the mathematical model is stochastic in nature. In setting up the mathematical model, care was taken to keep it as simple as possible to permit easy analysis, and yet to construct it so that it exhibits all the phenomena under consideration, as required. The actual construction of the mathematical model is deferred until the fourth section.

Selection of Solution Method.

From the Problem Definition one may easily observe that the easiest way to achieve the desired goal, namely, to find the optimum use strategy, is to treat the use strategy as a problem variable, and then solve the problem under investigation as an optimization problem. The resulting optimization problem is a mixed integer one, or simply an integer problem if the waiting times of the transfer vehicles and unloading facilities are approximated by integers. However, it was soon discovered that in order to solve the problem as an optimization one, drastic simplifications had to be made to the mathematical model to allow us to efficiently implement the solution in present-day computers. The reason for this is that all the solution methods required most, if not all, of the past history of the system to be stored in the computer memory. The drastic simplifications necessary made our methodology a very inefficient engineering tool. Last, but not least, if the use strategy obtained by solving the problem as an optimization one was very complicated, it probably would have been very difficult to implement in practice (because the system might be operating under external pressure). For this reason it would be very easy to violate a complicated optimum use strategy and to actually adopt a suboptimal solution whose merit cannot be estimated in any way, which is a very undesirable situation as it defeats the purpose of this analysis.

For the reasons given above it was decided to develop a methodology that will yield the desired solution, not necessarily as directly as it would have been provided by the optimization theory, but one which

1. could be implemented without requiring major simplifications in the mathematical model, and

2. could test logical and likely optimal use strategies which have a very high probability of being implemented in practice.

The method that satisfied all the above requirements was the digital simulation method, which was utilized in this study to obtain the desired solution. By this method the optimal solution was obtained by testing different use strategies that satisfied the second requirement given above. To develop these use strategies, one is guided by logic, especially in developing the first use strategy to be tested, and by the insight gained from the previous tries when this is available. In theory the true optimum can be found by examining all the possible use strategies, and although this can be a large number, it is always finite. However, from the above it should be clear that this is not necessary, as we wish to find the optimum solution that has also a very high probability of being implemented in practice. Fortunately, this can be achieved by a reasonably small number of tries. The discussion of the actual details of the methodology used in this study is deferred until the fifth section.

Problem Solution

This involves the preparation of the input required by the computer program. Special care must be taken when preparing the input of the parameters, whose magnitude is affected by environment state and breakdown considerations. Further discussion on this topic is deferred until later.

Evaluation of Results

With reference to Fig. 2-1, special care was taken that the only iteration required in the Solution Process is the preparation of new input data for the examination of a new use strategy, if the Evaluation of Results suggests it. It is anticipated that there will never be any need for the alteration of the first three steps of Fig. 2-1, as care was taken to make the methodology developed here general, in order to handle all cases likely to be encountered in practice. However, if a case arises where a change must be introduced in these three steps, the user must read very carefully the next three sections so that he may correctly alter the present method to suit his needs. Further discussion on this topic is deferred until later.

The above completes the introduction in the Solution Process. In the next section a detailed presentation of the Problem Definition will be given.

3. Problem Definition

In this section a detailed discussion of each step involved in the Problem Definition is given.

i) Identification of the Problem Variables

In view of the fact that the smaller the number of variables in a problem the more economical, and in many instances the more efficient, the solution process becomes, an attempt was made to keep the number of variables of this problem to a minimum. To do so it was necessary to introduce certain assumptions. However, special care was taken so that the nature and number of these assumptions was such as not to diminish the generality of our methodology. These assumptions will be enumerated in the fourth topic of this section, when the range of variation of the problem parameters is discussed.

As was mentioned earlier, in order to simplify our task of identifying our problem variables, the subsystems involved in our study were identified. These are shown diagrammatically in Fig. 3-1. For presentation purposes, the variables that are utilized to define each subsystem and at the same time appear in the computer input will be listed first, while the remaining variables necessary to complete each subsystem's description will be given later.

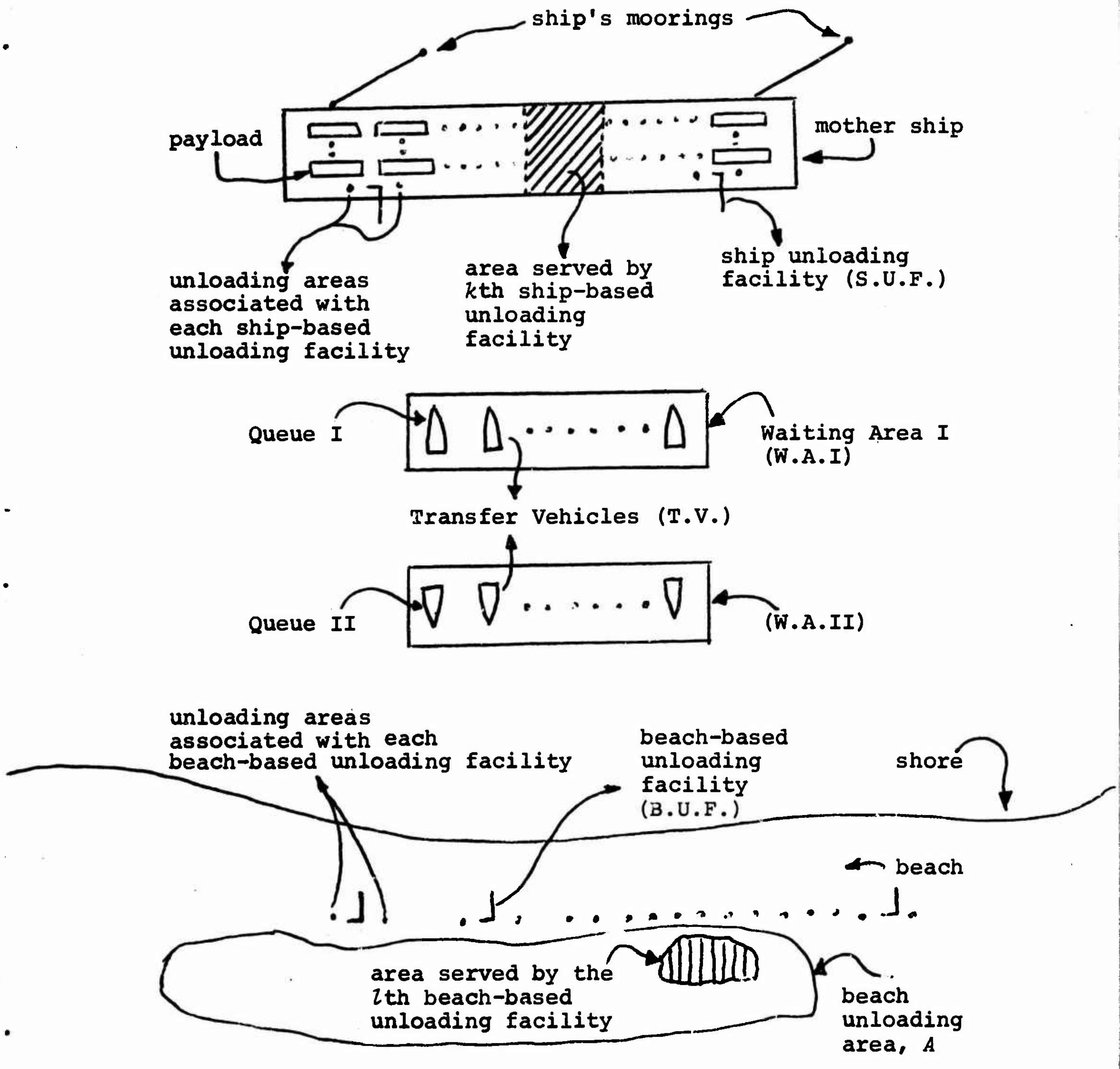


Fig. 3-1 GENERAL MODEL CONSTRUCTION

MOTHER SHIP DESCRIPTION

The variables* selected to describe the Mother Ship's performance are:

TAM giving the number of units of time after the start of the mission that the Mother Ship is expected to arrive in the theater of operations [$-999 \leq TAM \leq 9999$ (treated as a floating point number)].

T1 giving the number of units of time required to complete the mooring operations of the Mother Ship after it arrived in the theater of operations [$0. < T1 \leq 9999$ (treated as a floating point number)].

T2 giving the number of units of time required to free the Mother Ship from its moorings and make ready to travel after all S.U.F. are secured to position and all T.V. have cleared the Mother Ship [$0. < T2 \leq 9999$ (treated as a floating point number)].

*IDMA*** indicating the nature of the process concerning the arrival of the Mother Ship.

*ID1*** indicating the nature of the process concerning the mooring operation of the Mother Ship.

*ID2*** indicating the nature of the process concerning the operation of freeing the Mother Ship from its moorings.

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*The magnitude of all the variables selected to describe the Mother Ship's performance except the magnitude of *INMS*, *IN1*, *IN2* and *TIME* is affected by environmental state.

***IDMA*, *ID1*, *ID2* = *1* if the process is deterministic.
= *2* if the process is stochastic, drawn from *U(0,1)* distribution.
= *3,4...9999* if the process is stochastic, drawn from distributions to be developed by the user, if so desired.

INMS giving the seed of the *U(0,1)* distribution, which serves to predict the stochastic behavior of the Mother Ship's arrival process, if *IDMA* = 2*** [$1 \leq INMS \leq 10^9-1$].

AMINM giving the minimum value of the range of variation of *TAM*, if *IDMA* = 2***[$-999.99999 \leq AMINM < 9999.99999$].

AMAXM giving the maximum value of the range of variation of *TAM*, if *IDMA* = 2***[$-999.99999 < AMAXM \leq 9999.99999$].

IN1 giving the seed of the *U(0,1)* distribution, which serves to predict the stochastic behavior of the Mother Ship's mooring operation, if *ID1* = 2* [$1 \leq IN1 \leq 10^9-1$].

AMIN1 giving the minimum value of the range of variation of *T1* if *ID1* = 2*[$0. < AMIN1 < 9999.99999$]

AMAX1 giving the maximum value of the range of variation of *T1* if *ID1* = 2*[$0. < AMAX1 \leq 9999.99999$].

IN2 giving the seed of the *U(0,1)* distribution, which serves to predict the stochastic behavior of the operation of freeing the Mother Ship from its moorings, if *ID2* = 2**[$1 \leq ID2 \leq 10^9-1$].

AMIN2 giving the minimum value of the range of variation of *T2* if *ID2* = 2**[$0. < AMIN2 < 9999.99999$].

AMAX2 giving the maximum value of the range of variation of *T2* if *ID2* = 2**[$0. < AMAX2 \leq 9999.99999$].

TIME giving the units of time utilized in this study [$0 \leq$ *TIME* $\leq$ *12 alpha numeric characters*].

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*If *ID1=1* *IN1*, *AMIN1* and *AMAX1* are not problem variables.

**If *ID2=1* *IN2*, *AMIN2* and *AMAX2* are not problem variables.

***If *IDMA=1* *INMS*, *AMINM* and *AMAXM* are not problem variables.

PAYLOAD DESCRIPTION

The variables selected to describe the payload are:

N_k giving the number of payload units to be unloaded by each of the k $(k = 1,2...K)$ S.U.F. $\left[1 \le N_k \le 1000 \text{ and } \sum_{k=1}^{K} N_k \le 1000\right]$.

WC_n giving the weight of each of the n $\left(n = 1,2... \sum_{k=1}^{K} N_k\right)$ payload units plus that of their lashings $[0.<WC_n \le 99.99]$.

VC_n giving the volume of each of the n $\left(n = 1,2... \sum_{k=1}^{K} N_k\right)$ payload units together with that of their lashings* $[0.<VC_n \le 9999$ *(treated as a floating point number)*$]$.

$WGHT$ giving the units of weight utilized in this study $[0 \le WGHT \le 12$ *alpha numeric characters*$]$.

VOL giving the units of volume utilized in this study $[0 \le VOL \le 12$ *alpha numeric characters*$]$.

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*If all the T.V. employed in this study do not permit vertical stowing of the payload, VC_n can be utilized to give the volume per unit height plus the surface area required by their lashings rather than the volume of each of the n $(n=1,2...\sum_{k=1}^{K} N_k)$ payload units and that of their lashings, as this is a quantity much easier to estimate.

S.U.F. DESCRIPTION

The variables* selected to describe the S.U.F.'s performance are:

K giving the number of S.U.F.** involved in this case [$1 \leq K \leq 20$].

*ISUD**** indicating the nature of the unloading mode at the Mother Ship.

*ISCSL***** indicating which of the S.U.F. use strategies is to be used.

$TSC_{1,k}$ giving the time required for the *k*th ($k = 1,2...K$) S.U.F. to be made ready to start the unloading operation and reach the *k*th ship unloading area after the Mother Ship is properly moored [$0. < TSC_{1,k} \leq 9999$ *(treated as a floating point number)*].

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* The magnitude of all the variables selected to describe the S.U.F.'s performance except the magnitude of $INSC_{j_2,k}$ ($j_2 = 1,2 ... 5,7,8,9$; $k = 1,2 ... K$) is affected by the environment state.

** Each S.U.F. is identified by a distinct number, *k*, such that $1 \leq k \leq K$.

*** *ISUD* = *1* if the unloading mode at the Mother Ship is to be in parallel.
ISUD = *2* if the unloading mode at the Mother Ship is to be sequential.

**** If *ISCSL* = *1*, S.U.F. use strategy *SLSCA* is used to select the appropriate S.U.F. when necessary.
= *2*, S.U.F. use strategy *SLSCB* is used to select the appropriate S.U.F. when necessary.
= *3,4 ... 9*, additional S.U.F. use strategies to be developed by the user, if desired, for selecting the appropriate S.U.F. when necessary.

$TSC_{2,k}$ giving the time required for the kth $(k = 1,2...K)$ S.U.F. to travel to any of the N_k payload units from the kth ship unloading area [$0. < TSC_{2,k} \leq 9999$ *(treated as a floating point number)*].

$TSC_{3,k}$ giving the time required to release any of the N_k $(k = 1,2...K)$ payload units after the kth S.U.F. has reached the payload unit in question [$0. < TSC_{3,k} \leq 9999$ *(treated as a floating point number)*].

$TSC_{4,k}$ giving the time required to secure any of the N_k $(k = 1,2...K)$ payload units on the kth S.U.F. after the payload unit in question has been released [$0. < TSC_{4,k} \leq 9999$ *(treated as a floating point number)*].

$TSC_{5,k}$ giving the time required to transport any of the N_k $(k = 1,2...K)$ payload units to the kth ship unloading area after the payload unit in question has been secured on the S.U.F. [$0. < TSC_{6,k} \leq 9999$ *(treated as a floating point number)*].

$TSC_{7,k}$ giving the time required to unload and then free any of the N_k $(k = 1,2...K)$ payload units from the kth S.U.F. and to then make the kth S.U.F. ready to travel again. This operation is performed only if (a) the appropriate T.V. is properly secured in the kth ship unloading area and has completed its refueling (if refueling was necessary), (b) the previous payload unit unloaded by the S.U.F. in question is fully secured in the T.V. in question (this requirement is void if the payload unit in question is the first payload unit to be unloaded in any of the T.V.'s trips), and (c) the T.V.'s remaining capacity can accept the payload unit in question. If any of the above is not satisfied, the kth S.U.F. must wait

$TSC_{7,k}$ (cont'd.) until all three requirements are satisfied [0. < $TSC_{7,k} \leq 9999$ (treated as a floating point number)].

$TSC_{8,k}$ giving the time required for the kth ($k = 1,2...K$) S.U.F. to travel back to its original position from the kth ship unloading area after the last of the N_k payload units has been transferred onto the appropriate T.V. [0. < $TSC_{8,k} \leq 9999$ (treated as a floating point number)].

$TSC_{9,k}$ giving the time required for the kth ($k = 1,2...K$) S.U.F. to be secured to its original position.

$IDSC_{j_2,k}$* indicating the nature of each of the j_2 ($j_2 = 1,2...$ $...5,7,8,9$) processes described above for each of the k ($k = 1,2...K$) S.U.F.

$INSC_{j_2,k}$ giving the seed of the $U(0,1)$ distribution, which serves to predict the stochastic behavior of each of the j_2 ($j_2 = 1,2...5,7,8,9$) processes described above for each k ($k = 1,2...K$), if $IDSC_{j_2,k} = 2$** [$1 \leq INSC_{j_2,k} \leq 10^9 - 1$].

$AMINSC_{j_2,k}$ giving the minimum value of the range of variation of $TSC_{j_2,k}$ ($j_2 = 1,2...5,7,8,9$; $k = 1,2...K$), if $IDSC_{j_2,k}=2$** [0. < $AMINSC_{j_2,k}$ < 9999.99999].

$AMAXSC_{j_2,k}$ giving the maximum value of the range of variation of $TSC_{j_2,k}$ ($j_2 = 1,2...5,7,8,9$; $k = 1,2...K$), if $IDSC_{j_2,k} = 2$** [0. < $AMAXSC_{j_2,k} \leq 9999.99999$].

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*$IDSC_{j_2,k}$ = 1 if the process is deterministic.

= 2 if the process is stochastic, drawn from $U(0,1)$ distribution.

= 3,4...9999 if the process is stochastic, drawn from distributions to be developed by the user, if so desired.

**If $IDSC_{j_2,k}=1$ $INSC_{j_2,k}$, $AMINSC_{j_2,k}$ and $AMAXSC_{j_2,k}$ are not problem variables.

B.U.F. DESCRIPTION

The variables* selected to describe the B.U.F.'s performance are:

L giving the number of B.U.F.** involved in this case $[1 \leq L \leq 20]$.

*IBUD**** indicating the nature of the unloading mode at the beach.

*IBCSL***** indicating which of the B.U.F. use strategies is to be used.

$TBC_{1,\ell}$ giving the number of units of time after the start of the mission that the ℓth $(\ell = 1,2...L)$ B.U.F. is expected to depart from its base $[-999 \leq TBC_{1,\ell} \leq 9999$ *(treated as a floating point number)*].

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*The magnitude of all the variables selected to describe the B.U.F.'s performance except the magnitude of

$$INBC_{j_4,\ell} \quad (j_4 = 1,2...4,6,7...10; \ \ell = 1,2...L)$$

is affected by environment state.

**Each B.U.F. is identified by a distinct number, ℓ, such that $1 \leq \ell \leq L$.

***$IBUD = 1$ if the unloading mode at the beach is to be in parallel.

$= 2$ if the unloading mode at the beach is to be sequential.

****If $IBCSL = 1$, B.U.F. use strategy *SLBCA* is used to select the appropriate B.U.F. when necessary.

$= 2$, B.U.F. use strategy *SLBCB* is used to select the appropriate B.U.F. when necessary.

$= 3,4...9$, additional B.U.F. use strategies to be developed by the user if so desired, for selecting the appropriate B.U.F. when necessary.

$TBC_{2,\ell}$ giving the time required for the ℓth $(\ell = 1,2...L)$ B.U.F. to reach point A on the beach from its base [$0. < TBC_{2,\ell} \le 9999$ *(treated as a floating point number)*].

$TBC_{3,\ell}$ giving the time required for the ℓth $(\ell = 1,2...L)$ B.U.F. to be made ready to start the unloading operation after the ℓth B.U.F. has arrived at point A on the beach [$0. < TBC_{3,\ell} \le 9999$ *(treated as a floating point number)*].

$TBC_{4,\ell}$ giving the time required for the ℓth $(\ell = 1,2...L)$ B.U.F. to travel to the ℓth beach unloading area from point A on the beach after the ℓth B.U.F. has been made ready to travel [$0. < TBC_{4,\ell} \le 9999$ *(treated as a floating point number)*].

$TBC_{6,\ell}$ giving the time required to release any of the payload units utilizing the ℓth $(\ell = 1,2...L)$ B.U.F. This operation is performed only if the appropriate T.V. is beached and ready to commence the unloading operation and the ℓth B.U.F. has reached the ℓth beach unloading area. If that is not the case, the releasing of the payload unit must wait until the two requirements given above are satisfied [$0. < TBC_{6,\ell} \le 9999$ *(treated as a floating point number)*].

$TBC_{7,\ell}$ giving the time required to secure any of the payload unit on the ℓth $(\ell = 1,2...L)$ B.U.F. after the payload unit has been released [$0. < TBC_{7,\ell} \le 9999$ *(treated as a floating point number)*].

$TBC_{8,\ell}$ giving the time required after the payload unit in question has been secured on the ℓth $(\ell = 1,2...L)$ B.U.F. to (a) transport any of the payload units from the ℓth beach unloading area to point A on the beach by utilizing the ℓth B.U.F., (b) unload and free the

$TBC_{8,\ell}$ (cont'd.) payload unit from the ℓth B.U.F. and (c) make the ℓth B.U.F. ready to travel again [$0. < TBC_{8,\ell} \leq 9999$ (treated as a floating point number)].

$TBC_{9,\ell}$ giving the time required to prepare the ℓth ($\ell = 1,2...L$) B.U.F. for departure after it has terminated its mission [$0. < TBC_{9,\ell} \leq 9999$ (treated as a floating point number)].

$TBC_{10,\ell}$ giving the time required for the ℓth ($\ell = 1,2...L$) B.U.F. to reach its base after it has been made ready for departure [$0. < TBC_{10,\ell} \leq 9999$ (treated as a floating point number)].

$IDBC_{j_4,\ell}$* indicating the nature of each of the j_4 ($j_4 = 1,2,3,4,6,7,...10$) processes described above for each of the ℓ ($\ell = 1,2...L$) B.U.F.

$INBC_{j_4,\ell}$ giving the seed of the $U(0,1)$ distribution which serves to predict the stochastic behavior of each of the j_4 ($j_4 = 1,2,3,4,6,7...10$) processes described above for each ℓ ($\ell = 1,2...L$), if $IDBC_{j_4,\ell} = 2$** [$1 \leq INBC_{j_4,\ell} \leq 10^9 -1$].

$AMINBC_{j_4,\ell}$ giving the minimum value of the range of variation of $TBC_{j_4,\ell}$ ($j_4 = 1,2,3,4,6,7...10$; $\ell = 1,2...L$), if $IDBC_{j_4,\ell} = 2$** [$-999.99999 \leq AMINBC_{1,\ell} < 9999.99999$; $0. < AMINBC_{j_3,\ell} < 9999.99999$, $j_3 = 2,3,4,6,7...10$].

$AMAXBC_{j_4,\ell}$ giving the maximum value of the range of variation of $TBC_{j_4,\ell}$ ($j_4 = 1,2,3,4,6,7...10$; $\ell = 1,2...L$), if $IDBC_{j_4,\ell} = 2$** [$-999.99999 < AMAXBC_{1,\ell} \leq 9999.99999$; $0. < AMINBC_{j_3,\ell} \leq 9999.99999$, $j_3 = 2,3,4,6,7...10$].

---

*$IDBC_{j_4,\ell}$ = 1 if the process is deterministic.
= 2 if the process is stochastic, drawn from $U(0,1)$ distribution.
= 3,4...9999 if the process is stochastic, drawn from distributions to be developed by the user, if so desired.

**If $IDBC_{j_4,\ell}=1$, then $INBC_{j_4,\ell}$, $AMINBC_{j_4,\ell}$ and $AMAXBC_{j_4,\ell}$ are not problem variables.

T.V. DESCRIPTION

The variables* selected to describe the T.V.'s performance are:

I giving the number of T.V.** involved in this case $(1 \leq I \leq 20)$.

*IWA1SL**** indicating which of the T.V. use strategies is to be used in W.A.I.

*IWA2SL***** indicating which of the T.V. use strategies is to be used in W.A.II.

$AMAXTV_{6,i}$ giving the weight of payload together with that of the associated lashings that the *i*th $(i = 1,2...I)$ T.V. can carry in any of its trips $[0. < AMAXTV_{6,i} \leq 9999$ (treated as a floating point number)].

---

*The magnitude of the variables *IWA1SL*, *IWA2SL*, $AMAXTV_{7,i}$ $(i = 1,2...I)$, $TTV_{j_6,i}$ $(j_6=1,2,4...7,9,10,11,13,15,16,17)$, $IDTV_{j_7,i}$ $(j_7=1,2...5,9,10...13,15,16,17)$ $AMINTV_{j_7,i}$ and $AMAXTV_{j_7,i}$ is affected by the environment state. The magnitude of the variables *WT1MAX*, *WT2MAX*, $IDBRTV_{j_9,i}$ $(j_9=1,2...8)$ $BRKTV_{j_9,i}$ is affected by the environment state and breakdown considerations.

**Each T.V. is identified by a distinct number, *i*, such that $1 \leq i \leq I$.

***If *IWA1SL=1*, T.V. use strategy *ASLTVA* is used to select the appropriate T.V. from W.A.I when necessary.
=2, T.V. use strategy *ASLTVB* is used to select the appropriate T.V. from W.A.I when necessary.
=3,4...9, additional T.V. use strategies to be developed by the user, if so desired, for selecting the appropriate T.V. from W.A.I when necessary.

****If *IWA2SL=1*, T.V. use strategy *BSLTVA* is used to select the appropriate T.V. from W.A. II when necessary.
=2, T.V. use strategy *BSLTVB* is used to select the appropriate T.V. from W.A. II when necessary.
=3,4...9, additional T.V. use strategies to be developed by the user, if so desired, for selecting the appropriate T.V. from W.A.II when necessary.

$AMAXTV_{7,i}$ giving the volume of payload together with that of the associated lashings that the *i*th $(i = 1,2...I)$ T.V. can carry in any of its trips. Note that the definition of units of $AMAXTV_{7,i}$ must be the same as that of VC_n $(n = 1,2..\sum_{k=1}^{k} N_k)$ [$0 < AMAXTV_{7,i} \leq 99999$ *(treated as a floating point number)*].

$TTV_{1,i}$ giving the number of units of time after the start of the mission that the *i*th $(i = 1,2...I)$ T.V. is expected to depart from its base [$-999 \leq TTV_{1,i} \leq 9999$ *(treated as a floating point number)*

$TTV_{2,i}$ giving the time required for the *i*th $(i = 1,2...I)$ T.V. to reach W.A.I from its base [$0. < TTV_{2,i} \leq 9999$ *(treated as a floating point number)*]

$TTV_{4,i}$ giving the time required for the *i*th $(i = 1,2...I)$ T.V. to reach and hook up to any of the ship unloading areas from W.A.I and prepare the *i*th T.V. for the loading operation. Note that the *i*th T.V. can leave W.A.I only when there is a ship unloading area free to receive it. [$0. < TTV_{4,i} \leq 9999$ *(treated as a floating point number)*].

$TTV_{5,i}$ giving the time required for the *i*th $(i = 1,2...I)$ T.V. to refuel, when necessary, after it has hooked up at any of the ship unloading areas [$0. < TTV_{5,i} \leq 9999$ *(treated as a floating point number)*].

$TTV_{6,i}$ giving the time expected for the *i*th $(i=1,2...I)$ T.V. will operate at other than zero speed, during a complete cycle. [$0. < TTV_{6,i} \leq 9999$ *(treated as a floating point number)*].

$TTV_{7,i}$ giving the time expected that the *i*th $(i = 1,2...I)$ T.V. will operate at, other than zero speed, without refueling. [$0. < TTV_{7,i} \leq 9999$ *(treated as a floating number)*]

$TTV_{9,i}$ giving the time required for any payload unit to be secured on the *i*th *(i = 1,2...I)* T.V. after it has been unloaded into the *i*th T.V. and freed from the appropriate S.U.F., and after the S.U.F. in question has been made ready to travel again [$0. < TTV_{9,i} \leq 9999$ *(treated as a floating point number)*].

$TTV_{10,i}$ giving the time required for the *i*th *(i = 1,2...I)* T.V. to unhook and be made ready to travel after the last payload unit unloaded into the *i*th T.V. has been properly secured. [$0. \leq TTV_{10,i} \leq 9999$ *(treated as a floating point number)*].

$TTV_{11,i}$ giving the time required for the *i*th *(i = 1,2...I)* T.V. to reach W.A.II from any of the ship unloading areas [$0. < TTV_{11,i} \leq 9999$ *(treated as a floating point number)*].

$TTV_{13,i}$ giving the time required for the *i*th *(i = 1,2...I)* T.V. to reach any of the beach unloading areas from W.A.II and then beach and be made ready for the unloading operation. Note that the *i*th T.V. can leave W.A.II only when there is a beach unloading area free to receive it [$0. < TTV_{13,i} \leq 9999$ *(treated as a floating point number)*].

$TTV_{15,i}$ giving the time required for the *i*th *(i = 1,2...I)* T.V. to be made ready to travel again after the last payload unit carried on any of its trips has been secured to the appropriate B.U.F. [$0. < TTV_{15,i} \leq 9999$ *(treated as a floating point number)*].

$TTV_{16,i}$ giving the time required for the *i*th *(i = 1,2...I)* T.V. to reach W.A.I from any of the beach unloading areas after it has been made ready to travel [$0. < TTV_{16,i} \leq 9999$ *(treated as a floating point number)*].

$TTV_{17,i}$ giving the time required for the ith $(i = 1,2...I)$ T.V. to reach its base from any of the beach unloading areas after it has completed its mission [$0. < TTV_{17,i} \le 9999$ (treated as a floating point number)].

$IDTV_{j_7,i}$* indicating the nature of each of the j_7 $(1,2...5,9,10...13,15,16,17)$ processes described above** for each of the i $(i = 1,2...I)$ T.V.

$INTV_{j_7,i}$ giving the seed of the $U(0,1)$ distribution which serves to predict the stochastic behavior of each of the j_7 $(j_7 = 1,2...5,9,10...13,15,16,17)$ processes described above for each i $(i = 1,2...I)$, if $IDTV_{j_7,i} = 2$*** [$1 \le INTV_{j_7,i} \le 10^9 - 1$].

$AMINTV_{j_7,i}$ giving the minimum value of the range of variation of $TTV_{j_7,i}$ $(j_7 = 1,2...5,9,10...13,15,16,17;\ i = 1,2...I)$, if $IDTV_{j_7,i} = 2$***[$-999.99999 \le AMINTV_{1,i} < 9999.99999;\ 0. < AMINTV_{j_8,i} < 9999.99999,\ j_8 = 2,3...5,9,10...13,15,16,17$].

$AMAXTV_{j_7,i}$ giving the maximum value of the range of variation of $TTV_{j_7,i}$ $(j_7 = 1,2...5,9,10...13,15,16,17;\ i = 1,2...I)$, if $IDTV_{j_7,i} = 2$*** [$-999.99999 < AMAXTV_{1,i} \le 9999.99999;\ 0. < AMAXTV_{j_8,i} \le 9999.99999,\ j_8 = 2,3...5,9,10...13,15,16,17$].

---

*$IDTV_{j_7,i} = 1$ if the process is deterministic.
$= 2$ if the process is stochastic, drawn from $U(0,1)$ distribution.
$= 3,4...9999$ if the process is stochastic, drawn from distributions to be developed by the user, if so desired.

**Process 3 is the process associated with the waiting of a T.V. in W.A.I.
12 is the process associated with the waiting of a T.V. in W.A.II.

***If $IDTV_{j_7,i} = 1$, then $INTV_{j_7,i}$, $AMINTV_{j_7,i}$ and $AMAXTV_{j_7,i}$ are not problem variables.

WT1MAX giving the maximum time that any of the *I* T.V. is expected to wait in W.A.I at any time during the mission [$0. < WT1MAX \leq 9999999.99$].

WT2MAX giving the maximum time that any of the *I* T.V. is expected to wait in W.A.II at any time during the mission [$0. < WT2MAX \leq 9999999.99$].

$IDBRTV_{j_9,i}$* indicating the presence or absence of breakdown considerations for each of the j_9 ($j_9 = 1,2...8$) processes (see Table 3-1) for the ith ($i = 1,2...I$) T.V. and, in the event that breakdown considerations are present, their nature.

$INBRTV_{j_9,i}$ giving the seed of the $U(0,1)$ distribution which serves to predict the stochastic behavior of each of the j_9 ($j_9 = 1,2...8$) processes described above for each i ($i = 1,2...I$), if $IDBRTV_{j_9,i}=2$** [$1 \leq INBRTV_{j_9,i} \leq 10^9 -1$].

$BRKTV_{j_9,i}$ giving the probability that a breakdown will occur during the j_{10}th ($j_{10} = 1,3,4,6,7,8$) process for each i ($i = 1,2...I$), and the probability that a breakdown will occur if the ith T.V. waited *WT1MAX* or more units of time in W.A.I during the 2nd process*** and the probability that a breakdown will occur if the ith T.V. waited *WT2MAX* or more units of time in W.A.II during the 5th process***, if $IDBRTV_{j_9,i}=2$** [$0. < BRKTV_{j_9,i} < 1.0000$].

---

*$IDBRTV_{j_9,i}$ = 1 if there are no breakdown considerations.
= 2 if there are breakdown considerations which are drawn from a $U(0,1)$ distribution.
= 3,4...99 if there are breakdown considerations which are drawn from distributions to be developed by the user, if so desired.

** If $IDBRTV_{j_9,i}=1$, then $INBRTV_{j_9,i}$ and $BRKTV_{j_9,i}$ are not problem variables.

*** If the T.V. waited less the probability is scaled down linearly.

j_9	= 1	Describes the breakdown considerations of each T.V. regarding its trip to W.A.I from its base. The breakdown considerations of this process are a function of the T.V. involved.
	= 2	Describes the breakdown considerations of each T.V. regarding its waiting in W.A.I. The breakdown considerations of this process are a function of the T.V. involved and the waiting time.
	= 3	Describes the breakdown considerations of each T.V. regarding its trip to any of the ship unloading areas from W.A.I. The breakdown considerations of this process are a function of the T.V. involved.
	= 4	Describes the breakdown considerations of each T.V. regarding its trip to W.A.II from any of the ship unloading areas. The breakdown considerations of this process are a function of the T.V. involved.
	= 5	Describes the breakdown considerations of each T.V. regarding its waiting in W.A.II. The breakdown considerations of this process are a function of the T.V. involved and the waiting time.
	= 6	Describes the breakdown considerations of each T.V. regarding its trip to any of the beach unloading areas from W.A.II. The breakdown considerations of this process are a function of the T.V. involved.
	= 7	Describes the breakdown considerations of each T.V. regarding its trip to W.A.I from any of the beach unloading areas. The breakdown considerations of this process are a function of the T.V. involved.
	= 8	Describes the breakdown considerations of each T.V. regarding its trip to its base from any of the beach unloading areas. The breakdown considerations of this process are a function of the T.V. involved.

<u>Table 3-1</u>

<u>Processes Describing Breakdown Considerations</u>

With the above, the list of the variables that are utilized to define the five subsystems involved in our study and at the same time appear as input in our computer program is complete. There exist two additional inputs to the computer program which serve to control the program's performance and which for the sake of completeness we include here. These are:

NCASES giving the number of cases to be processed in each program execution [$1 \leq$ NCASES ≤ 99], and

NRUNS giving the number of runs to be processed for the j_1th (j_1 = 1,2...NCASES) case [$1 \leq$ NRUN ≤ 100].

We continue now by listing the remaining variables necessary to complete each subsystem's description.

MOTHER SHIP DESCRIPTION

The additional variables selected to complete the description of the Mother Ship's performance are:

TAMP, *T1P*, *T2P** giving the time fluctuation associated with *TAM*, *T1* and *T2* respectively.

TTM giving the total time taken by the Mother Ship to complete its operation. This includes the time taken to free the Mother Ship from its mooring and to make it ready for travel again after all S.U.F. are secured in position and all T.V. have cleared the Mother Ship.

*If *IDMA* and/or *ID1* and/or *ID2* equal *1*, then *TAMP* and/or *T1P* and/or *T2P* equal zero respectively. If that is not the case, *TAMP*, *T1P* and *T2P* are determined by drawing from the appropriate distribution, as dictated by the magnitude of *IDMA*, *ID1* and *ID2* respectively.

PAYLOAD DESCRIPTION

The variables given above suffice to describe the payload characteristics to the degree of accuracy and extent desired, and so no additional variables are needed.

S.U.F. DESCRIPTION

The additional variables selected to complete the description of the S.U.F.'s performance are:

$TSC_{6,k}$ giving the time that the kth $(k = 1,2...K)$ S.U.F. has to wait in the kth ship unloading area before it can unload the payload unit that it is transporting. The kth S.U.F. has to wait until the appropriate T.V. is properly secured in the kth ship unloading area or until the previously unloaded payload unit is properly secured in the T.V. in question.

$TSCP_{j_2,k}$* giving the time fluctuation associated with $TSC_{j_2,k}$ $(j_2 = 1,2...5,7,8,9;\ k = 1,2...K)$.

$AMAXSC_{6,k}$ giving the total time taken by the kth $(k = 1,2...K)$ S.U.F. to complete its mission. This includes the time taken to secure the S.U.F. in its original position.

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*If $IDSC_{j_2,k}$ equals 1, then $TSCP_{j_2,k}$ equals zero. If that is not the case, $TSCP_{j_2,k}$ is determined by drawing from the appropriate distribution, as dictated by the magnitude of $IDSC_{j_2,k}$.

B.U.F. DESCRIPTION

The additional variables selected to complete the description of the B.U.F.'s performance are:

$TBC_{5,\ell}$ giving the time that the ℓth $(\ell = 1,2...L)$ B.U.F. has to wait in any of the beach unloading areas before it can release the appropriate payload unit. The ℓth B.U.F. has to wait in a beach unloading area until the appropriate T.V. is properly beached and has been made ready for the unloading operation.

$TBCP_{j_4,\ell}$* giving the time fluctuation associated with $TBC_{j_4,\ell}$ $(j_4 = 1,2,3,4,6,7...10;\ \ell = 1,2...L)$.

$AMAXBC_{5,\ell}$ giving the total time taken by the ℓth $(\ell = 1,2...L)$ B.U.F. to complete its mission. This includes the time taken for the ℓth B.U.F. to reach its base.

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*If $IDBC_{j_4,\ell}$ equals 1, then $TBCP_{j_4,\ell}$ equals zero. If that is not the case, $TBCP_{j_4,\ell}$ is determined by drawing from the appropriate distribution, as dictated by the magnitude of $IDBC_{j_4,\ell}$.

T.V. DESCRIPTION

The additional variables selected to complete the description of the T.V.'s performance are:

$TTV_{3,i}$ giving the time that the *i*th $(i = 1,2...I)$ T.V. has to wait in W.A.I. The *i*th T.V. has to wait in W.A.I until the appropriate* ship unloading area becomes free to receive it. At the start of the mission, as soon as the Mother Ship is moored, all ship unloading areas become free. Subsequently, a ship unloading area becomes free as soon as the T.V. that is being served alongside the ship unloading area in question is unhooked and made ready to commence its journey to W.A.II.

$TTV_{8,i}$ giving the time that the *i*th $(i = 1,2...I)$ T.V. has to wait in any of the ship unloading areas awaiting the appropriate S.U.F.'s arrival.

$TTV_{12,i}$ giving the time that the *i*th $(i = 1,2...I)$ T.V. has to wait in W.A.II. The *i*th T.V. has to wait in W.A.II until the appropriate** beach unloading area becomes free to receive it. At the start of the mission, as soon as the ℓth $(\ell = 1,2...L)$ B.U.F. arrives at point *A*, the ℓth beach unloading area becomes free. Subsequently a beach unloading area becomes free as soon as the T.V. that is being served at the beach unloading area in question is made ready to travel again for W.A.I or its base.

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* Note that during the sequential loading mode if one ship unloading area is not free, then all ship unloading areas are considered busy.

**Note that during the sequential unloading mode if one beach unloading area is not free then all beach unloading areas are considered busy.

$TTV_{14,i}$ giving the time that the ith $(i = 1,2...I)$ T.V. has to wait in any of the beach unloading areas awaiting the appropriate B.U.F.'s arrival.

$TTVP_{j_7,i}$* giving the time fluctuation associated with $TTV_{j_7,i}$ $(j_7 = 1,2...5,9,10...13,15,16,17;\ i = 1,2...I)$.

$AMAXTV_{8,i}$ giving the total time taken by the ith $(i = 1,2...I)$ T.V. to complete its mission. This includes the time taken for the ith T.V. to reach its base.

The above completes the list of variables that we selected to describe our system for this study. In the continuation of this study, the list will be augmented as necessary to deal with the statistical considerations and the concept of antithetic variance. These considerations and this concept will be presented in a separate report which will follow the present one. The above completes the detailed discussion of the first topic of the Problem Definition. We now proceed with the second topic of the Problem Definition, which deals with the establishment of the relations among the problem variables.

---

*If $IDTV_{j_7,i}$ equals 1, then $TTVP_{j_7,i}$ equals zero. If that is not the case, $TTVP_{j_7,i}$ is determined by drawing from the appropriate distribution, as dictated by the magnitude of $IDTV_{j_7,i}$.

ii) Establishment of the Relations Among the Problem Variables

Because in the fourth section we will undertake to construct the mathematical model of our system, we should, before we proceed, establish all the relationships that exist among the variables that we selected to describe our system. This is because the mathematical model is, by definition, the replica of our system in the form of mathematical equations, and therefore any such relations must be part of it in order to permit it to be a true replica of the original. So we proceed by establishing all such relationships.

(3.1)

TAMP = 0 if *IDMA* = 1
= (*AMAXM*-*AMINM*)**R* + *AMINM* if *IDMA* = 2
where *R* is a random number generated from a *U*(0,1) distribution utilizing *INMS* as the first seed and then the updated *INMS* in subsequent generations.

T1P = 0 if *ID1* = 1 (3.2)
= (*AMAX1*-*AMIN1*)**R* + *AMIN1* if *ID1* = 2
where *R* is a random number generated from a *U*(0,1) distribution utilizing *IN1* as the first seed and then the updated *IN1* in subsequent generations.

T2P = 0 if *ID2* = 1 (3.3)
= (*AMAX2*-*AMIN2*)**R* + *AMIN2* if *ID2* = 2
where *R* is a random number generated from a *U*(0,1) distribution utilizing *IN2* as the first seed and then the updated *IN2* in subsequent generations.

$$TTM = TAM + TAMP + T1 + T1P + T2 + T2P + \max \left\{ \max_{k} \left[AMAXSC_{6,k} \right]^{*}, \max_{k} \left[TSCP_{6,k} \right]^{**} \right\} \quad (3.4)$$

where $TSCP_{6,k}$ records the last time that the kth $(k = 1,2...K)$ ship unloading area became free.

$$TSCP_{j_2,k} = 0 \quad \text{if } IDSC_{j_2,k} = 1 \quad (3.5)$$

$$= \left[AMAXSC_{j_2,k} - AMINSC_{j_2,k} \right] * R + AMINSC_{j_2,k}$$

$$\text{if } IDSC_{j_2,k} = 2$$

where R is a random number generated from a $U(0,1)$ distribution utilizing $INSC_{j_2,k}$ $(j_2 = 1,2...5,7,8,9;$ $k = 1,2...K)$ as the first seed and then the updated $INSC_{j_2,k}$ in subsequent generations.

$TSC_{6,k}$, $AMAXSC_{6,k}$ The relationships of $TSC_{6,k}$, $AMAXSC_{6,k}$ with the other problem variables are too cumbersome to be written in the form of mathematical equations, and so the reader is referred to the listing of the computer program, where the relationships in question are given in the form of computer coding. The mathematical form of these relationships can be obtained from the computer coding, if so desired, and it is similar to the form of equation (3.4). (3.6, 3.7)

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*The magnitude of $AMAXSC_{6,k}$ at the conclusion of the mission of the kth S.U.F.

**The magnitude of $TSCP_{6,k}$ immediately after the last of the N_k payload units has been unloaded and secured in the appropriate T.V., and after the T.V. in question has been unhooked and made ready to depart for W.A.II.

$$TBCP_{j_4,\ell} = 0 \quad \text{if } IDBC_{j_4,\ell} = 1 \tag{3.8}$$

$$= \left[AMAXBC_{j_4,\ell} - AMINBC_{j_4,\ell}\right] * R + AMINBC_{j_4,\ell}$$

if $IDBC_{j_4,\ell} = 2$
where R is a random number generated from a $U(0,1)$ distribution utilizing $INBC_{j_4,\ell}$ ($j_4 = 1,2,3,4,6,7...10;\ \ell = 1,2...L$) as the first seed and then the updated $INBC_{j_4,\ell}$ in subsequent generations.

$TBC_{5,\ell}$, $AMAXBC_{5,\ell}$ (3.9,10)

The comments given for equations (3.6) and (3.7) apply also for equations (3.9) and (3.10).

$$TTVP_{j_7,i} = 0 \quad \text{if } IDTV_{j_7,i} = 1 \tag{3.11}$$

$$= \left[AMAXTV_{j_7,i} - AMINTV_{j_7,i}\right] * R + AMINTV_{j_7,i}$$

if $IDTV_{j_7,i} = 2$

where R is a random number generated from a $U(0,1)$ distribution utilizing $INTV_{j_7,i}$ ($j_7 = 1,2...5,9,10...13,15,16,17;\ i = 1,2...I$) as the first seed and then the updated $INTV_{j_7,i}$ in subsequent generations.

$TTV_{j_{11},i}$, $AMAXTV_{8,i}$ (3.12-16)

$j_{11} = 3,8,12,14$

The comments given for equations (3.6) and (3.7) apply also for equations (3.12)-(3.16)

The above equations establish all the relationships that exist among the problem variables. Now we proceed with the discussion of the third topic in the Problem Definition, namely, the identification of the dependent and independent variables.

iii) Identification of the Dependent and Independent Variables

For reasons given in the previous section it is necessary, before we proceed any further, to classify the problem variables into dependent and independent ones. As a reminder, the independent variables are those variables which must be prescribed to completely describe our system as desired. The dependent variables are the ones remaining in our original list of variables after the independent ones have been removed. The value of the dependent variables can be obtained from the variable interrelationships.

The variable classification of dependent and independent variables can be accomplished in the following manner:

> For each interrelation, one of the variables involved is classed as a dependent variable and all the others are classed as independent variables. With this method, if the same variable is involved in more than one interrelation, it cannot be selected to serve as a dependent variable more than once.

In theory, any of the variables involved in an interrelation can be classed as a dependent variable. However, in practice, whenever it is possible we usually attempt to class as dependent variables the ones that allow us to simplify our methodology as much as possible, and we attempt to class as independent variables the ones which are the most meaningful to the user so he can assign their values with confidence. Whenever, as in our case, that is impossible because of the nature of the interrelations, we usually must compromise. The nature of the equations (3.1)-(3.16) forces us to class the variables appearing on the left-hand side of these equations as the dependent variations. However, although we have no choice in our selection, there was no compromise at all, as the resulting independent variables of our problem are both the most meaningful of the variables to the user, and at the same time they allow us to simplify our methodology the most.

So our dependent variables are:

$TAMP$, $T1P$, $T2P$, TTM,

$TSCP_{j_2,k}$, $TSC_{6,k}$, $AMAXSC_{6,k}$ $(j_2=1,2...5,7,8,9;k=1,2...K)$

$TBCP_{j_4,\ell}$, $TBC_{5,\ell}$, $AMAXBC_{5,\ell}$ $(j_4=1,2,3,4,6,7...10;\ell=1,2...L)$

$TTVP_{j_7,i}$, $TTV_{j_{11},i}$, $AMAXTV_{8,i}$ $(j_7=1,2...5,9,10...13,15,16,17;$
$j_{11}=3,8,12,14;\ i=1,2...I)$

and our independent variables are:

TAM, $T1$, $T2$, $IDMA$, $ID1$, $ID2$, $INMS$, $AMINM$, $AMAXM$, $IN1$, $AMIN1$, $AMAX1$, $IN2$, $AMIN2$, $AMAX2$,

N_k, WC_n, VC_n $\quad (k=1,2...K;\ n=1,2...\sum_{k=1}^{K} N_k)$

K, $ISUD$, $ISCSL$, $TSC_{j_2,k}$, $IDSC_{j_2,k}$, $INSC_{j_2,k}$, $AMINSC_{j_2,k}$, $AMAXSC_{j_2,k}$ $\quad (j_2=1,2...5,7,8,9;\ k=1,2...K)$

L, $IBUD$, $IBCSL$, $TBC_{j_4,\ell}$, $IDBC_{j_4,\ell}$, $INBC_{j_4,\ell}$, $AMINBC_{j_4,\ell}$, $AMAXBC_{j_4,\ell}$ $\quad (j_4 = 1,2,3,4,6,7...10;\ \ell=1,2...L)$

I, $IWA1SL$, $IWA2SL$, $AMAXTV_{6,i}$, $AMAXTV_{7,i}$, $TTV_{j_6,i}$, $IDTV_{j_7,i}$, $INTV_{j_7,i}$, $AMINTV_{j_7,i}$, $AMAXTV_{j_7,i}$, $WT1MAX$, $WT2MAX$, $IDBRTV_{j_9,i}$, $INBRTV_{j_9,i}$, $BRKTV_{j_9,i}$

$(j_6=1,2,4,5,6,7,9,10,11,13,15,16,17;\ j_7=1,2...5,9,10...$
$...13,15,16,17;\ j_9=1,2...8;\ i=1,2...I)$

TIME, *WGHT* and *VOL*.

The above completes our discussion about the identification of the dependent and independent variables of our problem, and now we may proceed with discussion of the establishment of the range of variation of our problem's parameters.

iv) Establishment of the Range of Variation of the Problem Parameters

For the reasons given in the previous section, it was found necessary to introduce limitations on the range of variation of our problem's parameters. The limitations introduced in our study* are enumerated and explained below. Methods for alleviating each limitation when it is found unacceptable are also given below, whenever it is deemed necessary. For clearer understanding of certain of the limitations listed below, the user is advised to refer to Fig. 3.1, where the subsystems involved in our study are shown diagrammatically.

1. The entire operation is assumed to have started** either when the mother ship arrives at the theater of operations or when one or more T.V. or B.U.F. start from their bases, whichever is sooner. This limitation can be alleviated easily by assuming that the entire operation commences at any prespecified time, as desired.

2. The entire operation finishes when the mother ship is freed from its moorings and is ready to depart, and all the T.V. and B.U.F. reach their appropriate bases. This limitation

*Please note that great care was taken in introducing the limitations on the range of variation of our problem's parameters so that they satisfy all the requirements about model universality, etc., given in Section 2 of the report.

**At the start of the operation the time counter in our program is initialized to zero.

can be alleviated easily by assuming that the entire operation terminates at any prespecified time, as desired.

3. As was already noted in the discussion of the first topic of this section, limitations of the form $y_{min} \leq y \leq y_{max}$ (where y is any of our independent variables or NCASES and NRUNS) were introduced controlling the magnitude variation of the different problem parameters. These limitations can be alleviated by changing the format and/or the dimension statements in the computer program.

4. The mission of each S.U.F. is such that it does not interfere with that of any other S.U.F.

5. Each of the K S.U.F. is assumed to complete its mission without any technical difficulties. This limitation can be alleviated by introducing breakdown considerations similar to those introduced for the T.V.

6. Each of the K S.U.F. requires no refuelling during its entire operation.

7. The unloading at the ship may be sequential or in parallel, but not both. In addition, the unloading mode at the ship is independent of that at the beach. Moreover, in the parallel unloading mode, the S.U.F. performance is not influenced by the number of S.U.F. that happen to be unloading at any instant of time.

8. The times $TSC_{2,3,4,5;k}$ depend on the S.U.F. characteristics only, and are independent of the payload unit they are to service.

9. The time $TSC_{7,k}$ depends on the S.U.F. characteristics only, and is independent of the payload unit that is being unloaded and the T.V. into which the payload unit in question is being loaded.

10. The payload units capable of self-induced rolling motion may be loaded into the T.V. by ramps. When this is done, the ramps are treated as regular S.U.F. and the times $TSC_{j_2,k'}$, $(j_2 = 1,2...5,7,8,9;\ k'=I.D.\ of\ ramps)$ of each ramp are determined by averaging the unloading characteristics of the payload units that are to be unloaded by the ramp in question.

11. Each payload unit loaded at the area associated with the kth $(k = 1,2...K)$ S.U.F. can be unloaded only by the kth S.U.F.

12. The kth $(k = 1,2...K)$ S.U.F. is assumed to be able to handle the heaviest and bulkiest payload unit that is loaded in the area that is associated with the S.U.F. in question.

13. Only one payload unit may be handled by a S.U.F. at any one time.

14. Once a T.V. hooks up at the kth $(k = 1,2...K)$ ship unloading area, only the kth S.U.F. may load it.

15. Each of the I T.V. may hook up at one ship unloading area only during the execution of any one of its trips.

16. Each of the K S.U.F. continues to load in any of the I T.V. during the execution of any one of its trips until
    - i) no more payload units can be loaded into the T.V. in question, because the weight capacity of the T.V. will be exceeded, or
    - ii) no more payload units can be loaded into the T.V. in question because the volume capacity of the T.V. will be exceeded, or
    - iii) there are no more payload units to be unloaded by the S.U.F. in question, or
    - iv) any combination of the above statements becomes true.

17. The mission of each B.U.F. is such that it does not interfere with that of any other B.U.F.

18. Each of the L B.U.F. is assumed to complete its mission without any technical difficulties. This limitation can be alleviated by introducing breakdown considerations similar to those introduced for the T.V.

19. Each of the I B.U.F. requires no refuelling during the entire operation.

20. The unloading at the beach may be sequential or in parallel, but not both. In addition, the unloading mode at the beach is independent of that at the ship. Moreover, in the parallel unloading mode the B.U.F. performance is not influenced by the number of B.U.F. that happens to be unloading at any instant of time.

21. Times $TBC_{6,7;\ell}$ depend on the B.U.F. characteristics only, and are independent of the payload unit that is being serviced and the T.V. from which the payload unit in question is being unloaded.

22. Time $TBC_{8,\ell}$ depends on the B.U.F. characteristics only, and is independent of the payload unit that is being serviced.

23. The payload units capable of self-induced rolling motion are unloaded from the T.V. by regular B.U.F. No special provisions have been made in this program to include any other type of beach unloading facilities.

24. Each of the L B.U.F. is assumed to be able to handle the heaviest and bulkiest payload unit.

25. Only one payload unit may be handled by B.U.F. at any one time.

26. Once a T.V. beaches at the ℓth $(\ell = 1,2...L)$ beach unloading area, only the ℓth B.U.F. may unload it.

27. Each of the *I* T.V. may beach at one beach unloading area only during the execution of any one of its trips.

28. Each of the *L* B.U.F. continues to unload from any of the *I* T.V. during the execution of any one of its trips until all the payload units carried by the T.V. in question in that particular trip have been unloaded.

29. When the *i*th $(i = 1,2...I)$ T.V. starts from its base it is assumed to have its normal fuel tanks fully loaded with fuel. In additional tanks that are so constructed as to not affect the volume of payload, sufficient fuel is carried to permit the *i*th T.V. to reach the W.A.I and then the appropriate ship unloading area where it hooks up and is made ready for the unloading operation, without using any of the fuel in the normal fuel tanks. Furthermore, it is assumed that the weight of this additional fuel is smaller than or equal to the weight of the payload.

30. The fuel stored in the regular fuel tanks must be sufficient to permit any T.V. to complete at least one round trip.

31. The fuel required for the T.V. to return to its base after execution of Step 11, as described in the mission of the *i*th $(i = 1,2...I)$ T.V. (see Section 4) is less than or equal to the fuel required for it to complete its round trip.

32. When a T.V. is to be refuelled, it is always refuelled completely.

33. The refuelling of the ith $(i = 1,2...I)$ T.V. is to be effected only when it is alongside the mother ship, and at whatever ship unloading area it is hooked up.

34. The fuel requirements of the T.V. while waiting in queues I and II, while hooked up alongside the mother ship, and while beached at the shore, are negligible.

35. The time $T_{5,i}$ depends on the T.V. characteristics only, and is independent of the ship unloading area that is being serviced.

36. Each of the I T.V. must be able to transport the heaviest and bulkiest payload unit in any of its trips.

37. The T.V. are to carry payload only when they are traveling between the mother ship and the beach. At all other times, they do not carry any payload.

38. The mission of each T.V. is such that it does not interfere with that of any other T.V.

39. None of the I T.V. requires the assistance of any of the S.U.F. to perform Steps 3 and 6 as described in the mission of the ith $(i = 1,2...I)$ T.V. (see Section 4).

40. None of the *I* T.V. requires the assistance of any of the B.U.F. to perform Steps 9 and 11 as described in the mission of the *i*th $(i = 1, 2 \ldots I)$ T.V. (see Section 4).

41. The times $T_{4,10,11;i}$ depend on the T.V. characteristics only, and are independent of the S.U.F. that is being serviced.

42. The time $T_{9,i}$ depends on the T.V. characteristics only, and is independent of the S.U.F. and the payload units that are being serviced.

43. The times $T_{13,16,17;i}$ depend on the T.V. characteristics only, and are independent of the B.U.F. that is being serviced.

44. Each T.V. must wait (even if it is for zero time) in queues I and II respectively until the appropriate unloading areas are free to receive them.

45. The breakdown considerations for processes 1, 3, 4, 6, 7 and 8 (see Table 3-1) are functions of *i* only and are time invariant.

46. The breakdown considerations of processes 2 and 5 (see Table 3-1) are functions of *i* and waiting time only and are again time invariant.

47. All steps (as described in the mission of the ith ($i = 1,2...I$) T.V.) that can be performed before the breakdown considerations forcibly remove a T.V. from our system, are executed. (It is important to be aware of this limitation so that the concept of antithetic variance be introduced correctly into our methodology. It can be relaxed at will by changing the computer program accordingly.)

48. When the ith ($i = 1,2...I$) T.V. is executing any other segment of its trip not covered by processes 1-8 of Table 3-1, it is assumed that it cannot malfunction.

The above completes our discussion of the fourth topic of the Problem Definition. We now proceed with the discussion of the final topic in the Problem Definition, namely, the Selection of the Figure of Merit.

v) Selection of the Figure of Merit

Finally, as was already stated in the two previous sections, the figure of merit (the measure of success) is the weighted combination of time and the level of risk and uncertainty. The above can be expressed mathematically as follows:

$$c = Minimize\ (W_1 T + W_2 U) \qquad (3.17)$$

where

c is the figure of merit,

W_1 & W_2 the weighting factors such that

$$0 \leq W_1, W_2 \leq 1$$

and $$W_1 + W_2 = 1,$$

T is the time component of the figure of merit involving the calculation of the maximum time elapsed since the start of the mission to

1. prepare the Mother Ship for departure after all the payload has been transferred to the T.V. and all T.V. have cleared the Mother Ship,

2. complete the payload transfer from the Mother Ship to point A on the beach,

3. return all T.V. to their bases,

4. return all B.U.F. to their bases,

i.e. $$T = \underset{\substack{k=1,2...K \\ \ell=1,2...L \\ i=1,2...I}}{Maximum} \left\{ TTM, AMAXSC_{6,k}, AMAXBC_{5,\ell}, AMAXTV_{8,i} \right\} \qquad (3.18)$$

and U is the level of risk and uncertainty component of the figure of merit involving the calculation of the percentage of T.V. that did not complete their mission (see Section 4) because of breakdown.

When our analysis involves no breakdown considerations, then U in equation (3.17) becomes zero and our figure of merit can simply be written as

$$c = Minimize\ (T)$$

which leads directly to the correct solution.

When breakdown considerations are involved in our analysis, however, equation (3.17) should be modified in order to give the correct measure of success for each case under investigation. This modification involves the normalization of the decision elements T and U to T' and U' , so that the normalized decision elements have the same effect on our decision.

One of the methods that can accomplish the above mentioned normalization is the following:

Let $$T' = \frac{T - T_{min}}{T_{max} - T_{min}} \quad (3.19)$$

and $$U' = \frac{U - U_{min}}{U_{max} - U_{min}} \quad (3.20)$$

where $$T_{min} \leq T \leq T_{max} \quad (3.21)$$

and $$U_{min} \leq U \leq U_{max}^{*} \quad (3.22)$$

where T_{min}, T_{max}, U_{min} and U_{max} can be determined after all the cases under investigation have been completed.

*When no breakdown considerations are involved in our analysis $U_{min} = U = U_{max} = 0$

Thus the mathematical form of the figure of merit used for our study is

$$c = \textit{Minimize}\ (W_1\ T' + W_2\ U') \qquad (3.23)$$

which always leads to the desired solution regardless of whether breakdown considerations are included in our study or not.

The above completes the discussion on the Problem Definition, and now we may proceed with the discussion on the formulation of the Mathematical Model for our system.

vi) Breakdown Considerations

If $IDBRTV_{j_g,i} = 1$ ($j_g = 1,2...8$; $i = 1,2...I$) there are no breakdown considerations involved in our analysis for the part of the journey of the ith T.V. described by the j_gth process, and so the discussion given here does not apply for that T.V. and that part of its journey.

Before the ith T.V. is allowed to complete its journey to W.A.I from its base, a random number, R, is generated from the appropriate distribution, as dictated by $IDBRTV_{1,i}$, utilizing $INBRTV_{1,i}$ as the first seed*. If

$$R < BRKTV_{1,i} \tag{4.1}$$

then the ith T.V. is assumed lost from our system. If equation (4.1) is not satisfied, then the ith T.V. is allowed to enter W.A.I and it is assumed that no breakdown has occurred in the part of the journey of the ith T.V. described above.

In the mathematical model of our system, a record of the T.V. lost at this stage is kept. If, at the end of the Mother Ship's mission, any of these T.V. has not been selected at all by the appropriate T.V. use strategy for W.A.I, a note to the user is given stating that fact.

Before the ith T.V. is allowed to depart from W.A.I, a random number, R, is generated from the appropriate

*The updated $INBRTV_{1,i}$ are used as the seeds of subsequent generations.

distribution, as dictated by $IDBRTV_{2,i}$ utilizing $INBRTV_{2,i}$ as the first seed*.

If

$$R < \frac{TTVP_{6,i}}{WT1MAX} * BRKTV_{2,i} \qquad (4.2)$$

where $TTVP_{6,i}$ = total waiting time of the ith T.V. in W.A.I in this trip of the T.V. in question.

$$\text{if} \qquad TTVP_{6,i} < WT1MAX \qquad (4.3)$$

$$\text{or if} \qquad R < BRKTV_{2,i} \qquad (4.2)$$

$$\text{if} \qquad TTVP_{6,i} \geq WT1MAX \qquad (4.3)$$

then the ith T.V. is assumed lost from our system. If equation (4.2) is not satisfied, then the ith T.V. is allowed to depart from W.A.I for the appropriate ship unloading area and it is assumed that no breakdown has occurred while the T.V. in question was waiting in W.A.I.

Before the ith T.V. is allowed to reach the appropriate ship unloading area from W.A.I, a random number, R, is generated from the appropriate distribution, as dictated by $IDBRTV_{3,i}$, utilizing $INBRTV_{3,i}$ as the first seed**.

If

$$R < BRKTV_{3,i} \qquad (4.4)$$

then the ith T.V. is assumed lost from our system. If equation (4.4) is not satisfied then the ith T.V. is allowed to reach

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*The updated $INBRTV_{2,i}$ are used as the seeds of subsequent generations.

**The updated $INBRTV_{3,i}$ are used as the seeds of subsequent generations.

the ship unloading area in question and it is assumed that no breakdown has occurred in the part of the trip of the ith T.V. described above.

Before the ith T.V. is allowed to reach W.A.II from the appropriate ship unloading area, a random number, R, is generated from the appropriate distribution, as dictated by $IDBRTV_{4,i}$, utilizing $INBRTV_{4,i}$ as the first seed*.

If $$R < BRKT_{4,i} \tag{4.5}$$

then the ith T.V. is assumed lost from our system. If equation (4.5) is not satisfied, then the ith T.V. is allowed to enter W.A.II and it is assumed that no breakdown has occurred in the part of the trip of the ith T.V. described above.

Before the ith T.V. is allowed to depart from W.A.II, a random number, R, is generated from the appropriate distribution, as dictated by $IDBRTV_{5,i}$, utilizing $INBRTV_{5,i}$ as the first seed**.

If $$R < \frac{TTVP_{6,i}}{WT2MAX} * BRKTV_{5,i} \tag{4.6}$$

where $TTVP_{6,i}$ = total waiting time of the ith T.V. in W.A.II in this trip of the ith T.V.

if $$TTVP_{6,i} < WT2MAX \tag{4.7}$$

or if $$R < BRKTV_{5,i} \tag{4.6}$$

if $$TTVP_{6,i} \geq WT2MAX \tag{4.7}$$

*The updated $INBRTV_{4,i}$ are used as the seeds of subsequent generations.

**The updated $INBRTV_{5,i}$ are used as the seeds of subsequent generations.

then the ith T.V. is assumed lost from our system. If equation (4.6) is not satisfied, then the ith T.V. is allowed to depart from W.A.II for the appropriate beach unloading area and it is assumed that no breakdown has occurred while the T.V. in question was waiting in W.A.II.

Before the ith T.V. is allowed to reach the appropriate beach unloading area from W.A.II, a random number, R, is generated from the appropriate distribution, as dictated by $IDBRTV_{6,i}$, utilizing $INBRTV_{6,i}$ as the first seed*. If

$$R < BRKTV_{6,i} \tag{4.8}$$

then the ith T.V. is assumed lost from our system. If equation (4.8) is not satisfied, then the ith T.V. is allowed to reach the beach unloading area in question and it is assumed that no breakdown has occurred in the part of the trip of the ith T.V. described above.

Before the ith T.V. is allowed to reach W.A.I from the appropriate beach unloading area, a random number, R, is generated from the appropriate distribution, as dictated by $IDBRTV_{7,i}$, utilizing $INBRTV_{7,i}$ as the first seed**. If

$$R < BRKTV_{7,i} \tag{4.9}$$

* The updated $INBRTV_{6,i}$ are used as the seeds of subsequent generations.

**The updated $INBRTV_{7,i}$ are used as the seeds of subsequent generations.

then the ith T.V. is assumed lost from our system. If equation (4.9) is not satisfied, then the ith T.V. is allowed to reach W.A.I and it is assumed that no breakdown has occurred in the part of the trip of the ith T.V. described above.

In our mathematical model the action taken as described above is forfeited for all the T.V. that happen to be in W.A.I immediately after the appropriate T.V. departed from W.A.I to load the last payload unit(s) from the Mother Ship. All these T.V. are assumed to have started for their respective bases at the times when they last started the execution of Step 11 given in the mission of the ith $(i = 1,2...I)$ T.V.

Before the ith T.V. is allowed to reach its base from the appropriate beach unloading area, a random number, R, is generated from the appropriate distribution, as dictated by $IDBRTV_{8,i}$, utilizing $INBRTV_{8,i}$ as the first seed*. If

$$R < BRKTV_{8,i} \tag{4.10}$$

then the ith T.V. is assumed lost from our system. If equation (4.10) is not satisfied, then the ith T.V. is allowed to reach its base and it is assumed that no breakdown has occurred in the part of the journey of the ith T.V. described above.

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* The updated $INBRTV_{8,i}$ are used as the seeds of subsequent generations.

vii) The Unloading Strategy of the Payload Units.

The payload units are first separated into K groups of N_k $(k = 1,2...K)$ units each. Next, the payload units of the first group are identified by distinct and ascending numbers. The numbers start from 1 and finish at N_1. Then the payload units of the second group are similarly identified by numbers starting from $(1+N_1)$ to (N_1+N_2). In the same manner, the payload units of the kth group are identified by numbers from $\left(1+\sum_{j=1}^{k-1} N_j\right)$ to $\left(\sum_{j=1}^{k} N_j\right)$ and so on, until the last payload unit of the last group is identified as the $\left(\sum_{j=1}^{K} N_j\right)$th payload unit. Once the above mentioned identification is complete, the payload units are loaded into the Mother Ship in the following manner. For each group*, the payload unit with the smallest identification number is loaded first into the appropriate location in the Mother Ship. After that, the j_kth payload unit of each of the K groups is loaded immediately after the (j_k-1)th payload unit of the same group into the appropriate location in the Mother Ship, where $2 + \sum_{j=1}^{k-1} N_j \leq j_k \leq \sum_{j=1}^{k} N_j$. This operation continues until all payload units have been loaded into the Mother Ship.

*Note that the loading operations of each of the K groups are totally independent of one another. The only point of interest to us is the loading order of the payload units of each of the K groups.

The unloading strategy we adopted for this study is the following. The payload units of each of the K groups* are to be unloaded in the exact reverse of the order in which they were loaded into the Mother Ship. Also, the payload units are to be unloaded at the beach in the exact reverse of the order in which they were loaded in the T.V. in question.

*The unloading sequences of each of the K groups are totally independent of one another.

viii) T.V. Use Strategy *A* for W.A.I.

This use strategy (see subroutine *ASLTVA*) is the first of the strategies incorporated in the mathematical model for selecting T.V. from W.A.I. It is basically a first come, first served strategy and is oriented towards volume-limited T.V. The T.V. selection is governed by the following rules:

1. First come, first selected*. In the event of a tie select the
2. T.V. with the biggest (available volume/time)**. In the event of a further tie select the
3. T.V. with the biggest (available weight capacity/time)***. In the event of a further tie select the
4. T.V. with the biggest available volume. In the event of a further tie select the
5. T.V. with the biggest available weight capacity. In the event of a further tie select the
6. Speedier**** T.V. In the event of a further tie select the
7. T.V. with the smallest identification.

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*Not necessarily in effect if the T.V. selected cannot be serviced immediately. All T.V. available in W.A.I before the appropriate ship unloading area is free are equally eligible as far as the first rule is concerned.

**Available volume specified by $AMAXTV_{7,i}$ $(i=1,2...I)$, time as measured by $(TTV_{4,i} + TTV_{10,i} + TTV_{11,i};\ i=1,2...I)$.

***Available weight capacity specified by $AMAXTV_{6,i}$ $(i=1,2...I)$

****Speed measured by the above mentioned time, noting that the smaller $(TTV_{4,i} + TTV_{10,i} + TTV_{11,i};\ i=1,2...I)$, then the speedier the T.V. is.

ix) T.V. Use Strategy *B* for W.A.I.

This use strategy (see subroutine *ASLTVB*) is the second of the strategies incorporated in the mathematical model for selecting T.V. from W.A.I.

It is again basically a first come, first served strategy but is oriented towards weight-limited T.V.

The T.V. selection is governed by the same rules given for the T.V. use strategy *A* for W.A.I, with the exception that the second rule is interchanged with the third, and the fourth with the fifth.

x) T.V. Use Strategy *A* for W.A.II.

This use strategy (see subroutine *BSLTVA*) is the first of the strategies incorporated into the mathematical model for selecting T.V. from W.A.II*. It is basically a first come, first served strategy and is oriented towards volume-limited T.V. (For this reason, it is logical that this use strategy should be employed for the T.V. selection from W.A.II when use strategy *A* for W.A.I is employed to select T.V. from W.A.I.) The T.V. selection is governed by the following rules:

1. First come, first selected**. In the event of a tie select the
2. T.V. with the biggest (available volume/time)***. In the event of a further tie select the
3. T.V. with the biggest (available weight capacity/time)****. In the event of a further tie select the
4. T.V. with the biggest available volume. In the event of a further tie select the
5. T.V. with the biggest available weight capacity. In the event of a further tie select the

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*The T.V. selected from W.A.I is retained until a T.V. is available at an earlier time in W.A.II.

**Not necessarily in effect if the T.V. selected cannot be serviced immediately. All T.V. available in W.A.II before the appropriate beach unloading area is free are equally eligible as far as the first rule is concerned.

***Available volume specified by $AMAXTV_{7,i}$ $(i=1,2...I)$, time as measured by $(TTV_{13,i} + TTV_{15,i} + TTV_{16,i};\ i=1,2...I)$.

****Available weight capacity specified by $AMAXTV_{6,i}$ $(i=1,2...I)$.

6. T.V. with the biggest (utilized volume/time)*. In the event of a further tie select the
7. T.V. with the biggest (utilized weight capacity/time)**. In the event of a further tie select the
8. T.V. with the biggest utilized volume. In the event of a further tie select the
9. T.V. with the biggest utilized weight capacity. In the event of a further tie select the
10. Speedier*** T.V. In the event of a further tie select the
11. T.V. with the smallest identification.

---

*Utilized volume is measured by summing up the volume of each payload unit and its lashings carried by the T.V. in question in that particular trip, time as measured by $(TTV_{13,i} + TTV_{15,i} + TTV_{16,i};\ i=1,2...I)$.

**Utilized weight capacity is measured by summing up the weight of each payload unit and its lashings carried by the T.V. in question in that particular trip.

***Speed measured by the above mentioned time, noting that the smaller $(TTV_{13,i} + TTV_{15,i} + TTV_{16,i})$, then the speedier the T.V. is.

xi) T.V. Use Strategy *B* for W.A.II.

This use strategy (see subroutine *BSLTVB*) is the second of the strategies incorporated into the mathematical model for selecting T.V. from W.A.II*.

It is again basically a first come, first served strategy but is oriented towards weight-limited T.V. (For this reason, it is logical that this use strategy should be employed for the T.V. selection from W.A.II when use strategy *B* for W.A.I is employed to select T.V. from W.A.I.)

The T.V. selection is governed by the same rules given for the T.V. use strategy *A* for W.A.II with the exception that the second rule is interchanged with the third, the fourth with the fifth, the sixth with the seventh, and the eighth with the ninth.

*The T.V. selected from W.A.I is retained until a T.V. is available at an earlier time in W.A.II.

xii) S.U.F. Use Strategy *A*

This use strategy (see subroutine *SLSCA*) is the first of the strategies incorporated into the mathematical model for selecting S.U.F. It is a first come, first served strategy. The S.U.F. selection is governed by the following rules:

1. The S.U.F. whose associated ship unloading area is first free is first selected. In the event of a tie, select the
2. S.U.F. that has the most cargo to unload at the time the above mentioned tie occurred. In the event of a further tie select the
3. S.U.F. that will be ready to commence its unloading cycle first*. In the event of a further tie select the
4. Speedier** S.U.F. In the event of a further tie select the
5. S.U.F. with the smallest identification.

---

*A. S.U.F. is ready to commence its unloading cycle at the instant it reaches the ship unloading area associated with it for the first time or at any other time immediately after the S.U.F. in question is made ready to travel again after it has unloaded the appropriate payload unit into the appropriate T.V.

**Speed measured by the time ($TSC_{2,k} + TSC_{3,k} + TSC_{4,k} + TSC_{5,k} + TSC_{7,k}$; $k=1,2...K$), noting that the smaller this time, then the speedier the S.U.F. is.

xiii) S.U.F. Use Strategy *B*.

This use strategy (see subroutine *SLSCB*) is the second of the strategies incorporated into the mathematical model for selecting S.U.F. It is basically a first come, first served strategy.

The S.U.F. selection is governed by the same rules given for S.U.F. use strategy *A*, with the exception that Rule 1 is not necessarily in effect if the S.U.F. has to await the arrival of a T.V. in W.A.I. In that case, all S.U.F. whose associated ship unloading areas are free before the arrival of the T.V. in question in W.A.I are equally eligible regarding the first rule.

xiv) B.U.F. Use Strategy *A*.

This use strategy (see subroutine *SLBCA*) is the first of the strategies incorporated into the mathematical model for selecting B.U.F. It is a first come, first served strategy. The B.U.F. selection is governed by the following rules:

1. The B.U.F. whose associated beach unloading area is first free is first selected. In the event of a tie select the
2. B.U.F. that will be ready to commence its unloading cycle first*. In the event of a further tie select the
3. Speedier** B.U.F. In the event of a further tie select the
4. B.U.F. with the smallest identification.

---

*B.U.F. is ready to commence its unloading cycle at the instant it is made ready for travel after it has reached point A on the beach for the first time or, at any other time, after the appropriate payload unit has been released at point A on the beach and the B.U.F. has been made ready to travel again.

**Speed measured by the time $(TBC_{4,\ell} + TBC_{6,\ell} + TBC_{7,\ell} + TBC_{8,\ell};\ \ell=1,2...L)$ noting that the smaller the above mentioned time, then the speedier the B.U.F. is.

xv) B.U.F. Use Strategy *B*.

This use strategy (see subroutine *SLBCB*) is the second of the strategies incorporated into the mathematical model for selecting B.U.F. It is basically a first come, first served strategy.

The B.U.F. selection is governed by the same rules given for B.U.F. use strategy *A*, with the exception that Rule 1 is not necessarily in effect if the B.U.F. has to await the arrival of a T.V. in W.A.II. In that case, all B.U.F. whose associated beach unloading areas are free before the arrival of the T.V. in question in W.A.II are equally eligible regarding the first rule.

The above completes our description of the formulation of the mathematical model for our study. We now proceed with a discussion of the solution method.

4. Formulation of the Mathematical Model

Instead of presenting the mathematical equations that make up the mathematical model for our study, the mission of each subsystem involved, the breakdown considerations, and the description of the use strategies are given. The reason for choosing this approach in describing the formulation of our mathematical model is because we achieve our goal more easily, as the nature of the underlying mathematical equations makes them very cumbersome to write. If the user desires to write the mathematical equations of the model, he can do so by referring to the computer code appended at the end of this study, or by translating the descriptions given here in the form of mathematical equations.

As was stated in the second section of this report, the mathematical model of our study is so formulated as to be an exact replica of the system under consideration to the degree of accuracy and extent desired. Also, because of the type of problem we are dealing with, the nature of the model is stochastic. In setting up the mathematical model, care was taken to keep it as simple as possible to permit easy analysis and yet to construct it so that it exhibits all the phenomena under consideration, as required.

The description of the formulation of our mathematical model is presented in the following manner:

i) Description of the mission of the Mother Ship.

ii) Description of the unloading procedure of the nth ($n = 1, 2 \ldots \sum_{k=1}^{K} N_k$) payload unit.

iii) Description of the mission of the kth ($k = 1, 2 \ldots K$) S.U.F.

iv) Description of the mission of the ℓth ($\ell = 1, 2 \ldots L$) B.U.F.

v) Description of the mission of the ith ($i = 1, 2 \ldots I$) T.V.

vi) Description of the breakdown considerations.

vii) Description of the payload unloading strategies.

viii) Description of the T.V. use strategy A for W.A.I.

ix) Description of the T.V. use strategy B for W.A.I.

x) Description of the T.V. use strategy A for W.A.II.

xi) Description of the T.V. use strategy B for W.A.II.

xii) Description of the S.U.F. use strategy A.

xiii) Description of the S.U.F. use strategy B.

xiv) Description of the B.U.F. use strategy A.

xv) Description of the B.U.F. use strategy B.

i) Mission of the Mother Ship.

Step 1. The Mother Ship arrives at the theater of operations.

Step 2. The Mother Ship is properly moored in position after it arrives at the theater of operations. Upon completion of this step, all ship unloading areas become free for the first time.

Step 3. The Mother Ship is freed from its moorings and is made ready to travel after all S.U.F. are secured in position and all T.V. have cleared the Mother Ship.

Upon completion of Step 3 given above, the Mother Ship's mission is completed.

ii) Unloading Procedure of the *n*th $(n = 1,2 ... \sum_{k=1}^{K} N_k)$ Payload Unit.

Step 1 The *n*th payload unit is released after the appropriate S.U.F. has reached the payload unit in question.

Step 2 The *n*th payload unit is secured on the appropriate S.U.F. after the payload unit in question has been released.

Step 3 The *n*th payload unit is transported to the appropriate ship unloading area after it has been secured on the S.U.F. in question.

Step 4 The *n*th payload unit is unloaded into the appropriate T.V. and then freed from the S.U.F. in question. This operation is performed only if

a) the appropriate T.V. has been properly secured in the ship unloading area and has been made ready for the loading operation and has completed its refueling (if refueling was necessary),

b) the previous payload unit unloaded by the S.U.F. in question is fully secured in the T.V. in question (this requirement is void if the *n*th payload unit is the first payload unit to be unloaded in any of the T.V.'s trips), and

c) the T.V.'s remaining capacity can accept the *n*th payload unit.

If that is not the case the *n*th payload unit will have to wait in the appropriate ship unloading area until the above requirements are satisfied.

<u>Step 5</u> The *n*th payload unit is secured in position on the T.V. in question after it has been freed from the appropriate S.U.F.

<u>Step 6</u>* The *n*th payload unit is transported to W.A.II from the appropriate ship's unloading area. This operation is performed only if

a) the capacity of the T.V. in question is such that it cannot accept the next payload unit or

b) the *n*th payload unit was the last payload unit associated with the S.U.F. in question. If thatis not the case, the *n*th payload unit will wait alongside the ship unloading area in question until one or both of the above requirements are satisfied. In addition, please note that the operation involved in Setp 6 is performed after

   a) the last payload unit unloaded into the T.V. in question in any of its trips has been properly secured, and

   b) after the T.V. in question has been unhooked from the appropriate ship unloading area and has been made ready for travel.

*Steps 6-11 will not be executed if the T.V. in question breaks down while on route to W.A.II from the Mother Ship. The *n*th payload unit together with the T.V. in question is then assumed lost from our system.

<u>Step 7</u>* The *n*th payload unit waits in W.A.II after it has arrived there until the appropriate B.U.F. is ready to receive the T.V. that carries the payload unit in question.

<u>Step 8</u>**The *n*th payload unit is transported to the appropriate beach unloading area from W.A.II after it has waited there appropriately until the beach unloading area in question is freed.

<u>Step 9</u> The *n*th payload unit is released, utilizing the appropriate B.U.F. The operation is performed only if the T.V. in question is beached and ready to commence the unloading operation, and the appropriate B.U.F. has reached the appropriate beach unloading area. If that is not the case, the releasing of the *n*th payload unit has to wait until the above requirements are satisfied.

<u>Step 10</u> The *n*th payload unit is secured on the appropriate B.U.F. after it has been released.

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*Steps 7-11 will not be executed if the T.V. in question breaks down while waiting in W.A.II. The *n*th payload unit together with the T.V. in question is then assumed lost from our system.

**Steps 8-11 will not be executed if the T.V. in question breaks down while on route to the beach from W.A.II. The *n*th payload unit together with the T.V. in question is then assumed lost from our system.

Step 11 After the nth payload unit is secured on the appropriate B.U.F. it is

a) transported from the appropriate beach unloading area to point A on the beach by utilizing the appropriate B.U.F.,

b) unloaded at point A, and then

c) freed from the B.U.F. in question.

Upon completion of Step 11 given above, the nth payload unit is considered to have reached its destination.

iii) Mission of the *k*th $(k = 1,2...K)$ S.U.F.

Step 1 The *k*th S.U.F. is made ready to start the unloading operation and is allowed to reach the *k*th ship unloading area after the Mother Ship is properly moored.

Step 2 The *k*th S.U.F. travels to the appropriate payload unit from the *k*th ship unloading area after it has been made ready to travel, or after the above step is completed.

Step 3 The *k*th S.U.F. releases the appropriate payload unit after the *k*th S.U.F. has reached the payload unit in question.

Step 4 The *k*th S.U.F. has the payload unit in question secured onto it after the payload unit in question has been released.

Step 5 The *k*th S.U.F. transports the payload unit in question to the *k*th ship unloading area after the above mentioned payload unit has been secured on the *k*th S.U.F.

Step 6 The *k*th S.U.F. unloads the payload unit in question into the appropriate T.V. and releases it, and then the *k*th S.U.F. is made ready to travel again. This operation is performed only if

a) the appropriate T.V. is properly secured in the kth ship unloading area and has been made ready for the loading operation and has completed its refueling (if refueling was necessary),

b) the previous payload unit unloaded by the kth S.U.F. is fully secured in the T.V. in question (this requirement is void if the payload unit in question is the first payload unit to be unloaded in any of the T.V.'s trips), and

c) the T.V.'s remaining capacity can accept the payload unit in question.

If any of the above is not satisfied, the kth S.U.F. must wait until all three requirements given above are satisfied.

Step 7. The kth S.U.F. is allowed to travel back to its original position from the kth ship unloading area and then be secured to its original position after all the N_k payload units have been unloaded into the T.V.

Upon completion of Step 7 given above, the mission of the kth S.U.F. is completed. Please note that when Steps 2-6 given above are executed, the kth S.U.F. is then said to have executed one unloading cycle. It then follows that during its mission, the kth S.U.F. will execute N_k unloading cycles. The completion of an unloading cycle automatically starts the next one until all N_k unloading cycles have been executed.

iv) Mission of the ℓth $(\ell = 1,2...L)$ B.U.F.

Step 1 The ℓth B.U.F. starts from its base having as its final destination point A on the beach.

Step 2 The ℓth B.U.F. is made ready to start the unloading operation after the ℓth B.U.F. has reached point A on the beach. Upon completion of this step, all beach unloading areas become free for the first time.

Step 3 The ℓth B.U.F. travels to the ℓth beach unloading area after it has been made ready to travel.

Step 4 The ℓth B.U.F. releases the appropriate payload unit after it has reached the ℓth beach unloading area. This operation, of course, is performed only if the appropriate T.V. is beached and is ready to commence the unloading operation. If that is not the case, the ℓth B.U.F. must wait for the T.V. in question to arrive, to be beached and to be made ready for the unloading operation.

Step 5 The ℓth B.U.F. has the payload unit in question secured onto it after the payload unit has been released.

Step 6 The ℓth B.U.F. (after the payload unit in question has been secured onto it) transports the payload unit in question from the ℓth beach unloading area to point A on the beach. After that, it releases the unit and the

B.U.F. in question is made ready to travel again.

<u>Step 7</u> The ℓth B.U.F. is secured in its original position and is prepared for departure after its unloading mission* has been completed.

<u>Step 8</u> The ℓth B.U.F. is allowed to return to its base after it has been prepared for departure.

Upon completion of Step 8 given above, the mission of the ℓth B.U.F. is completed. Please note that when Steps 3-6 given above are executed, the ℓth B.U.F. is said to have executed one unloading cycle. The completion of an unloading cycle automatically starts the next unloading cycle until the unloading mission of the B.U.F. in question has been completed.

*The unloading mission of the ℓth B.U.F. is assumed to be completed when the ℓth B.U.F. is not needed to unload any more payload units.

v) Mission of the *i*th $(i = 1,2...I)$ T.V.

Step 1* The *i*th T.V. starts from its base having as its final destination W.A.I, where it joins queue I.

Step 2** The *i*th T.V. waits in queue I after it arrives in W.A.I until the appropriate ship unloading area is freed.*** (As mentioned earlier at the start of the mission, as soon as the Mother Ship is moored, all ship unloading areas become free. Subsequently, a ship unloading area becomes free as soon as the T.V. that is being served alongside the ship unloading area in question is unhooked and made ready to commence its journey to W.A.II.)

Step 3**** The *i*th T.V. departs from W.A.I for the Mother Ship where it hooks up to the appropriate ship unloading area as soon as it is reached, and then the *i*th T.V. is made ready for the loading operation. The T.V. in question departs from W.A.I only after the appropriate ship unloading area is free to receive it.

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*Steps 1-13 will not be executed if the T.V. in question breaks down while on route to W.A.I from its base. The *i*th T.V. is then assumed lost from our system.

**Steps 2-13 will not be executed if the T.V. in question breaks down while waiting in W.A.I. The *i*th T.V. is then assumed lost from our system.

***In the sequential loading mode when one ship unloading area is not free, then all ship unloading areas are considered busy.

****Steps 3-13 will not be executed if the T.V. in question breaks down while on route from W.A.I to the appropriate ship unloading area. The *i*th T.V. is then assumed lost from our system.

<u>Step 4</u> The *i*th T.V. is refuelled (if refueling is necessary).

<u>Step 5</u> The appropriate payload unit is secured onto the *i*th T.V. after the payload unit in question has been unloaded into the *i*th T.V. and freed from the appropriate S.U.F., and after the S.U.F. in question has been made ready to travel. If the time taken in this trip for the *i*th T.V. to secure the payload unit previously unloaded (if there was one) onto the *i*th T.V. is less than the time taken to execute Steps 2-5 given in the mission of the *k*th *(1,2...K)* S.U.F., then the *i*th T.V. waits until the above mentioned Steps 2-5 are completed.

<u>Step 6</u> The *i*th T.V. is unhooked from the ship unloading area in question and is made ready to travel after the last payload unit to be unloaded into the *i*th T.V. in this trip of the T.V. in question has been properly secured. (As mentioned earlier, upon completion of this step, the ship unloading area in question becomes free.)

<u>Step 7*</u> The *i*th T.V. starts from the ship unloading area in question having as its final destination W.A.II, where it joins queue II after it has been made ready to travel.

*Steps 7-13 will not be executed if the *i*th T.V. breaks down while on route from the ship unloading area in question to W.A. II. The payload that was being transported on this trip of the *i*th T.V. and the T.V. itself are then assumed lost from our system.

Step 8* The ith T.V. waits in queue II after it arrives at W.A.II, until the appropriate beach unloading area is freed**. (As mentioned earlier at the start of the mission, as soon as the ℓth $(\ell = 1,2...L)$ B.U.F. arrives at point A, the ℓth beach unloading area becomes free. Subsequently, a beach unloading area becomes free as soon as the T.V. that is being served at the beach unloading area in question is made ready to travel again for W.A.I or its base.)

Step 9*** The ith T.V. departs from W.A.II for the shore, where it beaches at the appropriate beach unloading area as soon as it is reached and then the ith T.V. is made ready for the unloading operation. The T.V. in question departs from W.A.II only after the appropriate beach unloading area is free to receive it.

---

*Steps 8-13 will not be executed if the T.V. in question breaks down while waiting in W.A.II. The payload that was being transported on this trip of the ith T.V. and the T.V. itself are then assumed lost from our system.

**In the sequential unloading mode, when one beach unloading area is not free, then all beach unloading areas are considered busy.

***Steps 9-13 will not be executed if the T.V. in question breaks down while on route from W.A.II to the appropriate beach unloading area. The payload that was being transported on this trip of the ith T.V. and the T.V. itself are then assumed lost from our system.

<u>Step 10</u> The appropriate payload unit is released from the *i*th T.V. by the appropriate B.U.F. after the B.U.F. in question has reached the *i*th T.V. Next, the appropriate payload unit is secured onto the B.U.F. in question. While the above mentioned B.U.F. is executing first the sixth and then the third step described in the mission of the ℓth $(\ell = 1,2...L)$ B.U.F., the *i*th T.V. waits in the beach unloading area in question until the above mentioned two steps are completed.

<u>Step 11</u> The *i*th T.V. is made ready to travel after the last payload unit carried by the *i*th T.V. in this trip of the T.V. in question has been secured onto the appropriate B.U.F. (As mentioned earlier upon completion of this step the beach unloading area in question becomes free.)

Step 12* The *i*th T.V. starts from the beach unloading area in question having as its final destination W.A.I, where it joins queue I after it has been made ready to travel. This operation is performed only if the transporting mission** of the *i*th T.V. has not been completed.***

Step 13****The *i*th T.V. starts from the beach unloading area in question after it has been made ready to travel, having as its final destination the T.V.'s base.

Upon completion of Step 13 given above, the mission of the *i*th T.V. is completed. Please note that when Steps 2-12 given above are executed, the *i*th T.V. is said to have executed one complete trip. The completion of a trip automatically starts the next trip until the transporting mission of the T.V. in question is completed.

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*Steps 12 and 13 will not be executed if the *i*th T.V. breaks down while on route from the beach unloading area in question to W.A.I. The *i*th T.V. is then assumed lost from our system.

**The transporting mission of the *i*th T.V. is assumed to be completed when the *i*th T.V. is not needed to transport any more payload units.

***In our mathematical model Step 12 is always executed as long as there is even one payload unit on board the Mother Ship. However, this action is forfeited for all the T.V. that happen to be in W.A.I immediately after the appropriate T.V. departed W.A.I to load the last payload unit(s) from the Mother Ship.

****Step 13 will not be executed if the T.V. breaks down while on route from the beach unloading area in question to the T.V.'s base. The *i*th T.V. is then assumed lost from our system.

5. Solution Method

For the reasons given in Section 2, the method of digital simulation is selected to solve the problem under investigation. Because of the size of the problem, the use of digital computers is inevitable. The computer program for this method became most efficient when it was so structured that the main program served as a scheduler, passing control to the appropriate subroutine, which simulated the appropriate event at the time when control was passed. Collectively, the events simulate the entire mathematical model of our system. The definition of the events and of the scheduling mechanism used in our study is given below.

A) Event Definition

The events selected for our study are:

1. i) The arrival and mooring of Mother Ship,

   ii) The preparation of all S.U.F. for the unloading operation and their arrival at the appropriate ship unloading areas,

   iii) The arrival of all B.U.F. at point A on the beach and their preparation for the unloading operation, and

   iv) The arrival of all T.V. in W.A.I*.

2. a) The selection of a T.V. from W.A.I, or

   b) The selection of a T.V. from W.A.II.

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*If there are any breakdown considerations involved in our investigation for this part of the trip of the T.V. in question, then they must be taken into account.

3. a) The selection of a S.U.F. or

   b) The selection of a B.U.F.

4. a) The loading operation alongside the Mother Ship comprising

      i) Steps 2-4 of the mission of the ith $(i=1,2...I)$ T.V.*

      ii) Steps 2-6 of the mission of the kth $(k-1,2...K)$ S.U.F.**.

      iii) Steps 5-7 of the mission of the ith $(i=1,2...I)$ T.V.* or

   b) The unloading operation at the beach comprising

      i) Steps 8 and 9 of the mission of the ith $(i=1,2...I)$ T.V.*

      ii) Steps 3-6 of the mission of the ℓth $(\ell=1,2...L)$ B.U.F.

      iii) Steps 10-12 of the mission of the ith $(i=1,2...I)$ T.V.*

5. The closing of the entire operation *** by executing

      i) Event 2b,

      ii) Event 3b,

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*If there are any breakdown considerations involved in our investigation for this (these) part(s) of the trip of the T.V. in question, then they must be taken into account.

**Please note that as soon as the kth $(k=1,2...K)$ S.U.F. unloads its entire payload, step 7 of the mission of the kth $(k=1,2...K)$ S.U.F. is executed for the S.U.F. in question.

***This event is executed only when there are no more payload units to be unloaded from the Mother Ship.

iii) Steps 8 and 9 of the mission of the *i*th *(i=1,2...I)* T.V.* for all T.V. in W.A.II,

iv) Steps 3-6 of the mission of the *ℓ*th *(ℓ=1,2...L)* B.U.F.,

v) Steps 10 and 11 of the mission of the *i*th *(i=1,2...I)* T.V.* for all T.V. in W.A.II,

vi) Step 3 of the mission of the Mother Ship,

vii) Steps 7 and 8 of the mission of the *ℓ*th *(ℓ=1,2...L)* B.U.F., and

viii) Step 13** of the mission of the *i*th *(i=1,2...I)* T.V.*

B) <u>Scheduling Mechanism Definition</u>

The considerations leading to the definition of the scheduling mechanism that is to be used by the main program for scheduling the appropriate event at any given time are given below.

At the outset of our investigation it was found essential that our model should be provided with a simulation clock, which is to be used to record the start of an event execution, as this information was considered to be useful output. Next,

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*If there are any breakdown considerations involved in our investigation for this part of the trip of the T.V. in question, then they must be taken into account.

**The action taken by executing step 12 of the mission of the *i*th *(i=1,2...I)* T.V. is forfeited for all the T.V. that are in W.A.I when the execution of the fifth event commences.

it was noted that as our simulation is event structured, the simulation clock could also be used as the scheduling mechanism if

i) at the start of the entire operation the clock was initialized to a zero reference time,

ii) at subsequent times the clock was always updated to show the starting time of the last event executed, and

iii) the time at which an event is terminated is continuously updated.

This is so because we may now schedule the next event correctly by simply selecting the earliest available event after that just executed, as recorded by the simulation clock. The above description defines the scheduling mechanism employed in this study for scheduling the event that is to be executed at any given time.

In our mathematical model, once the correct event is decided by using the above mentioned method, the action taken is as follows:

Control is passed to the appropriate subroutine, which executes the event in question, updates all the relevant variables and the simulation clock, and then returns control to the scheduler, which repeats the above procedure until the fifth event is executed, terminating the analysis of the run under investigation.

From the above, it follows that because the simulation clock advances only in discrete jumps (including the zero jump), then we may collect any information relevant to the problem by examining the simulation only at the discrete times recorded by the simulation clock. This is so because no event may start at any other time, and as the entire simulation is represented by events, no additional information may be obtained by examining the simulation more frequently.

The above discussion completes our description of the event structure of our mathematical model and the scheduling mechanism, the two most important aspects of our method. All other aspects of our method, such as random number generation, tests for random number generators, etc., are not covered here as their treatment may be found elsewhere.

To permit the reader to fully understand the simulation process, a brief description of the computer program is given below, together with a general flow chart*, which will also serve to show the reader how to introduce new use strategies when this is found desirable.

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*For the sake of simplicity of presentation, the general flow chart does not include the breakdown considerations.

C. Computer Program Description.

MAIN

The MAIN program in our simulation serves as a scheduler, and operates as follows:

1. Reads the input specifying the number of cases to be processed by this computer run.
2. Passes control to Subroutine INPUT to read the input.
3. Passes control to Subroutine INOUT to print the input.
4. Initializes the model.
5. Passes control to Subroutine BEGIN to simulate the arrival of our resources in the theatre of operations.
6. Passes control to Subroutine ASLTVA or ASLTVB which in turn passes control to Subroutine BSLTVA or BSLTVB.
7. Passes control to Subroutine SLSCA or SLSCB or to Subroutine SLBCA or SLBCB, depending on the outcome of the above step.
8. Passes control to Subroutine LOAD or UNLOAD or repeats steps 6 and 7 given above, depending on the outcome of the two steps just mentioned.
9. Passes control to Subroutine FIN, which in turn passes control to Subroutines BSLTVA or BSLTVB and Subroutines SLBCA or SLBCB, until all T.V. in W.A.II are processed. Subroutine FIN then simulates the departure of our resources from the theatre of operations at the conclusion of our mission, and finally,

10. If no more runs are to be executed for the case under investigation, control is passed to Subroutine STATIC to compute the necessary statistics. If more runs are to be executed, steps 4-9 given above are repeated until the number of runs executed is equal to that prespecified.

It should be noted that the program is so arranged as to permit the processing of as many cases as is desired by simply providing the necessary input information. In addition, it should be noted that during the execution of any run, as soon as all transfer vehicles are found to be malfunctioning, the processing of this run is terminated and the processing of the next one (if any) is automatically started.

INPUT

This Subroutine reads all the input pertaining to the case under investigation.

The input for each case comprises:

1. The specification of the number of runs.
2. The specification of the units of the variables.
3. The specification of the variables defining the payload characteristics and its allocation.
4. The specification of the variables defining the Mother Ship characteristics.
5. The specification of the variables defining the S.U.F., the B.U.F. and the T.V.

In addition, the input specifies a) the loading mode at the Mother Ship, b) the unloading mode at the beach, and c) the use strategies to be used at each of the decision nodes. Furthermore, the input specifies whether a process is deterministic or stochastic. If the process is stochastic, the input designates the type of random number generator to be used, its seed, and the range of variation of the random numbers. Finally, the input indicates whether malfunctioning considerations are to be included in our analysis and, if so, supplies the necessary information.

Please note that, as was already mentioned in Section 3, the above input will be appropriately augmented in order to permit the specification of the statistical considerations and of the antithetic variance concept. These considerations and this concept will be developed in a separate report, which will follow the present one.

INOUT

This Subroutine, when developed, will print out all the input pertaining to the case under investigation. This subroutine has not yet been developed, as it is not needed for the computer program testing. Once the computer program is tested and its final form is decided, then the INOUT subroutine will be written. In this way, any changes and additions in the present input will be directly incorporated into INOUT with minimum labor.

RANDU

This Subroutine computes uniformly distributed random real numbers between zero and one. It is of the congruential type and is modeled after the subroutine listed in IBM's Scientific Subroutine Package*. With a seed equal to 65539, it has a cycle length of 2^{29} terms and it satisfies all the usual tests for randomness.

BEGIN

This Subroutine simulates the first event, described at the beginning of this section. If any breakdown considerations are to be included in this investigation for this part of the simulation, all T.V. found to be malfunctioning are refused entry into W.A.I.

ASLTVA

This Subroutine defines the first of the strategies incorporated in the model for selecting T.V. from W.A.I**. It is basically a first come, first served strategy and is oriented towards volume-limited transfer vehicles. The rules utilized by Subroutine ASLTVA for the above mentioned T.V. selection have already been given in Section 4 (see T.V. use strategy A for W.A.I).

*See the bibliography at the end of this report.

**Compare with event 2a, described at the beginning of this section.

ASLTVB

This Subroutine defines the second of the strategies incorporated in the model for selecting T.V. from W.A.I*. It is again basically a first come, first served strategy but is oriented towards weight-limited transfer vehicles. The rules utilized by Subroutine ASLTVB for the above mentioned selection have already been given in Section 4 (see T.V. use strategy B for W.A.I).

BSLTVA

This Subroutine defines the first of the strategies incorporated in the model for selecting T.V. from W.A.II**. It is basically a first come, first served strategy and is oriented towards volume-limited transfer vehicles. The rules utilized by Subroutine BSLTVA for the above mentioned T.V. selection have already been given in Section 4 (see T.V. use strategy A for W.A.II).

BSLTVB

This Subroutine defines the second of the strategies incorporated in the model for selecting T.V. from W.A.II.** It is again basically a first come, first served strategy but is oriented towards weight-limited transfer vehicles. The rules utilized

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*Compare with event 2a, described at the beginning of this section.

**Compare with event 2b, described at the beginning of this section.

by Subroutine BSLTVB for the above mentioned T.V. selection have already been given in Section 4 (see T.V. use strategy B for W.A.II).

SLSCA

This Subroutine defines the first of the strategies incorporated in the model for selecting S.U.F.* It is a first come, first served strategy. The rules utilized by Subroutine SLSCA for the above mentioned S.U.F. selection have already been given in Section 4 (see S.U.F. use strategy A).

SLSCB

This Subroutine defines the second of the strategies incorporated in the model for selecting S.U.F.*. It is basically a first come, first served strategy. The rules utilized by Subroutine SLSCB for the above mentioned S.U.F. selection have already been given in Section 4 (see S.U.F. use strategy B).

LOAD

This Subroutine simulates event 4a, described at the beginning of this section. If any breakdown considerations are to be included in this investigation for this part of the simulation, all T.V. found to be malfunctioning are refused departure from W.A.I, arrival at the ship unloading area in question, or entry into W.A.II, depending upon where the breakdown occurred.

*Compare with event 3a, described at the beginning of this section.

SLBCA

This Subroutine defines the first of the strategies incorporated in the model for selection B.U.F.* It is a first come, first served strategy. The rules utilized by Subroutine SLBCA for the above mentioned B.U.F. selection have already been given in Section 4 (see B.U.F. use strategy A).

SLBCB

This Subroutine defines the second of the strategies incorporated in the model for selecting B.U.F.* It is basically a first come, first served strategy. The rules utilized by Subroutine SLBCB for the above mentioned B.U.F. selection have already been given in Section 4 (see B.U.F. use strategy B).

UNLOAD

This Subroutine simulates event 4b, described at the beginning of this section. If any breakdown considerations are to be included in this investigation for this part of the simulation, all T.V. found malfunctioning are refused departure from W.A.II, arrival at the beach unloading area in question, or entry into W.A.I, depending upon where the breakdown occurred.

*Compare with event 3b, described at the beginning of this section.

FIN

This Subroutine simulates the fifth event, described at the beginning of this section. If any breakdown considerations are to be included in this investigation for this part of the simulation, all T.V. found malfunctioning are refused departure from W.A.II, arrival at the beach unloading area in question, or arrival at their bases, depending upon where the breakdown occurred.

STATIC

Provisions have been made to allow the introduction of subroutines which, when developed, will gather the sample points generated by our analysis, compute the statistics of interest, and output all quantities necessary for the final evaluation of alternative strategies. The development of these subroutines is deferred until the form of the desired output has been finalized, so that any changes and additions from the present output will be directly incorporated into STATIC with minimum labor.

The above, together with Fig. 5-1 (see next page) completes our discussion of the solution method. We now proceed with the discussion of the problem solution.

D. General Flow Chart

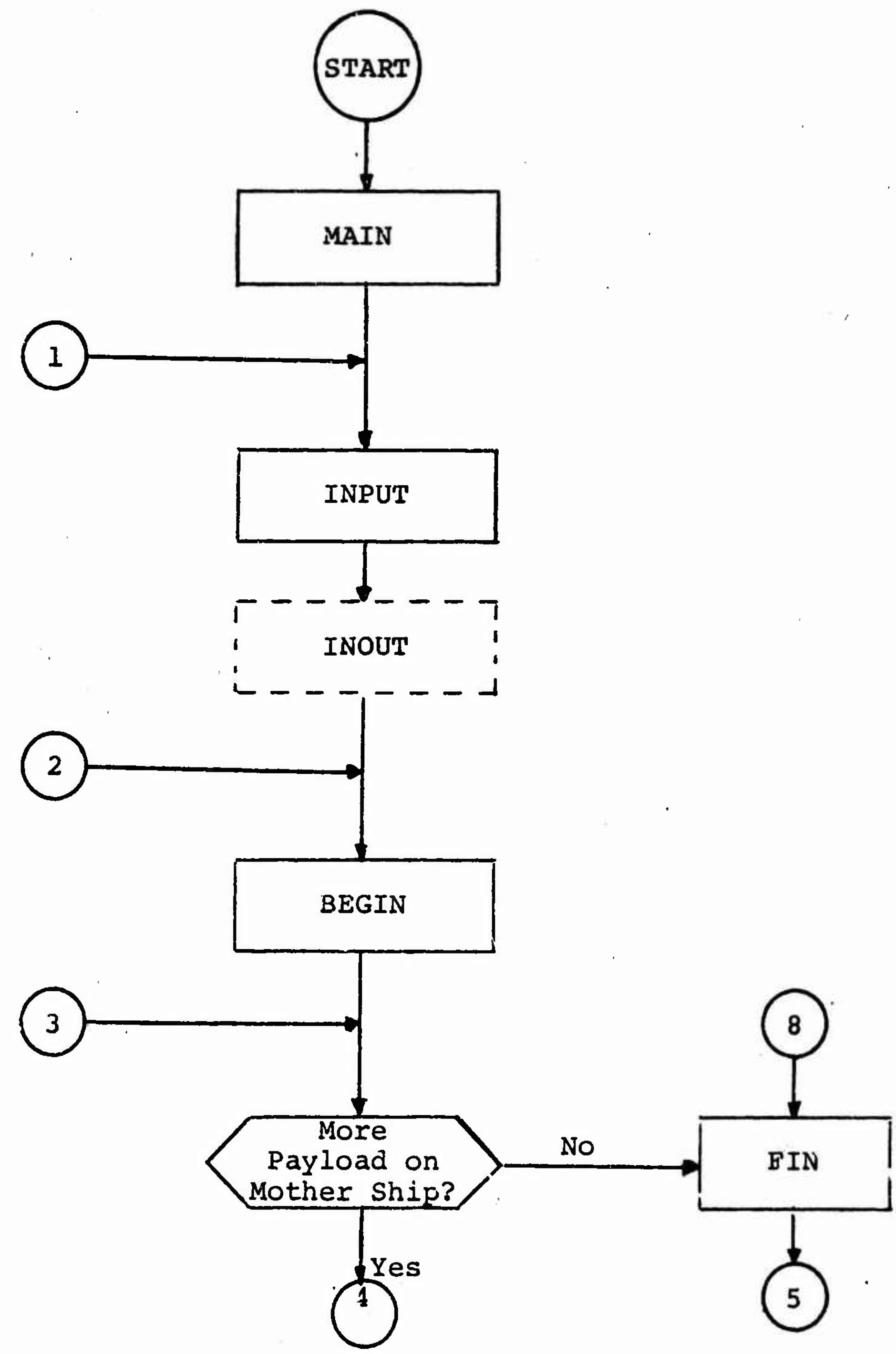


Fig. 5-1. General Flow Chart

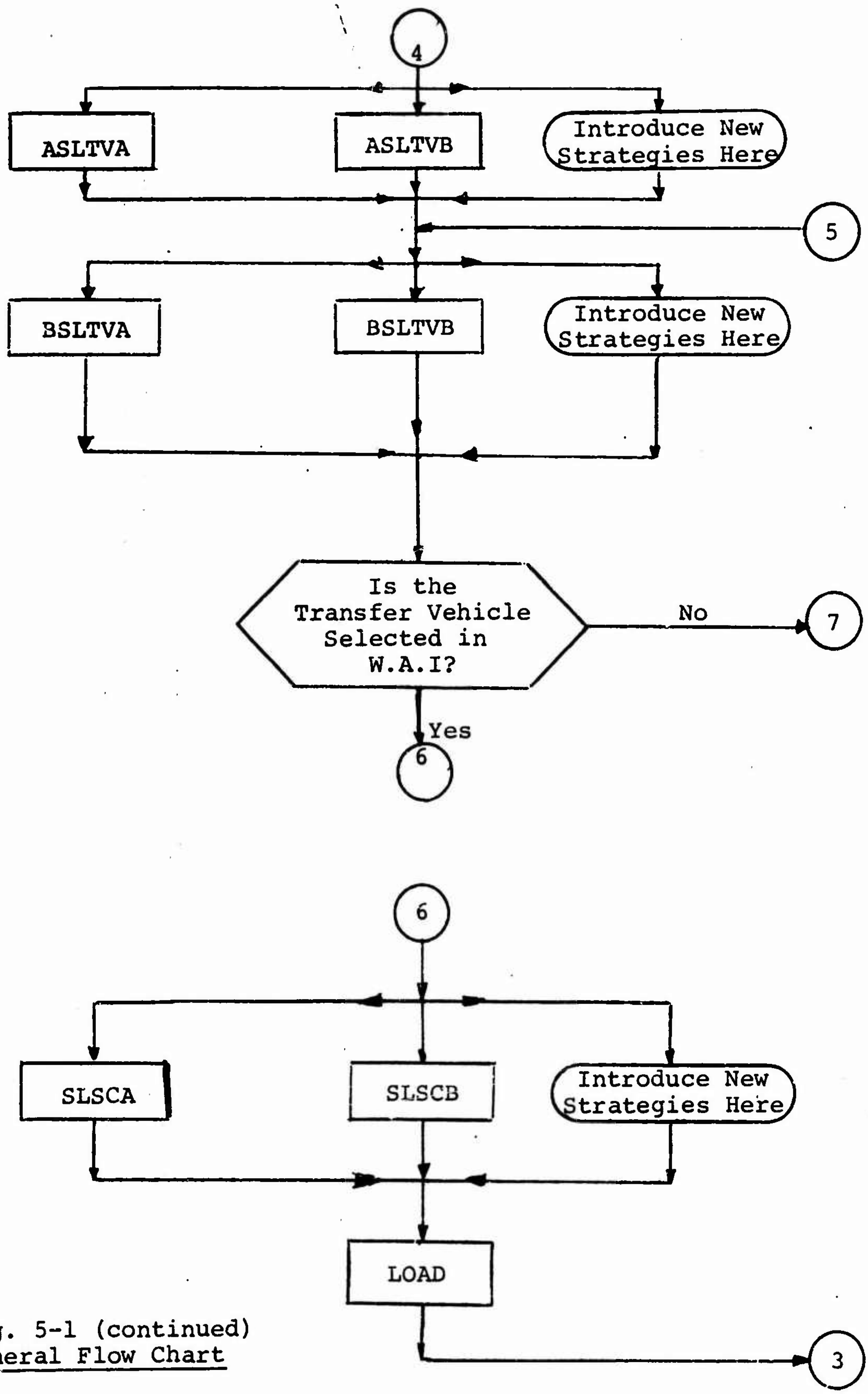


Fig. 5-1 (continued)
General Flow Chart

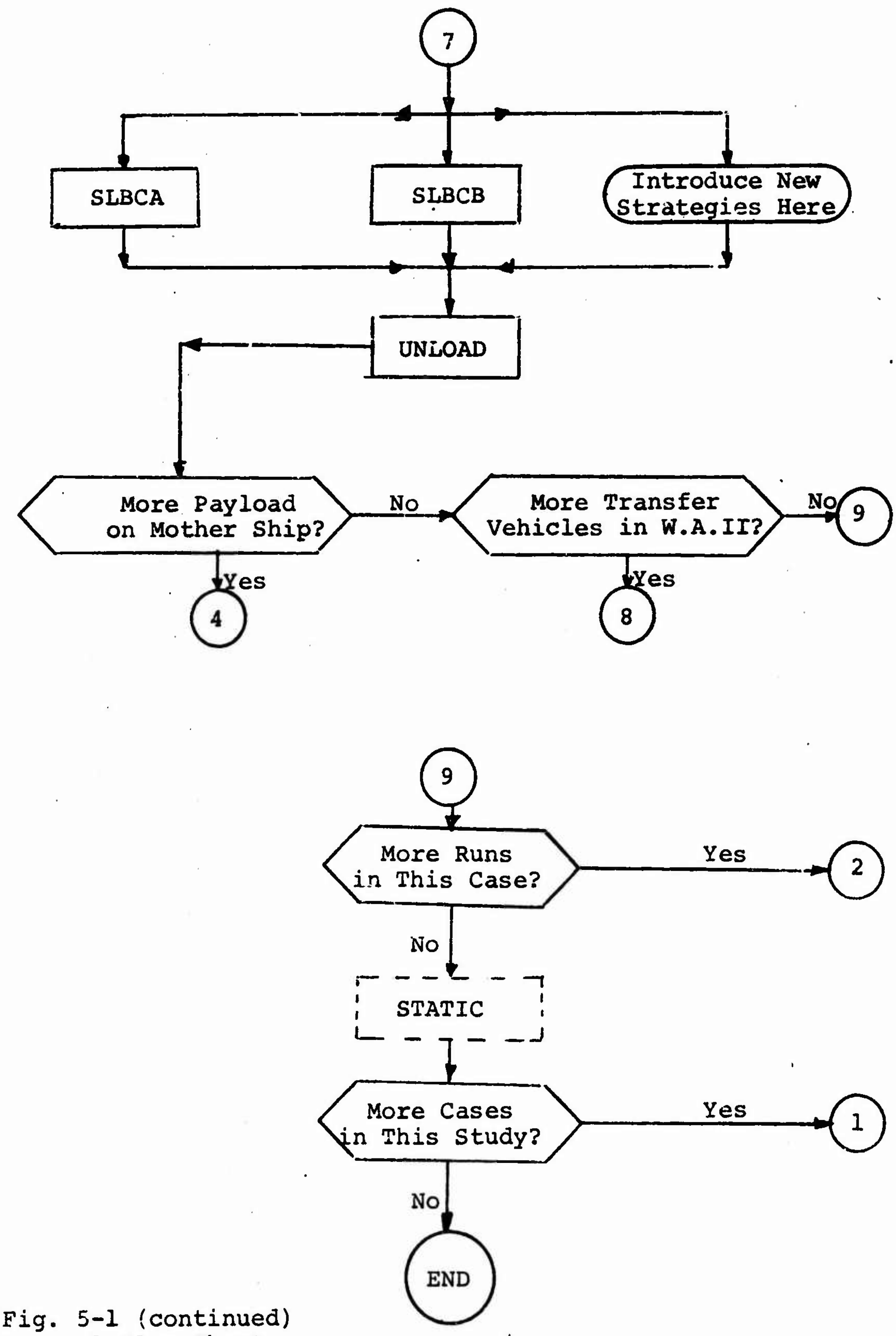


Fig. 5-1 (continued)
General Flow Chart

6. Problem Solution

The data setup for the computer program is shown in Figs. 6.1 - 6.17*, and must be followed if the computer program is to give a meaningful solution to the problem.

Because the development of the concept of antithetic variance is deferred until the next report, it is more profitable for us to delay the preparation of the input and the solution of the problem until then. It therefore follows that the last topic of the solution process, namely, the evaluation of results, must also be deferred until then.

The above completes the main body of this report. In the next and final section, future recommendations drawn from our analysis are given. Finally, in Appendix A of this report, the computer program** is listed for easy reference.

*The variables controlling the statistical considerations and the antithetic variance concept will be introduced in the next report.

**Please note that the computer program has been debugged, but its logic has not been exhaustively checked because it is more economical to await the development of the concept of the antithetic variance.

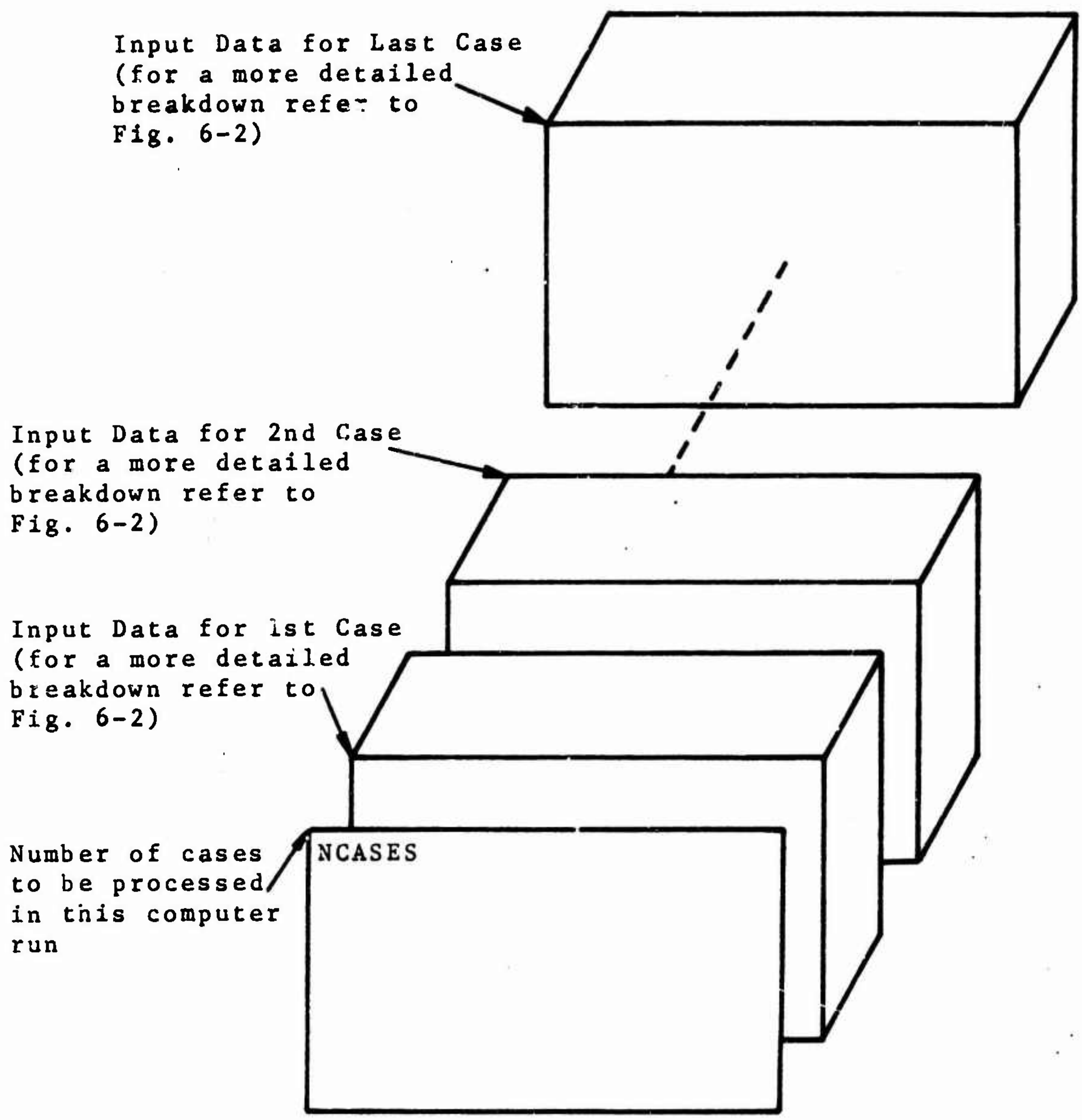


Fig. 6-1. General Data Setup

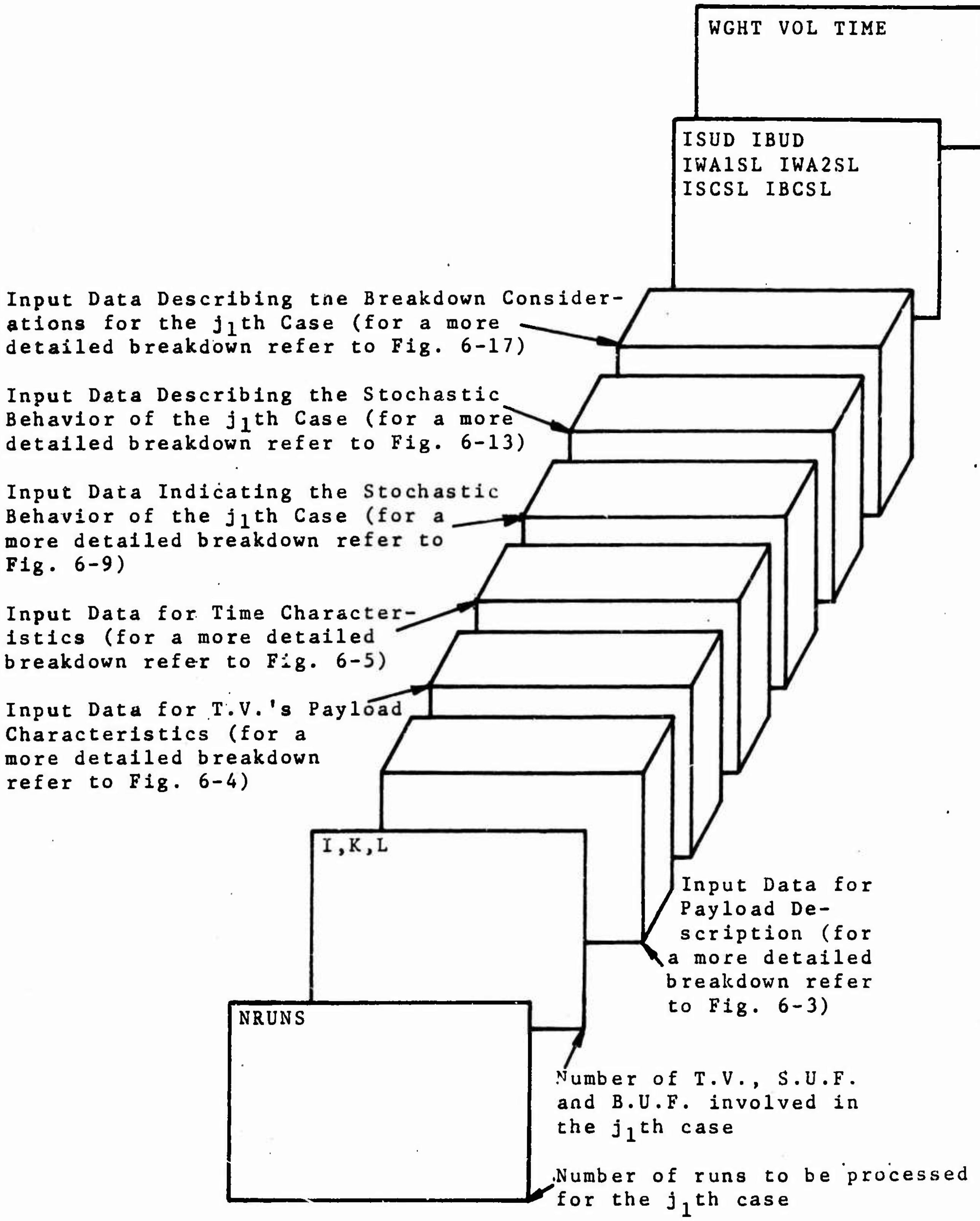


Fig. 6-2. Input Data Setup for the j_1th Case (j_1=1,2...NCASES)

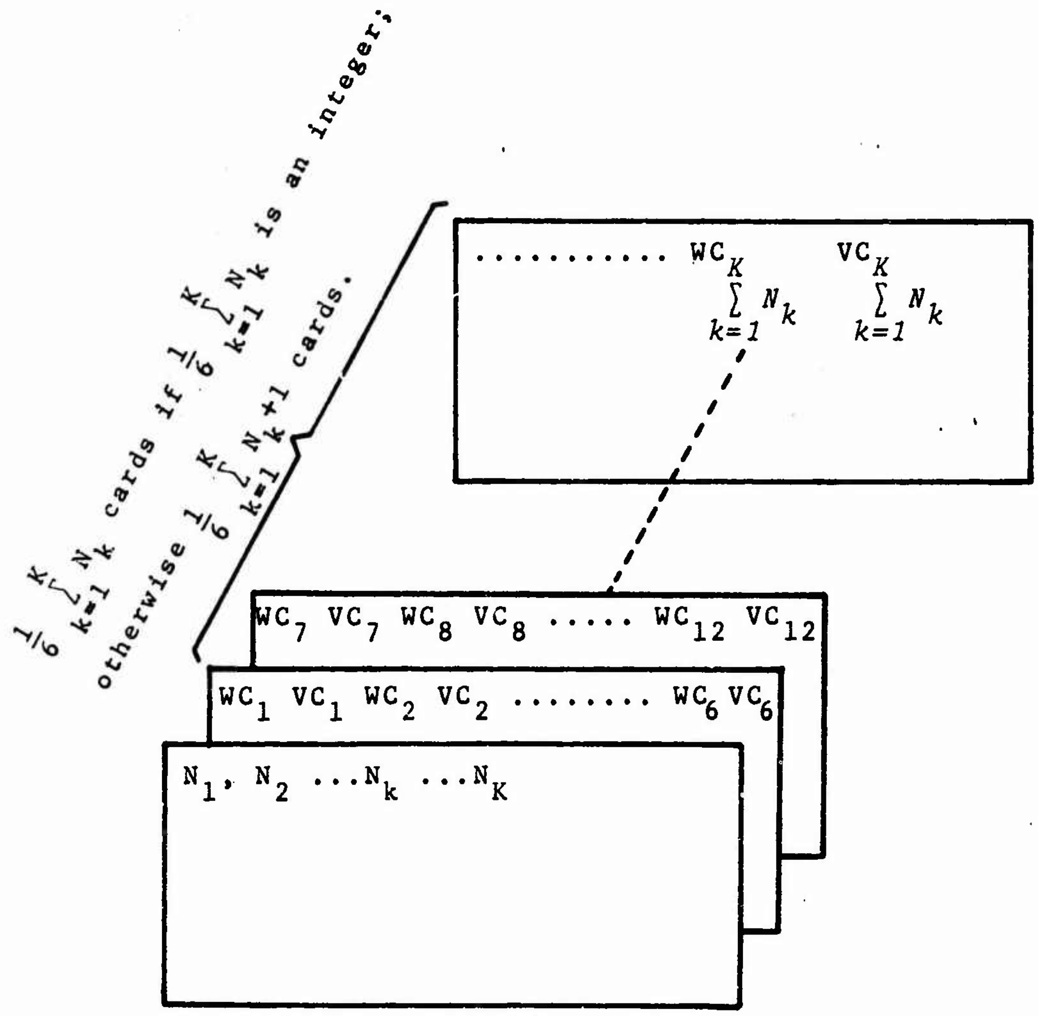


Fig. 6-3. Input Data Setup for the Payload Description

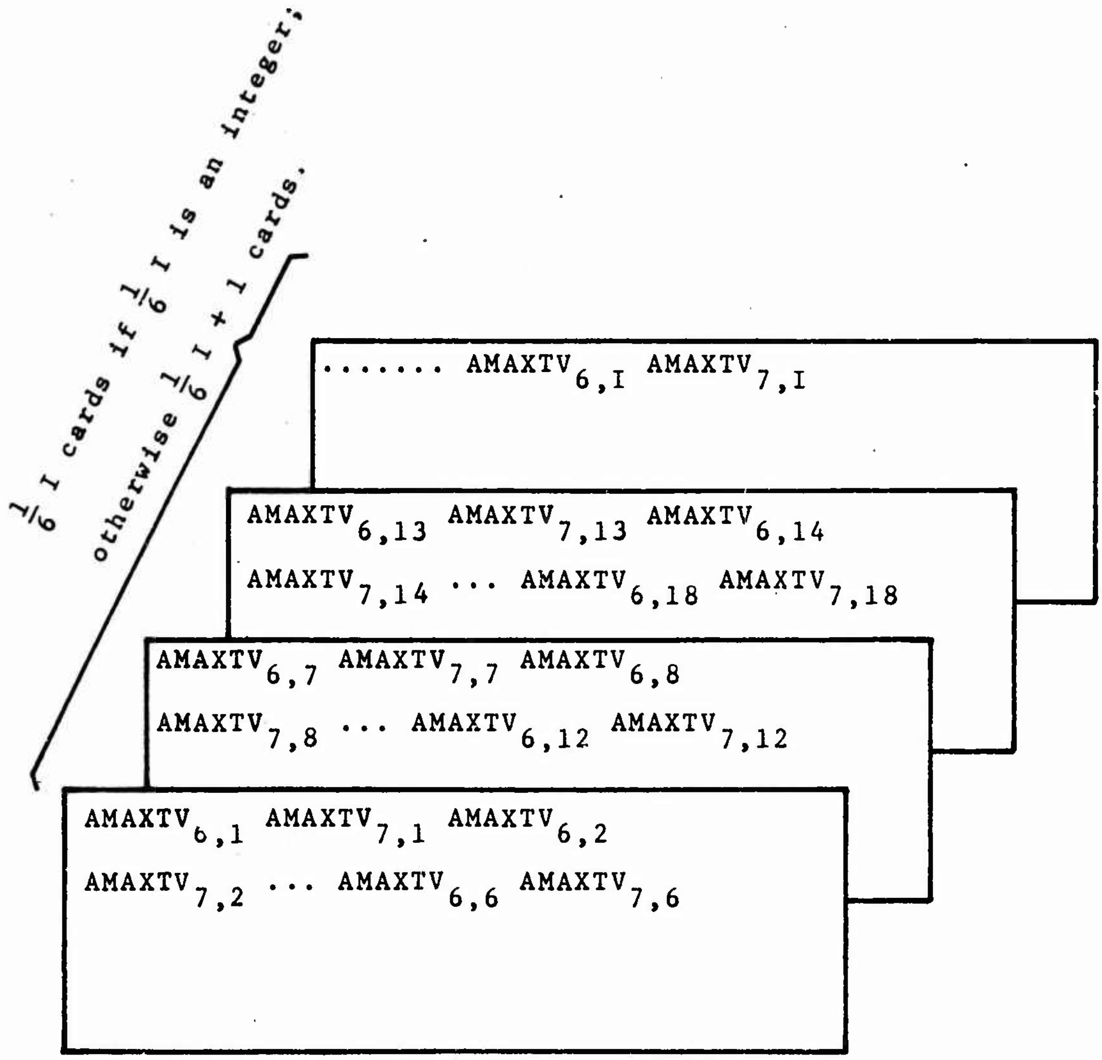


Fig. 6-4

Input Data Setup for the T.V.'s Payload Characteristics

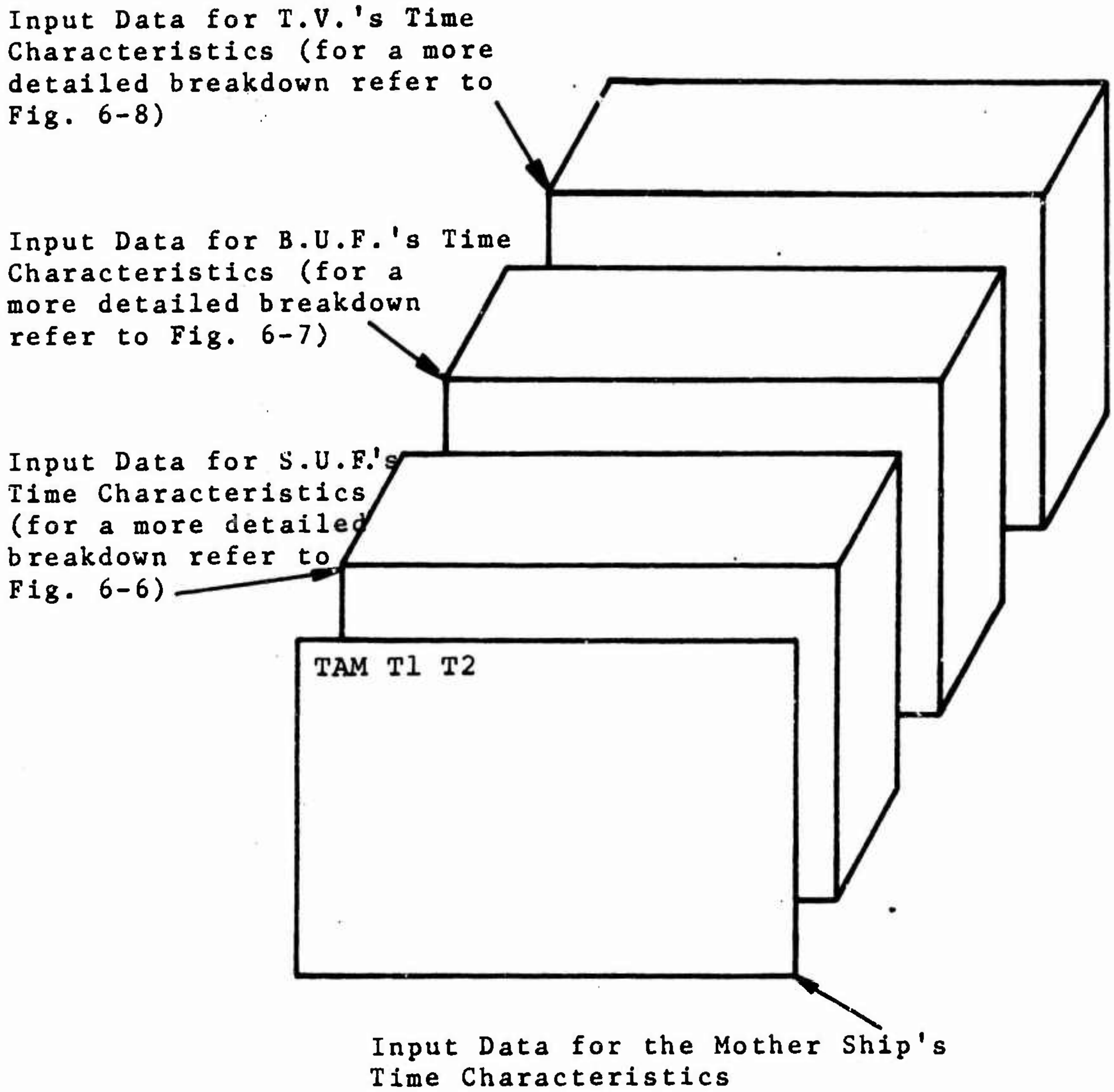


Fig. 6-5. Input Data Setup for the Time Characteristics

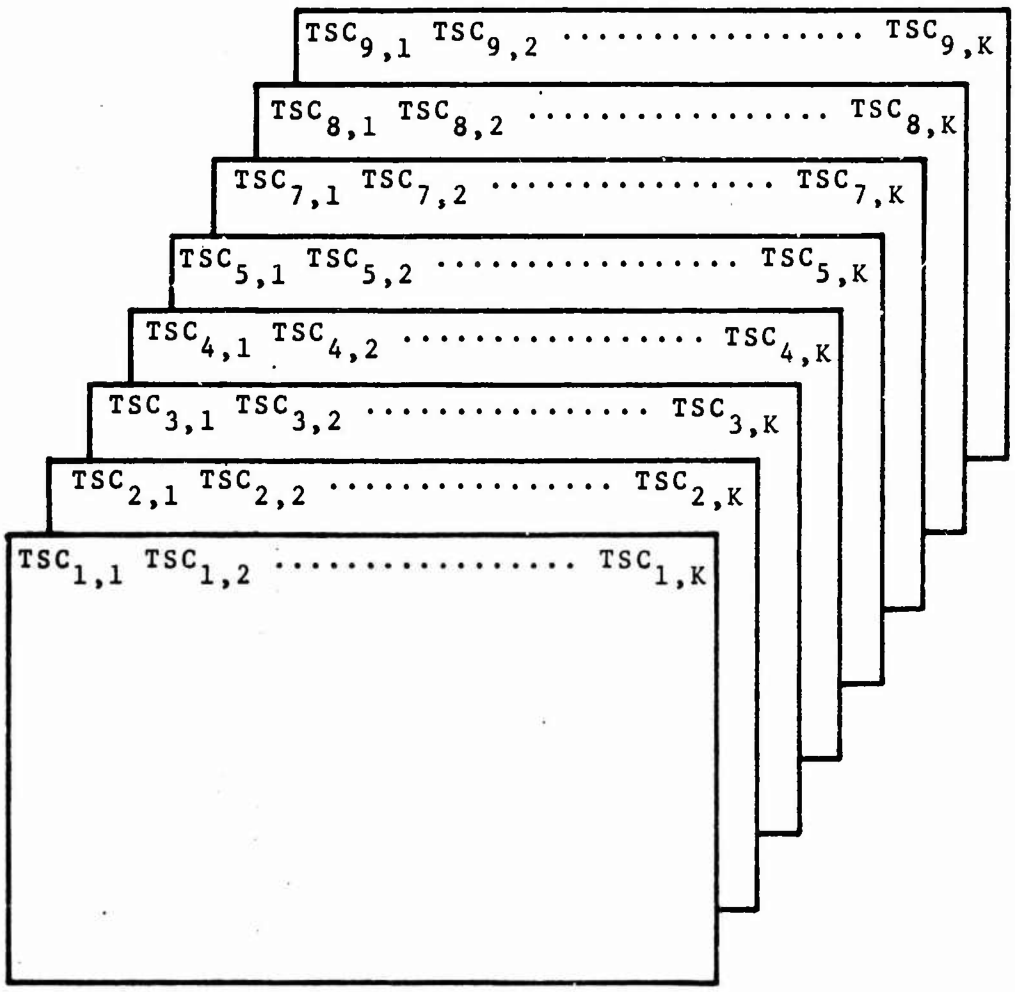


Fig. 6-6. Input Data Setup for the S.U.F.'s Time Characteristics

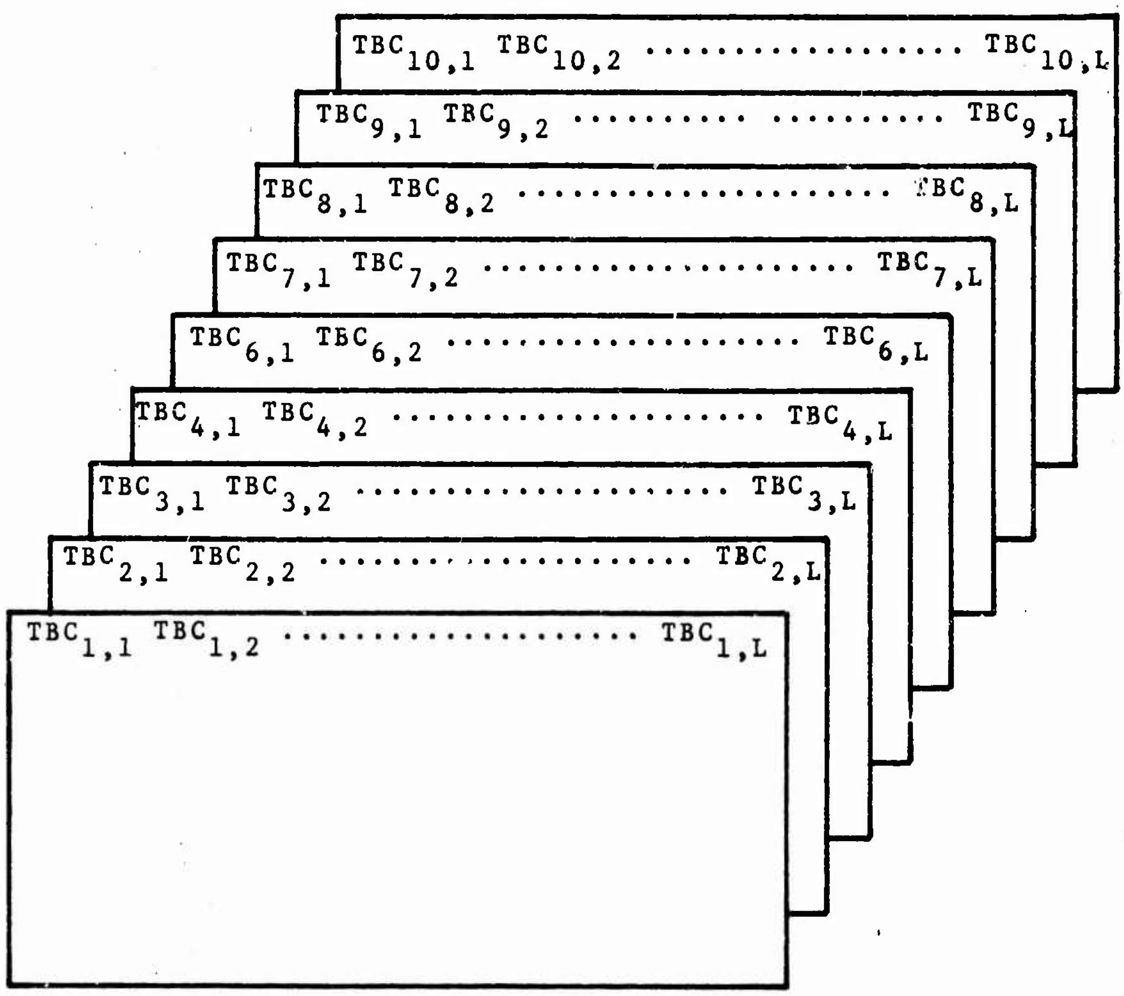


Fig. 6-7

Input Data Setup for the B.U.F.'s Time Characteristics

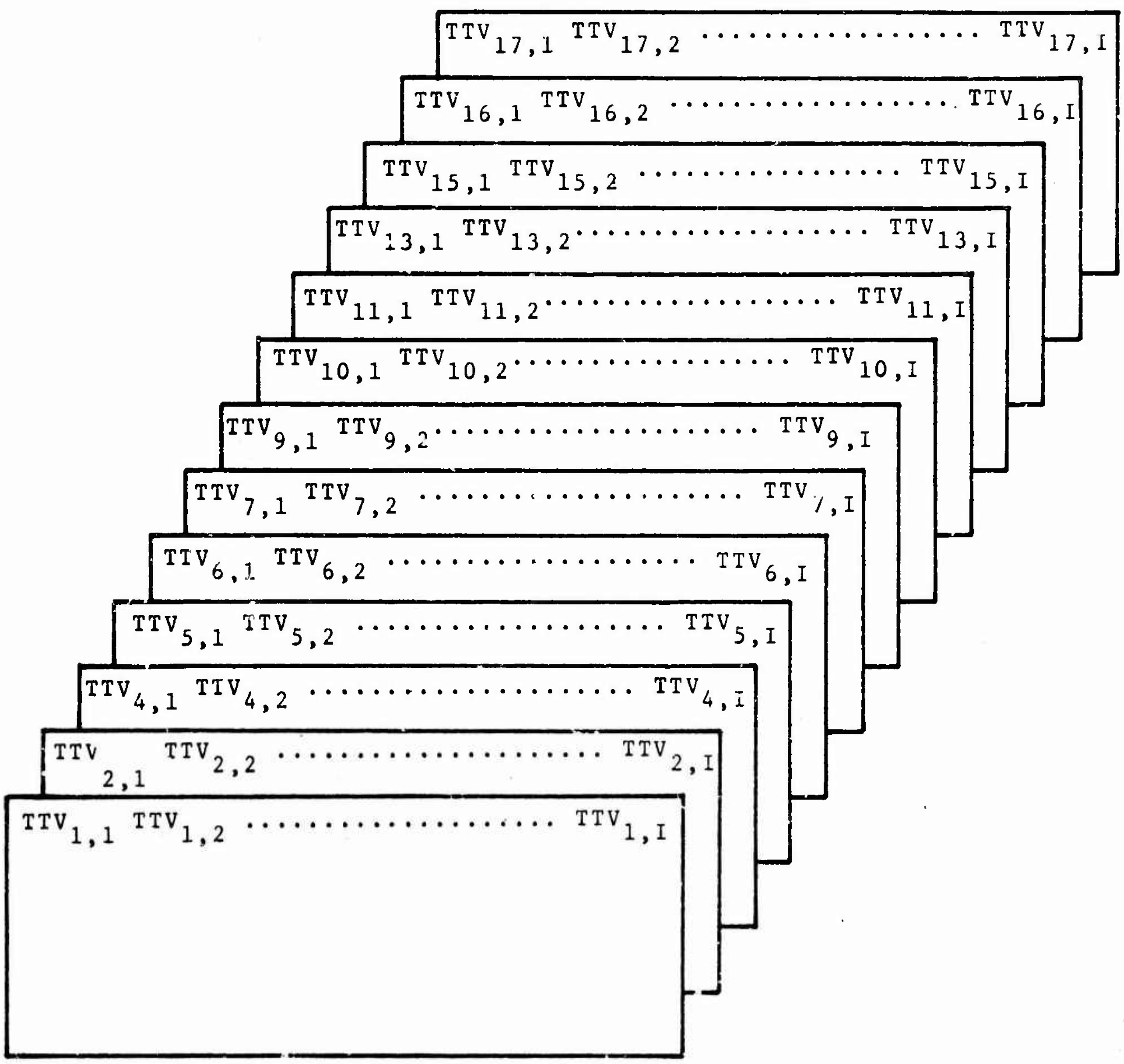


Fig. 6-8

Input Data Setup for the T.V.'s Time Characteristics

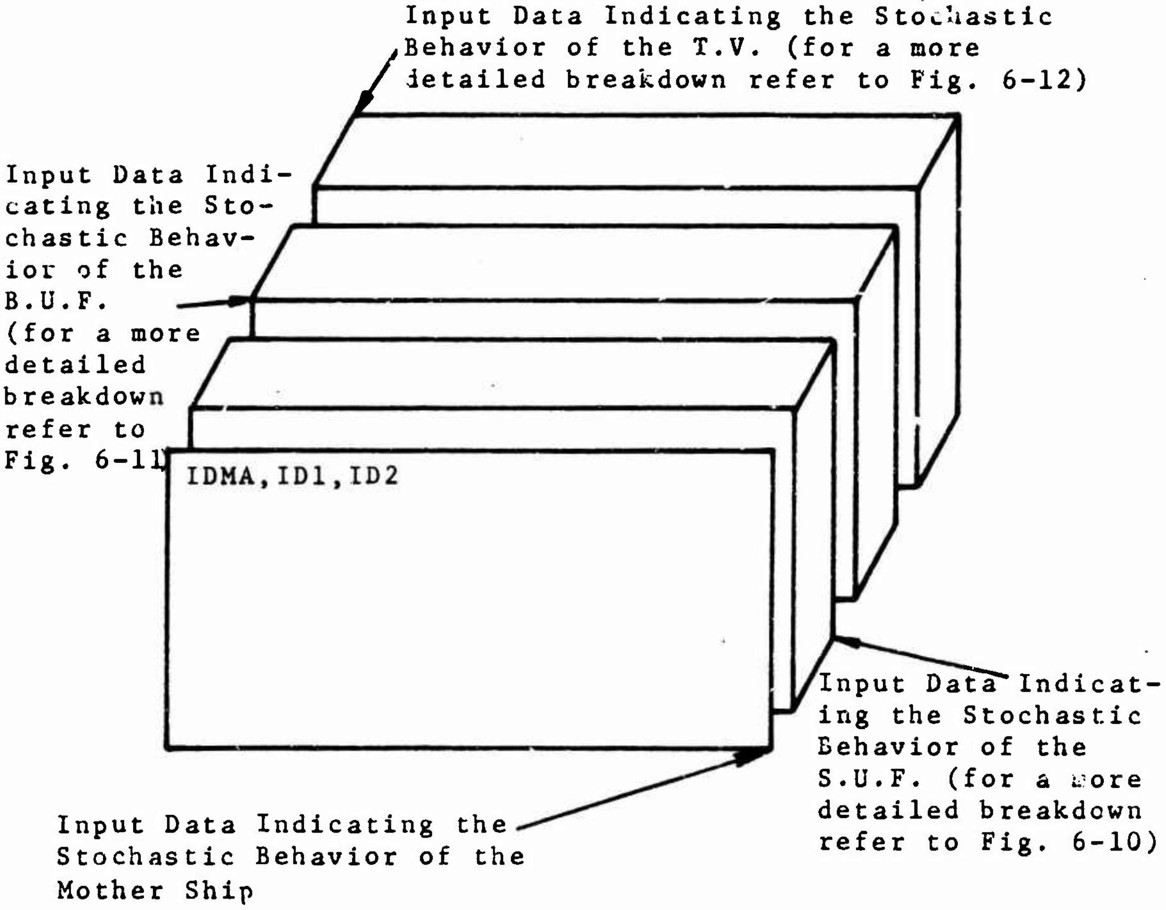


Fig. 6-9

Input Data Setup for the Indication of the Stochastic Behavior of the j_1th Case

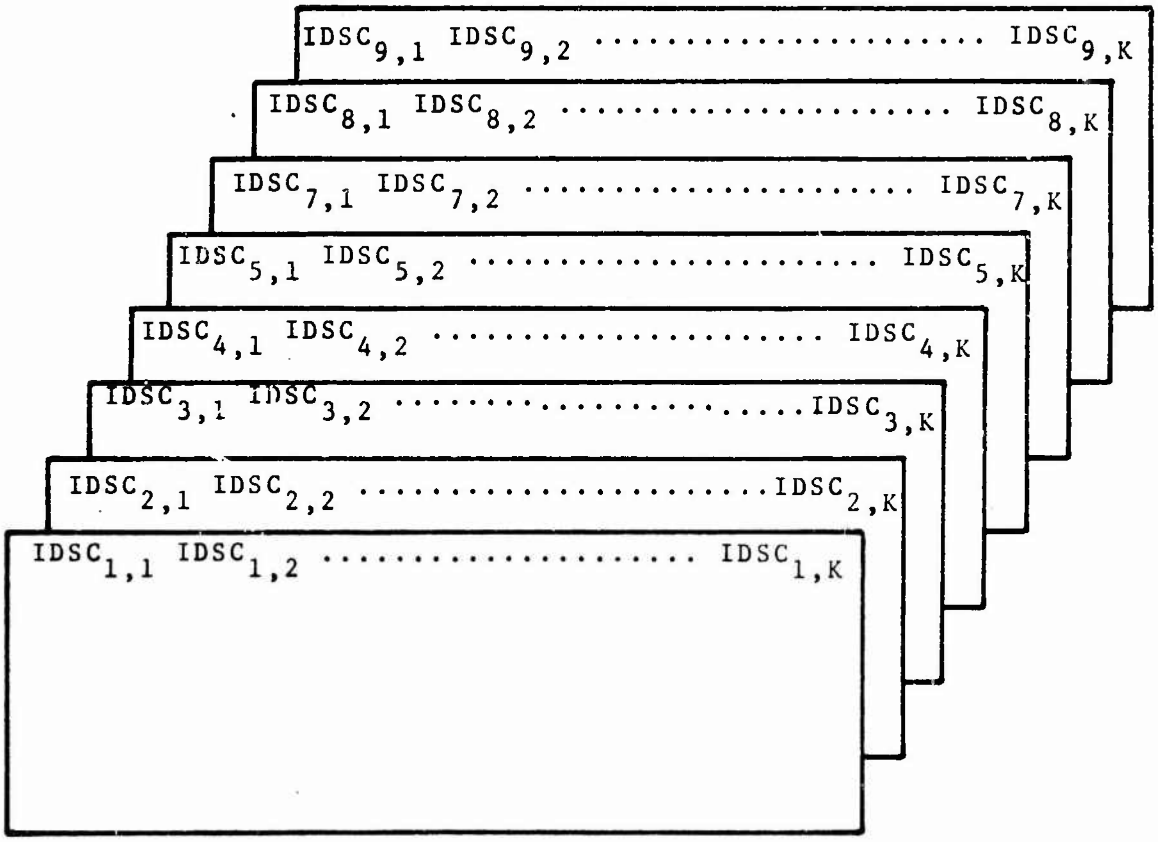


Fig. 6-10

Input Data Setup for the Indication of the Stochastic Behavior of the S.U.F.

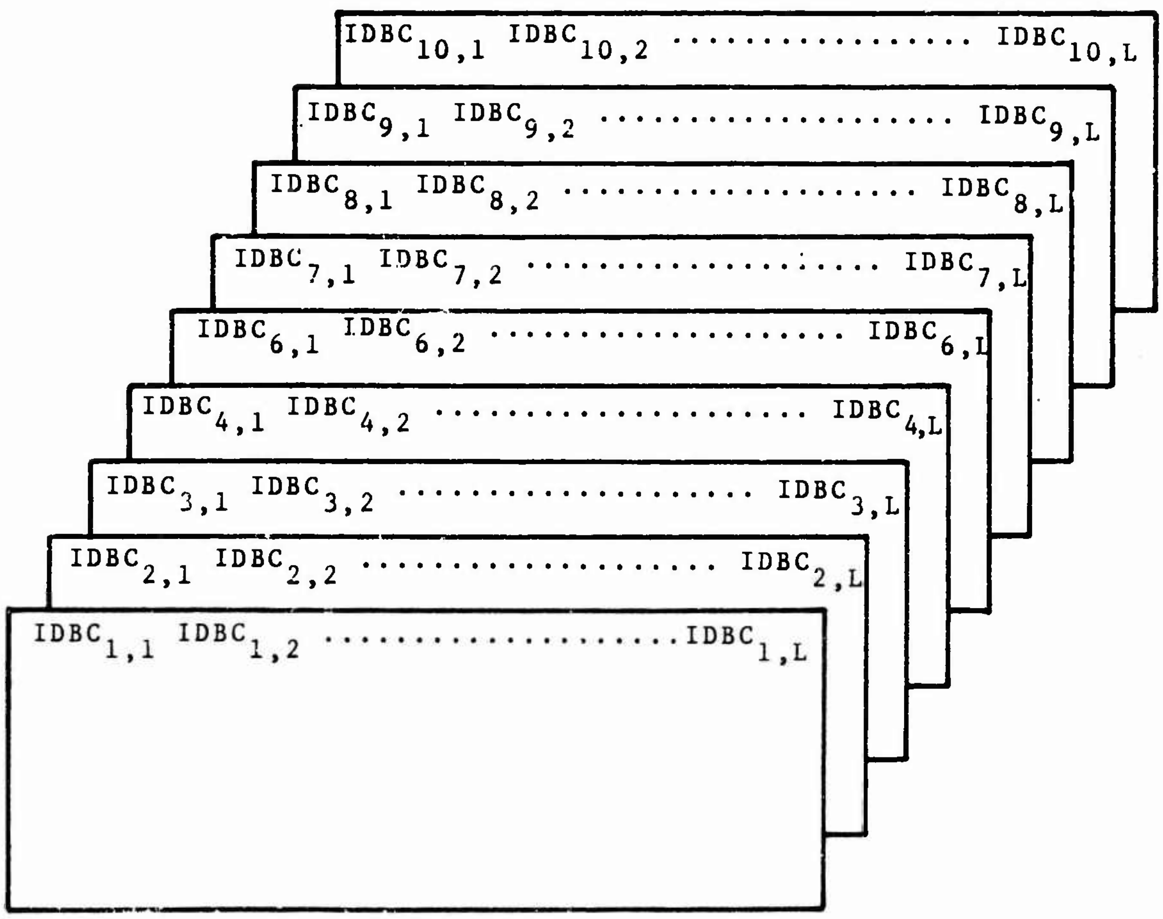


Fig. 6-11

Input Data Setup for the Indication of the Stochastic Behavior of the B.U.F.

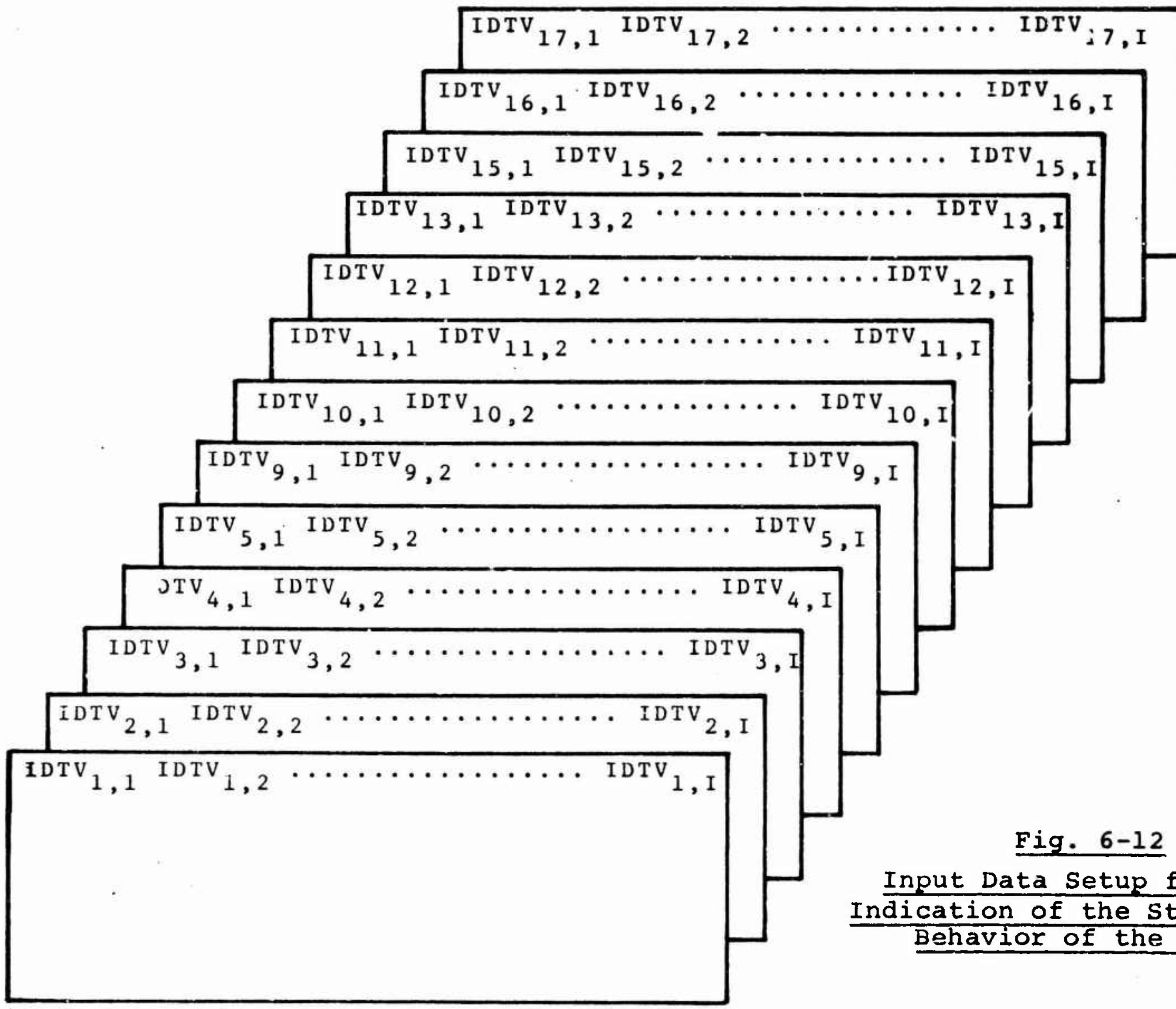


Fig. 6-12

Input Data Setup for the Indication of the Stochastic Behavior of the T.V.

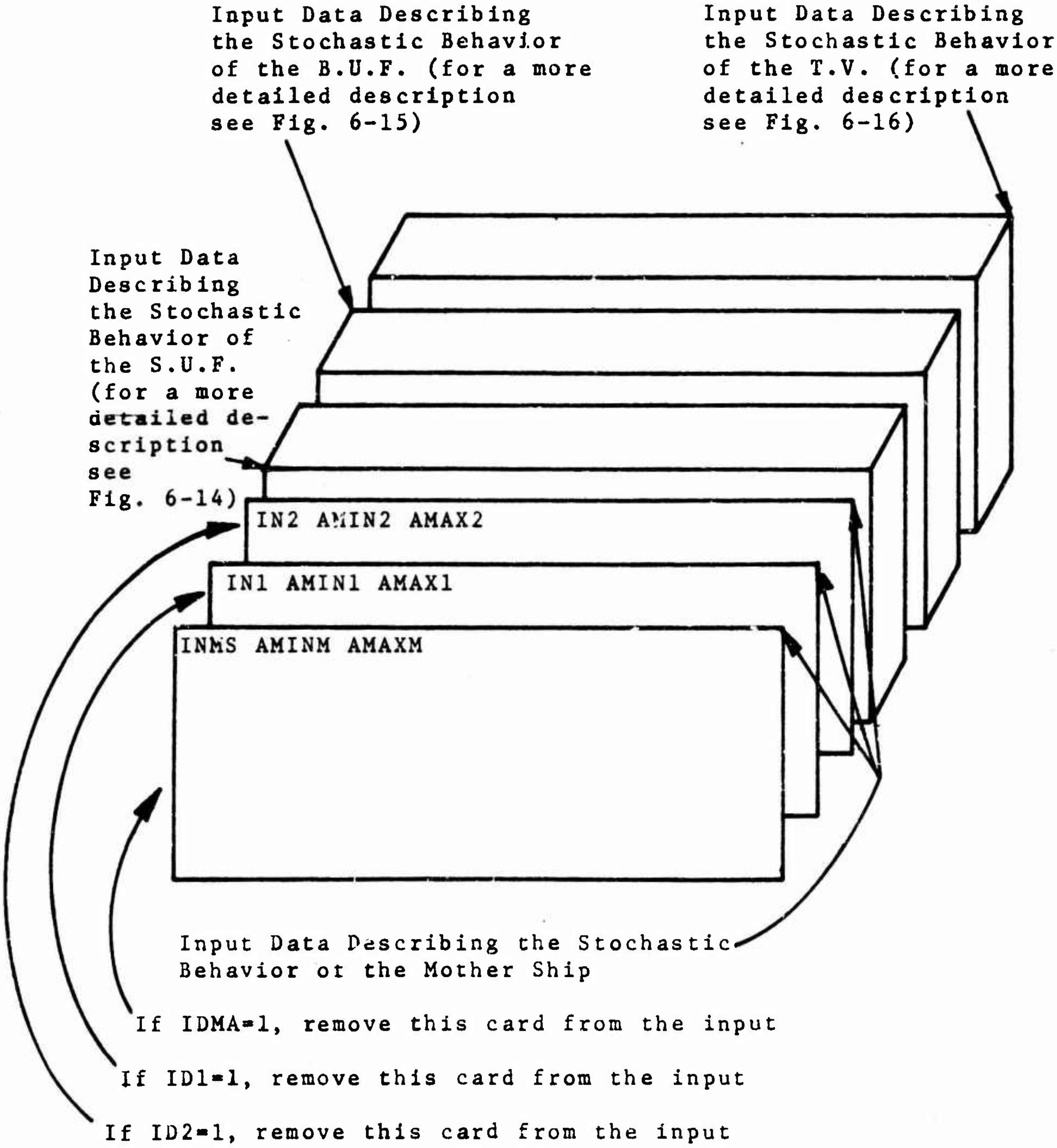


Fig. 6-13

Input Data Setup for the Description of the Stochastic Behavior of the j_1th Case

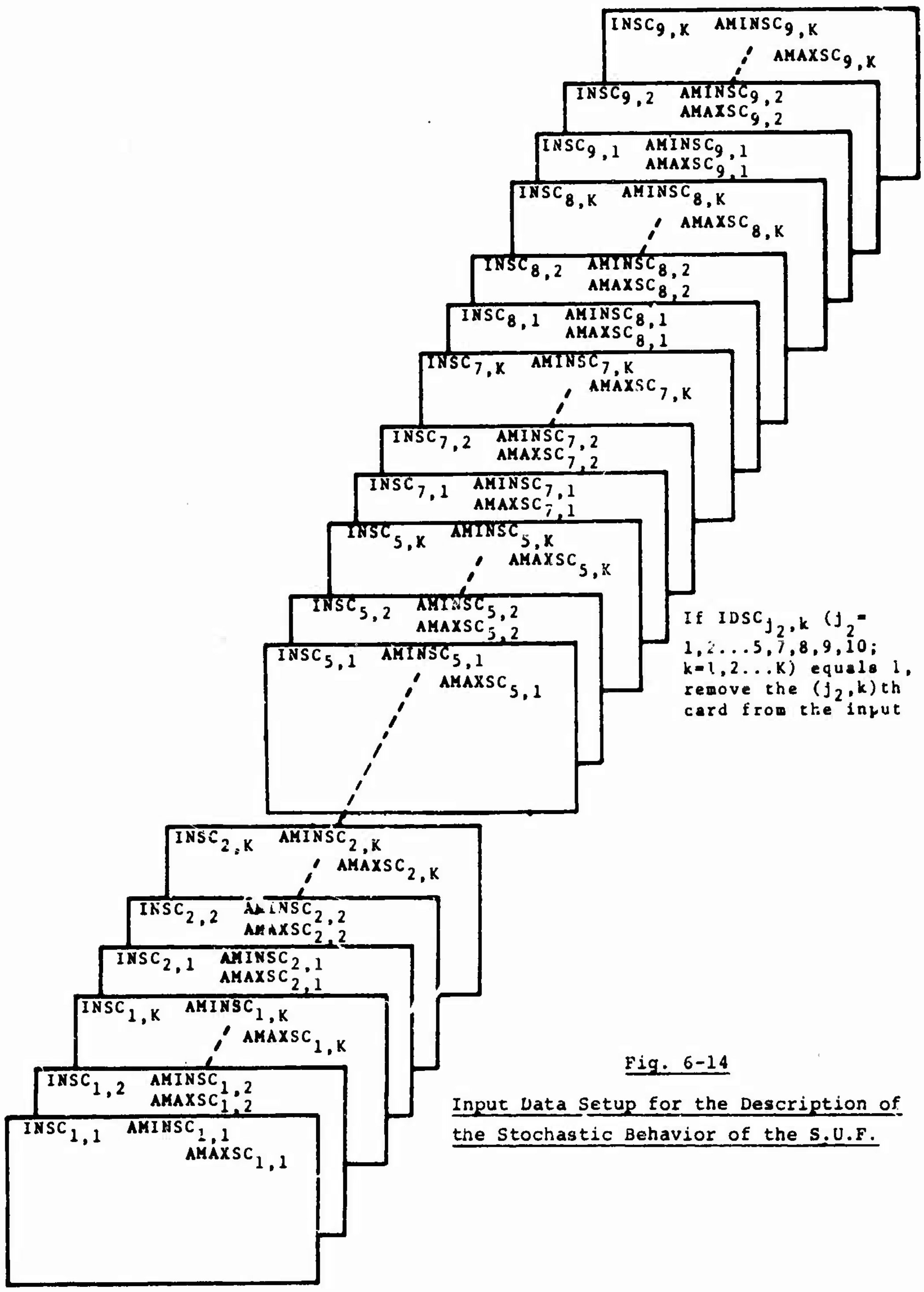


Fig. 6-14

Input Data Setup for the Description of the Stochastic Behavior of the S.U.F.

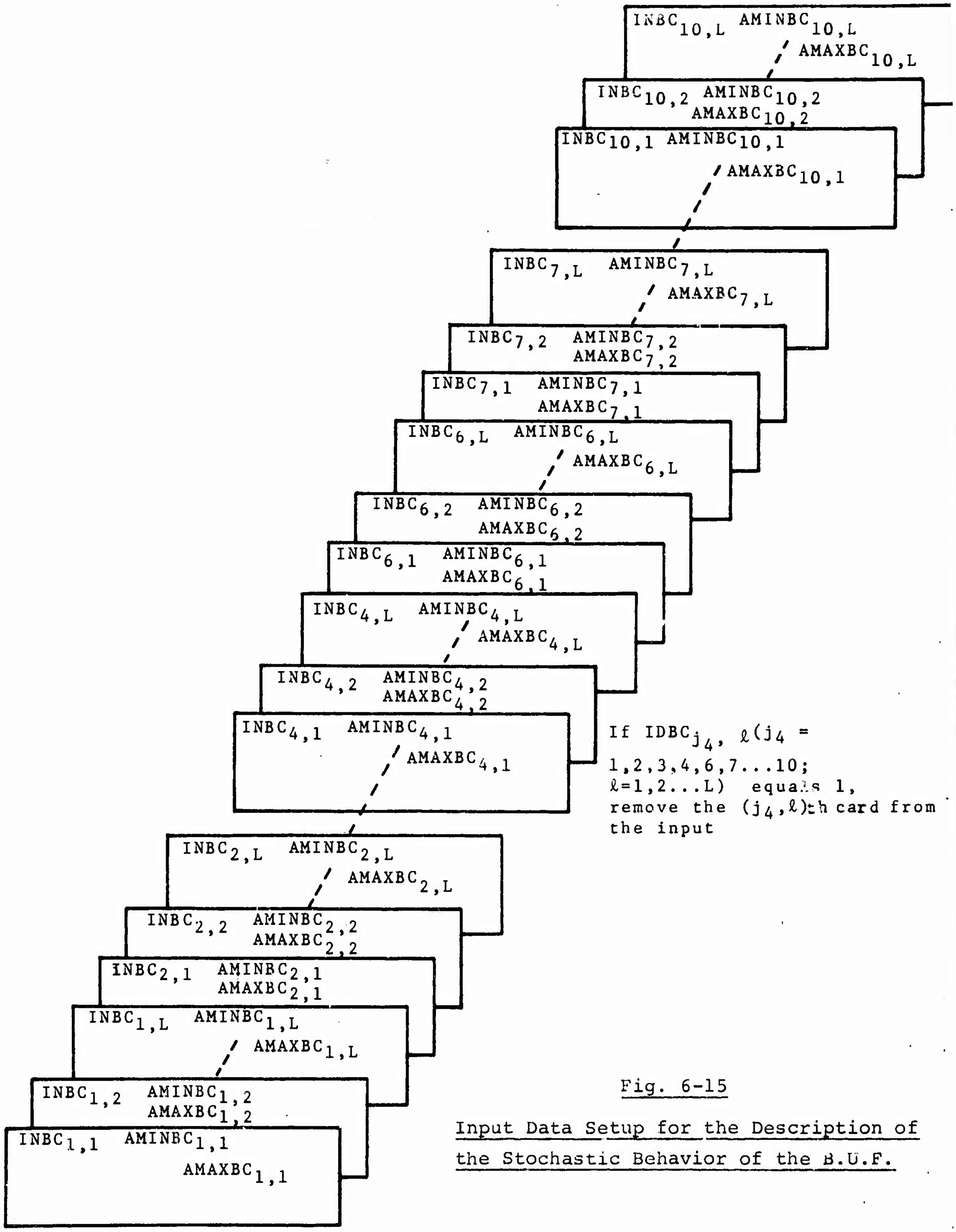
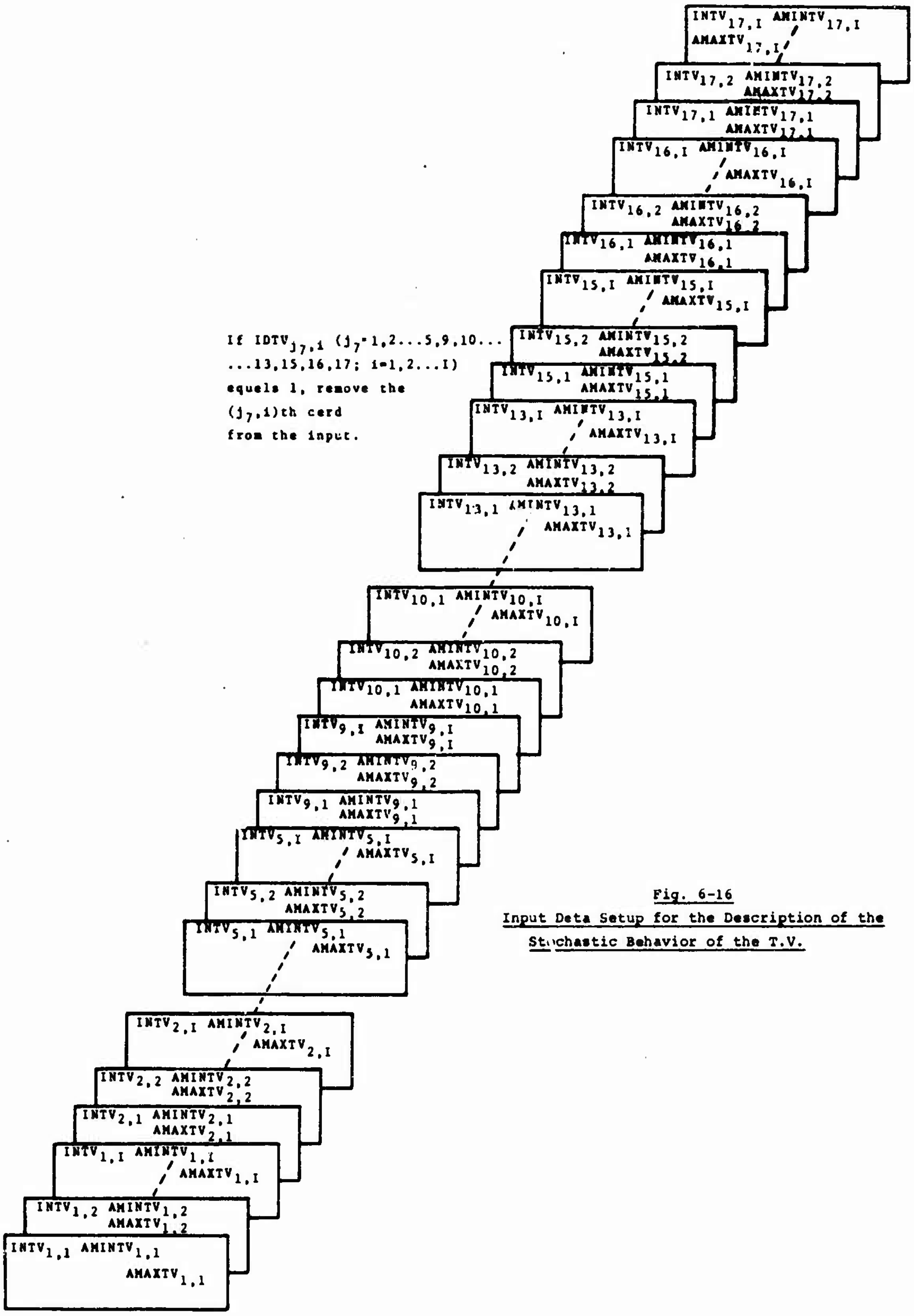


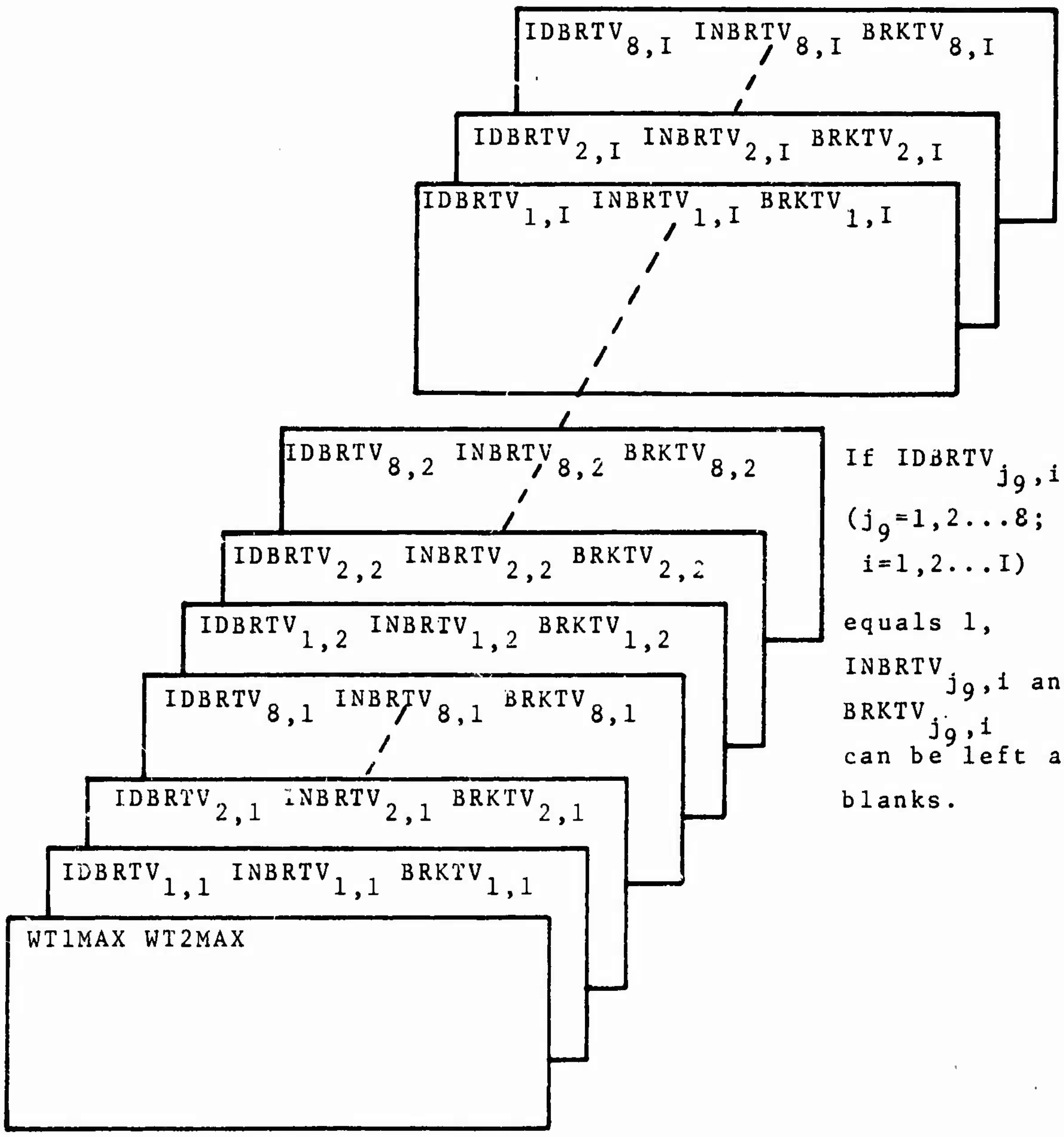
Fig. 6-15

Input Data Setup for the Description of the Stochastic Behavior of the B.U.F.



If $IDTV_{j_7,i}$ (j_7=1,2...5,9,10...
...13,15,16,17; i=1,2...I)
equals 1, remove the
(j_7,i)th card
from the input.

Fig. 6-16
Input Data Setup for the Description of the Stochastic Behavior of the T.V.



If $IDBRTV_{j_9,i}$ (j_9=1,2...8; i=1,2...I) equals 1, $INBRTV_{j_9,i}$ and $BRKTV_{j_9,i}$ can be left as blanks.

Fig. 6-17. Input Data Setup for the Description of the T.V.'s Breakdown Considerations

7. Future Recommendations

Before concluding this report, I would like to take the opportunity of discussing what I envision as Phase II (the next report) of this project.

First, the development of the antithetic variance concept for general congestion models. This not only applies to our case but also to any general congestion problem. The time-saving element will be the major reward of such an analysis, as it is anticipated that the simulation will be made twice as efficient. (The comparison is made between a simulation utilizing independent samples and one utilizing negatively correlated samples.) Secondly, the application of the concept of antithetic variance to our model. Thirdly, the development of the subroutine INOUT and of the subroutine package STATIC, and fourthly and finally, recommendations for a possible third stage which will include the graphic representation of our simulation as it is executed. This I believe to be very helpful, because the user can then follow the model visually and impose logical changes by assuming manual control whenever it becomes obvious that a previously selected strategy is inapplicable. This has been tried in the Civil Engineering Department of M.I.T. for a car assignment simulation, with relatively high success.

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Appendix A

COMPUTER PROGRAM LISTING

```
      COMMON NCASES,NRUNS,I,K,L,N,WC,VC,TAM,T1,T2,TSC,TBC,TTV,TAMP,T1P, MAIN
     1T2P,TSCP,TBCP,TTVP,IDMA,ID1,ID2,IDSC,IDBC,IDTV,INMS,IN1,IN2,INSC, MAIN
     2INBC,INTV,AMINM,AMIN1,AMIN2,AMINSC,AMINBC,AMINTV,AMAXM,AMAX1,AMAX2MAIN
     3,AMAXSC,AMAXBC,AMAXTV,ISUD,IBUD,IWA1SL,IWA2SL,ISCSL,IBCSL,INDEX1, MAIN
     4INDEX2,I1,K1,L1,ICASE,IRUN,TTM,NDUML,NDUMMY,WGHT,VOL,TIME,IBREAK, MAIN
     5WT1MAX,WT2MAX,IDBRTV,INBRTV,BRKTV,NDAMMY,INDEX                    MAIN
      DIMENSION WC(1000),VC(1000),N(20),TSC( 9,20),TBC(10,20),TTV(17,20)MAIN
     1,TSCP( 9,20),TBCP(10,20),TTVP(17,20),IDSC( 9,20),IDBC(10,20),IDTV(MAIN
     217,20),INSC( 9,20),INBC(10,20),INTV(17,20),AMINSC( 9,20),AMINBC(10MAIN
     3,20),AMINTV(17,20),AM[illegible] 9,20),AMAXBC(10,20),AMAXTV(17,20),NDUMMMAIN
     4Y(20),IDBRTV(8,20),IN[illegible]8,20),BRKTV(8,20),NDAMMY(20)              MAIN
 3000 FORMAT(I2)                                                        MAIN
 3100 FORMAT(1H1,18X,'SHIP TO SHORE UNLOADING SIMULATION.'////)         MAIN
 3110 FORMAT(6X,'THE NUMBER OF CASES TO BE INVESTIGATED IN THIS COMPUTERMAIN
     1RUN IS ',I2)                                                      MAIN
 3200 FORMAT(1H1,'THIS RUN IS TERMINATED AT THIS STAGE BECAUSE ALL THE TMAIN
     1RANSFER VEHICLES'/' ARE MALFUNCTIONING.')                         MAIN
      READ(5,3000) NCASES                                               MAIN
      WRITE(6,3100)                                                     MAIN
      WRITE(6,3110)NCASES                                               MAIN
      ICASE=0                                                           MAIN
 1000 IRUN=0                                                            MAIN
      CALL INPUT                                                        MAIN
      IDSC(6,1)=N(1)                                                    MAIN
      IF(K-1) 101,102,101                                               MAIN
  101 DO 100 KK=2,K                                                     MAIN
      IDSC(6,KK)=IDSC(6,KK-1)+N(KK)                                     MAIN
  100 CONTINUE                                                          MAIN
  102 N(1)=1                                                            MAIN
      IF(K-1) 103,104,103                                               MAIN
  103 DO 105 KK=2,K                                                     MAIN
      N(KK)=IDSC(6,KK-1)+1                                              MAIN
  105 CONTINUE                                                          MAIN
  104 NDUML=IDSC(6,K)                                                   MAIN
      CALL INOUT                                                        MAIN
 1100 DO 110 II=1,I                                                     MAIN
```

```
      TTVP(7,II)=TTV(7,II)                                              MAIN
      INTV(14,II)=0                                                     MAIN
  110 CONTINUE                                                          MAIN
      IRUN=IRUN+1                                                       MAIN
      INDEX=0                                                           MAIN
      INDEX1=0                                                          MAIN
      INDEX2=0                                                          MAIN
      IBREAK=I                                                          MAIN
      CALL BEGIN                                                        MAIN
      IF(IBREAK) 2001,2001,1200                                         MAIN
 2001 DO 2002 II=1,I                                                    MAIN
      IF(INTV(14,II)) 2003,2002,2003                                    MAIN
 2003 IDTV(8,II)=0                                                      MAIN
      TTVP(8,II)=9999999.                                               MAIN
 2002 CONTINUE                                                          MAIN
      WRITE(6,3200)                                                     MAIN
      GO TO 1400                                                        MAIN
 1200 DO 120 KK=1,K                                                     MAIN
      IF(INSC(6,KK)) 120,121,120                                        MAIN
  120 CONTINUE                                                          MAIN
      CALL FIN                                                          MAIN
      CONTINUE                                                          MAIN
      GO TO 1300                                                        MAIN
  121 CONTINUE                                                          MAIN
      GO TO (4001,4002),IWAISL                                          MAIN
 4001 CONTINUE                                                          MAIN
      CALL ASLTVA                                                       MAIN
      CONTINUE                                                          MAIN
      GO TO 4000                                                        MAIN
 4002 CONTINUE                                                          MAIN
      CALL ASLTVP                                                       MAIN
      CONTINUE                                                          MAIN
      GO TO 4000                                                        MAIN
 4000 IF(IDTV(8,II)-1)1300,131,130                                      MAIN
  131 CONTINUE                                                          MAIN
      GO TO (4101,4102),ISCSL                                           MAIN
```

```
 4101 CONTINUE                                                          MAIN  73
      CALL SLSCA                                                        MAIN  74
      CONTINUE                                                          MAIN  75
      GO TO 4100                                                        MAIN  76
 4102 CONTINUE                                                          MAIN  77
      CALL SLSCB                                                        MAIN  78
      CONTINUE                                                          MAIN  79
      GO TO 4100                                                        MAIN  80
 4100 IF(INDEX1) 131,141,121                                            MAIN  81
  141 CONTINUE                                                          MAIN  82
      CALL LOAD                                                         MAIN  83
      IF(IBREAK) 2001,2001,1200                                         MAIN  84
  130 CONTINUE                                                          MAIN  85
      GO TO (4201,4202),IBCSL                                           MAIN  86
 4201 CONTINUE                                                          MAIN  87
      CALL SLBCA                                                        MAIN  88
      CONTINUE                                                          MAIN  89
      GO TO 4200                                                        MAIN  90
 4202 CONTINUE                                                          MAIN  91
      CALL SLBCB                                                        MAIN  92
      CONTINUE                                                          MAIN  93
      GO TO 4200                                                        MAIN  94
 4200 IF(INDEX2)130,151,121                                             MAIN  95
  151 CONTINUE                                                          MAIN  96
      CALL UNLOAD                                                       MAIN  97
      IF(IBREAK) 2001,2001,121                                          MAIN  98
 1400 KL=K-1                                                            MAIN  99
      DO 1401 KK=1,KL                                                   MAIN 100
      IDSC(6,KK)=N(KK+1)-1                                              MAIN 101
 1401 CONTINUE                                                          MAIN 102
      IDSC(6,K)=NDUML                                                   MAIN 103
      GO TO 1402                                                        MAIN 104
 1300 CONTINUE                                                          MAIN 105
 1402 IF (IRUN-NRUNS) 1100,1403,1403                                    MAIN 106
 1403 CONTINUE                                                          MAIN 107
      IF (ICASE-NCASES) 1000,1404,1404                                  MAIN 108
 1404 CONTINUE                                                          MAIN 109
      END                                                               MAIN 110
```

```
      SUBROUTINE INPUT
      COMMON NCASES,NRUNS,I,K,L,N,WC,VC,TAM,T1,T2,TSC,TBC,TTV,TAMF,T1P,
     1T2P,TSCP,TBCP,TTVP,IDMA,IC1,IC2,IDSC,IDBC,IDTV,INMS,IN1,IN2,INSC,
     2INBC,INTV,AMINM,AMIN1,AMIN2,AMINSC,AMINBC,AMINTV,AMAXM,AMAX1,AMAX2
     3,AMAXSC,AMAXBC,AMAXTV,ISUD,IBUD,IWA1SL,IWA2SL,ISCSL,IBCSL,INDEX1,
     4INDEX2,I1,K1,L1,ICASE,IRUN,TTM,NDUML,NDUMMY,WGHT,VOL,TIME,IBREAK,
     5WT1MAX,WT2MAX,IDBRTV,INBRTV,BRKTV,NDAMMY,INDEX
      DIMENSION WC(1000),VC(1000),N(20),TSC( 9,20),TBC(10,20),TTV(17,20)
     1,TSCP( 9,20),TBCP(10,20),TTVP(17,20),IDSC( 9,20),IDBC(10,20),IDTV(
     217,20),INSC( 9,20),INBC(10,20),INTV(17,20),AMINSC( 9,20),AMINBC(10
     3,20),AMINTV(17,20),AMAXSC( 9,20),AMAXBC(10,20),AMAXTV(17,20),NDUMM
     4Y(20),IDBRTV(8,20),INBRTV(8,20),BRKTV(8,20),NDAMMY(20)
 1000 FORMAT(20I4)
 1100 FORMAT(20F4.0)
 1200 FORMAT(6(F5.2,1X,F4.0,2X))
 1300 FORMAT(6(F4.0,1X,F5.0,2X))
 1400 FORMAT(I10,2F10.5)
 1500 FORMAT(6(I1,1X))
 1600 FORMAT(9A4)
 1450 FORMAT(I2,I10,F6.4)
 1440 FORMAT(2F10.2)
      READ(5,1000) NRUNS
      READ(5,1000) I,K,L
      READ(5,1000) (N(KK),KK=1,K)
      NN=0
      DO 100 KK=1,K
      NN=NN+N(KK)
  100 CONTINUE
      READ(5,1200) (WC(NNN),VC(NNN),NNN=1,NN)
      READ(5,1300) (AMAXTV(6,II),AMAXTV(7,II),II=1,I)
      READ(5,1100) TAM,T1,T2
      READ(5,1100) ((TSC(JJ,KK),KK=1,K),JJ=1,5)
      READ(5,1100) ((TSC(JJ,KK),KK=1,K),JJ=7,9)
      READ(5,1100) ((TBC(JJ,LL),LL=1,L),JJ=1,4)
      READ(5,1100) ((TBC(JJ,LL),LL=1,L),JJ=6,10)
      READ(5,1100) ((TTV(JJ,II),II=1,I),JJ=1,2)
```

```
      READ(5,1100) ((TTV(JJ,II),II=1,I),JJ=4,7)
      READ(5,1100) ((TTV(JJ,II),II=1,I),JJ=9,11)
      READ(5,1100) (TTV(13,II),II=1,I)
      READ(5,1100) ((TTV(JJ,II),II=1,I),JJ=15,17)
      READ(5,1000) IDMA,ID1,ID2
      READ(5,1000) ((IDSC(JJ,KK),KK=1,K),JJ=1,5)
      READ(5,1000) ((IDSC(JJ,KK),KK=1,K),JJ=7,9)
      READ(5,1000) ((IDBC(JJ,LL),LL=1,L),JJ=1,4)
      READ(5,1000) ((IDBC(JJ,LL),LL=1,L),JJ=6,10)
      READ(5,1000) ((IDTV(JJ,II),II=1,I),JJ=1,5)
      READ(5,1000) ((IDTV(JJ,II),II=1,I),JJ=9,13)
      READ(5,1000) ((IDTV(JJ,II),II=1,I),JJ=15,17)
      GO TO (2000,2001),IDMA
 2001 READ(5,1400) INMS,AMINM,AMAXM
      GO TO 2000
 2000 CONTINUE
      GO TO (2010,2011),ID1
 2011 READ(5,1400) IN1,AMIN1,AMAX1
      GO TO 2010
 2010 CONTINUE
      GO TO (2020,2021),ID2
 2021 READ(5,1400) IN2,AMIN2,AMAX2
      GO TO 2020
 2020 CONTINUE
      JLOW=1
      JHIGH=5
      DO 230 J=1,2
      DO 231 JJ=JLOW,JHIGH
      DO 232 KK=1,K
      IDD=IDSC(JJ,KK)
      GO TO (232,2030),IDD
 2030 CONTINUE
      READ(5,1400) INSC(JJ,KK),AMINSC(JJ,KK),AMAXSC(JJ,KK)
      GO TO 232
  232 CONTINUE
  231 CONTINUE
```

```
      JLOW=7                                                            INPT  73
      JHIGH=9                                                           INPT  74
  230 CONTINUE                                                          INPT  75
      JLOW=1                                                            INPT  76
      JHIGH=4                                                           INPT  77
      DO 240 J=1,2                                                      INPT  78
      DO 241 JJ=JLOW,JHIGH                                              INPT  79
      DO 242 LL=1,L                                                     INPT  80
      IDD=IDBC(JJ,LL)                                                   INPT  81
      GO TO (242,2040),IDD                                              INPT  82
 2040 CONTINUE                                                          INPT  83
      READ(5,1400) INBC(JJ,LL),AMINBC(JJ,LL),AMAXBC(JJ,LL)              INPT  84
      GO TO 242                                                         INPT  85
  242 CONTINUE                                                          INPT  86
  241 CONTINUE                                                          INPT  87
      JLOW=6                                                            INPT  88
      JHIGH=10                                                          INPT  89
  240 CONTINUE                                                          INPT  90
      DO 250 J=1,3                                                      INPT  91
      GO TO (255,256,257),J                                             INPT  92
  255 JLOW=1                                                            INPT  93
      JHIGH=5                                                           INPT  94
      GO TO 253                                                         INPT  95
  256 JLOW=9                                                            INPT  96
      JHIGH=13                                                          INPT  97
      GO TO 253                                                         INPT  98
  257 JLOW=15                                                           INPT  99
      JHIGH=17                                                          INPT 100
  253 DO 251 JJ=JLOW,JHIGH                                              INPT 101
      DO 252 II=1,I                                                     INPT 102
      IDD=IDTV(JJ,II)                                                   INPT 103
      GO TO (252,2050),IDD                                              INPT 104
 2050 CONTINUE                                                          INPT 105
      READ(5,1400) INTV(JJ,II),AMINTV(JJ,II),AMAXTV(JJ,II)              INPT 106
      GO TO 252                                                         INPT 107
  252 CONTINUE                                                          INPT 108
```

```
251 CONTINUE
250 CONTINUE
    READ(5,1440) WT1MAX,WT2MAX
    READ(5,1450) ((IDBRTV(JJ,II),INBRTV(JJ,II),BRKTV(JJ,II),JJ=1,8),II
   1=1,I)
    READ(5,1500) ISLD,IBUD,IWA1SL,IWA2SL,ISCSL,IBCSL
    ICASE=ICASE+1
    READ(5,1600) WGHT,VOL,TIME
    RETURN
    END
```

```
      SUBROUTINE INCUT                                                  INCT
      COMMON NCASES,NRUNS,I,K,L,N,WC,VC,TAM,T1,T2,TSC,TBC,TTV,TAMF,T1P, INCT
     1T2P,TSCP,TBCP,TTVP,ICMA,IC1,ID2,IDSC,ICBC,IDTV,INMS,IN1,IN2,INSC, INCT
     2INBC,INTV,AMINM,AMIN1,AMIN2,AMINSC,AMINBC,AMINTV,AMAXM,AMAX1,AMAX2INCT
     3,AMAXSC,AMAXBC,AMAXTV,ISUD,IBUD,IWA1SL,IWA2SL,ISCSL,IBCSL,INDEX1, INCT
     4INDEX2,I1,K1,L1,ICASE,IRUN,TTM,NDUML,NDUMMY,WGHT,VOL,TIME,IBREAK, INCT
     5WT1MAX,WT2MAX,ICBRTV,INBRTV,BRKTV,NDAMMY,INDEX                    INCT
      DIMENSION WC(1000),VC(1000),N(20),TSC( 9,20),TBC(10,20),TTV(17,20)INCT
     1,TSCP( 9,20),TBCP(10,20),TTVP(17,20),ICSC( 9,20),ICBC(10,20),ICTV(INCT
     217,20),INSC( 9,20),INBC(10,20),INTV(17,20),AMINSC( 9,20),AMINBC(10INCT
     3,20),AMINTV(17,20),AMAXSC( 9,20),AMAXBC(10,20),AMAXTV(17,20),NDUMMINCT
     4Y(20),IDBRTV(8,20),INBRTV(8,20),BRKTV(8,20),NDAMMY(20)            INCT
      CONTINUE                                                          INCT
      RETURN                                                            INCT
      END                                                               INCT
```

```
      SUBROUTINE BEGIN                                                  BEGN
      COMMON NCASES,NRUNS,I,K,L,N,WC,VC,TAM,T1,T2,TSC,TBC,TTV,TAMF,T1P, BEGN
     1T2P,TSCP,TBCP,TTVP,IDMA,ID1,ID2,IDSC,IDBC,IDTV,INMS,IN1,IN2,INSC, BEGN
     2INBC,INTV,AMINM,AMIN1,AMIN2,AMINSC,AMINBC,AMINTV,AMAXM,AMAX1,AMAX2BEGN
     3,AMAXSC,AMAXBC,AMAXTV,ISUD,IBUD,IWA1SL,IWA2SL,ISCSL,IBCSL,INDEX1, BEGN
     4INDEX2,I1,K1,L1,ICASE,IRUN,TTM,NDUML,NDUMMY,WGHT,VOL,TIME,IBREAK, BEGN
     5WT1MAX,WT2MAX,IDBRTV,INBRTV,BRKTV,NDAMMY,INDEX                    BEGN
      DIMENSION WC(1000),VC(1000),N(20),TSC( 9,20),TBC(10,20),TTV(17,20)BEGN
     1,TSCP( 9,20),TBCP(10,20),TTVP(17,20),IDSC( 9,20),IDBC(10,20),IDTV(BEGN
     217,20),INSC( 9,20),INBC(10,20),INTV(17,20),AMINSC( 9,20),AMINBC(10BEGN
     3,20),AMINTV(17,20),AMAXSC( 9,20),AMAXBC(10,20),AMAXTV(17,20),NDUMMBEGN
     4Y(20),IDBRTV(8,20),INBRTV(8,20),BRKTV(8,20),NDAMMY(20)            BEGN
 1000 FORMAT(1H1,60X,'CASE NO. ',I2/57X,'TEST RUN NO. ',I2//27X,'MISSIONBEGN
     1 DESCRIPTION.'//' MOTHER SHIP ARRIVAL AND MOORING OPERATION.')    BEGN
 1010 FORMAT(' THE MOTHER SHIP ARRIVED AT THE THEATER OF OPERATIONS ',F8BEGN
     1.1,' UNITS OF'/' TIME AFTER THE START OF THE MISSION.')           BEGN
 1020 FORMAT(' THE MOTHER SHIP COMPLETED ITS MOORING OPERATION ',F8.1,' BEGN
     1UNITS OF TIME'/' AFTER THE START OF THE MISSION.'/)               BEGN
 1100 FORMAT(' PREPARATION OF SHIP BASED UNLOADING FACILITIES.'/1H ,F8.1BEGN
     1,' UNITS OF TIME AFTER THE START OF THE MISSION ALL SHIP BASED'/' BEGN
     2UNLOADING FACILITIES BECAME AVAILABLE.')                          BEGN
 1110 FORMAT(' SHIP UNLOADING FACILITY NO. ',I2,' WAS FREED FROM ITS SECBEGN
     1URING POSITION'/1H ,F8.1,' UNITS OF TIME AFTER THE START OF THE MIBEGN
     2SSION.')                                                          BEGN
 1210 FORMAT(' WITH THE ABOVE PROVISION BEACH BASED UNLOADING FACILITY NBEGN
     1O. ',I2,' DEPARTED'/' FROM ITS BASE',F8.1,' UNITS OF TIME AFTER THBEGN
     2E START OF THE MISSION.')                                         BEGN
 1220 FORMAT(1H ,F8.1,' UNITS OF TIME AFTER THE START OF THE MISSION BEABEGN
     1CH BASED'/' UNLOADING FACILITY NO. ',I2,' BECAME AVAILABLE AT THE BEGN
     2MOMENT OF ITS ARRIVAL'/' AT THE BEACH UNLOADING ZONE.')           BEGN
 1230 FORMAT(' BEACH BASED UNLOADING FACILITY NO. ',I2,' WAS MADE READY BEGN
     1TO COMMENCE ITS'/' UNLOADING OPERATION ',F8.1,' UNITS OF TIME AFTEBEGN
     2R THE START OF THE MISSION.')                                     BEGN
 1300 FORMAT(1H1,'DEPARTURE OF T.V. FROM RESPECTIVE BASES AND ARRIVAL ATBEGN
     1 W.A. 1.'/' FOR ANALYSIS PURPOSES IF AT THE TERMINATION OF THIS RUBEGN
     2N A T.V. IS FOUND'/' UNUSED THEN ALL DECISIONS MADE AT THIS STAGE BEGN
```

```
     3CONCERNING SUCH A T.V.'/' WILL BE FORFEITED.'//)                  BEGN  37
1310 FORMAT(' WITH THE ABOVE PROVISION T.V. NO. ',I2,' DEPARTED FROM ITBEGN  38
    1S BASE ',F8.1/' UNITS OF TIME AFTER THE START OF THE MISSION.')    BEGN  39
1320 FORMAT(' T.V. NO. ',I2,' ARRIVED AT W.A. 1 ',F8.1,' UNITS OF TIME BEGN  40
    1AFTER THE START OF'/' THE MISSION.')                               BEGN  41
1400 FORMAT(1H ,////' T.V. BREAKDOWN CONSIDERATIONS.'///)               BEGN  42
1410 FORMAT(' ALL TRANSFER VEHICLES HAVE SAFELY ENTERED W.A. 1.'///)   BEGN  43
1420 FORMAT(1H ,///)                                                    BEGN  44
1430 FORMAT(' T.V. NO. ',I2,' IS NOT ALLOWED TO ENTER W.A. 1 AS IT IS CBEGN  45
    1ONSIDERED TO BE'/' MALFUNCTIONING.  THE ABOVE CITED T.V. IS CONSIDBEGN  46
    2ERED LOST FROM OUR SYSTEM FOR THIS COMPUTER RUN.')                 BEGN  47
1200 FORMAT(1H1,'PREPARATION OF BEACH BASED UNLOADING FACILITIES.'/' FOBEGN  48
    1R ANALYSIS PURPOSES IF AT THE TERMINATION OF THIS RUN A BEACH BASEBEGN  49
    2D'/' UNLOADING FACILITY IS FOUND UNUSED THEN ALL DECISIONS MADE ATBEGN  50
    3 THIS'/' STAGE CONCERNING SUCH A FACILITY WILL BE FORFEITED.'//)  BEGN  51
     GO TO (2000,2001),IDMA                                             BEGN  52
2000 TAMP=0.                                                            BEGN  53
     GO TO 3000                                                         BEGN  54
2001 CONTINUE                                                           BEGN  55
     CALL RANDU(INMS,INMS,TAMP)                                         BEGN  56
     TAMP=(AMAXM-AMINM)*TAMP+AMINM                                      BEGN  57
     GO TO 3000                                                         BEGN  58
3000 CONTINUE                                                           BEGN  59
     GO TO (2010,2011),ID1                                              BEGN  60
2010 T1P=0.                                                             BEGN  61
     GO TO 3010                                                         BEGN  62
2011 CONTINUE                                                           BEGN  63
     CALL RANDU(IN1,IN1,T1P)                                            BEGN  64
     T1P=(AMAX1-AMIN1)*T1P+AMIN1                                        BEGN  65
     GO TO 3010                                                         BEGN  66
3010 CONTINUE                                                           BEGN  67
     TTM=TAM+TAMP                                                       BEGN  68
     WRITE(6,1000) ICASE,IRUN                                           BEGN  69
     WRITE(6,1010) TTM                                                  BEGN  70
     TTM=TTM+T1+T1P                                                     BEGN  71
     WRITE(6,1020) TTM                                                  BEGN  72
```

```
      WRITE(6,1100) TTM
      DO 100 KK=1,K
      IDD=IDSC(1,KK)
      GO TO (2020,2021),IDD
 2020 TSCP(1,KK)=0.
      GO TO 3020
 2021 IND=INSC(1,KK)
      CALL RANDU(IND,IND,TPD)
      INSC(1,KK)=IND
      TSCP(1,KK)=(AMAXSC(1,KK)-AMINSC(1,KK))*TPD+AMINSC(1,KK)
      GO TO 3020
 3020 AMAXSC(6,KK)=TTM+TSC(1,KK)+TSCP(1,KK)
      TSCP(6,KK)=TTM
      INSC(6,KK)=0
      WRITE(6,1110) KK,AMAXSC(6,KK)
  100 CONTINUE
      WRITE(6,1200)
      DO 110 LL=1,L
      DO 111 JJ=1,3
      IDD=IDBC(JJ,LL)
      GO TO (2030,2031),IDD
 2030 TBCP(JJ,LL)=0.
      GO TO 111
 2031 IND=INBC(JJ,LL)
      CALL RANDU(IND,IND,TPD)
      INBC(JJ,LL)=IND
      TBCP(JJ,LL)=(AMAXBC(JJ,LL)-AMINBC(JJ,LL))*TPD+AMINBC(JJ,LL)
      GO TO 111
  111 CONTINUE
      AMAXBC(5,LL)=TBC(1,LL)+TBCP(1,LL)
      WRITE(6,1210) LL,AMAXBC(5,LL)
      TBCP(5,LL)=AMAXBC(5,LL)+TBC(2,LL)+TBCP(2,LL)
      WRITE(6,1220) TBCP(5,LL),LL
      AMAXBC(5,LL)=TBCP(5,LL)+TBC(3,LL)+TBCP(3,LL)
      WRITE(6,1230) LL,AMAXBC(5,LL)
      IDBC(5,LL)=0
```

```
  110 CONTINUE                                                        BEGN 109
      WRITE(6,1300)                                                   BEGN 110
      DO 120 II=1,I                                                   BEGN 111
      DO 121 JJ=1,2                                                   BEGN 112
      IDD=IDTV(JJ,II)                                                 BEGN 113
      GO TO (2040,2041),IDD                                           BEGN 114
 2040 TTVP(JJ,II)=0.                                                  BEGN 115
      GO TO 121                                                       BEGN 116
 2041 INC=INTV(JJ,II)                                                 BEGN 117
      CALL RANDU(INC,INC,TPD)                                         BEGN 118
      INTV(JJ,II)=INC                                                 BEGN 119
      TTVP(JJ,II)=(AMAXTV(JJ,II)-AMINTV(JJ,II))*TPD+AMINTV(JJ,II)     BEGN 120
      GO TO 121                                                       BEGN 121
  121 CONTINUE                                                        BEGN 122
      AMAXTV(8,II)=TTV(1,II)+TTVP(1,II)                               BEGN 123
      WRITE(6,1310) II,AMAXTV(8,II)                                   BEGN 124
      AMAXTV(8,II)=AMAXTV(8,II)+TTV(2,II)+TTVP(2,II)                  BEGN 125
      IDTV(8,II)=1                                                    BEGN 126
      IDTV(14,II)=0                                                   BEGN 127
      TTVP(8,II)=AMAXTV(8,II)                                         BEGN 128
      TTVP(14,II)=10.**70                                             BEGN 129
  120 CONTINUE                                                        BEGN 130
      DO 130 II=1,I                                                   BEGN 131
      IDD=IDBRTV(1,II)                                                BEGN 132
      GO TO (130,2050),IDD                                            BEGN 133
 2050 INC=INBRTV(1,II)                                                BEGN 134
      CALL RANDU(INC,INC,TPD)                                         BEGN 135
      INBRTV(1,II)=INC                                                BEGN 136
      IF(BRKTV(1,II)-TPD)130,130,3050                                 BEGN 137
 3050 IBREAK=IBREAK-1                                                 BEGN 138
      IF(IBREAK+1-I) 3062,3063,3062                                   BEGN 139
 3063 CONTINUE                                                        BEGN 140
      WRITE(6,1400)                                                   BEGN 141
 3062 INTV(14,II)=1                                                   BEGN 142
      WRITE(6,1430) II                                                BEGN 143
      GO TO 130                                                       BEGN 144
```

```
  130 CONTINUE                                                    BEGN 145
      DO 140 II=1,I                                               BEGN 146
      IF(ICPRTV(1,II)-1) 140,140,141                              BEGN 147
  140 CONTINUE                                                    BEGN 148
      GO TO 3061                                                  BEGN 149
  141 IF(IBREAK-I) 3065,3066,3065                                 BEGN 150
 3066 CONTINUE                                                    BEGN 151
      WRITE(6,1400)                                               BEGN 152
      WRITE(6,1410)                                               BEGN 153
      GO TO 3061                                                  BEGN 154
 3065 IF(IBREAK) 3067,3067,3068                                   BEGN 155
 3068 CONTINUE                                                    BEGN 156
      WRITE(6,1420)                                               BEGN 157
 3061 DO 150 II=1,I                                               BEGN 158
      IF(INTV(14,II))150,3069,150                                 BEGN 159
 3069 CONTINUE                                                    BEGN 160
      WRITE(6,1320) II,AMAXTV(8,II)                               BEGN 161
  150 CONTINUE                                                    BEGN 162
 3067 CONTINUE                                                    BEGN 163
      RETURN                                                      BEGN 164
      END                                                         BEGN 165
```

```
      SUBROUTINE ASLTVA                                                  ATVA
      COMMON NCASES,NFUNS,I,K,L,N,WC,VC,TAM,T1,T2,TSC,TBC,TTV,TAMP,T1P,  ATVA
     1T2P,TSCP,TBCP,TTVP,IDMA,ID1,ID2,IDSC,IDBC,IDTV,INMS,IN1,IN2,INSC,  ATVA
     2INBC,INTV,AMINM,AMIN1,AMIN2,AMINSC,AMINBC,AMINTV,AMAXM,AMAX1,AMAX2ATVA
     3,AMAXSC,AMAXBC,AMAXTV,ISUC,IBUC,IWA1SL,IWA2SL,ISCSL,IBCSL,INDEX1,  ATVA
     4INDEX2,I1,K1,L1,ICASE,IRUN,TTM,NDUML,NDUMMY,WGHT,VCL,TIME,IBREAK,  ATVA
     5WT1MAX,WT2MAX,IDBRTV,INBRTV,BRKTV,NDAMMY,INDEX                     ATVA
      DIMENSION WC(1000),VC(1000),N(20),TSC( 9,20),TBC(10,20),TTV(17,20)ATVA
     1,TSCP( 9,20),TBCP(10,20),TTVP(17,20),IDSC( 9,20),IDBC(10,20),IDTV(ATVA
     217,20),INSC( 9,20),INBC(10,20),INTV(17,20),AMINSC( 9,20),AMINBC(10ATVA
     3,20),AMINTV(17,20),AMAXSC( 9,20),AMAXBC(10,20),AMAXTV(17,20),NDUMMATVA
     4Y(20),IDBRTV(8,20),INBRTV(8,20),BRKTV(8,20),NDAMMY(20)             ATVA
      I1=1                                                               ATVA
      IF(I-1) 1000,1000,100                                              ATVA
  100 I2=2                                                               ATVA
  150 IF(TTVP(8,I1)-TTVP(8,I2)) 110,120,130                              ATVA
  130 I1=I2                                                              ATVA
  110 IF(I2-I) 140,2000,2000                                             ATVA
  140 I2=I2+1                                                            ATVA
      GO TO 150                                                          ATVA
  120 IF(IDTV(8,I1)-1) 110,160,110                                       ATVA
  160 A1=TTV(4,I1)+TTV(10,I1)+TTV(11,I1)                                 ATVA
      A2=TTV(4,I2)+TTV(10,I2)+TTV(11,I2)                                 ATVA
      IF((AMAXTV(7,I1)/A1)-(AMAXTV(7,I2)/A2)) 130,111,110                ATVA
  111 IF((AMAXTV(6,I1)/A1)-(AMAXTV(6,I2)/A2)) 130,112,110                ATVA
  112 IF(AMAXTV(7,I1)-AMAXTV(7,I2)) 130,113,110                          ATVA
  113 IF(AMAXTV(6,I1)-AMAXTV(6,I2)) 130,114,110                          ATVA
  114 IF(A1-A2) 110,110,130                                              ATVA
 2000 IF(INTV(14,I1)) 2010,2020,2010                                     ATVA
 2010 IDTV(8,I1)=0                                                       ATVA
      TTVP(8,I1)=10.**70                                                 ATVA
      I1=1                                                               ATVA
      GO TO 100                                                          ATVA
 2020 CONTINUE                                                           ATVA
      GO TO(1001,1002),IWA2SL                                            ATVA
 1001 CONTINUE                                                           ATVA
```

```
      CALL RSLTVA                                                       ATVA  37
      CONTINUE                                                          ATVA  38
      GO TO 1000                                                        ATVA  39
 1002 CONTINUE                                                          ATVA  40
      CALL RSLTVB                                                       ATVA  41
      CONTINUE                                                          ATVA  42
      GO TO 1000                                                        ATVA  43
 1000 CONTINUE                                                          ATVA  44
      RETURN                                                            ATVA  45
      END                                                               ATVA  46
```

```
      SUBROUTINE ASLTVR                                                 ATVB
      COMMON NCASES,NRUNS,I,K,L,N,WC,VC,TAM,T1,T2,TSC,TBC,TTV,TAMF,T1P, ATVB
     1T2P,TSCP,TBCP,TTVP,IDMA,ID1,ID2,IDSC,IDBC,IDTV,INMS,IN1,IN2,INSC, ATVB
     2INBC,INTV,AMINM,AMIN1,AMIN2,AMINSC,AMINBC,AMINTV,AMAXM,AMAX1,AMAX2ATVB
     3,AMAXSC,AMAXBC,AMAXTV,ISUC,IBUD,IWA1SL,IWA2SL,ISCSL,IBCSL,INDEX1, ATVB
     4INDEX2,I1,K1,L1,ICASE,IRUN,TTM,NDUML,NDUMMY,WGHT,VOL,TIME,IBREAK,  ATVB
     5WT1MAX,WT2MAX,IDBRTV,INBRTV,BRKTV,NDAMMY,INDEX                    ATVB
      DIMENSION WC(1000),VC(1000),N(20),TSC( 9,20),TBC(10,20),TTV(17,20)ATVB
     1,TSCP( 9,20),TBCP(10,20),TTVP(17,20),IDSC( 9,20),IDBC(10,20),IDTV(ATVB
     217,20),INSC( 9,20),INBC(10,20),INTV(17,20),AMINSC( 9,20),AMINBC(10ATVB
     3,20),AMINTV(17,20),AMAXSC( 9,20),AMAXBC(10,20),AMAXTV(17,20),NDUMMATVB
     4Y(20),IDBRTV(8,20),INBRTV(8,20),BRKTV(8,20),NDAMMY(20)            ATVB
      I1=1                                                              ATVB
      IF(I1-1) 1000,1000,100                                            ATVB
  100 I2=2                                                              ATVB
  150 IF(TTVP(8,I1)-TTVP(8,I2)) 110,120,130                             ATVB
  130 I1=I2                                                             ATVB
  110 IF(I2-I) 140,2000,2000                                            ATVB
  140 I2=I2+1                                                           ATVB
      GO TO 150                                                         ATVB
  120 IF(IDTV(8,I1)-1) 110,160,110                                      ATVB
  160 A1=TTV(4,I1)+TTV(10,I1)+TTV(11,I1)                                ATVB
      A2=TTV(4,I2)+TTV(10,I2)+TTV(11,I2)                                ATVB
      IF((AMAXTV(6,I1)/A1)-(AMAXTV(6,I2)/A2)) 130,111,110               ATVB
  111 IF((AMAXTV(7,I1)/A1)-(AMAXTV(7,I2)/A2)) 130,112,110               ATVB
  112 IF(AMAXTV(6,I1)-AMAXTV(6,I2)) 130,113,110                         ATVB
  113 IF(AMAXTV(7,I1)-AMAXTV(7,I2)) 130,114,110                         ATVB
  114 IF(A1-A2) 110,110,130                                             ATVB
 2000 IF(INTV(14,I1)) 2010,2020,2010                                    ATVB
 2010 IDTV(8,I1)=0                                                      ATVB
      TTVP(8,I1)=10.**70                                                ATVB
      I1=1                                                              ATVB
      GO TO 100                                                         ATVB
 2020 CONTINUE                                                          ATVB
      GO TO(1001,1002),IWA2SL                                           ATVB
 1001 CONTINUE                                                          ATVB
```

```
      CALL BSLTVA                                                       ATVB  37
      CONTINUE                                                          ATVB  38
      GO TO 1000                                                        ATVB  39
 1002 CONTINUE                                                          ATVB  40
      CALL BSLTVB                                                       ATVB  41
      CONTINUE                                                          ATVB  42
      GO TO 1000                                                        ATVB  43
 1000 CONTINUE                                                          ATVB  44
      RETURN                                                            ATVB  45
      END                                                               ATVB  46
```

```
      SUBROUTINE BSLTVA
      COMMON NCASES,NRUNS,I,K,L,N,WC,VC,TAM,T1,T2,TSC,TBC,TTV,TAMF,T1F,
     1T2P,TSCP,TBCP,TTVP,IDMA,ID1,ID2,IDSC,IDBC,IDTV,INMS,IN1,IN2,INSC,
     2INBC,INTV,AMINM,AMIN1,AMIN2,AMINSC,AMINBC,AMINTV,AMAXM,AMAX1,AMAX2
     3,AMAXSC,AMAXBC,AMAXTV,ISUC,IBLD,IWA1SL,IWA2SL,ISCSL,IBCSL,INDEX1,
     4INDEX2,I1,K1,L1,ICASE,IRUN,TTM,NDUML,NDUMMY,WGHT,VOL,TIME,IBREAK,
     5WT1MAX,WT2MAX,IDBRTV,INBRTV,BRKTV,NDAMMY,INDEX
      DIMENSION WC(1000),VC(1000),N(20),TSC( 9,20),TBC(10,20),TTV(17,20)
     1,TSCP( 9,20),TBCP(10,20),TTVP(17,20),IDSC( 9,20),IDBC(10,20),IDTV(
     217,20),INSC( 9,20),INBC(10,20),INTV(17,20),AMINSC( 9,20),AMINBC(10
     3,20),AMINTV(17,20),AMAXSC( 9,20),AMAXBC(10,20),AMAXTV(17,20),NDUMM
     4Y(20),IDBRTV(8,20),INBRTV(8,20),BRKTV(8,20),NDAMMY(20)
      I2=1
  240 IF(TTVP(8,I1)-TTVP(14,I2)) 210,210,220
  210 IF(I2-I) 230,1000,1000
  230 I2=I2+1
      GO TO 240
  220 I1=I2
  260 IF(I2-I) 250,1000,1000
  250 I2=I2+1
      IF(TTVP(14,I1)-TTVP(14,I2)) 260,270,220
  270 A1=TTV(13,I1)+TTV(15,I1)+TTV(16,I1)
      A2=TTV(13,I2)+TTV(15,I2)+TTV(16,I2)
      IF((AMAXTV(7,I1)/A1)-(AMAXTV(7,I2)/A2)) 220,271,260
  271 IF((AMAXTV(6,I1)/A1)-(AMAXTV(6,I2)/A2)) 220,272,260
  272 IF(AMAXTV(7,I1)-AMAXTV(7,I2)) 220,273,260
  273 IF(AMAXTV(6,I1)-AMAXTV(6,I2)) 220,274,260
  274 IF((AMINTV(7,I1)/A1)-(AMINTV(7,I2)/A2)) 220,275,260
  275 IF((AMINTV(6,I1)/A1)-(AMINTV(6,I2)/A2)) 220,276,260
  276 IF(AMINTV(7,I1)-AMINTV(7,I2)) 220,277,260
  277 IF(AMINTV(6,I1)-AMINTV(6,I2)) 220,278,260
  278 IF(A1-A2) 260,260,220
 1000 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE BSLTVB                                                 BTVB
      COMMON NCASES,NRUNS,I,K,L,N,WC,VC,TAM,T1,T2,TSC,TBC,TTV,TAMF,T1P, BTVB
     1T2P,TSCP,TBCP,TTVP,IDMA,ID1,ID2,IDSC,IDBC,IDTV,INMS,IN1,IN2,INSC, BTVB
     2INBC,INTV,AMINM,AMIN1,AMIN2,AMINSC,AMINBC,AMINTV,AMAXM,AMAX1,AMAX2BTVB
     3,AMAXSC,AMAXBC,AMAXTV,ISUD,IBUD,IWA1SL,IWA2SL,ISCSL,IBCSL,INDEX1, BTVB
     4INDEX2,I1,K1,L1,ICASE,IRUN,TTM,NDUML,NDUMMY,WGHT,VCL,TIME,IBREAK, BTVB
     5WT1MAX,WT2MAX,IDBRTV,INBRTV,BRKTV,NDAMMY,INDEX                    BTVB
      DIMENSION WC(1000),VC(1000),N(20),TSC( 9,20),TBC(10,20),TTV(17,20)BTVB
     1,TSCP( 9,20),TBCP(10,20),TTVP(17,20),IDSC( 9,20),IDBC(10,20),IDTV(BTVB
     217,20),INSC( 9,20),INBC(10,20),INTV(17,20),AMINSC( 9,20),AMINBC(10BTVB
     3,20),AMINTV(17,20),AMAXSC( 9,20),AMAXBC(10,20),AMAXTV(17,20),NDUMMBTVB
     4Y(20),IDBRTV(8,20),INBRTV(8,20),BRKTV(8,20),NDAMMY(20)            BTVB
      I2=1                                                              BTVB
  240 IF(TTVP(8,I1)-TTVP(14,I2)) 210,210,220                            BTVB
  210 IF(I2-I) 230,1000,1000                                            BTVB
  230 I2=I2+1                                                           BTVB
      GO TO 240                                                         BTVB
  220 I1=I2                                                             BTVB
  260 IF(I2-I) 250,1000,1000                                            BTVB
  250 I2=I2+1                                                           BTVB
      IF(TTVP(14,I1)-TTVP(14,I2)) 260,270,220                           BTVB
  270 A1=TTV(13,I1)+TTV(15,I1)+TTV(16,I1)                               BTVB
      A2=TTV(13,I2)+TTV(15,I2)+TTV(16,I2)                               BTVB
      IF((AMAXTV(6,I1)/A1)-(AMAXTV(6,I2)/A2)) 220,271,260               BTVB
  271 IF((AMAXTV(7,I1)/A1)-(AMAXTV(7,I2)/A2)) 220,272,260               BTVB
  272 IF(AMAXTV(6,I1)-AMAXTV(6,I2)) 220,273,260                         BTVB
  273 IF(AMAXTV(7,I1)-AMAXTV(7,I2)) 220,274,260                         BTVB
  274 IF((AMINTV(6,I1)/A1)-(AMINTV(6,I2)/A2)) 220,275,260               BTVB
  275 IF((AMINTV(7,I1)/A1)-(AMINTV(7,I2)/A2)) 220,276,260               BTVB
  276 IF(AMINTV(6,I1)-AMINTV(6,I2)) 220,277,260                         BTVB
  277 IF(AMINTV(7,I1)-AMINTV(7,I2)) 220,278,260                         BTVB
  278 IF(A1-A2) 260,260,220                                             BTVB
 1000 CONTINUE                                                          BTVB
      RETURN                                                            BTVB
      END                                                               BTVB
```

```
      SUBROUTINE SLSCA                                                  SSCA
      COMMON NCASES,NRUNS,I,K,L,N,WC,VC,TAM,T1,T2,TSC,TBC,TTV,TAMF,T1P, SSCA
     1T2P,TSCP,TBCP,TTVP,IDMA,ID1,ID2,IDSC,IDBC,IDTV,INMS,IN1,IN2,INSC, SSCA
     2INBC,INTV,AMINM,AMIN1,AMIN2,AMINSC,AMINBC,AMINTV,AMAXM,AMAX1,AMAX2SSCA
     3,AMAXSC,AMAXBC,AMAXTV,ISUD,IBUD,IWA1SL,IWA2SL,ISCSL,IBCSL,INDEX1, SSCA
     4INDEX2,I1,K1,L1,ICASE,IRUN,TTM,NDUML,NDUMMY,WGHT,VOL,TIME,IBREAK, SSCA
     5WT1MAX,WT2MAX,IDBRTV,INBRTV,BRKTV,NDAMMY,INDEX                    SSCA
      DIMENSION WC(1000),VC(1000),N(20),TSC( 9,20),TBC(10,20),TTV(17,20)SSCA
     1,TSCP( 9,20),TBCP(10,20),TTVP(17,20),IDSC( 9,20),IDBC(10,20),IDTV(SSCA
     217,20),INSC( 9,20),INBC(10,20),INTV(17,20),AMINSC( 9,20),AMINBC(10SSCA
     3,20),AMINTV(17,20),AMAXSC( 9,20),AMAXBC(10,20),AMAXTV(17,20),NDUMMSSCA
     4Y(20),IDBRTV(8,20),INBRTV(8,20),BRKTV(8,20),NDAMMY(20)            SSCA
 3000 FORMAT(1H1,'THE SELECTION OF T.V. NO. ',I2,' FROM W.A. 1 MADE AT 'SSCA
     1,F8.1,' UNITS OF TIME'/' AFTER THE START OF THE MISSION IS FORFEITSSCA
     2ED BECAUSE THERE IS NO SHIP'/' UNLOADING FACILITY AVAILABLE TO RECSSCA
     3EIVE IT.'/' SHIP UNLOADING FACILITY NO. ',I2,' IS THE FIRST ONE TOSSCA
     4 BECOME AVAILABLE AT '/1H ,F8.1,' UNITS OF TIME AFTER THE START OFSSCA
     5 THE MISSION.'/' THE DEPARTURE TIME OF ALL TRANSFER VEHICLES IN W.SSCA
     6A. 1 THAT COULD DEPART'/' BEFORE THE ABOVE MENTIONED SHIP UNLOADINSSCA
     7G FACILITY BECAME AVAILABLE IS'/' SET EQUAL TO ',F8.1,' UNITS OF TSSCA
     8IME.')                                                            SSCA
 3100 FORMAT(1H1,'T.V. AND SHIP UNLOADING FACILITY SELECTION.'//' T.V. NSSCA
     1O. ',I2,' AND SHIP UNLOADING FACILITY NO. ',I2,' ARE SELECTED AT'/SSCA
     21H ,F8.1,' AND ',F8.1,' UNITS OF TIME AFTER THE START OF THE MISSISSCA
     3ON'/' RESPECTIVELY.')                                             SSCA
      IF(INDEX1) 100,100,1000                                           SSCA
  100 K1=1                                                              SSCA
      IF(K-1) 1010,1010,110                                             SSCA
  110 IF(INSC(6,K1)) 120,130,120                                        SSCA
  120 K1=K1+1                                                           SSCA
      GO TO 110                                                         SSCA
  130 IF(K1-K) 140,1010,1010                                            SSCA
  140 K2=K1+1                                                           SSCA
  142 IF(TSCP(6,K1)-TSCP(6,K2))150,160,170                              SSCA
  170 K1=K2                                                             SSCA
  150 IF(K2-K) 141,1010,1010                                            SSCA
```

```
  141 K2=K2+1                                                          SSCA  37
      GO TO 142                                                        SSCA  38
  160 IF(IDSC(6,K1)-N(K1)-IDSC(6,K2)-N(K2)) 170,180,150                SSCA  39
  180 IF(AMAXSC(6,K1)-AMAXSC(6,K2)) 150,190,170                        SSCA  40
  190 A1=TSC(2,K1)+TSC(3,K1)+TSC(4,K1)+TSC(5,K1)+TSC(7,K1)             SSCA  41
      A2=TSC(2,K2)+TSC(3,K2)+TSC(4,K2)+TSC(5,K2)+TSC(7,K2)             SSCA  42
      IF(A1-A2) 150,150,170                                            SSCA  43
 1010 IF(INDEX1) 1000,195,1000                                         SSCA  44
  195 DO 196 II=1,I                                                    SSCA  45
      TTVP(6,II)=0.                                                    SSCA  46
  196 CONTINUE                                                         SSCA  47
 1000 IF(TSCP(6,K1)-TTVP(8,I1)) 200,200,210                            SSCA  48
  200 TTV(3,I1)=0.                                                     SSCA  49
      WRITE(6,3100) I1,K1,TTVP(8,I1),TSCP(6,K1)                        SSCA  50
      TTVP(8,I1)=10.**70                                               SSCA  51
      IDTV(8,I1)=2                                                     SSCA  52
      IDTV(14,I1)=IDTV(14,I1)+1                                        SSCA  53
      AMINTV(6,I1)=0.                                                  SSCA  54
      AMINTV(7,I1)=0.                                                  SSCA  55
      INDEX1=0                                                         SSCA  56
      GO TO 2000                                                       SSCA  57
  210 CONTINUE                                                         SSCA  58
      WRITE(6,3000) I1,TTVP(8,I1),K1,TSCP(6,K1),TSCP(6,K1)             SSCA  59
      I1=1                                                             SSCA  60
  220 IF(IDTV(8,I1)-1) 240,230,240                                     SSCA  61
  240 IF(I1-I) 250,260,260                                             SSCA  62
  250 I1=I1+1                                                          SSCA  63
      GO TO 220                                                        SSCA  64
  230 TTV(3,I1)=TSCP(6,K1)-TTVP(8,I1)                                  SSCA  65
      IF(TTV(3,I1)) 240,240,241                                        SSCA  66
  241 TTVP(6,I1)=TTV(3,I1)                                             SSCA  67
      AMAXTV(8,I1)=TSCP(6,K1)                                          SSCA  68
      TTVP(8,I1)=AMAXTV(8,I1)                                          SSCA  69
      GO TO 240                                                        SSCA  70
  260 INDEX1=1                                                         SSCA  71
 2000 CONTINUE                                                         SSCA  72

      RETURN                                                           SSCA  73
      END                                                              SSCA  74
```

```
      SUBROUTINE SLSCB                                                  SSCB
      COMMON NCASES,NRUNS,I,K,L,N,WC,VC,TAM,T1,T2,TSC,TBC,TTV,TAMF,T1P, SSCB
     1T2P,TSCP,TBCP,TTVP,IDMA,ID1,ID2,IDSC,IDBC,IDTV,INMS,IN1,IN2,INSC, SSCB
     2INBC,INTV,AMINM,AMIN1,AMIN2,AMINSC,AMINBC,AMINTV,AMAXM,AMAX1,AMAX2SSCB
     3,AMAXSC,AMAXBC,AMAXTV,ISUD,IBUD,IWA1SL,IWA2SL,ISCSL,IBCSL,INDEX1, SSCB
     4INDEX2,I1,K1,L1,ICASE,IRUN,TTM,NDUML,NDUMMY,WGHT,VOL,TIME,IBREAK, SSCB
     5WT1MAX,WT2MAX,IDBRTV,INBRTV,BRKTV,NDAMMY,INDEX                    SSCB
      DIMENSION WC(1000),VC(1000),N(20),TSC( 9,20),TBC(10,20),TTV(17,20)SSCB
     1,TSCP( 9,20),TBCP(10,20),TTVP(17,20),IDSC( 9,20),IDBC(10,20),IDTV(SSCB
     217,20),INSC( 9,20),INBC(10,20),INTV(17,20),AMINSC( 9,20),AMINBC(10SSCB
     3,20),AMINTV(17,20),AMAXSC( 9,20),AMAXBC(10,20),AMAXTV(17,20),NDUMMSSCB
     4Y(20),IDBRTV(8,20),INBRTV(8,20),BRKTV(8,20),NDAMMY(20)            SSCB
 3000 FORMAT(1H1,'THE SELECTION OF T.V. NO. ',I2,' FROM W.A. 1 MADE AT 'SSCB
     1,F8.1,' UNITS OF TIME'/' AFTER THE START OF THE MISSION IS FORFEITSSCB
     2ED BECAUSE THERE IS NO SHIP'/' UNLOADING FACILITY AVAILABLE TO RECSSCB
     3EIVE IT.'/' SHIP UNLOADING FACILITY NO. ',I2,' IS THE FIRST ONE TOSSCB
     4 BECOME AVAILABLE AT '/1H ,F8.1,' UNITS OF TIME AFTER THE START OFSSCB
     5 THE MISSION.'/' THE DEPARTURE TIME OF ALL TRANSFER VEHICLES IN W.SSCB
     6A. 1 THAT COULD DEPART'/' BEFORE THE ABOVE MENTIONED SHIP UNLOADINSSCB
     7G FACILITY BECAME AVAILABLE IS'/' SET EQUAL TO ',F8.1,' UNITS OF TSSCB
     8IME.')                                                            SSCB
 3100 FORMAT(1H1,'T.V. AND SHIP UNLOADING FACILITY SELECTION.'//' T.V. NSSCB
     1O. ',I2,' AND SHIP UNLOADING FACILITY NO. ',I2,' ARE SELECTED AT'/SSCB
     21H ,F8.1,' UNITS OF TIME AFTER THE START OF THE MISSION.')        SSCB
 3200 FORMAT(1H1,'THE SELECTION OF SHIP UNLOADING FACILITY NO. ',I2,' MASSCB
     1DE AT ',F8.1,' UNITS'/' OF TIME AFTER THE START OF THE MISSION IS SSCB
     2FORFEITED BECAUSE THERE WAS'/' NO T.V. IN W.A. 1 TO BE SERVICED.'/SSCB
     3' T.V. NO. ',I2,' WILL BE THE FIRST ONE TO ARRIVE IN W.A. 1 AT ',FSSCB
     48.1,' UNITS'/' OF TIME AFTER THE START OF THE MISSION.'/' THE TIMESSCB
     5 AT WHICH SHIP UNLOADING FACILITIES BECOME AVAILABLE FOR ALL'/' SUSSCB
     6CH FACILITIES THAT WERE FREE BEFORE THE ARRIVAL OF THE ABOVE CITEDSSCB
     7'/' T.V. IN W.A. 1 IS SET EQUAL TO ',F8.1,' UNITS OF TIME.')      SSCB
      IF(INDEX1) 100,100,1000                                           SSCB
  100 K1=1                                                              SSCB
      IF(K-1) 1010,1010,110                                             SSCB
  110 IF(INSC(6,K1)) 120,130,120                                        SSCB
```

```
  120 K1=K1+1                                                           SSCB  37
      GO TO 110                                                         SSCB  38
  130 IF(K1-K) 140,1010,1010                                            SSCB  39
  140 K2=K1+1                                                           SSCB  40
  142 IF(TSCP(6,K1)-TSCP(6,K2))150,160,170                              SSCB  41
  170 K1=K2                                                             SSCB  42
  150 IF(K2-K) 141,1010,1010                                            SSCB  43
  141 K2=K2+1                                                           SSCB  44
      GO TO 142                                                         SSCB  45
  160 IF(IDSC(6,K1)-N(K1)-IDSC(6,K2)-N(K2)) 170,180,150                 SSCB  46
  180 IF(AMAXSC(6,K1)-AMAXSC(6,K2)) 150,190,170                         SSCB  47
  190 A1=TSC(2,K1)+TSC(3,K1)+TSC(4,K1)+TSC(5,K1)+TSC(7,K1)              SSCB  48
      A2=TSC(2,K2)+TSC(3,K2)+TSC(4,K2)+TSC(5,K2)+TSC(7,K2)              SSCB  49
      IF(A1-A2) 150,150,170                                             SSCB  50
 1010 IF(INDEX1) 1000,195,1000                                          SSCB  51
  195 DO 196 II=1,I                                                     SSCB  52
      TTVP(6,II)=0.                                                     SSCB  53
  196 CONTINUE                                                          SSCB  54
 1000 IF(TSCP(6,K1)-TTVP(8,I1)) 270,200,210                             SSCB  55
  200 TTV(3,I1)=0.                                                      SSCB  56
      WRITE(6,3100) I1,K1,TTVP(8,I1)                                    SSCB  57
      TTVP(8,I1)=10.**70                                                SSCB  58
      IDTV(8,I1)=2                                                      SSCB  59
      IDTV(14,I1)=IDTV(14,I1)+1                                         SSCB  60
      AMINTV(6,I1)=0.                                                   SSCB  61
      AMINTV(7,I1)=0.                                                   SSCB  62
      INDEX1=0                                                          SSCB  63
      GO TO 2000                                                        SSCB  64
  210 CONTINUE                                                          SSCB  65
      WRITE(6,3000) I1,TTVP(8,I1),K1,TSCP(6,K1),TSCP(6,K1)              SSCB  66
      I1=1                                                              SSCB  67
  220 IF(IDTV(8,I1)-1) 240,230,240                                      SSCB  68
  240 IF(I1-I) 250,260,260                                              SSCB  69
  250 I1=I1+1                                                           SSCB  70
      GO TO 220                                                         SSCB  71
  230 TTV(3,I1)=TSCP(6,K1)-TTVP(8,I1)                                   SSCB  72
```

```
      IF(TTV(3,I1)) 240,240,241                                         SSCB  73
  241 TTVP(6,I1)=TTV(3,I1)                                              SSCB  74
      AMAXTV(8,I1)=TSCP(6,K1)                                           SSCB  75
      TTVP(8,I1)=AMAXTV(8,I1)                                           SSCB  76
      GO TO 240                                                         SSCB  77
  260 INDEX1=1                                                          SSCB  78
      GO TO 2000                                                        SSCB  79
  270 TTV(3,I1)=0.                                                      SSCB  80
      WRITE(6,3200) K1,TSCP(6,K1),I1,TTVP(8,I1),TTVP(8,I1)              SSCB  81
      K1=1                                                              SSCB  82
  280 IF(INSC(6,K1)) 290,300,290                                        SSCB  83
  290 IF(K1-K) 320,310,310                                              SSCB  84
  320 K1=K1+1                                                           SSCB  85
      GO TO 280                                                         SSCB  86
  300 A1=TSCP(6,K1)-TTVP(8,I1)                                          SSCB  87
      IF(A1) 330,290,290                                                SSCB  88
  330 TSCP(6,K1)=TTVP(8,I1)                                             SSCB  89
      GO TO 290                                                         SSCB  90
  310 INDEX1=-1                                                         SSCB  91
 2000 CONTINUE                                                          SSCB  92
      RETURN                                                            SSCB  93
      END                                                               SSCB  94
```

```
      SUBROUTINE LOAD                                                   LOAD
      COMMON NCASES,NFUNS,I,K,L,N,WC,VC,TAM,T1,T2,TSC,TBC,TTV,TAMP,T1P, LOAD
     1T2P,TSCP,TBCP,TTVP,IDMA,ID1,ID2,IDSC,IDBC,IDTV,INMS,IN1,IN2,INSC, LOAD
     2INBC,INTV,AMINM,AMIN1,AMIN2,AMINSC,AMINBC,AMINTV,AMAXM,AMAX1,AMAX2LOAD
     3,AMAXSC,AMAXBC,AMAXTV,ISUD,IBUD,IWA1SL,IWA2SL,ISCSL,IBCSL,INDEX1, LOAD
     4INDEX2,I1,K1,L1,ICASE,IRUN,TTM,NDUML,NDUMMY,WGHT,VOL,TIME,IBREAK,  LOAD
     5WT1MAX,WT2MAX,IDBRTV,INBRTV,BRKTV,NDAMMY,INDEX                    LOAD
      DIMENSION WC(1000),VC(1000),N(20),TSC( 9,20),TBC(10,20),TTV(17,20)LOAD
     1,TSCP( 9,20),TBCP(10,20),TTVP(17,20),IDSC( 9,20),IDBC(10,20),IDTV(LOAD
     217,20),INSC( 9,20),INBC(10,20),INTV(17,20),AMINSC( 9,20),AMINBC(10LOAD
     3,20),AMINTV(17,20),AMAXSC( 9,20),AMAXBC(10,20),AMAXTV(17,20),NDUMMLOAD
     4Y(20),IDBRTV(8,20),INBRTV(8,20),BRKTV(8,20),NDAMMY(20)            LOAD
 4000 FORMAT(' T.V. NO. ',I2,' DEPARTED W.A. 1 FOR SHIP UNLOADING AREA NLOAD
     1O. ',I2,', 'F8.1/' UNITS OF TIME AFTER THE START OF THE MISSION.')LOAD
 4010 FORMAT(' T.V. NO. ',I2,' REACHED SHIP UNLOADING AREA NO. ',I2,' HOLOAD
     1OKED UP AND WAS MADE'/' READY FOR THE UNLOADING OPERATION ',F8.1,'LOAD
     2 UNITS OF TIME AFTER THE'/' START OF THE MISSION.'//)             LOAD
 4020 FORMAT(' T.V. NO. ',I2,' COMPLETED ITS REFUELLING OPERATION ',F8.1LOAD
     1,' UNITS OF TIME'/' AFTER THE START OF THE MISSION.')             LOAD
 4030 FORMAT(' '//' ALL TIME MEASUREMENTS IN THE FOLLOWING TABLE HAVE ASLOAD
     1 A COMMON ORIGIN'/' THE START OF THE MISSION.')                   LOAD
 4040 FORMAT(1H ,//' OPERATION TO UNLOAD CARGO UNIT NO. ',I4//' CARGO UNLOAD
     1IT CHARACTERISTICS:'/' WEIGHT',47X,F5.2,1X,3A4/' VOLUME',49X,F4.0,LOAD
     21X,3A4/)                                                          LOAD
 4050 FORMAT(' SHIP UNLOADING FACILITY (S.U.F.) OPERATION:'/' S.U.F. REALOAD
     1CHES THE ABOVE CITED CARGO UNIT AFTER',3X,F8.1,1X,3A4)            LOAD
 4060 FORMAT(' THE ABOVE CITED CARGO UNIT IS RELEASED AFTER',6X,F8.1,1X,LOAD
     13A4)                                                              LOAD
 4070 FORMAT(' IS SECURED TO THE S.U.F. AFTER',20X,F8.1,1X,3A4)         LOAD
 4080 FORMAT(' AND IS TRANSPORTED TO THE UNLOADING AREA AFTER',4X,F8.1,1LOAD
     1X,3A4)                                                            LOAD
 4090 FORMAT(' THE S.L.F. WILL COMMENCE UNLOADING AFTER',10X,F8.1,1X,3A4LOAD
     1//' T.V. OPERATION:')                                             LOAD
 4100 FORMAT(' THE CARGO UNIT UNLOADING IS COMPLETED AFTER',7X,F8.1,1X,3LOAD
     1A4)                                                               LOAD
 4110 FORMAT(' AND IT IS PROPERLY SECURED IN THE T.V. AFTER',6X,F8.1,1X,LOAD
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      13A4)                                                            LOAD
 4120 FORMAT(1H ,////' ALL CARGC UNITS ASSCCIATED WITH S.U.F. NC. ',I2,'LCAC
     1 HAVE BEEN UNLCADEC SC THE'/' OPERATION OF S.U.F. NO. ',I2,' HAS TLCAD
     2ERMINATED.'/' THE ABCVE CITEC S.U.F. REACHES ITS CRIGINAL PCSITICNLCAD
     3 ',F8.1,' UNITS CF'/' TIME AFTER THE START OF THE MISSICN AND IS PLOAC
     4RCPERLY SECURED IN')                                             LOAD
 4130 FORMAT(' PCSITICN ',F8.1,' UNITS CF TIME AFTER THE START CF THE MI LCAC
     1SSICN.')                                                         LCAD
 4140 FORMAT(1H ,////' THE UNLCADING CPERATICN HAS TC TERMINATE BECAUSE LOAD
     1OTHERWISE THE WEIGHT'/' PAYLOAD OF T.V. NO. ',I2,' WILL BE EXCEEDELCAD
     2C.')                                                             LCAC
 4150 FCRMAT(' IN ADDITICN')                                           LOAD
 4160 FCRMAT(' THE UNLCADING OPERATICN HAS TC TERMINATE BECAUSE CTHERWISLCAC
     1E THE VOLUME'/' PAYLCAD CF T.V. NO. ',I2,' WILL BE EXCEEDED.')   LCAC
 4170 FCRMAT(1H ,////' T.V. NC. ',I2,' WAS UNHOOKED AND WAS READY TC STALCAC
     1RT FOR W.A. 2 ',F8.1/' UNITS OF TIME AFTER THE START OF THE MISSIOLOAC
     2N')                                                              LCAC
 4180 FORMAT(' AND AT THE SAME TIME SHIP UNLCADING AREA NC. ',I2,' BECAMLCAC
     1E ONCE MORE'/' AVAILABLE.')                                      LCAC
 4190 FCRMAT(' AND AT THE SAME TIME ALL SHIP UNLOADING AREAS BECAME CNCELCAD
     1 MCRE AVAILABLE.')                                               LOAD
 4200 FCRMAT(1H ,////' T.V. NC. ',I2,' ARRIVEC AT W.A. 2 ',F8.1,' UNITS LCAC
     1CF TIME AFTER THE START CF'/' THE MISSICN.')                     LCAD
 4001 FORMAT(1H ,///' T.V. BREAKDCWN CCNSICERATICNS. '///' T.V. NC. ',I2LOAC
     1,' IS NCT ALLOWED TO DEPART W.A. 1 AS IT IS CCNSIDEREC TC BE'/' MALCAC
     2LFUNCTIONING.  THE ABCVE CITED T.V. IS CONSICEREC LCST FROM OUR'/'LOAD
     3 SYSTEM FOR THIS CCMPUTER RUN.  IN ACCITICN THE ABOVE MENTICNEC T.LCAC
     4V. AND'/' SHIP UNLOADING FACILITY SELECTION IS FORFEITED.')      LOAD
 4002 FORMAT(1H ,///' T.V. BREAKDCWN CCNSICERATICNS. '///' T.V. NC. ',I2LCAC
     1,' HAS SAFELY DEPARTED W.A. 1.'///)                              LCAD
 4003 FCRMAT(1H ,///)                                                  LCAC
 4011 FORMAT(1H ,///' T.V. BREAKDCWN CCNSICERATICNS. '///' T.V. NC. ',I2LCAC
     1,' IS NCT ALLCWED TO REACH THE MOTHER SHIP AS IT IS CCNSIDERED'/' LCAC
     2TO BE MALFUNCTICNING.  THE ABCVE CITEC T.V. IS CONSIDEREC LCST FROLOAD
     3M OUR'/' SYSTEM FOR THIS CCMPUTER RUN.  IN ADDITICN THE ABCVE MENTLCAC
     4ICNED T.V. AND'/' SHIP UNLCADING FACILITY SELECTICN IS FORFEITED.'LCAC
```

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      5)                                                                 LOAD  73
 4012 FORMAT(1H ,///' T.V. BREAKDOWN CONSIDERATIONS. '///' T.V. NO. ',I2LOAD  74
     1,' HAS SAFELY REACHED THE MOTHER SHIP.'////)                       LOAD  75
 4021 FORMAT(1H ,///' T.V. BREAKDOWN CONSIDERATIONS. '///' T.V. NO. ',I2LOAD  76
     1,' IS NOT ALLOWED TO ENTER W.A. 2 AS IT IS CONSIDERED TO BE'/' MALLOAD  77
     2FUNCTIONING.  THE ABOVE CITED T.V. AND ITS ENTIRE PAYLOAD IS'/' COLOAD  78
     3NSIDERED LOST FROM OUR SYSTEM FOR THIS COMPUTER RUN.')             LOAD  79
 4022 FORMAT(1H ,///' T.V. BREAKDOWN CONSIDERATIONS. '///' T.V. NO. ',I2LOAD  80
     1,' HAS SAFELY ENTERED W.A. 2.')                                    LOAD  81
      DO 100 JJ=3,4                                                      LOAD  82
      IDD=IDTV(JJ,I1)                                                    LOAD  83
      GO TO (2000,2001),IDD                                              LOAD  84
 2000 TTVP(JJ,I1)=0.                                                     LOAD  85
      GO TO 100                                                          LOAD  86
 2001 IND=INTV(JJ,I1)                                                    LOAD  87
      CALL RANDU(IND,INC,TPD)                                            LOAD  88
      INTV(JJ,I1)=INC                                                    LOAD  89
      TTVP(JJ,I1)=(AMAXTV(JJ,I1)-AMINTV(JJ,I1))*TPD+AMINTV(JJ,I1)        LOAD  90
      GO TO 100                                                          LOAD  91
  100 CONTINUE                                                           LOAD  92
      IDD=IDBRTV(2,I1)                                                   LOAD  93
      GO TO (207,201),IDD                                                LOAD  94
  201 TTVP(6,I1)=TTVP(6,I1)+TTVP(3,I1)                                   LOAD  95
      TTVP(6,I1)=TTVP(6,I1)/WT1MAX                                       LOAD  96
      IF(TTVP(6,I1)-1.) 202,203,203                                      LOAD  97
  202 TTVP(6,I1)=TTVP(6,I1)*BRKTV(2,I1)                                  LOAD  98
      GO TO 204                                                          LOAD  99
  203 TTVP(6,I1)=BRKTV(2,I1)                                             LOAD 100
  204 IND=INBRTV(2,I1)                                                   LOAD 101
      CALL RANDU(IND,INC,TPD)                                            LOAD 102
      INBRTV(2,I1)=INC                                                   LOAD 103
      IF(TTVP(6,I1)-TPD) 200,200,205                                     LOAD 104
  205 IDTV(14,I1)=IDTV(14,I1)-1                                          LOAD 105
      IDTV(8,I1)=0                                                       LOAD 106
      IBREAK=IBREAK-1                                                    LOAD 107
      WRITE(6,4001) I1                                                   LOAD 108
```

```
      GO TO 206
  200 CONTINUE
      WRITE(6,4002) I1
      GO TO 208
  207 CONTINUE
      WRITE(6,4003)
  208 AMAXTV(8,I1)=AMAXTV(8,I1)+TTV(3,I1)+TTVP(3,I1)
      WRITE(6,4000) I1,K1,AMAXTV(8,I1)
      IDD=IDBRTV(3,I1)
      GO TO (210,211),IDD
  211 IND=INBRTV(3,I1)
      CALL RANDU(IND,INC,TPD)
      INBRTV(3,I1)=INC
      IF(BRKTV(3,I1)-TPD) 213,213,212
  212 IDTV(14,I1)=IDTV(14,I1)-1
      IDTV(8,I1)=0
      IBREAK=IBREAK-1
      WRITE(6,4011) I1
      GO TO 206
  213 CONTINUE
      WRITE(6,4012) I1
      GO TO 214
  210 CONTINUE
      WRITE(6,4003)
  214 AMAXTV(8,I1)=AMAXTV(8,I1)+TTV(4,I1)+TTVP(4,I1)
      WRITE(6,4010) I1,K1,AMAXTV(8,I1)
      TTVP(7,I1)=TTVP(7,I1)-TTV(6,I1)
      IF(TTVP(7,I1)) 1000,1101,1101
 1000 IDD=IDTV(5,I1)
      GO TO (2010,2011),IDD
 2010 TTVP(5,I1)=0.
      GO TO 3010
 2011 IND=IDTV(5,I1)
      CALL RANDU(IND,IND,TPD)
      INTV(5,I1)=INC
      TTVP(5,I1)=(AMAXTV(5,I1)-AMAXTV(5,I1))*TPD+AMINTV(5,I1)
```

```
      GO TO 3010                                                        LOAD 145
 3010 AMAXTV(8,I1)=AMAXTV(8,I1)+TTV(5,I1)+TTVP(5,I1)                    LOAD 146
      TTVP(7,I1)=TTV(7,I1)                                              LOAD 147
      WRITE(6,4020) I1,AMAXTV(8,I1)                                     LOAD 148
 1101 NDUMMY(I1)=IDSC(6,K1)                                             LOAD 149
      WRITE(6,4030)                                                     LOAD 150
      NTEMP=IDSC(6,K1)                                                  LOAD 151
      AMINTV(6,I1)=AMINTV(6,I1)+WC(NTEMP)                               LOAD 152
      AMINTV(7,I1)=AMINTV(7,I1)+VC(NTEMP)                               LOAD 153
 1100 DO 110 JJ=2,5                                                     LOAD 154
      IDD=IDSC(JJ,K1)                                                   LOAD 155
      GO TO (2020,2021),IDD                                             LOAD 156
 2020 TSCP(JJ,K1)=0.                                                    LOAD 157
      GO TO 110                                                         LOAD 158
 2021 IND=INSC(JJ,K1)                                                   LOAD 159
      CALL RANDU(IND,IND,TPD)                                           LOAD 160
      INSC(JJ,K1)=IND                                                   LOAD 161
      TSCP(JJ,K1)=(AMAXSC(JJ,K1)-AMINSC(JJ,K1))*TPD+AMINSC(JJ,K1)       LOAD 162
      GO TO 110                                                         LOAD 163
  110 CONTINUE                                                          LOAD 164
      WRITE(6,4040) NTEMP,WC(NTEMP),WGHT,VC(NTEMP),VOL                  LOAD 165
      AMAXSC(6,K1)=AMAXSC(6,K1)+TSC(2,K1)+TSCP(2,K1)                    LOAD 166
      WRITE(6,4050) AMAXSC(6,K1),TIME                                   LOAD 167
      AMAXSC(6,K1)=AMAXSC(6,K1)+TSC(3,K1)+TSCP(3,K1)                    LOAD 168
      WRITE(6,4060) AMAXSC(6,K1),TIME                                   LOAD 169
      AMAXSC(6,K1)=AMAXSC(6,K1)+TSC(4,K1)+TSCP(4,K1)                    LOAD 170
      WRITE(6,4070) AMAXSC(6,K1),TIME                                   LOAD 171
      AMAXSC(6,K1)=AMAXSC(6,K1)+TSC(5,K1)+TSCP(5,K1)                    LOAD 172
      WRITE(6,4080) AMAXSC(6,K1),TIME                                   LOAD 173
      IF(AMAXSC(6,K1)-AMAXTV(8,I1)) 1200,1200,1300                      LOAD 174
 1200 TTV(8,I1)=0.                                                      LOAD 175
      TSC(6,K1)=AMAXTV(8,I1)-AMAXSC(6,K1)                               LOAD 176
      GO TO 1210                                                        LOAD 177
 1300 TSC(6,K1)=0.                                                      LOAD 178
      TTV(8,I1)=AMAXSC(6,K1)-AMAXTV(8,I1)                               LOAD 179
 1210 AMAXSC(6,K1)=AMAXSC(6,K1)+TSC(6,K1)                               LOAD 180
```

```
      AMAXTV(8,I1)=AMAXSC(6,K1)                                         LOAD 181
      WRITE(6,4090) AMAXSC(6,K1),TIME                                   LOAD 182
      IDD=IDSC(7,K1)                                                    LOAD 183
      GO TO (2030,2031),IDD                                             LOAD 184
 2030 TSCP(7,K1)=0.                                                     LOAD 185
      GO TO 3030                                                        LOAD 186
 2031 INC=INSC(7,K1)                                                    LOAD 187
      CALL RANDU (INC,INC,TPD)                                          LOAD 188
      INSC(7,K1)=IND                                                    LOAD 189
      TSCP(7,K1)=(AMAXSC(7,K1)-AMINSC(7,K1))*TPD+AMINSC(7,K1)           LOAD 190
      GO TO 3030                                                        LOAD 191
 3030 AMAXSC(6,K1)=AMAXSC(6,K1)+TSC(7,K1)+TSCP(7,K1)                    LOAD 192
      AMAXTV(8,I1)=AMAXSC(6,K1)                                         LOAD 193
      WRITE(6,4100) AMAXSC(6,K1),TIME                                   LOAD 194
      IDSC(6,K1)=IDSC(6,K1)-1                                           LOAD 195
      IF(IDSC(6,K1)-N(K1)) 1500,1400,1400                               LOAD 196
 1500 INSC(6,K1)=1                                                      LOAD 197
      DO 120 JJ=8,9                                                     LOAD 198
      IDD=IDSC(JJ,K1)                                                   LOAD 199
      GO TO (2040,2041),IDD                                             LOAD 200
 2040 TSCP(JJ,K1)=0.                                                    LOAD 201
      GO TO 120                                                         LOAD 202
 2041 INC=INSC(JJ,K1)                                                   LOAD 203
      CALL RANDU(INC,INC,TPD)                                           LOAD 204
      INSC(JJ,K1)=IND                                                   LOAD 205
      TSCP(JJ,K1)=(AMAXSC(JJ,K1)-AMINSC(JJ,K1))*TPD+AMINSC(JJ,K1)       LOAD 206
      GO TO 120                                                         LOAD 207
  120 CONTINUE                                                          LOAD 208
 1400 IDD=IDTV(9,I1)                                                    LOAD 209
      GO TO (2050,2051),IDD                                             LOAD 210
 2050 TTVP(9,I1)=0.                                                     LOAD 211
      GO TO 3050                                                        LOAD 212
 2051 IND=INTV(9,I1)                                                    LOAD 213
      CALL RANDU(INC,INC,TPD)                                           LOAD 214
      INTV(9,I1)=INC                                                    LOAD 215
      TTVP(9,I1)=(AMAXTV(9,I1)-AMINTV(9,I1))*TPD+AMINTV(9,I1)           LOAD 216
```

```
      GO TO 3050                                                        LOAD 217
 3050 AMAXTV(8,I1)=AMAXTV(8,I1)+TTV(9,I1)+TTVF(9,I1)                    LOAD 218
      WRITE(6,4110) AMAXTV(8,I1),TIME                                   LOAD 219
      IF(IDSC(6,K1)-N(K1)) 1601,1700,1700                               LOAD 220
 1601 AMAXSC(6,K1)=AMAXSC(6,K1)+TSC(8,K1)+TSCF(8,K1)                    LOAD 221
      WRITE(6,4120) K1,K1,AMAXSC(6,K1)                                  LOAD 222
      AMAXSC(6,K1)=AMAXSC(6,K1)+TSC(9,K1)+TSCF(9,K1)                    LOAD 223
      WRITE(6,4130) AMAXSC(6,K1)                                        LOAD 224
      IF(K1-K) 1602,1603,1602                                           LOAD 225
 1602 IDSC(6,K1)=N(K1+1)-1                                              LOAD 226
      NDAMMY(I1)=N(K1)                                                  LOAD 227
      GO TO 1600                                                        LOAD 228
 1603 IDSC(6,K)=NDUML                                                   LOAD 229
      NDAMMY(I1)=N(K)                                                   LOAD 230
      GO TO 1600                                                        LOAD 231
 1700 NTEMP=IDSC(6,K1)                                                  LOAD 232
      AMINTV(6,I1)=AMINTV(6,I1)+WC(NTEMP)                               LOAD 233
      AMINTV(7,I1)=AMINTV(7,I1)+VC(NTEMP)                               LOAD 234
      IF(AMAXTV(6,I1)-AMINTV(6,I1)) 1710,1720,1720                      LOAD 235
 1710 AMINTV(6,I1)=AMINTV(6,I1)-WC(NTEMP)                               LOAD 236
      WRITE(6,4140) I1                                                  LOAD 237
      IF(AMAXTV(7,I1)-AMINTV(7,I1)) 1730,1740,1740                      LOAD 238
 1730 CONTINUE                                                          LOAD 239
      WRITE(6,4150)                                                     LOAD 240
 1750 CONTINUE                                                          LOAD 241
      WRITE(6,4160) I1                                                  LOAD 242
 1740 AMINTV(7,I1)=AMINTV(7,I1)-VC(NTEMP)                               LOAD 243
      IDSC(6,K1)=IDSC(6,K1)+1                                           LOAD 244
      NDAMMY(I1)=IDSC(6,K1)                                             LOAD 245
      GO TO 1600                                                        LOAD 246
 1720 IF(AMAXTV(7,I1)-AMINTV(7,I1)) 1760,1100,1100                      LOAD 247
 1760 AMINTV(6,I1)=AMINTV(6,I1)-WC(NTEMP)                               LOAD 248
      GO TO 1750                                                        LOAD 249
 1600 IDD=IDTV(10,I1)                                                   LOAD 250
      GO TO (2060,2061),IDD                                             LOAD 251
 2060 TTVP(10,I1)=0.                                                    LOAD 252
```

```
      GO TO 3060
 2061 IND=INTV(10,I1)
      CALL RANDU(IND,IND,TPD)
      INTV(10,I1)=IND
      TTVP(10,I1)=(AMAXTV(10,I1)-AMINTV(10,I1))*TPD+AMINTV(10,I1)
      GO TO 3060
 3060 AMAXTV(8,I1)=AMAXTV(8,I1)+TTV(10,I1)+TTVP(10,I1)
      WRITE(6,4170) I1,AMAXTV(8,I1)
      IF(ISUC-1) 1800,1900,1800
 1800 KLOOP=K
      KT=1
      WRITE(6,4190)
      GO TO 1810
 1900 KLOOP=1
      KT=K1
      WRITE(6,4180) K1
 1810 DO 130 KK=1,KLOOP
      TSOP(6,KT)=AMAXTV(8,I1)
      KT=KT+1
  130 CONTINUE
      ICD=ICTV(11,I1)
      GO TO (2070,2071),ICD
 2070 TTVP(11,I1)=0.
      GO TO 3070
 2071 IND=INTV(11,I1)
      CALL RANDU(IND,IND,TPD)
      INTV(11,I1)=IND
      TTVP(11,I1)=(AMAXTV(11,I1)-AMINTV(11,I1))*TPD+AMINTV(11,I1)
      GO TO 3070
 3070 IDD=IDBRTV(4,I1)
      GO TO (220,221),IDD
  221 IND=INBRTV(4,I1)
      CALL RANDU(IND,IND,TPD)
      INBRTV(4,I1)=IND
      IF(BRKTV(4,I1)-TPD) 223,223,222
  222 ICTV(14,I1)=ICTV(14,I1)-1
```

```
      ICTV(8,I1)=0                                                      LOAD 289
      IBREAK=IBREAK-1                                                   LOAD 290
      WRITE(6,4021) I1                                                  LOAD 291
      GO TO 206                                                         LOAD 292
  223 CONTINUE                                                          LOAD 293
      WRITE(6,4022) I1                                                  LOAD 294
  220 AMAXTV(8,I1)=AMAXTV(8,I1)+TTV(11,I1)+TTVP(11,I1)                  LOAD 295
      TTVP(14,I1)=AMAXTV(8,I1)                                          LOAD 296
      WRITE(6,4200)I1,AMAXTV(8,I1)                                      LOAD 297
  206 CONTINUE                                                          LOAD 298
      RETURN                                                            LOAD 299
      END                                                               LOAD 300
```

```
      SUBROUTINE SBCA                                                   SBCA
      COMMON NCASES,NRUNS,I,K,L,N,WC,VC,TAM,T1,T2,TSC,TBC,TTV,TAMP,T1P, SBCA
     1T2P,TSCP,TBCP,TTVP,IDMA,ID1,ID2,IDSC,IDBC,IDTV,INMS,IN1,IN2,INSC, SBCA
     2INBC,INTV,AMINM,AMIN1,AMIN2,AMINSC,AMINBC,AMINTV,AMAXM,AMAX1,AMAX2SBCA
     3,AMAXSC,AMAXBC,AMAXTV,ISLC,IBUC,IWA1SL,IWA2SL,ISCSL,IBCSL,INDEX1, SBCA
     4INDEX2,I1,K1,L1,ICASE,IRUN,TTM,NDUML,NDUMMY,WGHT,VCL,TIME,IBREAK, SBCA
     5WT1MAX,WT2MAX,IDBRTV,INBRTV,BRKTV,NDAMM',INDEX                    SBCA
      DIMENSION WC(1000),VC(1000),N(20),TSC( 9,20),TBC(10,20),TTV(17,20)SBCA
     1,TSCP( 9,20),TBCP(10,20),TTVP(17,20),IDSC( 9,20),IDBC(10,20),IDTV(SBCA
     217,20),INSC( 9,20),INBC(10,20),INTV(17,20),AMINSC( 9,20),AMINBC(10SBCA
     3,20),AMINTV(17,20),AMAXSC( 9,20),AMAXBC(10,20),AMAXTV(17,20),NDUMMSBCA
     4Y(20),IDBRTV(8,20),INBRTV(8,20),BRKTV(8,20),NDAMMY(20)            SBCA
 3000 FORMAT(1H1,'THE SELECTION OF T.V. NO. ',I2,' FROM W.A. 2 MADE AT 'SBCA
     1,F8.1,' UNITS OF TIME'/' AFTER THE START OF THE MISSION IS FORFEITSBCA
     2ED BECAUSE THERE IS NO BEACH'/' UNLOADING FACILITY AVAILABLE TO RESBCA
     3CEIVE IT.'/' BEACH UNLOADING FACILITY NO. ',I2,' IS THE FIRST ONE SBCA
     4TO BECOME AVAILABLE AT '/1H ,F8.1,' UNITS OF TIME AFTER THE START SBCA
     5OF THE MISSION.'/' THE DEPARTURE TIME OF ALL TRANSFER VEHICLES IN SBCA
     6W.A. 2 THAT COULD DEPART'/' BEFORE THE ABOVE CITED BEACH UNLOADINGSBCA
     7 FACILITY BECAME AVAILABLE IS SET'/' EQUAL TO ',F8.1,' UNITS OF TISBCA
     8ME.')                                                             SBCA
 3100 FORMAT(1H1,'T.V. AND BEACH UNLOADING FACILITY SELECTION.'//' T.V. SBCA
     1NO. ',I2,' AND BEACH UNLOADING FACILITY NO. ',I2,' ARE SELECTED ATSBCA
     2'/1H ,F8.1,' AND ',F8.1,' UNITS OF TIME AFTER THE START OF THE MISSBCA
     3SION'/' RESPECTIVELY.')                                           SBCA
      IF(INDEX2) 100,100,1000                                           SBCA
  100 L1=1                                                              SBCA
      IF(L-1) 1010,1010,110                                             SBCA
  110 L2=2                                                              SBCA
  120 IF(TBCP(5,L1)-TBCP(5,L2)) 130,140,150                             SBCA
  150 L1=L2                                                             SBCA
  130 IF(L2-L) 160,1010,1010                                            SBCA
  160 L2=L2+1                                                           SBCA
      GO TO 120                                                         SBCA
  140 IF(AMAXBC(5,L1)-AMAXBC(5,L2))130,170,150                          SBCA
  170 A1=TBC(4,L1)+TBC(6,L1)+TBC(7,L1)+TBC(8,L1)                        SBCA
```

```
      A2=TBC(4,L2)+TBC(6,L2)+TBC(7,L2)+TBC(8,L2)
      IF(A1-A2) 130,130,150
 1010 IF(INDEX2) 1000,195,1000
  195 DO 196 II=1,I
      TTVP(6,II)=0.
  196 CONTINUE
 1000 IF(TBCP(5,L1)-TTVP(14,I1)) 200,200,210
  200 TTV(12,I1)=0.
      WRITE(6,3100) I1,L1,TTVP(14,I1),TBCP(5,L1)
      TTVP(14,I1)=10.**70
      ICBC(5,L1)=ICBC(5,L1)+1
      ICTV(8,I1)=1
      INDEX2=0
      GO TO 2000
  210 CONTINUE
      WRITE(6,3000) I1,TTVP(14,I1),L1,TBCP(5,L1),TBCP(5,L1)
      I1=1
  220 IF(ICTV(8,I1)-1) 230,230,240
  230 IF(I1-I) 250,260,260
  250 I1=I1+1
      GO TO 220
  240 TTV(12,I1)=TBCP(5,L1)-TTVP(14,I1)
      IF(TTV(12,I1)) 230,230,270
  270 AMAXTV(8,I1)=TBCP(5,L1)
      TTVP(14,I1)=AMAXTV(8,I1)
      TTVP(6,I1)=TTV(12,I1)
      GO TO 230
  260 INDEX2=1
 2000 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE SLBCB                                                  SBCB
      COMMON NCASES,NRUNS,I,K,L,N,WC,VC,TAM,T1,T2,TSC,TBC,TTV,TAMP,T1P, SBCB
     1T2P,TSCP,TBCP,TTVP,IDMA,ID1,ID2,IDSC,IDBC,IDTV,INMS,IN1,IN2,INSC, SBCB
     2INBC,INTV,AMINM,AMIN1,AMIN2,AMINSC,AMINBC,AMINTV,AMAXM,AMAX1,AMAX2SBCB
     3,AMAXSC,AMAXBC,AMAXTV,ISUD,IBUD,IWA1SL,IWA2SL,ISCSL,IBCSL,INDEX1, SBCB
     4INDEX2,I1,K1,L1,ICASE,IRUN,TTM,NDUML,NDUMMY,WGHT,VCL,TIME,IBREAK, SBCB
     5WT1MAX,WT2MAX,IDBRTV,INBRTV,BRKTV,NDAMMY,INDEX                    SBCB
      DIMENSION WC(1000),VC(1000),N(20),TSC( 9,20),TBC(10,20),TTV(17,20)SBCB
     1,TSCP( 9,20),TBCP(10,20),TTVP(17,20),IDSC( 9,20),IDBC(10,20),IDTV(SBCB
     217,20),INSC( 9,20),INBC(10,20),INTV(17,20),AMINSC( 9,20),AMINBC(10SBCB
     3,20),AMINTV(17,20),AMAXSC( 9,20),AMAXBC(10,20),AMAXTV(17,20),NDUMMSBCB
     4Y(20),IDBRTV(8,20),INBRTV(8,20),BRKTV(8,20),NDAMMY(20)            SBCB
 3000 FORMAT(1H1,'THE SELECTION OF T.V. NO. ',I2,' FROM W.A. 2 MADE AT 'SBCB
     1,F8.1,' UNITS OF TIME'/' AFTER THE START OF THE MISSION IS FORFEITSBCB
     2ED BECAUSE THERE IS NO BEACH'/' UNLOADING FACILITY AVAILABLE TO RESBCB
     3CEIVE IT.'/' BEACH UNLOADING FACILITY NO. ',I2,' IS THE FIRST ONE SBCB
     4TO BECOME AVAILABLE AT '/1H ,F8.1,' UNITS OF TIME AFTER THE START SBCB
     5OF THE MISSION.'/' THE DEPARTURE TIME OF ALL TRANSFER VEHICLES IN SBCB
     6W.A. 2 THAT COULD DEPART'/' BEFORE THE ABOVE CITED BEACH UNLOADINGSBCB
     7 FACILITY BECAME AVAILABLE IS SET'/' EQUAL TO ',F8.1,' UNITS OF TISBCB
     8ME.')                                                             SBCB
 3100 FORMAT(1H1,'T.V. AND BEACH UNLOADING FACILITY SELECTION.'//' T.V. SBCB
     1NO. ',I2,' AND BEACH UNLOADING FACILITY NO. ',I2,' ARE SELECTED ATSBCB
     2'/1H ,F8.1,' UNITS OF TIME AFTER THE START OF THE MISSION.')      SBCB
 3200 FORMAT(1H1,'THE SELECTION OF BEACH UNLOADING FACILITY NO. ',I2,' MSBCB
     1ADE AT ',F8.1,' UNITS'/' OF TIME AFTER THE START OF THE MISSION ISSBCB
     2 FORFEITED BECAUSE THERE WAS'/' NO T.V. IN W.A. 2 TO BE SERVICED.'SBCB
     3/' T.V. NO. ',I2,' WILL BE THE FIRST ONE TO ARRIVE IN W.A. 2 AT ',SBCB
     4F8.1,' UNITS'/' OF TIME AFTER THE START OF THE MISSION.'/' THE TIMSBCB
     5E AT WHICH BEACH UNLOADING FACILITIES BECOME AVAILABLE FOR ALL'/' SBCB
     6SUCH FACILITIES THAT WERE FREE BEFORE THE ARRIVAL OF THE ABOVE CITSBCB
     7ED'/' T.V. IN W.A. 2 IS SET EQUAL TO ',F8.1,' UNITS OF TIME.')    SBCB
      IF(INDEX2) 100,100,1000                                           SBCB
  100 L1=1                                                              SBCB
      IF(L-1) 1010,1010,110                                             SBCB
  110 L2=2                                                              SBCB
```

```
  120 IF(TBCP(5,L1)-TBCP(5,L2)) 130,140,150
  150 L1=L2
  130 IF(L2-L) 160,1010,1010
  160 L2=L2+1
      GO TO 120
  140 IF(AMAXBC(5,L1)-AMAXBC(5,L2))130,170,150
  170 A1=TBC(4,L1)+TBC(6,L1)+TBC(7,L1)+TBC(8,L1)
      A2=TBC(4,L2)+TBC(6,L2)+TBC(7,L2)+TBC(8,L2)
      IF(A1-A2) 130,130,150
 1010 IF(INDEX2) 1000,195,1000
  195 DO 196 II=1,I
      TTVP(6,II)=0.
  196 CONTINUE
 1000 IF(TBCP(5,L1)-TTVP(14,I1)) 300,200,210
  200 TTV(12,I1)=0.
      WRITE(6,3100) I1,L1,TTVP(14,I1)
      TTVP(14,I1)=10.**70
      IDBC(5,L1)=IDBC(5,L1)+1
      IDTV(8,I1)=1
      INDEX2=0
      GO TO 2000
  210 CONTINUE
      WRITE(6,3000) I1,TTVP(14,I1),L1,TBCP(5,L1),TBCP(5,L1)
      I1=1
  220 IF(IDTV(8,I1)-1) 230,230,240
  230 IF(I1-I) 250,260,260
  250 I1=I1+1
      GO TO 220
  240 TTV(12,I1)=TBCP(5,L1)-TTVP(14,I1)
      IF(TTV(12,I1)) 230,230,270
  270 AMAXTV(8,I1)=TBCP(5,L1)
      TTVP(14,I1)=AMAXTV(8,I1)
      TTVP(6,I1)=TTV(12,I1)
      GO TO 230
  260 INDEX2=1
      GO TO 2000
```

```
  300 TTV(12,I1)=0.                                                    SBCB  73
      WRITE(6,3200) L1,TBCP(5,L1),I1,TTVP(14,I1),TTVP(14,I1)           SBCB  74
      L1=1                                                             SBCB  75
  350 IF(TBCP(5,L1)-TTVP(14,I1)) 310,320,320                           SBCB  76
  310 TBCP(5,L1)=TTVP(14,I1)                                           SBCB  77
  320 IF(L1-L) 330,340,340                                             SBCB  78
  330 L1=L1+1                                                          SBCB  79
      GO TO 350                                                        SBCB  80
  340 INDEX2=-1                                                        SBCB  81
 2000 CONTINUE                                                         SBCB  82
      RETURN                                                           SBCB  83
      END                                                              SBCB  84
```

```
      SUBROUTINE UNLOAD                                                 UNLD
      COMMON NCASES,NRUNS,I,K,L,N,WC,VC,TAM,T1,T2,TSC,TBC,TTV,TAMP,T1P, UNLD
     1T2P,TSCP,TBCP,TTVP,IDMA,ID1,ID2,IDSC,IDBC,IDTV,INMS,IN1,IN2,INSC, UNLD
     2INBC,INTV,AMINM,AMIN1,AMIN2,AMINSC,AMINBC,AMINTV,AMAXM,AMAX1,AMAX2UNLD
     3,AMAXSC,AMAXBC,AMAXTV,ISLC,IBUC,IWA1SL,IWA2SL,ISCSL,IBCSL,INDEX1, UNLD
     4INDEX2,I1,K1,L1,ICASE,IRUN,TTM,NDUML,NDUMMY,WGHT,VOL,TIME,IBREAK, UNLD
     5WT1MAX,WT2MAX,IDBRTV,INBRTV,BRKTV,NDAMMY,INDEX                    UNLD
      DIMENSION WC(1000),VC(1000),N(20),TSC( 9,20),TBC(10,20),TTV(17,20)UNLD
     1,TSCP( 9,20),TBCP(10,20),TTVP(17,20),IDSC( 9,20),IDBC(10,20),IDTV(UNLD
     217,20),INSC( 9,20),INBC(10,20),INTV(17,20),AMINSC( 9,20),AMINBC(10UNLD
     3,20),AMINTV(17,20),AMAXSC( 9,20),AMAXBC(10,20),AMAXTV(17,20),NDUMMUNLD
     4Y(20),IDBRTV(8,20),INBRTV(8,20),BRKTV(8,20),NDAMMY(20)            UNLD
 4000 FORMAT(1H ,///' T.V. BREAKDOWN CONSIDERATIONS.'//)                UNLD
 4001 FORMAT(' T.V. NO. ',I2,' IS NOT ALLOWED TO DEPART W.A. 2 AS IT IS UNLD
     1CONSIDERED TO BE'/' MALFUNCTIONING.  THE ABOVE CITED T.V. AND ITS UNLD
     2ENTIRE PAYLOAD IS'/' CONSIDERED LOST FROM OUR SYSTEM FOR THIS COMPUNLD
     3UTER RUN.  IN ADDITION THE'/' ABOVE MENTIONED T.V. AND BEACH UNLOAUNLD
     4DING FACILITY SELECTION IS'/' FORFEITED.')                        UNLD
 4002 FORMAT(' T.V. NO. ',I2,' HAS SAFELY DEPARTED W.A. 2.')            UNLD
 4003 FORMAT(1H ,///' T.V. NO. ',I2,' DEPARTED W.A. 2 FOR BEACH UNLOADINUNLD
     1G AREA NO. ',I2,', ',F8.1/' UNITS OF TIME AFTER THE START OF THE MUNLD
     2ISSION.')                                                         UNLD
 4010 FORMAT(' T.V. NO. ',I2,' IS NOT ALLOWED TO REACH THE BEACH AS IT IUNLD
     1S CONSIDERED TO BE'/' MALFUNCTIONING.  THE ABOVE CITED T.V. AND ITUNLD
     2S ENTIRE PAYLOAD IS'/' CONSIDERED LOST FROM OUR SYSTEM FOR THIS COUNLD
     3MPUTER RUN.  IN ADDITION THE'/' ABOVE MENTIONED T.V. AND BEACH UNLUNLD
     4OADING FACILITY SELECTION IS'/' FORFEITED.')                      UNLD
 4011 FORMAT(' T.V. NO. ',I2,' HAS SAFELY REACHED THE BEACH.')          UNLD
 4012 FORMAT(1H ,///' T.V. NO. ',I2,' REACHED BEACH UNLOADING AREA NO. 'UNLD
     1,I2,' BEACHED AND WAS MADE'/' READY FOR THE UNLOADING OPERATION ',UNLD
     2F8.1,' UNITS OF TIME AFTER THE'/' START OF THE MISSION.')         UNLD
 4020 FORMAT(1H ,//' ALL TIME MEASURMENTS IN THE FOLLOWING TABLE HAVE ASUNLD
     1 A COMMON ORIGIN'/' THE START OF THE MISSION.')                   UNLD
 4030 FORMAT(1H ,//' OPERATION TO UNLOAD CARGO UNIT NO. ',I4//' CARGO UNUNLD
     1IT CHARACTERISTICS:'/' WEIGHT',47X,F5.2,1X,3A4/' VOLUME',48X,F4.0,UNLD
     21X,3A4/)                                                          UNLD
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4040 FORMAT(' BEACH UNLOADING FACILITY (B.U.F.) OPERATION:'/' B.U.F. REUNLD  37
    1ACHES BEACH UNLOADING AREA NO. ',I2,' AFTER',2X,F8.1,1X,3A4)       UNLD  38
4050 FORMAT(' THE B.U.F. WILL COMMENCE UNLOADING AFTER',10X,F8.1,1X,3A4UNLD  39
    1)                                                                  UNLD  40
4060 FORMAT(' THE ABOVE CITED CARGO UNIT IS RELEASED AFTER',6X,F8.1,1X,UNLD  41
    13A4)                                                               UNLD  42
4070 FORMAT(' IS SECURED TO THE B.U.F. AFTER',20X,F8.1,1X,3A4)          UNLD  43
4080 FORMAT(' AND IS TRANSPORTED TO THE UNLOADING ZONE AFTER',4X,F8.1,1UNLD  44
    1X,3A4)                                                             UNLD  45
4090 FORMAT(1H ,////' THE UNLOADING OPERATION IS TERMINATED AS THE ENTIUNLD  46
    1RE PAYLOAD OF T.V.'/' NO. ',I2,' HAS BEEN OFFLOADED.'////' T.V. NOUNLD  47
    2. ',I2,' WAS READY TO DEPART FROM THE BEACH ',F8.1,' UNITS OF TIMEUNLD  48
    3'/' AFTER THE START OF THE MISSION')                               UNLD  49
4100 FORMAT(' AND AT THE SAME TIME BEACH UNLOADING AREA NO. ',I2,' BECAUNLD  50
    1ME ONCE MORE'/' AVAILABLE.')                                       UNLD  51
4110 FORMAT(' AND AT THE SAME TIME ALL BEACH UNLOADING AREAS BECAME ONCUNLD  52
    1E MORE'/' AVAILABLE.')                                             UNLD  53
4120 FORMAT(1H ,////' FOR ANALYSIS PURPOSES T.V. NO. ',I2,' IS ASSUMED UNLD  54
    1TO PROCEED FOR W.A. 1.'/' HOWEVER, IF AT THE TERMINATION OF THIS RUNLD  55
    2UN IT IS FOUND THAT THE ABOVE'/' CITED T.V. COULD PROCEED DIRECTLYUNLD  56
    3 TO ITS BASE (FROM BEACH UNLOADING'/' AREA NO. ',I2,') WITHOUT DELUNLD  57
    4AYING THE MISSION ALL DECISIONS MADE AT THIS'/' STAGE WILL BE FORFUNLD  58
    5EITED, AND THE ABOVE CITED T.V. WILL PROCEED DIRECTLY'/' TO ITS BAUNLD  59
    6SE.')                                                              UNLD  60
4130 FORMAT(1H , 'T.V. NO. ',I2,' IS NOT ALLOWED TO ENTER W.A. 1 AS IT UNLD  61
    1IS CONSIDERED TO BE'/' MALFUNCTIONING.  THE ABOVE CITED T.V. IS (WUNLD  62
    2ITH THE ABOVE PROVISION)'/' CONSIDERED LOST FROM OUR SYSTEM FOR THUNLD  63
    3IS COMPUTER RUN.')                                                 UNLD  64
4140 FORMAT(' T.V. NO. ',I2,' HAS SAFELY ENTERED W.A. 1.')              UNLD  65
4150 FORMAT(1H ,////' T.V. NO. ',I2,' ARRIVED AT W.A. 1 ',F8.1,' UNITS UNLD  66
    1OF TIME AFTER THE START OF'/' THE MISSION.')                       UNLD  67
4160 FORMAT(1H ,////' SINCE THE ENTIRE MOTHER SHIP',1H','S PAYLOAD HAS UNLD  68
    1BEEN OFFLOADED INTO TRANSFER'/ ' VEHICLES THE ABOVE CITED T.V. WILUNLD  69
    2L PROCEED DIRECTLY TO ITS BASE.')                                  UNLD  70
     DO 100 JJ=12,13                                                    UNLD  71
     ICD=ICTV(JJ,I1)                                                    UNLD  72
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```
      GO TO (2000,2001),IDD
 2000 TTVP(JJ,I1)=0.
      GO TO 100
 2001 IND=IDTV(JJ,I1)
      CALL RANDU(INC,IND,TPD)
      INTV(JJ,I1)=INC
      TTVP(JJ,I1)=(AMAXTV(JJ,I1)-AMINTV(JJ,I1))*TPD+AMINTV(JJ,I1)
      GO TO 100
  100 CONTINUE
      IDD=IDBRTV(5,I1)
      GO TO (3000,3001),IDD
 3001 TTVP(6,I1)=TTVP(6,I1)+TTVP(12,I1)
      TTVP(6,I1)=TTVP(6,I1)/WT1MAX
      IF(TTVP(6,I1)-1.) 3002,3003,3003
 3002 TTVP(6,I1)=TTVP(6,I1)*BRKTV(5,I1)
      GO TO 3004
 3003 TTVP(6,I1)=BRKTV(5,I1)
 3004 IND=INBRTV(5,I1)
      CALL RANDU(INC,IND,TPD)
      INBRTV(5,I1)=INC
      IF(TTVP(6,I1)-TPD) 3005,3005,3006
 3006 IDTV(14,I1)=IDTV(14,I1)-1
      IDTV(8,I1)=0
      IBREAK=IBREAK-1
      IDBC(5,L1)=IDBC(5,L1)-1
      WRITE(6,4000)
      WRITE(6,4001) I1
      GO TO 3007
 3005 CONTINUE
      WRITE(6,4000)
      WRITE(6,4002) I1
 3000 CONTINUE
      AMAXTV(8,I1)=AMAXTV(8,I1)+TTV(12,I1)+TTVP(12,I1)
      WRITE(6,4003) I1,L1,AMAXTV(8,I1)
      IDD=IDBRTV(6,I1)
      GO TO (3008,3009),IDD
```

```
3009 IND=INBRTV(6,I1)                                                UNLD 109
     CALL RANDU(IND,INC,TPD)                                         UNLD 110
     INBRTV(6,I1)=INC                                                UNLD 111
     IF(BRKTV(6,I1)-TPD) 3011,3011,3012                              UNLD 112
3012 ICTV(14,I1)=ICTV(14,I1)-1                                       UNLD 113
     ICTV(8,I1)=0                                                    UNLD 114
     IBREAK=IBREAK-1                                                 UNLD 115
     ICBC(5,L1)=ICBC(5,L1)-1                                         UNLD 116
     WRITE(6,4000)                                                   UNLD 117
     WRITE(6,4010) I1                                                UNLD 118
     GO TO 3007                                                      UNLD 119
3011 CONTINUE                                                        UNLD 120
     WRITE(6,4000)                                                   UNLD 121
     WRITE(6,4011) I1                                                UNLD 122
3008 CONTINUE                                                        UNLD 123
     AMAXTV(8,I1)=AMAXTV(8,I1)+TTV(13,I1)+TTVP(13,I1)                UNLD 124
     WRITE(6,4012) I1,L1,AMAXTV(8,I1)                                UNLD 125
     WRITE(6,4020)                                                   UNLD 126
     NTEMP=NDAMMY(I1)                                                UNLD 127
1200 ICC=ICBC(4,L1)                                                  UNLD 128
     GO TO (2010,2011),ICC                                           UNLD 129
2010 TBCP(4,L1)=0.                                                   UNLD 130
     GO TO 3010                                                      UNLD 131
2011 IND=INBC(4,L1)                                                  UNLD 132
     CALL RANDU(IND,INC,TPD)                                         UNLD 133
     INBC(4,L1)=INC                                                  UNLD 134
     TBCP(4,L1)=(AMAXBC(4,L1)-AMINBC(4,L1))*TPD+AMINBC(4,L1)         UNLD 135
     GO TO 3010                                                      UNLD 136
3010 AMAXBC(5,L1)=AMAXBC(5,L1)+TBC(4,L1)+TBCP(4,L1)                  UNLD 137
     WRITE(6,4030) NTEMP,WC(NTEMP),WGHT,VC(NTEMP),VCL                UNLD 138
     WRITE(6,4040) L1,AMAXBC(5,L1),TIME                              UNLD 139
     IF(AMAXBC(5,L1)-AMAXTV(8,I1)) 1000,1000,1100                    UNLD 140
1000 TTV(14,I1)=0.                                                   UNLD 141
     TBC(5,L1)=AMAXTV(8,I1)-AMAXBC(5,L1)                             UNLD 142
     GO TO 1010                                                      UNLD 143
1100 TTV(14,I1)=AMAXBC(5,L1)-AMAXTV(8,I1)                            UNLD 144
```

```
      TBC(5,L1)=0.                                                      UNLD 145
 1010 AMAXTV(8,I1)=AMAXTV(8,I1)+TTV(14,I1)                              UNLD 146
      AMAXBC(5,L1)=AMAXBC(5,L1)+TBC(5,L1)                               UNLD 147
      WRITE(6,4050) AMAXBC(5,L1),TIME                                   UNLD 148
      DO 110 JJ=6,8                                                     UNLD 149
      IDD=IDBC(JJ,L1)                                                   UNLD 150
      GO TO (2020,2021),IDD                                             UNLD 151
 2020 TBC(JJ,L1)=0.                                                     UNLD 152
      GO TO 110                                                         UNLD 153
 2021 IND=INBC(JJ,L1)                                                   UNLD 154
      CALL RANDU(IND,IND,TPD)                                           UNLD 155
      INBC(JJ,L1)=IND                                                   UNLD 156
      TBCP(JJ,L1)=(AMAXBC(JJ,L1)-AMINBC(JJ,L1))*TPD+AMINBC(JJ,L1)       UNLD 157
      GO TO 110                                                         UNLD 158
  110 CONTINUE                                                          UNLD 159
      AMAXTV(8,I1)=AMAXTV(8,I1)+TBC(6,L1)+TBCP(6,L1)                    UNLD 160
      AMAXBC(5,L1)=AMAXBC(5,L1)+TBC(6,L1)+TBCP(6,L1)                    UNLD 161
      WRITE(6,4060) AMAXBC(5,L1),TIME                                   UNLD 162
      AMAXTV(8,I1)=AMAXTV(8,I1)+TBC(7,L1)+TBCP(7,L1)                    UNLD 163
      AMAXBC(5,L1)=AMAXBC(5,L1)+TBC(7,L1)+TBCP(7,L1)                    UNLD 164
      WRITE(6,4070) AMAXBC(5,L1),TIME                                   UNLD 165
      AMAXBC(5,L1)=AMAXBC(5,L1)+TBC(8,L1)+TBCP(8,L1)                    UNLD 166
      WRITE(6,4080) AMAXBC(5,L1),TIME                                   UNLD 167
      NTEMP=NTEMP+1                                                     UNLD 168
      IF(NDUMMY(I1)-NTEMP) 1300,1200,1200                               UNLD 169
 1300 DO 120 JJ=15,16                                                   UNLD 170
      IDD=IDTV(JJ,I1)                                                   UNLD 171
      GO TO (2040,2041),IDD                                             UNLD 172
 2040 TTVP(JJ,I1)=0.                                                    UNLD 173
      GO TO 120                                                         UNLD 174
 2041 IND=INTV(JJ,I1)                                                   UNLD 175
      CALL RANDU(IND,IND,TPD)                                           UNLD 176
      INTV(JJ,I1)=IND                                                   UNLD 177
      TTVP(JJ,I1)=(AMAXTV(JJ,I1)-AMINTV(JJ,I1))*TPD+AMINTV(JJ,I1)       UNLD 178
      GO TO 120                                                         UNLD 179
  120 CONTINUE                                                          UNLD 180
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```
      AMAXTV(8,I1)=AMAXTV(8,I1)+TTV(15,I1)+TTVP(15,I1)
      AMAXTV(14,I1)=AMAXTV(8,I1)
      WRITE(6,4090) I1,I1,AMAXTV(8,I1)
      IF(IBUD-1) 1400,1500,1400
 1400 LLCCP=L
      LT=1
      WRITE(6,4110)
      GO TO 1410
 1500 LLCCP=1
      LT=L1
      WRITE(6,4100) L1
 1410 DO 130 LL=1,LLCCP
      TBCP(5,LT)=AMAXTV(14,I1)
      LT=LT+1
  130 CONTINUE
      IF(INDEX) 1600,1600,1601
 1601 IDTV(8,I1)=-1
      WRITE (6,4160)
      GO TO 3007
 1600 CONTINUE
      WRITE (6,4120) I1,L1
      IDD=IDRRTV(7,I1)
      GO TO (3100,3101),IDD
 3101 IND=INRRTV(7,I1)
      CALL RANDU(IND,IND,TPD)
      INRRTV(7,I1)=IND
      IF(BRKTV(7,I1)-TPD) 3110,3110,3111
 3111 IDTV(14,I1)=IDTV(14,I1)-1
      INTV(14,I1)=-1
      IBREAK=IBREAK-1
      WRITE(6,4000)
      WRITE(6,4130) I1
      GO TO 3100
 3110 CONTINUE
      WRITE(6,4000)
      WRITE(6,4140) I1
 3100 AMAXTV(8,I1)=AMAXTV(8,I1)+TTV(16,I1)+TTVP(16,I1)
      TTVP(8,I1)=AMAXTV(8,I1)
      WRITE(6,4150) I1,AMAXTV(8,I1)
 3007 CONTINUE
      RETURN
      END
```

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      SUBROUTINE FIN                                                    SFIN
      COMMON NCASES,NRUNS,I,K,L,N,WC,VC,TAM,T1,T2,TSC,TBC,TTV,TAMF,T1P, SFIN
     1T2P,TSCP,TBCP,TTVP,IDMA,ID1,ID2,IDSC,IDBC,IDTV,INMS,IN1,IN2,INSC, SFIN
     2INBC,INTV,AMINM,AMIN1,AMIN2,AMINSC,AMINBC,AMINTV,AMAXM,AMAX1,AMAX2SFIN
     3,AMAXSC,AMAXBC,AMAXTV,ISUD,IBUD,IWA1SL,IWA2SL,ISCSL,IBCSL,INDEX1, SFIN
     4INDEX2,I1,K1,L1,ICASE,IRUN,TTM,NDUML,NDUMMY,WGHT,VOL,TIME,IBREAK, SFIN
     5WT1MAX,WT2MAX,IDBRTV,INBRTV,BRKTV,NDAMMY,INDEX                    SFIN
      DIMENSION WC(1000),VC(1000),N(20),TSC( 9,20),TBC(10,20),TTV(17,20)SFIN
     1,TSCP( 9,20),TBCP(10,20),TTVP(17,20),IDSC( 9,20),IDBC(10,20),IDTV(SFIN
     217,20),INSC( 9,20),INBC(10,20),INTV(17,20),AMINSC( 9,20),AMINBC(10SFIN
     3,20),AMINTV(17,20),AMAXSC( 9,20),AMAXBC(10,20),AMAXTV(17,20),NDUMMSFIN
     4Y(20),IDBRTV(8,20),INBRTV(8,20),BRKTV(8,20),NDAMMY(20)            SFIN
 4000 FORMAT(1H1,'WITH THE OPERATION JUST DESCRIBED THE TRANSFER OF THE SFIN
     1ENTIRE MOTHER'/' SHIP',1H','S PAYLOAD INTO TRANSFER VEHICLES WAS CSFIN
     2OMPLETED.  THEREFORE, IN'/' ORDER TO COMPLETE THE TRANSFER MISSIONSFIN
     3 WE ONLY NEED TO TRANSPORT THE'/' CARGO AWAITING IN, OR ON ROUTE TSFIN
     4O, W.A. 2, TO ITS DESTINATION.  THIS'/' OPERATION IS DESCRIBED IN SFIN
     5THE FOLLOWING PAGES.')                                            SFIN
 4010 FORMAT(1H1,'WITH THE OPERATION JUST DESCRIBED THE TRANSFER  MISSIOSFIN
     1N IS COMPLETED.'/' THE QUANTITIES THAT WILL BE CALCULATED IN WHAT SFIN
     2FOLLOWS ARE NECESSARY'/' FOR THE STATISTICAL ANALYSIS.'////)      SFIN
 4020 FORMAT(' MOTHER SHIP',1H','S DEPARTURE OPERATION.'//' THE DEPARTURSFIN
     1E OPERATION FOR THE MOTHER SHIP COMMENCED ',F8.1/' UNITS OF TIME ASFIN
     2FTER THE START OF THE MISSION AND WAS COMPLETED')                 SFIN
 4030 FORMAT(1H ,F8.1,' OF TIME AFTER THE START OF THE MISSION.')       SFIN
 4040 FORMAT(1H1,'DEPARTURE OF BEACH BASED UNLOADING FACILITIES (B.U.F.)SFIN
     1.'////)                                                           SFIN
 4050 FORMAT(' B.U.F. NO. ',I2,' CAN BE REMOVED FROM OUR SYSTEM AS IT HASFIN
     1S NOT BEEN USED.'/)                                               SFIN
 4060 FORMAT(' B.U.F. NO. ',I2,' WAS READY TO DEPART THE UNLOADING ZONE SFIN
     1',F8.1,' UNITS OF'/' TIME AFTER THE START OF THE MISSION AND ARRIVSFIN
     2ED AT ITS DESTINATION')                                           SFIN
 4070 FORMAT(1H ,F8.1,' UNITS OF TIME AFTER THE START OF THE MISSION.'/)SFIN
 4080 FORMAT(1H1,'DEPARTURE OF TRANSFER VEHICLES.'////)                 SFIN
 4090 FORMAT(' T.V. NO. ',I2,' HAS BEEN REMOVED FROM OUR SYSTEM AS IT WASFIN
     1S MALFUNCTIONING.'/)                                              SFIN
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4100 FORMAT(' T.V. NO. ',I2,' CAN BE REMOVED FROM OUR SYSTEM AS IT HAS SFIN  37
    1NOT BEEN USED.  (FORFEIT'/' PREVIOUS DECISION CONCERNING T.V. NO. SFIN  38
    2',I2,2H.)/)                                                       SFIN  39
4110 FORMAT(' T.V. NO. ',I2,' CAN BE REMOVED FROM OUR SYSTEM AS IT HAS SFIN  40
    1NOT BEEN USED.  (FORFEIT'/' PREVIOUS DECISION AND MALFUNCTIONING CSFIN  41
    2ONSIDERATIONS CONCERNING T.V.'/' NO. ',I2,2H.)/)                  SFIN  42
4120 FORMAT(' T.V. NO. ',I2,' DEPARTED THE BEACH UNLOADING AREA ',F8.1,SFIN  43
    1' UNITS OF TIME'/' AFTER THE START OF THE MISSION.')              SFIN  44
4130 FORMAT(' BREAKDOWN CONSIDERATIONS.')                              SFIN  45
4140 FORMAT(' T.V. NO. ',I2,' DID NOT REACH ITS BASE AS IT MALFUNCTIONESFIN  46
    1D ON ROUTE.'/)                                                    SFIN  47
4150 FORMAT(' T.V. NO. ',I2,' ARRIVED SAFELY AT ITS BASE ',F8.1,' UNITSSFIN  48
    1 OF TIME AFTER THE'/' START OF THE MISSION.'/)                    SFIN  49
4160 FORMAT(' (FORFEIT PREVIOUS DECISION CONCERNING T.V. NO. ',I2,1H)) SFIN  50
4170 FORMAT(' (FORFEIT PREVIOUS DECISION AND MALFUNCTIONING CONSIDERATISFIN  51
    1ONS CONCERNING'/' T.V. NO. ',I2,1H))                              SFIN  52
     WRITE(6,4000)                                                     SFIN  53
     INDEX=1                                                           SFIN  54
1100 I1=1                                                              SFIN  55
     TOMMY=TTVP(8,1)                                                   SFIN  56
     TTVP(8,1)=10.**70                                                 SFIN  57
     GO TO (1001,1002),IWA2SL                                          SFIN  58
1001 CONTINUE                                                          SFIN  59
     CALL BSLTVA                                                       SFIN  60
     CONTINUE                                                          SFIN  61
     GO TO 1000                                                        SFIN  62
1002 CONTINUE                                                          SFIN  63
     CALL BSLTVB                                                       SFIN  64
     CONTINUE                                                          SFIN  65
     GO TO 1000                                                        SFIN  66
1000 TTVP(8,1)=TOMMY                                                   SFIN  67
     GO TO (1011,1012),IBCSL                                           SFIN  68
1011 CONTINUE                                                          SFIN  69
     CALL SLPCA                                                        SFIN  70
     CONTINUE                                                          SFIN  71
     GO TO 1010                                                        SFIN  72
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1012 CONTINUE                                                    SFIN  73
     CALL SLRCP                                                  SFIN  74
     CONTINUE                                                    SFIN  75
     GO TO 1010                                                  SFIN  76
1010 IF (INDEX2) 1000,1020,1100                                  SFIN  77
1020 CONTINUE                                                    SFIN  78
     CALL UNLOAD                                                 SFIN  79
     DO 100 II=1,I                                               SFIN  80
     IF(IDTV(8,II)-1) 100,100,1100                               SFIN  81
 100 CONTINUE                                                    SFIN  82
     WRITE(6,4010)                                               SFIN  83
1200 KE1=1                                                       SFIN  84
     KE2=1                                                       SFIN  85
     IF(K-1) 1210,1211,1210                                      SFIN  86
1210 KF=2                                                        SFIN  87
1250 IF(AMAXSC(6,KE1)-AMAXSC(6,KF)) 1220,1230,1230               SFIN  88
1220 KE1=KF                                                      SFIN  89
1230 IF(TSCP(6,KE2)-TSCP(6,KF))1221,1231,1221                    SFIN  90
1221 KE2=KF                                                      SFIN  91
1231 IF(KF-K) 1240,1211,1211                                     SFIN  92
1240 KF=KF+1                                                     SFIN  93
     GO TO 1250                                                  SFIN  94
1211 CONTINUE                                                    SFIN  95
     GO TO (1261,1262),ID2                                       SFIN  96
1261 T2P=0.                                                      SFIN  97
     GO TO 1260                                                  SFIN  98
1262 CONTINUE                                                    SFIN  99
     CALL RANDU(IN2,IN2,T2P)                                     SFIN 100
     T2P=(AMAX2-AMIN2)*T2P+AMIN2                                 SFIN 101
     GO TO 1260                                                  SFIN 102
1260 IF(AMAXSC(6,KE1)-TSCP(6,KE2)) 1271,1271,1272                SFIN 103
1271 TTM=TSCP(6,KE2)+T2+T2P                                      SFIN 104
     WRITE(6,4030) TSCP(6,KE2)                                   SFIN 105
     GO TO 1270                                                  SFIN 106
1272 TTM=AMAXSC(6,KE1)+T2+T2P                                    SFIN 107
     WRITE(6,4020) AMAXSC(6,KE1)                                 SFIN 108
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 1270 CONTINUE                                                            SFIN 109
      WRITE(6,4030) TTM                                                   SFIN 110
      WRITE(6,4040)                                                       SFIN 111
      DO 110 LL=1,L                                                       SFIN 112
      IF(IDBC(5,LL)) 1300,1310,1300                                       SFIN 113
 1310 AMAXBC(5,LL)=0.                                                     SFIN 114
      WRITE(6,4050) LL                                                    SFIN 115
      GO TO 110                                                           SFIN 116
 1300 DO 120 JJ=9,10                                                      SFIN 117
      IDD=IDBC(JJ,LL)                                                     SFIN 118
      GO TO (1321,1322),IDD                                               SFIN 119
 1321 TBCP(JJ,LL)=0.                                                      SFIN 120
      GO TO 120                                                           SFIN 121
 1322 INC=INBC(JJ,LL)                                                     SFIN 122
      CALL RANDU(INC,IND,TPD)                                             SFIN 123
      INBC(JJ,LL)=IND                                                     SFIN 124
      TBCP(JJ,LL)=(AMAXBC(JJ,LL)-AMINBC(JJ,LL))*TPD+AMINBC(JJ,LL)         SFIN 125
      GO TO 120                                                           SFIN 126
  120 CONTINUE                                                            SFIN 127
      AMAXBC(5,LL)=AMAXBC(5,LL)+TBC(9,LL)+TBCP(9,LL)                      SFIN 128
      WRITE(6,4060) LL,AMAXBC(5,LL)                                       SFIN 129
      AMAXBC(5,LL)=AMAXBC(5,LL)+TBC(10,LL)+TBCP(10,LL)                    SFIN 130
      WRITE(6,4070) AMAXBC(5,LL)                                          SFIN 131
  110 CONTINUE                                                            SFIN 132
      WRITE (6,4080)                                                      SFIN 133
      DO 130 II=1,I                                                       SFIN 134
      IF(IDTV(8,II)) 1401,1402,1403                                       SFIN 135
 1401 CONTINUE                                                            SFIN 136
      WRITE(6,4120) II,AMAXTV(14,II)                                      SFIN 137
 1410 IDD=IDTV(17,II)                                                     SFIN 138
      GO TO (2001,2002),IDD                                               SFIN 139
 2001 TTVP(17,II)=0.                                                      SFIN 140
      GO TO 2000                                                          SFIN 141
 2002 INC=INTV(17,II)                                                     SFIN 142
      CALL RANDU(INC,IND,TPD)                                             SFIN 143
      INTV(17,II)=IND                                                     SFIN 144
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      TTVP(17,II)=(AMAXTV(17,II)-AMINTV(17,II))*TPC+AMINTV(17,II)        SFIN 145
      GO TO 2000                                                         SFIN 146
 2000 IDD=IDERTV(8,II)                                                   SFIN 147
      GO TO (2011,2012),IDD                                              SFIN 148
 2012 IND=INPRTV(8,II)                                                   SFIN 149
      CALL RANDU(IND,IND,TPC)                                            SFIN 150
      INPRTV(8,II)=IND                                                   SFIN 151
      IF(BRKTV(8,II)-TPC) 2013,2013,2014                                 SFIN 152
 2014 IBREAK=IBREAK-1                                                    SFIN 153
      WRITE(6,4130)                                                      SFIN 154
      WRITE(6,4140) II                                                   SFIN 155
      GO TO 130                                                          SFIN 156
 2013 CONTINUE                                                           SFIN 157
      WRITE(6,4130)                                                      SFIN 158
 2011 AMAXTV(8,II)=AMAXTV(14,II)+TTV(17,II)+TTVP(17,II)                  SFIN 159
      WRITE(6,4150) II,AMAXTV(8,II)                                      SFIN 160
      GO TO 130                                                          SFIN 161
 1402 CONTINUE                                                           SFIN 162
      WRITE(6,4090) II                                                   SFIN 163
      GO TO 130                                                          SFIN 164
 1403 IF(INTV(14,II)) 1411,1412,1413                                     SFIN 165
 1411 IDTV(14,II)=IDTV(14,II)+1                                          SFIN 166
      IBREAK=IBREAK+1                                                    SFIN 167
      WRITE(6,4120) II,AMAXTV(14,II)                                     SFIN 168
      WRITE(6,4170) II                                                   SFIN 169
      GO TO 1410                                                         SFIN 170
 1413 IBREAK=IBREAK+1                                                    SFIN 171
      WRITE (6,4110) II,II                                               SFIN 172
      GO TO 130                                                          SFIN 173
 1412 IF(IDTV(14,II))1420,1420,1421                                      SFIN 174
 1420 WRITE (6,4100) II,II                                               SFIN 175
      GO TO 130                                                          SFIN 176
 1421 CONTINUE                                                           SFIN 177
      WRITE (6,4120) II,AMAXTV(14,II)                                    SFIN 178
      WRITE (6,4160) II                                                  SFIN 179
      GO TO 1410                                                         SFIN 180
  130 CONTINUE                                                           SFIN 181
      RETURN                                                             SFIN 182
      END                                                                SFIN 183
```