

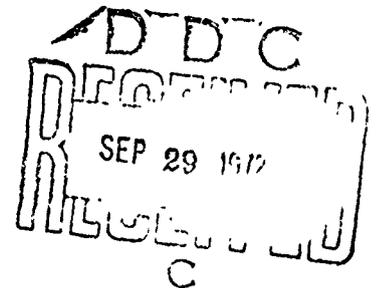
AD 748791

**SIMULATION OF RAPID SHIP UNLOADING BY HELICOPTER**

**Bruce F. Powers  
Martin Goldberg**

**Professional Paper No. 96**

**July 1972**



**CENTER FOR NAVAL ANALYSES**

**1401 Wilson Boulevard  
Arlington, Virginia 22209**

Reproduced by  
**NATIONAL TECHNICAL  
INFORMATION SERVICE**  
U.S. Department of Commerce  
Springfield, VA 22151

**DISTRIBUTION STATEMENT A**  
Approved for public release;  
Distribution is unlimited

SIMULATION OF RAPID SHIP UNLOADING BY HELICOPTER

Bruce F. Powers  
Center for Naval Analyses  
University of Rochester  
Arlington, Virginia

Martin Goldberg  
Industrial Engineering Department  
Northwestern University  
Evanston, Illinois

December 1971

UNCLASSIFIED

SIMULATION OF RAPID SHIP UNLOADING BY HELICOPTER\*

INTRODUCTION AND SUMMARY

A ship with helicopters aboard arrives in the vicinity of a shoreline. The commander intends to operate the helicopters so as to unload the ship as rapidly as possible. The ship's cargo is to be delivered to a specific point ashore by the helicopters. The arrival rate of the cargo at that point will measure the effectiveness of the unloading operation. The commander must decide at what distance to station the ship from the unloading point ashore, how many of his helicopters to use for the unloading, and the grouping of the participating helicopters. He knows, or has reliable estimates of, the time spent by helicopters while loading or refueling on the ship, unloading at the point ashore, and flying between the ship and point ashore. This paper describes a simulation model which can assist the commander with his decisions.

DISCUSSION

This problem is faced by the amphibious forces of the U.S. Navy and exercises are conducted by the Navy to train forces and to test different policies for helicopter unloadings. The development of a model of the unloading process would permit testing alternate unloading policies without the expense of sending a ship to sea. It would permit examination of the implications of changes in the design of the ship, the design of helicopters, or the capacity of the unloading point.

Another problem is also faced by the Navy. If victims of a disaster such as a flood or earthquake require evacuation, the Navy would probably assign a ship with helicopters to the task. For medical reasons or because of the threat of loss of life, the helicopter evacuation may have to be conducted as rapidly as possible. The applicability of a model of ship unloading could readily be transferred to the evacuation problem.

The model could also be useful for examination of harbor operation policies where sufficient berthing space for waiting ships is unavailable. Under such conditions, the use of helicopters for unloading ships while in the roadstead might be an attractive alternative to having the ships wait for berthing space. The model can aid development of costing information to permit choice among these alternative harbor management policies.

---

\* This paper was presented at the Fifth Conference on the Applications of Simulation, held in New York City in December, 1971. (The conference is also known as the 1971 Winter Simulation Conference, sponsored by ACM/AIIE/IEEE/SHARE/SCI/TIMS.)

UNCLASSIFIED

## DESCRIPTION OF THE SYSTEM

The ship arrives in the unloading area and takes station as shown in figure 1.

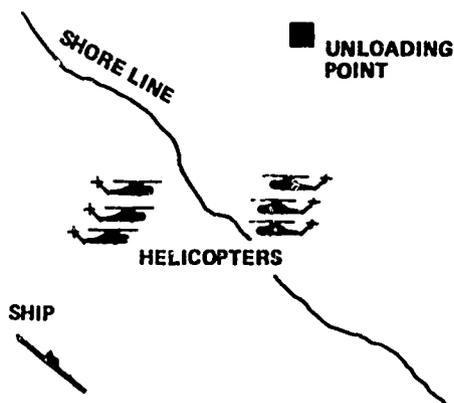


FIGURE 1: SKETCH OF SYSTEM

Helicopters are stored on the ship with rotors folded to conserve space. When needed to ferry cargo, helicopters are brought up to the flight deck and prepared for flight. Because helicopter storage capacity beneath the flight deck exceeds the flight deck capacity when rotors are unfolded, several deckloads of helicopters are often available for unloading the ship. Helicopters operating from the ship are grouped into waves. In general, a deckload of helicopters makes up more than one wave and more than one deckload is used for an unloading. The waves flow through a system consisting of two primary nodes, the ship and the unloading point (called the landing zone). The activity of the first wave, which is typical, consists of an initial launch without cargo, movement to a marshaling area near the ship, return to the flight deck when all waves are airborne, loading of cargo, launch for the transit to the landing zone ashore, landing in the zone, unloading of cargo, launch for return to the ship, and re-landing on the ship for loading of more cargo and/or refueling. The cycle is then repeated by the first and other waves until the ship's cargo is unloaded.

The build-up of the system to steady state operation is accomplished by launching all waves empty except the last deckload of waves to be launched. After the last deckload of waves is jointly launched with cargo for the landing zone, the empty airborne helicopters return to the ship, queue, land, load, and then proceed for subsequent delivery to the landing zone. (For an initial maximum effort, all helicopters might be held offshore until all helicopters are loaded. The contents of all helicopters might then be landed as quickly as possible at a landing zone whose position will surprise an opponent ashore.) Steady state cyclic operations are underway when each wave has made its first delivery to the landing zone. The measures of effectiveness for the steady state operation of the system are the rate of build-up of cargo ashore and the total unproductive flying time (time spent in queues). The first measure is to be maximized while the second is minimized.

The system being simulated operates under many constraints, including:

- (a) The number of helicopters participating in the unloading is limited by the capacity of the ship to store helicopters while transiting to the unloading area.
- (b) The capacities of both the ship's flight deck and the landing zone are limited, generally to values less than the number of helicopters participating in the unloading.
- (c) During an unloading, helicopters will find it necessary to refuel during some stops on the ship for cargo pick-up. The time required for refueling and cargo pick-up on the flight deck generally exceeds the time required for cargo pick-up alone.
- (d) There is a minimum distance that the ship can be stationed from the landing zone ashore. The minimum distance is fixed by the distance from the landing zone to the shore line.

#### BACKGROUND

Some analytic work has been performed in the past on the problem of unloading ships by helicopter. An earlier paper\* summarized known efforts, and also treated analytically the question of trading off fuel carried for more cargo payload. In particular, the earlier paper showed that the maximum cargo delivery rate occurs

---

\* D. E. Willhite and B. F. Powers, "The Marine H-34 Helicopter in Combat Ship-to-Shore Operations," unpublished manuscript, C.N.A., 1969.

when helicopters are refueled less frequently than every stop at the ship for cargo pick-up, but more frequently than the number of stops permitted by a full fuel load. (The optimum scheme requires that the cargo payload be incremented at each pick-up such that the sum of fuel weight and cargo weight remains a constant.) The earlier analysis is based on an expected value model wherein the action times at system nodes are deterministic and equal to the expected values of measured distributions. Such an analysis, although valuable in indicating an appropriate trade-off policy, fails to treat the real-world problem of how to minimize queues that build during an actual unloading.

Data collection, although tedious, presented no real difficulty. An observer was stationed with a full view of the flight deck during an unloading lasting several hours. Landing and launch times were recorded along with the reason for the flight deck stops. Distributions of these on-deck times were then prepared. Similarly, a second observer was given earphones to listen to helicopter pilot radio transmissions. Times of arrival in the vicinity of the landing zone were recorded based on these radio transmissions. From these data, distributions of flight time between ship and landing zone were prepared. The only data which was unavailable was the distribution of unloading times in the landing zone; stationing an observer there was relatively difficult. The simulation used the distribution of flight deck loading times for the landing zone unloading time distribution. (Observation of the back-loading of cargo after conclusion of the unloading exercise indicated this substitution was a good approximation.)

#### FEATURES OF THE SIMULATION

A simulation model of the unloading operation has been written in the GPSS language and coded for use on either the UNIVAC 1108 or the IBM/360. Features of the model include:

- (a) Times spent by waves
  - (1) on the ship's flight deck,
  - (2) flying to the landing zone,
  - (3) in the landing zone, and

(4) flying back

are all treated stochastically.

- (b) Within waves, individual helicopters are permitted variations in behavior such as different action times at system nodes.
- (c) Extreme deviations in individual helicopter behavior are permitted. For example, a helicopter may be returned to the ship for repairs immediately on observation of maintenance difficulties or damage. When a simulated emergency occurs, the helicopter separates from the others in its wave and proceeds directly to the ship's flight deck. It waits at the ship until its parent wave returns to the flight deck, and rejoins the wave there.
- (d) The possibility of complete loss of a helicopter is included, with the loss being replaced when the parent wave next stops at the ship.
- (e) Fuel on board helicopters is decremented as flight time accrues, and refueling is scheduled as necessary during cargo pick-up stops at the ship.
- (f) Considerable generality is incorporated in the model. The following can be varied from run to run:
  - (1) The capacity of the flight deck and of the landing zone.
  - (2) The number of helicopters in a full-strength wave.
  - (3) The number of minutes of flight corresponding to a full fuel load.
  - (4) The probability that helicopters encounter malfunction or damage in flight.
  - (5) The probability that a helicopter's resulting difficulty is so severe that loss of the helicopter results.
  - (6) The separation distance between ship and landing zone.

## VALIDATION OF THE MODEL

The simulation model has been verified by comparison to actual data collected during an unloading. The physical characteristics of the actual unloading were introduced as model inputs. Time distributions for loading and refueling on the deck had been carefully measured during the actual unloading; so had flight times between the ship and landing zone. These measured distributions were entered into the program. Three hours of unloading were then simulated, which was the actual unloading time during which data had been collected. The queue distributions resulting from the simulation run were then compared to the queue distributions (for flight deck and landing zone) measured during the actual unloading and the agreement was good.

Tables I and II show characteristics of the actual and simulation distributions of times spent by waves in the queues for the flight deck and for the landing zone. Symbols are on page 11.

TABLE I

### QUEUE FOR FLIGHT DECK ACTUAL VERSUS SIMULATION RESULTS

	ACTUAL	SIMULATION
WAVES QUEUING	38	38
PERCENT WITH $Q = 0$	65	55
$\bar{Q}$ (MINUTES)	2.9	2.1
$\sigma_Q$ (MINUTES)	5.1	4.2

TABLE II

### QUEUE FOR LANDING ZONE ACTUAL VERSUS SIMULATION RESULTS

	ACTUAL	SIMULATION
WAVES QUEUING	38	37
PERCENT WITH $Q = 0$	72	89
$\bar{Q}$ (MINUTES)	0.4	0.1
$\sigma_Q$ (MINUTES)	0.9	0.3

The close agreement of these distributions lends considerable validity to the simulation model. The model has thus been used to consider alternate modes of operation of helicopters with a view toward finding the mode which maximizes cargo delivery rate while minimizing queuing time.

#### USE OF THE MODEL

Once validated, the model generated results for consideration by Navy decision makers. The model was used to examine the implications of changes, generally in one variable at a time, in the conditions under which unloadings take place. For example, the results shown in tables I and II are for a landing zone capacity of eight (8) helicopters. Other runs were made to examine the effect on cargo arrival rate and queue size of variation in landing zone capacity. The results of such capacity variation, with all other variables held fixed, are shown in table III. (The length of steady-state unloading is three hours in table III and all other tables.)

TABLE III  
VARIATION IN ZONE CAPACITY

ZONE CAPACITY	HELICOPTERS ARRIVING	$\bar{Q}$
2	127	8.7
4	149	1.3
8	144	0.1
12	144	0

The capacity of the landing zone is not generally under the control of a ship's commander, so the results in table III are of most use in choosing among alternate sites ashore for cargo placement. (In a combat unloading, the tactical situation ashore will be the prime determinant of the cargo landing site.) The table III results show little variation in helicopter loads delivered as a function of zone capacity, but substantial inverse dependence of waiting time on capacity. Based on table III, a commander might select a site ashore which has larger capacity but a less favorable position so as to minimize wasted flying time.

The effect of crowding was also examined. Tables I and II were constructed from runs in which 6 waves of 4 helicopters each were cycled through the system. Table IV shows the effect of changes in the number of waves of 4 helicopters each, with all other variables held constant.

TABLE IV  
VARIATION IN NUMBER OF WAVES

WAVES	HELICOPTERS ARRIVING		$\bar{Q}$	
	ZONE	SHIP	ZONE	SHIP
4	114	132	0	0.1
6	144	176	10	2.1
8	179	240	.13	3.1
10	218	269	.56	5.0

The delivery rate can be seen from table IV to increase with the number of participating waves. Within the range of values simulated, the delivery rate goes up with crowding. However, the delivery rate increase is obtained at the expense of a more rapid increase in the amount of time spent by helicopters in queues. The ship's commander must balance off long-term considerations (extra hours of flight will require that scheduled maintenance come sooner) against the short-term consideration of as rapid a cargo delivery as possible.

An option available to the commander besides crowding more waves of helicopters into the unloading process is to alter the flying distance to the landing zone by moving the ship closer to shore. Simulation runs were made wherein the flying time distribution was manipulated to reflect changes in the ship's distance from the landing zone. For instance, all randomly selected values from the flight time distribution were multiplied by 1/2 during one run to examine the effect of cutting the ship-to-zone distance in half. Table V contains the results of simulation runs where flying times were so manipulated. In the table V runs, 6 waves of 4 helicopters each unload the ship for 3 hours into a landing zone of capacity 8 helicopters.

TABLE V

## VARIATION OF FLYING DISTANCE

FACTOR	HELICOPTERS ARRIVING		$\bar{Q}$	
	ZONE	SHIP	ZONE	SHIP
1/2	245	272	.11	0.9
1	144	176	.10	2.1
2	94	120	.17	1.3

The effect of crowding is not apparent in the queue times of table V as it was in table IV. Moving the ship closer to shore does, however, greatly increase the delivery rate to the landing zone. Table V suggests that, with 24 helicopters grouped into waves of 4 helicopters each, the ship be moved as close to the landing zone as possible to maximize delivery rate.

Another important decision facing the ship's commander is how to group the available helicopters into waves. The model was used to examine alternate groupings of 40 helicopters. With a flight deck capacity of 10 helicopters and maximum utilization of flight deck space consistent with a policy which calls for landing or launch simultaneously by all helicopters of a wave, table VI shows the results of simulations where 40 helicopters are grouped differently. Landing zone capacity is 12.

TABLE VI

## ALTERNATE GROUPINGS

HELICOPTERS/ WAVE	WAVES	ARRIVALS AT ZONE	$\bar{Q}$	
			SHIP	ZONE
5	8	216	6.1	0.3
4	10	213	6.0	0.1
3	13	222	4.0	0

Maximum delivery rate is achieved with a wave size of 3 helicopters, although the variation in the number of helicopters arriving is very small. Minimum queue length at the ship occurs for a wave size of 3 helicopters, also. The choice of 3 helicopters in each wave can be made over either 4 or 5 helicopters because both measures of effectiveness are optimized with 3 helicopters per wave. (The value of 2 helicopters per wave was not simulated because the model uses ASSEMBLE blocks. If 2 members of an assembly set are not always available, the program will not continue running.) It appears that the smaller number of helicopters per wave when 13 waves are operated permits taking better advantage of deck or landing zone space when it becomes available. This conclusion might well change if the policy of landing/launching all helicopters of a wave simultaneously were abandoned.

#### COMMENTS ON THE MODEL

The model is straightforward. The waves of helicopters are first generated and then allowed to move back and forth between ship and landing zone. (The model treats this movement by aggregating all helicopters of a wave into one transaction.) It is the variation on this movement that introduces complexity into the model. Some of the helicopters will encounter difficulty and require repairs. When they do, they are separated from their parent waves (a new transaction is created) and return to the ship. The model places such returning helicopters on a user chain to simulate repair time; the helicopter in repair is freed from the user chain when its parent wave returns to the ship.

The model corresponds closely to reality when the loss of a helicopter is simulated. In the actual situation, the difficulty encountered by an airborne helicopter may be so severe as to cause the loss of the helicopter. When that occurs, the other helicopters in the wave suffering the loss return to the ship after rescue efforts for the downed crew. While on the flight deck, a fresh helicopter is brought up from storage on a lower deck. The fresh helicopter is made ready to fly and launches with the wave which was deficient on landing. The model simulates this activity by use of branch points. The model tests waves arriving at the flight deck to see if the sum of arriving helicopters and helicopters in repair from that wave is equal to the nominal wave size. If not, access is granted to coding which generates a sufficient number of replacement helicopters.

The GPSS language was selected for this simulation because it is very well suited to describing the physical process simulated. Basically, the information sought about the physical process is the rate of flow of helicopters through a closed loop and the nature of the queues preceding nodes of limited capacity. GPSS was designed to describe this type of physical process, and no other language

could have produced as much useful information with similar programming ease.

Development of the simulation model took approximately four man-months, with one of the analysts well versed in the subject of ship unloading by helicopter primarily through data collection whose results were used in the simulation. About 150 runs were made as the model was refined, consuming a total of about one hour of computer time with 50,000 words of UNIVAC 1108 core usage per run.

SYMBOLS FROM TABLES:

$Q$  = time spent in queue

$\bar{Q}$  = mean time in queue

$\sigma_Q$  = standard deviation of queue time distribution

## List of CNA Professional Papers\*

- PP 1  
Brown, George F. and Lloyd, Richmond M., "Static Models of Bank Credit Expansion," 27 pp., 23 Sep 1969, (Published in the Journal of Financial and Quantitative Analysis, Jun 1971) AD 703 925
- PP 2  
Lando, Mordechai E., "The Sex-Differential in Canadian Unemployment Data," 5 pp., 9 Jan 1970, AD 699 512
- PP 3  
Brown, George F.; Corcoran, Timothy M. and Lloyd, Richmond M., "A Dynamic Inventory Model with Delivery Lag and Repair," 16 pp., 1 Aug 1969, AD 699 513
- PP 4  
Kadane, Joseph B., "A Moment Problem for Order Statistics," 14 pp., 13 Jan 1970, (Published in the Annals of Mathematical Statistics, Apr 1971) AD 699 514
- PP 5  
Kadane, Joseph B., "Optimal Whereabouts Search," 28 pp., Oct 1969, (Published in the Journal of the Operations Research Society of America, Vol. XIX, 1971) AD 699 515
- PP 6 - Classified
- PP 7  
Friedheim, Robert L., "The Continental Shelf Issue at the United Nations: A Quantitative Content Analysis," 25 pp., 7 Jan 1970, (Published in "Pacem in Maribus," edited by Elaine H. Burnell and Piers von Simson, Center for the Study of Democratic Institutions, Royal University of Malta Press, 1971) (See also PP 28) AD 699 516
- PP 8  
Rose, Marshall and White, Alex, "A Comparison of the Importance of Economic Versus Non-Economic Factors Affecting the Residential Housing Market During the Two Decades Subsequent to World War II," 128 pp., 15 Jan 1970, AD 699 517
- PP 9  
Rose, Marshall, "A Thesis Concerning the Existence of Excess Capacity at Naval Shipyards Prior to the Escalation of Hostilities in Southeast Asia in 1964," 67 pp., 9 Jan 1970, AD 699 518
- PP 10 - Classified
- PP 11  
O'Neill, David M., "The Effect of Discrimination on Earnings: Evidence from Military Test Score Results," 19 pp., 3 Feb 1970, (Published in the Journal of Human Resources, Summer 1970) AD 703 926
- PP 12  
Brown, George F. and Lloyd, Richmond M., "Dynamic Models of Bank Credit Expansion Under Certainty," 29 pp., 3 Feb 1970, AD 703 931
- PP 13  
Overholt, John L., "Analysis Data Inputs and Sensitivity Tests in War Games," 30 pp., Mar 1971, AD 722 858
- PP 14  
Rose, Marshall, "Determination of the Optimal Investment in End Products and Repair Resources," 38 pp., 18 Feb 1970, (Published in the Annual Meeting of the American Association of Cost Engineers Proceedings, Jun 1971, Montreal, Canada) AD 702 450
- PP 15  
Rose, Marshall, "Computing the Expected-End Product Service Time Using Extreme Value Properties of Sampling Distribution," 29 pp., 18 Feb 1970, (Published in Operations Research, Mar-Apr 1971) AD 702 451
- PP 16  
Rose, Marshall, "Study of Repairable Item Resupply Activities," 35 pp., 18 Feb 1970, AD 702 457
- PP 17  
Brown, Lee (Lt, USN) and Rose, Marshall, "An

\*CNA Professional Papers with an AD number may be obtained from the National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22151 Other papers are available from the author at the Center for Naval Analyses, 1401 Wilson Boulevard, Arlington, Virginia 22209

CNA Professional Papers

PP 17 (Continued)

Incremental Production for the End-Item Repair Process," 17 pp., 3 Mar 1970, (Published in Annual Conference of the American Institute of Industrial Engineers Transactions, May 1970, Cleveland, Ohio) AD 702 453

PP 18

Rose, Marshall, "Inventory and the Theory of the Firm," 14 pp., 18 Feb 1970, AD 702 454

PP 19

Rose, Marshall, "A Decomposed Network Computation for End-Product Repair Curves," 24 pp., 18 Feb 1970, AD 702 455

PP 20

Brown, George F.; Corcoran, Timothy M. and Lloyd, Richmond M., "Inventory Models with a Type of Dependent Demand and Forecasting, with an Application to Repair," 4 pp., 10 Feb 1970, (Published in Management Science: Theory Section, Mar 1971) AD 702 456

PP 21

Silverman, Lester P., "Resource Allocation in a Sequential Flow Process," 21 pp., 5 Mar 1970, AD 702 457

PP 22

Gorlin, Jacques, "Israeli Reprisal Policy and the Limits of U.S. Influence," 27 pp., 23 Mar 1970, AD 703 534

PP 23

Rose, Marshall, "An Aircraft Rework Cost-Benefit Model," 13 pp., 12 Mar 1970, (Published in the 5th Annual DoD Cost Research Symposium Proceedings, Mar 1970) AD 702 514

PP 24

Lloyd, Richmond and Sutton, S. Scott, "An Application of Network Analysis to the Determination of Minimum Cost Aircraft Pipeline Factors," 51 pp., 31 Mar 1970, (Presented at NATO Conference on Problems in the Organization and Introduction of Large Logistic Support Systems, May 1970, Luxembourg) AD 703 536

PP 25

Saperstone, Stephen, "An Approach to Semi-Markov Processes," 38 pp., 23 Mar 1970, AD 703 537

PP 26

Brown, George F. and Corcoran, Timothy M., "The Reliability of a Complex System with Spares, Repair, and Cannibalization," 45 pp., 23 Mar 1970, AD 703 538

PP 27

Fain, Janice B.; Fain, William W.; Feldman, Leon and Simon, Susan, "Validation of Combat Models Against Historical Data," 18 pp., 14 Apr 1970, (Published in 9th Symposium of the National Gaming Council Proceedings, Apr 1970) AD 704 744

PP 28

Friedheim, Robert L. and Kadane, Joseph B., "Quantitative Content Analysis of the United Nations Seabed Debates: Methodology and a Continental Shelf Case Study," 32 pp., 24 Mar 1970, (Published in International Organization, Vol. XXIV, No. 3, 1970) AD 703 539

PP 29

Saperstone, Stephen H., "Controllability of Linear Oscillatory Systems Using Positive Controls," 27 pp., Apr 1970, AD 704 745

PP 30

DeVany, Arthur S., "The Effect of Social Policy on the Social and Private Value of a Child," 20 pp., 27 Apr 1970, AD 704 746

PP 31

DeVany, Arthur S., "Time in the Budget of the Consumer," 51 pp., 27 Apr 1970, AD 704 747

PP 32

Overholt, John L., "Fitting Korean War Data by Statistical Method," 11 pp., 5 May 1970, (Presented at the 9th Symposium of the National Gaming Council, Apr 1970, Washington, D.C.) AD 705 349

PP 33

DeVany, Arthur S., "A Theory of Household Demand and Labor Supply," 23 pp., 5 May 1970, AD 705 350

PP 34

Kadane, Joseph B. and Fisher, Franklin M., "The Covariance Matrix of the Limited Information Estimator and the Identification Test. Comment," 6 pp., 14 May 1970, (To be published in *Econometrica*) AD 706 310

CNA Professional Papers

PP 17 (Continued)

Incremental Production for the End-Item Repair Process," 17 pp., 3 Mar 1970, (Published in Annual Conference of the American Institute of Industrial Engineers Transactions, May 1970, Cleveland, Ohio) AD 702 453

PP 18

Rose, Marshall, "Inventory and the Theory of the Firm," 14 pp., 18 Feb 1970, AD 702 454

PP 19

Rose, Marshall, "A Decomposed Network Computation for End-Product Repair Curves," 24 pp., 18 Feb 1970, AD 702 455

PP 20

Brown, George F.; Corcoran, Timothy M. and Lloyd, Richmond M., "Inventory Models with a Type of Dependent Demand and Forecasting, with an Application to Repair," 4 pp., 10 Feb 1970, (Published in Management Science: Theory Section, Mar 1971) AD 702 456

PP 21

Silverman, Lester P., "Resource Allocation in a Sequential Flow Process," 21 pp., 5 Mar 1970, AD 702 457

PP 22

Gorlin, Jacques, "Israeli Reprisal Policy and the Limits of U.S. Influence," 27 pp., 23 Mar 1970, AD 703 534

PP 23

Rose, Marshall, "An Aircraft Rework Cost-Benefit Model," 13 pp., 12 Mar 1970, (Published in the 5th Annual DoD Cost Research Symposium Proceedings, Mar 1970) AD 702 514

PP 24

Lloyd, Richmond and Sutton, S. Scott, "An Application of Network Analysis to the Determination of Minimum Cost Aircraft Pipeline Factors," 51 pp., 31 Mar 1970, (Presented at NATO Conference on Problems in the Organization and Introduction of Large Logistic Support Systems, May 1970, Luxembourg) AD 703 536

PP 25

Saperstone, Stephen, "An Approach to Semi-Markov Processes," 38 pp., 23 Mar 1970, AD 703 537

PP 26

Brown, George F. and Corcoran, Timothy M., "The Reliability of a Complex System with Spares, Repair, and Cannibalization," 45 pp., 23 Mar 1970, AD 703 538

PP 27

Fain, Janice B.; Fain, William W.; Feldman, Leon and Simon, Susan, "Validation of Combat Models Against Historical Data," 18 pp., 14 Apr 1970, (Published in 9th Symposium of the National Gaming Council Proceedings, Apr 1970) AD 704 744

PP 28

Friedheim, Robert L. and Kadane, Joseph B., "Quantitative Content Analysis of the United Nations Seabed Debates: Methodology and a Continental Shelf Case Study," 32 pp., 24 Mar 1970, (Published in International Organization, Vol. XXIV, No. 3, 1970) AD 703 539

PP 29

Saperstone, Stephen H., "Controllability of Linear Oscillatory Systems Using Positive Controls," 27 pp., Apr 1970, AD 704 745

PP 30

DeVany, Arthur S., "The Effect of Social Policy on the Social and Private Value of a Child," 20 pp., 27 Apr 1970, AD 704 746

PP 31

DeVany, Arthur S., "Time in the Budget of the Consumer," 51 pp., 27 Apr 1970, AD 704 747

PP 32

Overholt, John L., "Fitting Korean War Data by Statistical Method," 11 pp., 5 May 1970, (Presented at the 9th Symposium of the National Gaming Council, Apr 1970, Washington, D.C.) AD 705 349

PP 33

DeVany, Arthur S., "A Theory of Household Demand and Labor Supply," 23 pp., 5 May 1970, AD 705 350

PP 34

Kadane, Joseph B. and Fisher, Franklin M., "The Covariance Matrix of the Limited Information Estimator and the Identification Test. Comment," 6 pp., 14 May 1970, (To be published in *Econometrica*) AD 706 310

- PP 34 (Continued)  
\*Department of Economics, Massachusetts Institute of Technology
- PP 35  
Lando, Mordechai E., "Full Employment and the New Economics--A Comment," 4 pp., 14 May 1970, (Published in the Scottish Journal of Political Economy, Vol. XVII, Feb 1969) AD 706 420
- PP 36  
DeVany, Arthur S., "Time in the Budget of the Consumer: The Theory of Consumer Demand and Labor Supply Under a Time Constraint," 151 pp., 15 Jun 1970, AD 708 348
- PP 37  
Kadane, Joseph B., "Testing a Subset of the Over-identifying Restrictions," 7 pp., 19 Jun 1970, (To be published in Econometrica) AD 708 349
- PP 38  
Saperstone, Stephen H., "The Eigenvectors of a Real Symmetric Matrix are Asymptotically Stable for Some Differential Equation," 19 pp., Jul 1970, AD 708 502
- PP 39  
Hardy, W. C. and Blyth, T. S.\*, "Quasi-Residuated Mappings and Baer Assemblies," 22 pp., 14 Jul 1970, (To be published by the Royal Society of Edinburgh)  
\*Mathematical Institute, University of St. Andrew
- PP 40  
Silverman, Lester P. and Forst, Brian E., "Evaluating Changes in the Health Care Delivery System: An Application to Intensive Care Monitoring," 19 pp., Jul 1970, AD 710 631
- PP 41  
Piersall, Charles H (LCdr), "An Analysis of Crisis Decision-Making," 55 pp Aug 1970, (To be published in the American Political Science Review) AD 719 705
- PP 42  
Sullivan, John A., "Measured Mental Ability, Service School Achievement and Job Performance," 22 pp., 31 Jul 1970, AD 720 359
- PP 43  
Forst Brian E., "Estimating Utility Functions Using Preferences Revealed under Uncertainty," 13 pp., Jun 1971, (Presented at the 39th National Meeting of the Operations Research Society of America, 5 May 1971) AD 726 472
- PP 44  
Schick, Jack M., "Conflict and Integration in the Near East: Regionalism and the Study of Crises," 43 pp., Oct 1970, (Presented at the 66th Annual Meeting of the American Political Science Association, Sep 1970)
- PP 45  
Brown, George F. and Lloyd, Richmond M., "Fixed Shortage Costs and the Classical Inventory Model," 13 pp., Jul 1970, AD 713 057
- PP 46  
Hardy, William C. and Blyth, T. S.\*, "A Coordination of Lattices by One-Sided Baer Assemblies," 21 pp., Jul 1970, (To be published by the Royal Society of Edinburgh)  
\*Mathematical Institute, University of St. Andrew
- PP 47  
Silverman, Lester P., "Resource Allocation in a Sequential Flow Process with an Application to the Naval Resupply System," 18 pp., Oct 1970, (Presented at the 11th American Meeting of the Institute of Management Sciences, Oct 1970, Presented at the 26th Meeting of the Military Operations Research Society, Nov 1970) AD 713 028
- PP 48  
Gray, Burton C., "Writeup for B34TCNA A Step-Wise Multiple Regression Program," 15 pp., Oct 1970, AD 713 029
- PP 49  
Friedheim, Robert L., "International Organizations and the Uses of the Ocean," 88 pp., Oct 1970, (Published in Multinational Cooperation, Oxford University Press, 1972) AD 714 387
- PP 50  
Friedheim, Robert L. and Kadane Joseph B., "Ocean Science in the United Nations Political Arena," 45 pp Jun 1971, (Published in the Journal of Maritime Law Commerce, Vol. 3, No. 3, Apr 1972) AD 731 865
- PP 51  
Saperstone, Stephen H., "Global Controllability of

CNA Professional Papers

PP 51 (Continued)

Linear Systems with Positive Controls," 29 pp., Nov 1970, AD 714 650

PP 52

Forst, Brian E., "A Decision-Theoretic Approach to Medical Diagnosis and Treatment," 14 pp., Nov 1970, (Presented at the Fall 1970 11th American Meeting of the Institute of Management Sciences, Oct 1970, Los Angeles, California) AD 714 651

PP 53

Kadane, Joseph B., "On Division of the Question," 12 pp., Nov 1970, (Published in Public Choice, Fall 1971) AD 714 652

PP 54

Kadane, Joseph B., "How to Burgle If You Must: A Decision Problem," 13 pp., May 1971, AD 723 850

PP 55

Brown, George F., "Optimal Management of Bank Reserves," 35 pp., Aug 1970, AD 715 569

PP 56

Horowitz, Stanley A., "Economic Principles of Liability and Financial Responsibility for Oil Pollution," 26 pp., Mar 1971, AD 722 376

PP 57

Lando, Mordechai E., "A Comparison of the Military and Civilian Health Systems," 20 pp., Dec 1970, AD 716 897

PP 58

Kadane, Joseph B., "Chronological Ordering of Archeological Deposits by the Minimum Path Length Method," 16 pp., Jun 1971, AD 726 475

PP 59

Dyckman, Zachary Y., "An Analysis of Negro Employment in the Building Trades," 309 pp., Jan 1971

PP 60

Lando, Mordechai E., "Health Services in the All Volunteer Armed Force," 33 pp., Jan 1971, (Published in Studies Prepared for the President's Commission on an All-Volunteer Force, Government Printing Office, Nov 1970) AD 716 899

PP 61

Robinson, Jack, "Classification Management Training and Operations, An Approach," 14 pp., Jul 1971, (Presented at the 7th Annual Seminar, National Classification Management Society, Washington, D.C., 13-16 Jul 1971) AD 727 719

PP 62

Brown, George F. and Schwartz, Arnold N., "The Cost of Squadron Operation: A Theoretical and Empirical Investigation," 10 pp., Jan 1971 (Published in the Transactions of the 1971 American Association of Cost Engineers International Meeting, Jun 1971) AD 722 377

PP 63

Lockman, Robert F., "Analyses of Selection and Performance Measures for CNA Support Personnel," 45 pp., Feb 1971, AD 720 360

PP 64

Utgoff, Victor A. and Kashyap, R. L.\*, "On Behavior Strategy Solutions in Two-Person Zero-Sum Finite Extended Games with Imperfect Information," 37 pp., Feb 1971, (Accepted for publication in the SIAM Journal on Applied Mathematics) AD 720 361

\*School of Electrical Engineering, Purdue University

PP 65

O'Neill, David M.; Gray, Burton C. and Horowitz, Stanley, "Educational Equality and Expenditure Equalization Orders: The Case of Hobson V. Hansen," 43 pp., Feb 1971, AD 720 362

PP 66

Schwartz, Arnold N.; Sheler, James A. (LCdr) and Cooper, Carl R. (Cdr), "Dynamic Programming Approach to the Optimization of Naval Aircraft Rework and Replacement Policies," 39 pp., Mar 1971, (To be published in the Naval Research Logistics Quarterly) AD 720 363

PP 67

Kuzmack, Richard A., "Measures of the Potential Loss from Oil Pollution," 16 pp., Mar 1971, (Published as Chapter 13 in Legal, Economic, and Technical Aspects of Liability and Financial Responsibility as Related to Oil Pollution, The George Washington University, Dec 1970) AD 722 378

- PP 68  
Blechman, Barry M. and Holt, James, T., "Cost/Effectiveness Analysis of Foreign Policy Alternatives: Need, Approach, and Prospects," 41 pp., Mar 1971, (Presented at the 1971 Western Regional Meeting of the International Studies Association, Mar 1971) AD 722 379
- PP 69  
Rogers, Warren F. (Cdr), "Exact Null Distributions of Rank Test Statistics," 47 pp., Mar 1971, AD 722 380
- PP 70  
Rogers, Warren F. (Cdr), "On A Theorem of Weyl," 17 pp., Mar 1971, AD 722 381
- PP 71  
Lloyd, Richmond M., "Dynamic Programming Models of Short Term Bank Reserve Management," 233 pp., Mar 1971, AD 727 724
- PP 72  
Kadane, Joseph B. and Iversen, Gudmund R.\*, "Estimation of Multinomial Process When Only the Sum and the Number Governed by Each Process is Observed," 13 pp., Apr 1971, AD 722 382  
\*University of Michigan
- PP 73  
Victor A. Utgoff and Kashyap, R L.\*. "On Behavior Strategy Solutions in Two-Person Zero-Sum Finite Extended Games with Imperfect Information, Part II. Determination of a Minimally Complex Behavior Strategy Solution in a Medical Decision Process," 22 pp., May 1971, (Accept for publication in the SIAM Journal on Applied Mathematics) AD 723 851  
\*School of Electrical Engineering, Purdue University
- PP 74  
Brown, Jr George F., Silverman, Lester P and Perlman, Bernard L (AWF3), "Optimal Positioning of Inventory Stock in a Multi-Echelon System," 37 pp., May 1971, (Presented at the 39th Annual Meeting of the Operations Research Society of America, May 1971) AD 723 852
- PP 75  
Stoloff, Peter H., "The Navy Personal Response Program Review. Evaluation and Recommendations," 22 pp Jul 1971, AD 727 725
- PP 76  
Canes, Michael E., "Measurement and Selection of Defense," 21 pp., Aug 1971, AD 731 868
- PP 77  
McConnell, James M., "The Soviet Navy in the Indian Ocean," 16 pp., Aug 1971, AD 731 869
- PP 78  
Blechman, Barry M., "A Quantitative Description of Arab-Israeli Interactions, 1949-1969: Data Sets and Processor," 43 pp., Sep 1971, AD 731 870
- PP 79  
Wilson, Desmond P. and Brown, Nicholas (Cdr), "Warfare at Sea: Threat of the Seventies," 14 pp., Nov 1971, AD 734 856
- PP 80  
Weinland, Robert G., "The Changing Mission Structure of the Soviet Navy," 15 pp., Nov 1971, AD 734 077
- PP 81  
Forst, Brian, E., "The Grisly Analytics of Death, Disability, and Disbursements," 20 pp., Nov 1971, (Presented at the 40th National Meeting of the Operations Research Society of America, 28 Oct 71) AD 732 555
- PP 82  
Forst, Brian E., "A Doctor's Introduction to Decision Analysis," 22 pp., Nov 1971, (Presented at the Engineering Foundation Conference on Quantitative Decision Making for the Delivery of Ambulatory Care, 22 Jul 1971) AD 732 556
- PP 83  
Weiher, Rodney and Horowitz, Stanley A., "The Relative Costs of Formal and On-the-Job Training for Navy Enlisted Occupations," 44 pp., Nov 1971, AD 734 857
- PP 84  
Weiher, Rodney and Horowitz Stanley A., "A Production Function for Trained Recruits," 27 pp., Nov 1971, AD 734 858
- PP 85  
Brown, Jr Georg F., "Comparison of Forecast Accuracy When the Disturbances Are Small. Directly Estimated Reduced Forms vs K Class Induced Reduced Forms," 17 pp., Dec 1971, AD 736 355

CNA Professional Papers

- PP 86  
Harrison, Robert A., "Multivariate Regression Analysis and Slaughter Livestock," 33 pp., Dec 1971, AD 736 356
- PP 87  
Harkins, James A., "Computer Software: A Major Weapon System Component," 9 pp., Jan 1972, (Presented at the Washington Chapter ACM 10th Annual Symposium, 24 Jun 71, National Bureau of Standards, Gaithersburg, Md.), AD 736 357
- PP 88  
Lockman, Robert F., "An Evaluation of the Applicant Interview Form for CNA Support Jobs," 19 pp., Mar 1972, AD 740 995
- PP 89  
Barney, Gerald O., "System Dynamics and the Analysis of Social Policy," 27 pp., Apr 1972, (Presented at the XIX International Meeting of the Institute of Management Sciences, 4-8 Apr 1972, Houston, Texas) AD 744 191
- PP 90  
Heider, Dr. Charles H., "An N-Step, 2-Variable Search Algorithm for the Component Placement Problem," 58 pp., Apr 1972, AD 740 996
- PP 91  
Piersall, Jr. Charles H. and Borgstrom, Robert E., "Cost Analysis of Optional Methods of Shipboard Domestic Waste Disposal," 23 pp., Apr 1972, (Presented at the Annual Northeast Regional Antipollution Conference at the University of Rhode Island, Jul 1972) AD 744 192
- PP 92  
Forst, Brian E., "Decision Analysis and Medical Malpractice," 30 pp., May 1972, (Presented at the 41st National Meeting of the Operations Research Society of America, New Orleans, Louisiana, 27 Apr 1972) AD 744 193
- PP 93  
Zedlewski, Edwin W., "Estimation and Inference in Binary Response Regressions," 52 pp., May 1972, AD 744 194
- PP 94  
Weinland, Robert G., "Soviet Transits of Turkish Straits 1945-1970—An Historical Note on the Establishment and Dimensions of the Soviet Naval Presence in the Mediterranean," 20 pp., 14 Apr 1972, AD 745 042
- PP 95  
Robinson, Jack, "The British Official Secrets Act, An Examination," 23 pp., Jul 1972, (Presented at the 8th Annual Seminar, National Classification Management Society, 18-20 Jul 1972, Palo Alto, California), AD 745 043
- PP 96  
Powers, Bruce F. and Goldberg, Martin\*, "Simulation of Rapid Ship Unloading by Helicopter," 12 pp., Jul 1972, (Presented at the 5th Conference on the Applications of Simulation, New York, New York, Dec 1971)  
\*Industrial Engineering Department, Northwestern University
- PP 97  
Friedheim, Robert L., "A Law of the Sea Conference — Who Needs It?," 31 pp., Aug 1972, (Presented at the Symposium on International Relations and the Future of Ocean Space, Columbia, South Carolina, 12 Apr 1972)