Research Report 1324

A DESCRIPTION OF THE ARI CREW PERFORMANCE MODEL

Robert C. Schwalm, Lloyd M. Crumley,
Jay S. Coke, and Sidney A. Sachs

ARI FIELD UNIT AT FORT SILL, OKLAHOMA

U. S. Army
Research Institute for the Behavioral and Social Sciences

April 1981

Approved for public release: distribution unlimited.

U. S. ARMY RESEARCH INSTITUTE

FOR THE BEHAVIORAL AND SOCIAL SCIENCES

A Field Operating Agency under the Jurisdiction of the

Deputy Chief of Staff for Personnel

JOSEPH ZEIDNER
Technical Director

L. NEALE COSBY
Colonel, IN
Commander

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER Research Report 1324	2. GOVT ACCESSION NO. AD-A113 793	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A Description of the ARI Crew Performance Model		5. TYPE OF REPORT & PERIOD COVERED Final Report 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Robert C. Schwalm, Lloyd M. Crumley, Jay S. Coke, and Sidney A. Sachs		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Research Institute for the Behavioral and Social Sciences PERI-SS 5001 Eisenhower Ave., Alexandria, VA 22333		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 2Q263743A790
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Field Artillery School Fort Sill, OK 73503		12. REPORT DATE April 1981 13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Computer Simulation	M109A1 Howitzer
Computer Modeling	Task Analysis
Crew Performance	Crew Size
Crew-Served Systems	Crew Structure

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A computer-based model which simulates the performance of howitzer crews and other crew-served systems was developed. The model can be used to simulate the speed of performance of crews varying in size and/or task assignments. The model is based on probabilistic modeling methods and consists of three segments: A task library containing the relevant crew tasks and their associated performance times; an input program for entering the crew size,

the tasks to be performed by each man, and the order in which the tasks are to be performed; and the main program for integrating the input information and calculating summary performance measures based on that information. These performance measures can then be used for evaluating the speed and relative efficiency of crews varying in size or structure.

Research Report 1324

A DESCRIPTION OF THE ARI CREW PERFORMANCE MODEL

Robert C. Schwalm, Lloyd M. Crumley,
Jay S. Coke, and Sidney A. Sachs

Submitted by:
James A. Bynum, Chief
ARI FIELD UNIT AT FORT SILL, OKLAHOMA

Approved by:
Edgar M. Johnson, Director
SYSTEMS RESEARCH LABORATORY

U.S. ARMY RESEARCH INSTITUTE FOR THE BEHAVIORAL AND SOCIAL SCIENCES
5001 Eisenhower Avenue, Alexandria, Virginia 22333

Office, Deputy Chief of Staff for Personnel
Department of the Army

April 1981

Army Project Number
2Q263743A790

Crew Design

ARI Research Reports and Technical Reports are intended for sponsors of R&D tasks and for other research and military agencies. Any findings ready for implementation at the time of publication are presented in the last part of the Brief. Upon completion of a major phase of the task, formal recommendations for official action normally are conveyed to appropriate military agencies by briefing or Disposition Form.

FOREWORD

The US Army Research Institute Fort Sill Field Unit conducts research of relevance to the Field Artillery in particular and to the Army as a whole. Among its ongoing efforts is a program to evaluate the effects of inadequate sleep and work-rest cycles on the perfomance of M109A1 howitzer crews over extended periods of continuous operations. This initial phase in that evaluation was the development of a computer-based model which simulates howitzer crew performance under optimal conditions. This report describes the development, content, and capabilities of the Crew Performance Model. Subsequent research will explore the effects on performance of inadequate sleep and work-rest cycles, selected environmental conditions, and other factors. The model will then be expanded to evaluate the effects of these factors on crew performance. This research is a portion of Army Research Project 2Q263743A790.

JOSEPH ZEIDNER
Technical Director

A DESCRIPTION OF THE ARI CREW PERFORMANCE MODEL

BRIEF

Requirement:

The Army Research Institute was requested to determine whether M109A1 howitzer sections will be able to maintain an acceptable level of performance during extended periods of intense, continuous combat operations. Furthermore, given that crew performance will deteriorate somewhat under such conditions, what is the relationship between crew size and the point at which performance is no longer considered acceptable?

Procedure:

A computer-based model which simulates the performance of howitzer crews was developed. The model can be modified for use with any crew-served system. Using the model requires only a knowledge of the tasks and subtasks which make up the system being simulated. The model can be used to simulate the speed of performance of crews of any size; the tasks making up the system can be assigned by the user to determine the crew size/task structure to be modeled. The model is based on Monte Carlo (probabilistic) modeling methods and consists of three segments. The task library contains all the tasks and subtasks which might be performed by an M109A1 howitzer section. Associated with each task are certain relevant parameters, including task performance times and requisite and concurrent tasks. The input program allows the user to specify the number of men in the crew, the tasks assigned to each, and the order in which the tasks are to be performed by each man. The main program integrates this input information and calculates summary performance measures based on it, allowing the user to obtain estimates of individual and crew performance under various combinations of crew size/task assignment. Several error messages are built into the main program to alert the user to errors in the logic of task assignments.

Findings:

Although several measures of individual and crew performance can be derived from the model, the information routinely output from the model includes a probability distribution of the total time required by a crew to execute a sequence of tasks. This information can be used as a basis for comparing overall performance of crews differing in size and/or crew structure. The routine statistical information also includes measures of which crew member worked the most and the percentage of idle time for each man on the crew. These measures provide the information necessary for the user to structure a crew in the most efficient task arrangement possible.

Utilization of Findings:

The ARI Crew Performance Model is an easy-to-use, cost-efficient, realistic tool for studying crew performance. Although developed for use in evaluating M109A1 howitzer sections, the model can be modified for use with any crew-served system, thereby making its potential applicability Army-wide. The model can serve as a tool for studying the effects on performance of changes in crew size and task assignment. It can also be used to study the potential effects of new or proposed equipment changes within the operational system or changes within the crew itself (e.g., through crew turbulence or cross training). The development of the Crew Performance Model is only the first phase of a research plan designed to evaluate the effects of inadequate sleep and work-rest cycles and other incident environmental factors (e.g., extreme temperatures, NBC conditions) on the performance of howitzer crews.

A DESCRIPTION OF THE ARI CREW PERFORMANCE MODEL

CONTENTS

FIGURES

A DESCRIPTION OF THE ARI CREW PERFORMANCE MODEL

INTRODUCTION

The US Army Research Institute (ARI) Fort Sill Field Unit is conducting a research program to obtain data and develop a method which will permit Field Artillery decision makers to evaluate the effects of crew size and crew member task assignments on the ability of M109A1 howitzer sections to adequately perform their duties during extended periods of continuous combat. This research program is made necessary by the scenario being projected should NATO and threat forces ever meet. Such a combat scenario is likely to be characterized by extended periods (8-10 days) of intense combat. Recent technological improvements in night operations guarantee that the fighting will take place both day and night.

Information must, therefore, be made available to decision makers to determine how best to handle the problems presented by such a scenario. Two points become clear: First, extended periods of continuous operations will lead to deteriorated crew performance due to lack of adequate sleep and the effects of fatigue. Under such conditions crewmen tend not to move as fast, react as quickly, or attend as well. The net effect is that fewer rounds get fired, more risks are taken, and more errors are made.

The second conclusion drawn from this scenario is that any decision on crew size must take into account the effects of inadequate sleep and fatigue. Unless crews are to be unduly large, some system of shift work must be set up to allow crewmen time for at least partial recovery from the deleterious effects of continuous operations. Adequate crew size must be determined not only by the number of men necessary to operate the weapon, but also by the manpower required to offset the fatigue which develops as the battle wears on.

ARI has approached these problems by developing a computer-based crew simulation model. The model enables researchers and artillery personnel to study in a timely and cost-effective manner the effects of varying crew size and task assignments during continuous operations without the need to observe crews actually performing howitzer section duties.

A schematic of the ARI crew model approach is shown in Figure 1. The approach involved three major thrusts: determination of the tasks (and their times) performed by a howitzer crew, development of a computer-based model to simulate various configurations of crew size and task assignments, and development and inclusion of data on parameters which affect crew performance over extended combat operations and under various stressful environments.

Previous reports (Coke, Crumley, & Schwalm, in press; Crumley, Note 1, Note 2) by ARI Fort Sill Field Unit have described the development of a complete list of the tasks which are performed by howitzer crews; also described are the measurement and the distributions of the times required

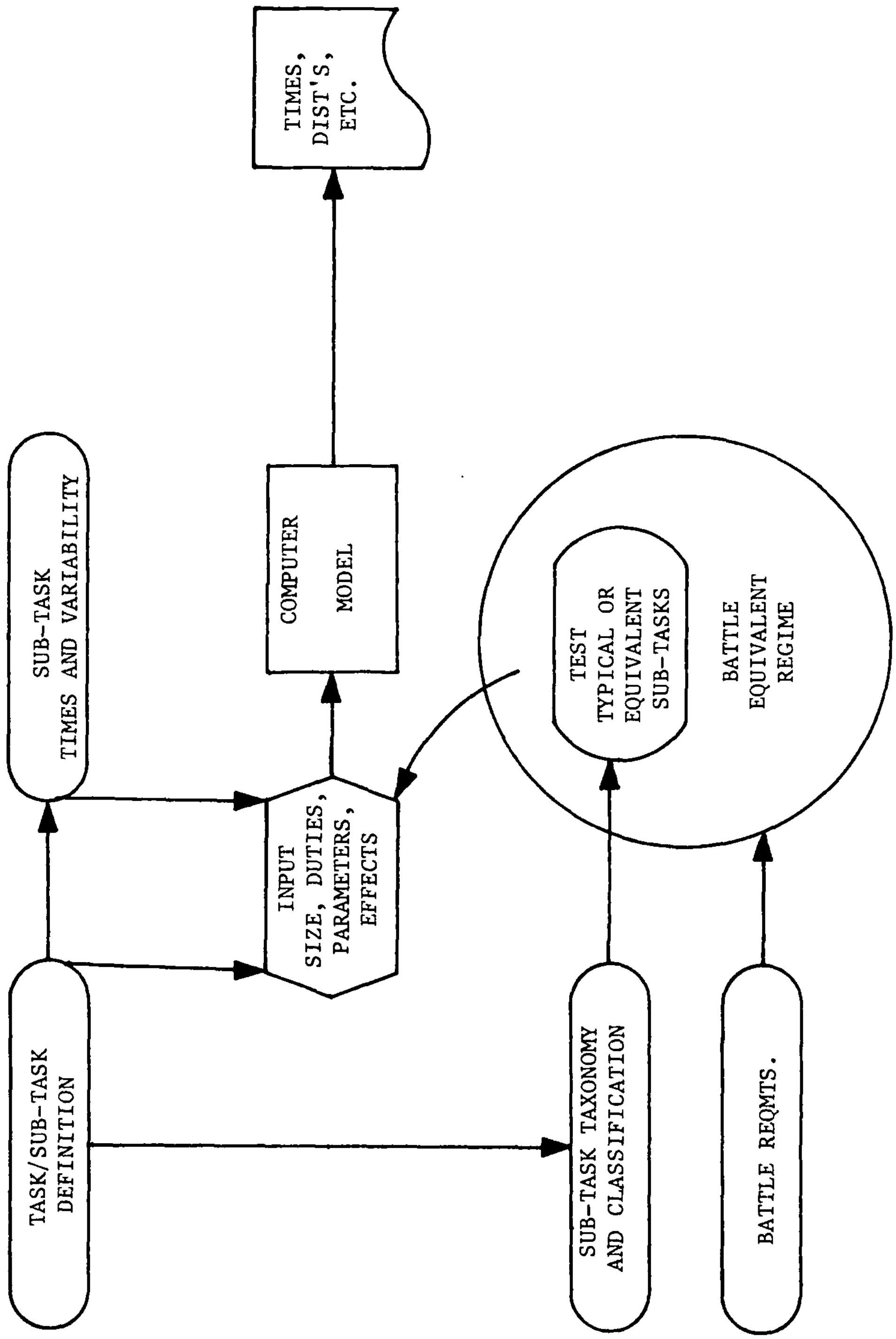

Figure 1. A schematic of the approach to development of the ARI Crew Performance Model.

to perform those tasks. This report describes a computer model which simulates crew performance based on those tasks and their times, and it provides the information necessary to understand the implementation and applications of the model.

Because the model simulates performance at the level of very narrowly defined tasks, certain tasks--by their very nature--are better handled outside the model. These tasks are referred to as level-of-effort or support tasks. They consist primarily of tasks which are to be performed in addition to those necessary for emplacing, firing, and march ordering the howitzer. Although these support tasks have definable start and stop points, their performance times vary widely and are largely a matter of accomodating manpower availability with the essentialness of the task. For these tasks, quicker is not necessarily better and performance tends not to vary with practice. Support tasks include in-transit activities, setting up camouflage, digging foxholes, stationing perimeter guards, and so on. These support duties are performed only to the extent (level) that time and manpower allow. As such, these tasks are not simulated within the model. They are best considered as tasks which must be performed in addition to those laid out in the model. They are best scheduled as activities which require a certain number of man-hours per day which must be allowed for if they are to be performed.

The model, therefore, is limited to tasks performed while moving and firing the howitzer. The moving and firing tasks tend to be discrete, with readily defined start and stop points, and little variation in performance times. These tasks tend to be small units of behavior, usually making up larger logical units of behavior. Examples of discrete tasks include carrying a projectile from the section vehicle to the howitzer, opening a cab window, giving a command, and so on.

A further restriction placed on the model is that it simulates crew performance only. It is certainly true that the performance of the fire direction center (FDC) and forward observer (FO) have a direct effect on how quickly and how accurately a howitzer crew delivers its rounds. However, the model necessarily assumes the FDC and FO provide their information to a howitzer crew in a timely and accurate manner. Those systems are therefore not modeled as part of howitzer crew performance.

Before presenting the model in further detail, it is necessary to explain how the performance of a howitzer crew can be affected by changes in crew size or the assignment of tasks for a given crew size (i.e., crew structure). Army doctrine (DA, Note 3, Note 4; USAFAS, Note 5) dictates that M109A1 howitzer crews consist of ten men. In reality, few crews are actually manned to that level. One characteristic of a full ten-man crew, in which all crew members are involved in performing the tasks related to moving and firing the gun, is that many crewmen experience much time when they are not actively involved in performing any tasks. This idle time is usually due to crewmen having no assigned duties at the time or having to wait for other crewmen to perform tasks before being able to continue with their own duties. The Crew Performance Model enables the user to modify crew size and task assignment structure so as to determine how efficient various crew configurations can be.

Depending on the tasks involved, reducing the size of a howitzer crew usually has the initial effect of reducing the idle time experienced by its crewmen.[1] This reduction in idle time occurs because tasks have been reassigned to some of the remaining crewmen so that they are no longer allowed to be idle. Therefore, the immediate effect of reduced crew size on total completion time for a series of tasks (e.g., the elapsed time for emplacing a howitzer) is minimal when the crew is restructured to "plug the gaps" in the scheduling of tasks.

At some point, however, reductions in crew size are no longer compensated for by reduction in idle time. It is at that point that an increase in total completion time occurs. This increase reflects the nature of the tasks as much as the reduction in crew size. In any series of crew tasks, some tasks can be performed in parallel, while some must be performed sequentially. For tasks which can be performed concurrently (e.g., preparing the projectile and the powder charge), a reduction in crew size, up to a point shows, up as a reduction in idle time; crew members with free time can be reassigned to assist with such tasks. An increase in total completion time need not occur because the efficient reassignment of tasks acts to reduce waiting time for tasks which can be performed in parallel.

For tasks which must be performed sequentially, however, reducing crew size often has the effect of increasing total performance time. As an example, consider the time required to prepare a projectile and the powder charge and to deliver them to the howitzer for loading. Five men might most quickly perform these tasks--two to prepare the projectile and the charge, two to deliver them, and one to load them. Although the loading of the projectile and the charge are intrinsically sequential (i.e., sequential regardless of crew size), preparation of the projectile and the charge (or their delivery to the howitzer) can be performed concurrently. With only three men, however, the tasks must then necessarily be performed sequentially: One man prepares the projectile and the other delivers it to the man in the howitzer for loading. Only after the projectile has been prepared can it be delivered; and only after the projectile has been prepared can the cannoneer begin work on the charge. With this reduced crew size, a sequence has been externally imposed on the tasks (i.e., made extrinsically sequential) and an increase in performance time will be evident. Thus, speed of performance can no longer be maintained when tasks that could be done in parallel must be performed sequentially because all assigned crew members are already working. However, those tasks which are intrinsically sequential (e.g., preparing the projectile and delivering it) will not be affected by

---

[1]Throughout this paper, speed is taken as the critical measure of crew performance. While it is certainly true that reductions in crew size or amount of sleep eventually lead to an increase in errors, most of these errors are difficult to observe and many are ultimately corrected before a task sequence is fully executed. Either way, the process of correcting errors takes time. Consider the example of a cannoneer who initially attaches the wrong fuze to a projectile. Built-in checks will likely catch the error. Although the error is corrected, its existence is reflected in an unusually long task performance time. Speed, therefore, remains a reliable measure of performance.

a change in crew size. By their very nature, they must be performed sequentially.

There is a trade-off, then, between idle time and total completion time as a result of changes in crew size/task structure. That trade-off is made clear if total completion time is viewed as the sum of time spent actually working and the time spent not working (i.e., total time = work time + idle time). Up to a point, as crew size is decreased, idle time also decreases; and if the task structure is efficiently organized, total completion time does not increase. However, reducing crew size will lead to an increase in total performance time if the task reassignments are not efficient, thereby not reducing idle time, or if the reassignment of tasks necessitates that tasks which might be performed concurrently with a larger crew must now be performed sequentially, leading to an increase in work time. It is, therefore, a balance between idle time and total completion time--a minimum of idle time across crew members without an increase in total time--that characterizes an efficient crew. By exploring the effects of crew size and task structure on these variables, the model can serve as a valuable tool for examining crew performance and for evaluating crew structures to determine the best possible arrangement of task assignments.

Before proceeding, it must also be said that in order for the model to be of use, confidence in the validity of its results must first be established. This is a two-step procedure. First, it must be established that the model does indeed simulate the performance of howitzer crews. The model must accurately reflect the behavior of members of howitzer crews. Second, it must be established that the task times upon which the model operates are valid, i.e., representative of M109A1 howitzer crews.

Several efforts to establish the validity of the model have been successful. With a sequence of artificial tasks and task times, including scheduling constraints, it was determined that the model was able to predict the total completion times for that sequence and variations of it. Furthermore, with the tasks and task times currently in use, the model accurately predicts logical differences in crew performance (e.g., all other things being equal, as crew size decreases, total completion time increases). The model, therefore, seems to realistically reflect the tasks and the times required to emplace, fire, and march order a howitzer section.

As discussed in a later section, slightly over half of the task times currently in use were obtained either from videotapes of two howitzer crews in operation or from subject-matter experts' estimates of "typical" performance times. There is a chance, then, that some of the tasks times currently in use are not representative of crew performance.[2] However, it is

---

[2]In an effort to obtain task times which can be considered fully representative of well trained howitzer crews, a field exercise is scheduled for the summer of 1982. Sixteen crews will receive extensive practice and new task times will be collected from these crews. Aside from providing representative task times, this project offers another opportunity to further establish the validity of the model itself. To the extent that the model is valid, it should be able to predict the total completion times actually obtained in the field.

only necessary that the task times be relatively accurate, although absolute task times would be of interest. That is, for the purposes for which the model was intended, it is more useful to know the relative decrement in performance which can be expected as crew size is decreased or as the amount of sleep is reduced than it is to know the exact amount of time required by a crew to deliver a round. For that purpose, then, the model and its tasks and task times are valid.

OBJECTIVE

The long-term objective of the ARI howitzer crew performance project is to provide a method to examine the performance, over extended operational periods in various stressful environments, of crews differing in size, task assignment, or crew structure. While a computer-simulation model would seem to be the method of choice, such a model must be flexible enough to handle changes in crew size and task structure and at the same time be economical, efficient, and realistic.

Because the scenario of the future foresees continuous battle operations in high-intensity battle situations, the effects of extended operations, including the resulting inadequate sleep and fatigue, must ultimately be considered. The model must also be capable of simulating the effects of other operational requirements and environmental parameters (e.g., NBC equipment, extreme temperatures) which will likely degrade performance over an extended period.

The program segment reported here presents the development of the software necessary for a computer-based model which permits the simulation of crews differing in size and the assignment of tasks. Ultimately, the model will be expanded so that it is capable of handling crew performance over extended periods of operation and under a variety of incident environmental conditions.

APPROACH

The modeling approach selected is an application of Monte Carlo or probabilistic modeling methods. The model considers the tasks to be performed, the time to perform each task, the order of performance, and the number of men doing the tasks. The model itself consists of a task library, an input program, and the main program.

The Task Library

The task library, illustrated in Figure 2 and detailed in Appendix A, contains the tasks and subtasks which might be performed by the members of an M109A1 howitzer section. (See Coke, Crumley, & Schwalm, 1981, for a description of how the tasks and task times shown in Appendix A were obtained. A task library could similarly be built for any crew-served system, provided the discrete tasks making up that system can be defined.)

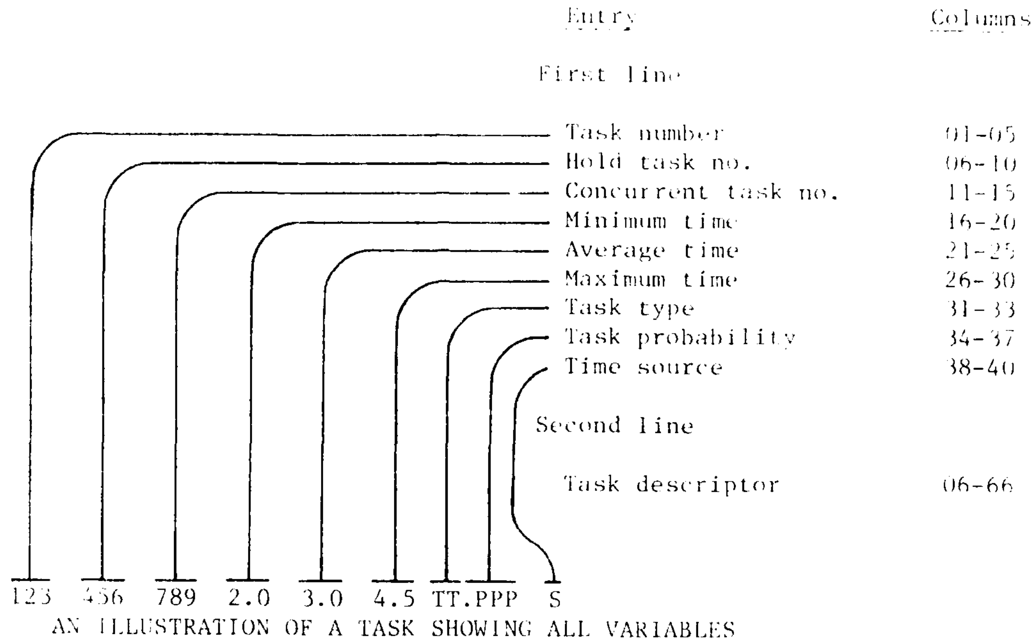

Figure 2. Example of an entry in the task library.

For convenience, the task library has been organized into four parts, with tasks grouped according to type of activity: emplacement, fire mission, march order, and general locomotion. In actual use, the general locomotion tasks are appended to each of the other activity libraries. Each task in the library is discretely and narrowly defined, has start and stop times specified as minimum, average, and maximum performance times, and takes into account requisite and concurrent tasks. As shown in Figure 2, each entry into the task library contains the following information, right-adjusted (placed in the right-most columns) in the fields as described.

1. Task number (col. 1-5) - Each task entry within each activity group or library has a unique task number associated with it. The task number is the identifier used by the model to select a task and its associated information. Within each activity library, tasks generally assigned (by doctrine) to a particular crew member are numbered in groups for ease of identification and categorization. Thus, in each activity library, tasks numbered 0-99 refer to tasks usually assigned to the Chief of Section, tasks 100-199 to tasks assigned to the Gunner, and tasks 200-299 to tasks assigned to the Assistant Gunner. Tasks usually reserved for Cannoneers 1-5 are numbered 300-799, respectively, in intervals of 100. Tasks numbered 800-899 apply to the Howitzer Driver and 900-999 to the Section Vehicle Driver. Tasks numbered 1000 and above are reserved for general locomotion tasks.

2. Hold task number (col. 6-10) - Some tasks cannot be performed until other tasks have first been completed. For instance, before the crewman acting as 1st Cannoneer can move to load the projectile (Fire Mission library - Task Number 300), the projectile must first be carried to him from the section vehicle (Fire Mission library - Task Number 502). In this case, the former task--"Receives projectile + moves to load position"--must "hold" until the latter requisite task--"Carries projectile to howitzer"--has been performed. The hold number (in this case, Task Number 502) identifies which task must be performed before the main task can be completed.[3] It should be noted that the order in which tasks are input also implicitly defines prerequisite tasks. Thus, for any individual crewman, the tasks assigned to him are performed in the order in which they are listed in the input program.

3. Concurrent task number (col. 11-15) - Certain tasks require the coordinated effort of two or more crewmen. For instance, while a fuze is being attached to a projectile (Fire Mission library - Task Number 404), a second crewman often holds the projectile steady (Fire Mission library - Task Number 500). Those two tasks--"Affixes + sets fuze" and "Holds projectile"--can be performed concurrently. The concurrent task number identifies the task which must be performed concurrently.[4] In the example, Task Number 404 is listed as the concurrent task for Task Number 500. Note that the reciprocal listing is not always true, as in this case where the fuze can be affixed and set (Task Number 404) without having as a concurrent task another crewman holding the projectile (Task Number 500). Therefore, no concurrent task is assigned for Task Number 404 while one (i.e., Task Number 404) must necessarily exist for Task Number 500.

4. Performance times (col. 16-20, 21-25, 26-30) - The next three fields of information are the minimum, average, and maximum performance times (in seconds) for a particular task. The times were obtained from videotapes of howitzer crews in operation or from one of the other sources described in the section (para. 7) on time sources. These values set the range and central tendency

---

[3]It is conceivable that a task might have to hold for multiple (concurrent) tasks preceding it. Although multiple concurrent (or hold) tasks cannot be assigned directly, the model is equipped to handle such events indirectly. To do so, the user must ensure that the multiple prerequisite tasks are assigned as concurrents. The task number of either of the concurrents can be used to identify the hold task. The model will then hold for whichever of the concurrent tasks has the longer completion time.

[4]In the unlikely event that more than two tasks are to be performed concurrently, the model must be given that information indirectly. The user must arrange for each of the concurrent tasks to be paired at least once (e.g., task A is made concurrent with task B which is made concurrent with task C which is made concurrent with task A).

around which the main program constructs a triangular distribution of performance times for each task. It is from this distribution that individual task performance times are randomly selected on any given iteration of the model. A triangular time distribution with the tail to the right, similar to most common RT functions, has been assumed because of the nature of the time required to perform most of these tasks.[5] Usually there is some minimum time in which a task can be performed, and that minimum time is relatively close to the average performance time. On certain occasions, however, a task may require a considerably longer performance time, and these longer times can extend further beyond the average than the minimum can fall short of the average. For example, there is some minimum time in which a fuze can be attached, but if the wrong fuze is attached and must be replaced, the maximum performance time can be quite long.

5. Task type (col. 31-33) - If it is assumed that all tasks can be categorized on the basis of commonality of activity (e.g., cognitive tasks), it follows that tasks within the same category should be similarly affected--usually negatively--by certain internal and external factors (e.g., fatigue, cold). Therefore, the task type identifier built into the model will enable the user to evaluate the effects of such factors by having the model apply different decrements to the distributions of performance times for tasks of different types. These attenuation factors will allow the model to more realistically simulate crew performance over time and across environmental conditions by having the deterioration of performance of each task be handled by type rather than by simply applying an "average" performance decrement to all tasks. The software for this portion of the model has been completed; the categorization of tasks and the implementation of performance decrements for the task types due to certain combat-incident variables will be completed in the near future.

6. Task probability (col. 34-37) - In the course of operating a system such as a howitzer, certain tasks are not performed each time a weapon is fired. However, the times required for those tasks--when performed--must be taken into account when calculating total completion time. For instance, boresighting the weapon is performed relatively infrequently. But because it is a time-consuming procedure, its performance time must be added in on

---

[5]The shape of the distribution for the performance times of each task actually more closely approximates a beta distribution. However, the triangular distribution was used instead because a triangular distribution is similar in shape to a beta distribution and because the algorithm for determining points along the triangular distribution was available while the algorithm for the beta distribution was not.

that proportion of the iterations when boresighting does occur. Therefore, in the course of the model's iterative cycle, a probabilistic task would affect the scheduling of tasks and the total completion times (and other time-dependent measures) only on the specified proportion of iterations. That proportion of iterations, based on the probability of the event occurring, is indicated in the field specifying task probability. (The task libraries, as they currently exist as shown in Appendix A, contain no probabilistic tasks, hence the zeroes (blank spaces) in that field.)

7. Time source (col. 38-40) - The source of the task performance times is indicated in the time source field. (See Coke, Crumley, & Schwalm (1981) for details of the procedure for obtaining the task times.) A "1" indicates task times observed directly from videotapes of two howitzer crews in operation; a "2" is for task times inferred from those films. The times for the remaining tasks were obtained either by timing subject-matter experts as they performed the tasks ("3") or simply by having them provide estimates of performance times ("4"). Approximately 58% of the times were obtained using the first three methods; 70% of those were obtained directly from the films. The time source information serves primarily for the user's benefit as an indication of the source, and hence the reliability, of the task performance times.

8. Task descriptor (second line, col. 6-66, left adjusted) - A brief description of the task is included for the user's convenience. It might be noted that most of the task descriptors do not indicate which crewmen are to perform the tasks. This was intended to encourage flexibility in the assignment of tasks.

The task library operates as an independent portion of the model. Tasks may be added or deleted and times or other parameters may be changed as the need arises or as better data become available.[6] Only one activity library (e.g., Fire Mission library) can be used during any simulation.

The Input Program

The input program directs the operation of the model in simulating the performance of crews varying in size or task assignments. In order to model a particular crew structure, the user has only to specify the number of men in the crew, and then to assign tasks, by task number, to individual crew members in the order in which the tasks are to be performed. Figure 3 shows a typical howitzer crew structure as laid out in the input program. In this example, the input to simulate an eight-man crew during a fire mission is presented. These data, crew size and crew member task assignments, are the user's primary input.

---

[6] Schwalm & Coke (Note 6) describes the procedures for creating new task libraries or for modifying the existing libraries.

Entry	Columns
First line	
Crew size	01-02
Max. no. tasks	03-06
No. iterations	07-09
Computer device	10-11
Following lines	
Crewman's number	01-04
Task numbers	Consecutive four-column fields

```
 8 100200 7
   1 002 004 006 008 012 014 020 024
   2 100 102 104
   3 200 202
   4 300 302 304 306 308 310 312 314 316 318
   5 400 402 404
   6 500 502 504
   7 600 602 604 606 608
   8 700 702
```

Figure 3. Example of an input program with task assignments for an eight-man crew.

The crew size/task information is input as a set of parameters. The first line entered has four fields; all values are right-adjusted within each field. The first field (col. 1-2) specifies the number of men in the crew. In the second field (col. 3-6), the maximum number of tasks expected to be used in that particular run of the model is specified. The third field (col. 7-9) lists the number of iterations (up to 999) through which the model will cycle. The fourth field (col. 10-11) of the first line lists the computer input device for calling the task library into use. The example, then, shows that an eight-man crew is to be modeled. A maximum of 100 tasks will be used during 200 iterations. The final entry--a 7 in this case--indicates that the task library is to be accessed from disc.

After the first line, an additional line is needed for each crewman assigned on a run. Thus, eight lines are shown in this example. Each of these lines contains the crewman's number (col. 1-4) and the numbers of those tasks assigned to him (consecutive four-column fields through col. 80, continuing if necessary on the next line, with man number again listed). These task numbers are used by the model in accessing the tasks and task information assigned to each crewman. As mentioned previously, the order in which the tasks are assigned to each crewman is the order in which the tasks are executed by each crewman within the model. This order, then, determines the scheduling of tasks.[7]

The Main Program

The main program consists of several subroutines and function programs. The software statements for the main program are presented in Appendix B. Essentially, the main program is designed to calculate the total time required for the crew to complete the tasks as scheduled by the input program. Specifically, total completion time is dependent upon (1) the ordering of the tasks and the crewmen to whom the tasks are assigned, (2) the scheduling constraints due to any hold or concurrent tasks which are involved, and (3) the distributions of task performance times from which individual task times are generated.

To take each in turn, the model executes tasks in the assigned order when possible. Shorter tasks are finished before those with long task times. Tasks are scheduled to be performed to minimize delays (idle time) while meeting the specific constraints of hold and concurrent tasks. Those tasks which are affected by these constraints (i.e., those downstream of the hold or concurrent task) are held up until the requirement are met. Any tasks which are unaffected by constraints continue to be performed.

Individual task times are randomly selected from a triangular distribution of times constructed for each task. The exact parameters of each distribution are determined by the minimum, average, and maximum performance times stored with the tasks in the task library. Each task time, therefore, has a certain probability of being selected on any given iteration, and that probability is defined by the specific triangular distribution constructed for that task by the model.

On the basis of this scheduling of tasks, with consideration of all constraints and the individual task times, total completion time and related statistics are calculated. This procedure is repeated for each of the specified number of iterations. The result is the output described in detail in the next section.

---

[7]For greater detail on how to create or modify an input program, the reader is directed to Schwalm & Coke (Note 6).

In the event of an error in the logic of ordering the tasks in the input program, the model is equipped with several error messages to alert the user of an error and its nature. Among the error messages is a statement informing the user that a loop exists (e.g., man A is waiting for man B who is waiting for man C who is, in turn, waiting for man A). Other error messages instruct the user that hold or concurrent requirements have not been met, e.g., when the required tasks have not been assigned through the input program or do not exist in the task library.

INFORMATION PROVIDED BY THE MODEL

While total processing time (i.e., the total completion time for the entire crew) and measures of the critical man and idle time (described below) are routinely output, several other individual and crew subtotals are calculated and can be output upon request. The user can access files to determine, among other things, the finishing time for each man, the actual working time for each crew member, and the elapsed time through a given task.

Long Format

The model's output can be obtained in any of several different formats depending on the user's needs. The output format which provides the most information is illustrated by the example presented in Figures 4 through 6. This long format provides information in five segments. The first segment (see Figure 4) is essentially a reiteration of the task information provided in the input program (cf. Figure 3). It is a listing of the task assignments in the order of performance for each man.

```
MAN  1 HAS TASKS    2    4    6    8   12   14   20   24
MAN  2 HAS TASKS  100  102  104
MAN  3 HAS TASKS  200  202
MAN  4 HAS TASKS  300  302  304  306  308  310  312  314  316  318
MAN  5 HAS TASKS  400  402  404
MAN  6 HAS TASKS  500  502  504
MAN  7 HAS TASKS  600  602  604  606  608
MAN  8 HAS TASKS  700  702
```

Figure 4. Task assignments reproduced in long format of model output.

The information in the second segment (see Figure 5) is a sequential listing by task number of the assigned tasks including the information stored for each task in the task library. The first line of each pair includes, in addition to the task number, the number of the crewman performing the task and the serial position of the assigned task in each man's task assignment schedule. In the example presented, Task Number 300 ("Receives projectile + moves to load position") is shown as having been the first task assigned to man number 4. The fourth and fifth fields of information, when present, are the hold and concurrent task numbers. In this example, Task Number 300 must hold for Task Number 502 ("Carries projectile to howitzer"); no concurrent task is assigned. Fields 6-8 are the minimum, average, and maximum performance times as provided by the user. For Task Number 300, the performance times range from 3.0-15.0 seconds. Fields 9-10 list the task type and the task probability. Because the appropriate values for these parameters have not yet been determined, both fields currently contain only zeroes. The last field of the first line lists the source of the task times. Times for most of the fire mission tasks, including Task Number 300, were obtained directly from the tapes as described previously. The second line of each pair in this segment is, of course, the task descriptor as listed in the task library.

Figure 6 shows the third segment of information provided in the long output format. This segment is also all the information which is provided by the short format (to be described next). The information consists of three summary measures of performance. Total completion time indicates the time required for the entire crew to perform all their tasks (cf. elapsed time). The sampling distribution of total completion times is based on N=the number of iterations specified in the input program. The completion times for every tenth percentile from the fastest to the longest total completion time are output by the model. The 50th percentile, of course, is the median total completion time. In the present example, the median total completion time for the eight-man crew to prepare and fire a round was 99.51 seconds.

The second summary performance measure is the "critical man". In the present context, the critical man is that man who showed the most working time on a trial or iteration; in that sense, the critical man is the busiest man. In this example, crewman number 5 was the critical man, having worked more than any of the other crew members on 119 of the 200 iterations.

The final summary measure is idle time. Idle time is shown for each crewman as that percentage of time when he was not actively involved in the performance of a task. (The complement of this value, of course, is the time spent actually working.) In the example presented in Figure 6, crewman number 5, who was the busiest man as indicated previously, was idle on the average 33.9% of the time. This average is also based on N=the number of iterations specified in the input program. Idle time is an important statistic because, as mentioned previously, efficiency can be defined as minimizing idle time for all crew members while keeping it relatively constant across crew members. Thus, this statistic is particularly useful information for structuring crews more efficiently.

TASK	CREW	JOB									
2	1	1	0	0	3.0	4.0	7.0	0.	.000	1	RECEIVES + ANNOUNCES FIRE MISSION
4	1	2	0	0	3.0	4.0	7.0	0.	.000	1	ANNOUNCES PROJECTILE
6	1	3	0	0	3.0	4.0	7.0	0.	.000	1	ANNOUNCES CHARGE
8	1	4	0	0	3.0	4.0	7.0	0.	.000	1	ANNOUNCES FUZE
12	1	5	0	0	3.0	4.0	7.0	0.	.000	1	ANNOUNCES DEFLECTION
14	1	6	0	0	3.0	4.0	7.0	0.	.000	1	ANNOUNCES QUADRANT
20	1	7	104	0	2.0	2.5	3.0	0.	.000	4	VERIFIES ADJUSTMENT OF FIRE CONTROL INSTRUMENTS
24	1	8	310	0	2.0	2.5	3.0	0.	.000	4	INSURES WEAPON IS SAFE TO FIRE. GIVES COMMAND TO FIRE
100	2	1	12	0	2.5	5.5	10.5	0.	.000	1	SETS DEFLECTION
102	2	2	0	0	4.0	9.0	13.0	0.	.000	1	TRAVERSES TUBE
104	2	3	202	0	2.0	3.0	4.0	0.	.000	1	AFTER AG CALLS SET. ENSURES BUBBLES ARE LEVEL + CALLS READY
200	3	1	14	0	2.0	4.5	10.5	0.	.000	1	SETS QUADRANT
202	3	2	0	0	3.0	8.0	19.5	0.	.000	1	ELEVATES TUBE TO FIRING POSITION. CALLS SET
300	4	1	502	0	3.0	7.1	15.0	0.	.000	1	RECEIVES PROJECTILE + MOVES TO LOAD POSITION
302	4	2	202	0	6.0	9.0	11.0	0.	.000	1	LOADS PROJECTILE + SETS RAMMER
304	4	3	700	0	1.0	1.5	2.0	0.	.000	1	RECEIVES CHARGE AND MOVES TO LOAD POSITION
306	4	4	0	0	2.0	4.7	7.0	0.	.000	1	LOADS PROPELLANT CHARGE + SETS FIRING MECHANISM
308	4	5	0	0	3.0	6.0	10.5	0.	.000	1	INSERTS PRIMER + CLOSES BREECH BLOCK
310	4	6	0	0	2.0	4.5	11.0	0.	.000	1	ATTACHES LANYARD TO FIRING MECHANISM
312	4	7	24	0	2.0	5.0	9.0	0.	.000	1	FIRES WEAPON AND CALLS QUADRANT + ROUND, IF NECESSARY
314	4	8	0	0	5.5	9.2	15.0	0.	.000	1	SWABS AND CLEANS POWDER CHAMBER
316	4	9	0	0	3.0	5.0	8.0	0.	.000	1	INSPECTS BORE + ANNOUNCES BORE CLEAR
318	4	10	0	0	3.5	3.8	4.1	0.	.000	1	UNHOOKS LANYARD
400	5	1	4	0	18.0	40.0	95.0	0.	.000	1	SELECTS + PREPARES PROJECTILE
402	5	2	8	0	3.0	6.3	18.0	0.	.000	1	SELECTS PROPER FUZE
404	5	3	0	500	5.5	20.0	42.0	0.	.000	1	AFFIXES + SETS FUZE
500	6	1	0	0	5.5	20.0	42.0	0.	.000	1	HOLDS PROJECTILE WHILE ANOTHER AFFIXES + SETS FUZE
502	6	2	0	0	3.0	6.3	10.0	0.	.000	1	CARRIES PROJECTILE TO HOWITZER
504	6	3	0	0	3.0	3.9	4.5	0.	.000	1	RETURNS TO REAR OF SECTION VEHICLE [PROJO]
600	7	1	6	0	10.0	13.0	16.0	0.	.000	1	SELECTS + UNPACKS CHARGE
602	7	2	0	0	3.0	15.0	25.0	0.	.000	4	CUTS PROPER CHARGE
604	7	3	0	0	2.5	3.0	4.0	0.	.000	4	HANDS CHARGE TO MOTOR DRIVER
606	7	4	0	0	6.0	7.5	10.0	0.	.000	4	CARRIES EXCESS POWDER TO POWDER DUMP
608	7	5	312	0	6.0	7.5	10.0	0.	.000	4	RETURNS FROM POWDER DUMP TO SECTION VEHICLE
700	8	1	604	0	3.0	4.3	7.5	0.	.000	1	RECEIVES CHARGE. MOVES TO HOWITZER. PASSES CHARGE IN
702	8	2	0	0	3.0	3.9	4.5	0.	.000	1	RETURNS TO REAR OF SECTION VEHICLE [CHARGE]

Figure 5. Tasks and task information provided by the model in the long format.

COMPLETION TIMES, FASTEST TO SLOWEST, EVERY 10TH PERCENTILE

85.1290	92.6210	95.0255	97.0192	98.1835	99.5112	100.9307
102.5858	105.0422	107.1239	111.6978			

CRITICAL MAN	1	0	2	0	3	0	4	79	5	119
6	0	7	2	8	0					
IDLE TIME	1	66.9	2	81.9	3	84.1	4	40.1	5	33.9
6	67.5	7	54.0	8	91.2					

Figure 6. Completion times, critical man, and idle time are the summary performance measures routinely output by the model.

Short Format

In the event that the user has no need for information other than the statistical results of the model, a short output format is available. With this format (see Figure 6, only the total completion times (for every tenth percentile), the critical man, and the percentage of idle time for each man are provided. No information regarding tasks or task assignments is given. Because this format, unlike the long format, provides no diagnostic messages in the event of errors, the short format is generally reserved for use only when an error-free task assignment sequence has been assured.

Narrative Format

A third output format, while not providing any statistical information, is particularly useful as a visual guide to laying out the tasks in order of performance. As shown in Figure 7, in the narrative format the task number and task descriptor are given for each man in the order in which the tasks were assigned. This concise narrative format assists the user in following the logic of differing task arrangements.

RESULTS

The ARI Crew Performance Model has been applied to the evaluation of differences in the speed and efficiency of performance among various crew sizes and structures. At present, crews ranging in size from 4-10 men have been simulated during the emplacement, firing, and march order of a howitzer section. The model has also been used to estimate the time savings which would accrue if certain minor equipment changes were to be made in the M109A1/M548 combination. The results of these analyses are presented elsewhere (Crumley, Schwalm, & Coke, Note 7) and can presently be made available by contacting any of the authors.

1	2	RECEIVES + ANNOUNCES FIRE MISSION
1	4	ANNOUNCES PROJECTILE
1	6	ANNOUNCES CHARGE
1	8	ANNOUNCES FUZE
1	12	ANNOUNCES DEFLECTION
1	14	ANNOUNCES QUADRANT
1	20	VEPIFIES ADJUSTMENT OF FIRE CONTROL INSTRUMENTS
1	24	INSURES WEAPON IS SAFE TO FIRE, GIVES COMMAND TO FIRE
2	100	SETS DEFLECTION
2	102	TRAVERSES TUBE
2	104	AFTER AG CALLS SET, ENSURES BUBBLES ARE LEVEL + CALLS READY
3	200	SETS QUADRANT
3	202	ELEVATES TUBE TO FIRING POSITION, CALLS SET
4	300	RECEIVES PROJECTILE + MOVES TO LOAD POSITION
4	302	LOADS PROJECTILE + SETS RAMMER
4	304	RECEIVES CHARGE AND MOVES TO LOAD POSITION
4	306	LOADS PROPELLANT CHARGE + SETS FIRING MECHANISM
4	308	INSERTS PRIMER + CLOSES BREECH BLOCK
4	310	ATTACHES LANYARD TO FIRING MECHANISM
4	312	FIRES WEAPON AND CALLS QUADRANT + ROUND, IF NECESSARY
4	314	SWABS AND CLEANS POWDER CHAMBER
4	316	INSPECTS BORE + ANNOUNCES BORE CLEAR
4	318	UNHOOKS LANYARD
5	400	SELECTS + PREPARES PROJECTILE
5	402	SELECTS PROPER FUZE
5	404	AFFIXES + SETS FUZE
6	500	HOLDS PROJECTILE WHILE ANOTHER AFFIXES + SETS FUZE
6	502	CARRIES PROJECTILE TO HOWITZER
6	504	RETURNS TO REAR OF SECTION VEHICLE [PROJO]
7	600	SELECTS + UNPACKS CHARGE
7	602	CUTS PROPER CHARGE
7	604	HANDS CHARGE TO MOTOR DRIVER
7	606	CARRIES EXCESS POWDER TO POWDER DUMP
7	6C8	RETURNS FROM POWDER DUMP TO SECTION VEHICLE
8	700	RECEIVES CHARGE, MOVES TO HOWITZER, PASSES CHARGE IN
8	702	RETURNS TO REAR OF SECTION VEHICLE [CHARGE]

Figure 7. Descriptive narration of crew structure.

CONCLUSIONS

The computer-simulation model developed by the Army Research Institute to study crew performance is now available for the following applications:

1. Evaluation of the effects of varying crew size and crew member task assignments on the performance of M109A1 howitzer sections.

2. Evaluation of the effects of equipment changes (by adding relevant tasks to the task library and simulating their effects within the model).

3. Development of task libraries for use in similar evaluations of other crew-served systems.

Expansion of the model to evaluate performance decrements (or increments) as a result of factors such as extended combat, extreme temperatures, NBC conditions, crew turbulence, or training will soon be completed. The effects of these factors in interaction with changes in crew size/task assignments will then be examined.

REFERENCE NOTES

1. Crumley, L. M. Tasks and typical task assignments for a ten-man crew emplacing, firing, and march ordering an M109A-1 howitzer section. ARI Fort Sill Field Unit Working Paper 79-3, 1979.

2. Crumley, L. M. Tasks and possible task assignments for a ten-man crew, divided into two five-man units emplacing, firing, and march ordering and M109A-1 howitzer section. ARI Fort Sill Field Unit Working Paper 79-4, 1979.

3. Department of the Army. 155MM howitzer M109, M109A1, self-propelled (FM 6-88). Washington, DC: Department of the Army, Headquarters, June 1974.

4. Department of the Army. Operation and maintenance manual (User) for howizter, medium, self-propelled: 155MM M109 (2350-00-440-8811) and 155MM M109A1 (2350-00-485-9662) (TM 9-2350-217-10N). Washington, DC: Department of the Army, Headquarters, September 1974.

5. US Army Field Artillery School. Duties of the personnel of the 155MM howitzer M109/M109A1 self-propelled section (WCXXMG, HO). Fort Sill, Weapons Department, January 1975.

6. Schwalm, R. C. & Coke, J. S. User's manual for the ARI Crew Performance Model. ARI Fort Sill Field Unit Working Paper, in preparation.

7. Crumley, L. M., Schwalm, R. C., & Coke, J. S. An evaluation of the effects of various task assignment alternatives on M109A1 howitzer crew performance. ARI Fort Sill Field Unit Working Paper, in preparation.

REFERENCE

Coke, J. S., Crumley, L. M., & Schwalm, R. C. Emplacing, firing and march ordering an M109A1 howitzer: Tasks and task times (RR 1312). Fort Sill, OK: US Army Research Institute for the Behavioral and Social Sciences, 1981.

APPENDIX A Task Library for M109A1 Howitzer Sections

EMPLACEMENT LIBRARY

```
002         800  2.0  2.8  3.0        1
   DIRECTS MD IN BACKING ON TO SPADES
004  800         3.0  4.0  6.0        3
   CHECKS SPADE STRUTS
006  800         0.0  0.0  0.0        4
   DIRECTS MD TO SET BRAKES AND TURN OFF VEHICLE [WHILE MOVING]
008              1.0  2.0  3.0        4
   CHECKS FRONT RECUPERATOR GUIDE PINS
010             11.0 13.0 16.0        3
   CHECKS REAR RECUP PINS, REPLEN GAUGE, + RECOIL SYSTEM
012  126         3.0  5.0 10.0        3
   VERIFIES LAY OF HOWITZER
014              2.0  3.0  5.0        4
   SELECTS ALTERNATIVE AIMING POINT
016  132         2.0  3.0  5.0        4
   INFORMS G OF ALTERNATIVE AIMING POINT
018  134         1.5  2.0  2.5        4
   DIRECTS G + AG TO MEASURE SITE TO CREST
020  136        12.0 16.0 22.0        4
   ESTIMATES DISTANCE TO CREST, REPORTS TO XO + FDC
022  136         1.5  2.0  2.5        4
   DIRECTS G + AG TO BORESIGHT
024         140 40.0 70.0220.0        4
   SUPERVISES BORE SIGHTING
026              5.0  7.0 10.0        4
   VERIFIES BORE SIGHTING
100              2.0  2.5  3.5        3
   OPENS LEFT CAB DOOR
102              1.0  1.5  2.5        3
   MOVES TO DEPRESS LEFT PEDAL LATCH, RETURNS TO STATION
104         602  6.0  8.0 11.0        4
   REMOVES COLLIMATOR, PASSES IT OUT, DIRECTS MAN TO LOCATION
106              1.0  1.5  2.5        3
   SETS CAB POWER SWITCH TO ON, SETS TRAVERSE CONTROL SWITCH
108         806  3.0  6.0 11.0        4
```

Note: The reader might note that none of the tasks contained in the libraries in Appendix A shows task type or task probability values (col. 31-33 and 34-37, respectively). These omissions were intentional. Although the model has the software necessary for adjusting crew performance depending on the types of tasks involved and the probability of each task, neither of those parameters has been included in simulation efforts to date. The task types have not been fully determined nor all tasks assigned a type, and all tasks assigned during a simulation have been assumed to be performed on each iteration. Initial task type and task probability entries will be completed in the near future.

```
   AS DIRECTED BY MD, G RAISES TUBE
110  806        4.0 13.2 29.0           1
   DEPRESSES TUBE TO MINIMUM ELEVATION
112             1.0  1.2  2.0           3
   SELECTS AG POSITION FOR POWER ELEVATION CONTROL
114  810        1.0  1.5  2.5           3
   G RELEASES LATCHES ON BALLISTIC COVER
116            12.0 16.0 24.0           3
   OBTAINS AND INSTALLS PANORAMIC TELESCOPE
118       708   2.0  3.0  6.0           4
   G + GUN GUIDE DECIDE LOCATIONS FOR AIMING POSTS
120             6.0 15.0 35.0           3
   SETS DEFLECTION, TRAVERSES WEAPON TO AIMING POINT
122            12.0 22.3 40.0           1
   TALKS WITH XO, TRAVERSES, ANNOUNCES READY FOR RECHECK [1ST]
124             9.5 13.1 17.0           1
   TALKS WITH XO, TRAVERSES, ANNOUNCES READY FOR RECHECK [2ND]
126             8.0 10.0 15.0           1
   WHEN XO SAYS 0 MILS, G REPORTS GUN LAID, RECORDS DEFLECTION
128  606  608 10.5 45.1110.0            1
   DIRECTS MAN IN ALIGNMENT OF COLLIMATOR, RECORDS DEFLECTION
130             2.0  4.0  8.0           4
   RESETS COUNTER TO 3200 MILS
132  708  710 45.0 85.3142.0            1
   DIRECTS MAN IN PLACEMENT OF AIMING POSTS, RECORDS DEFLECTION
134  016       10.0 17.0 37.0           4
   MOVES PANTEL TO ALTERNATIVE AIMING POINT, RECORDS IT
136  018       30.0 60.0180.0           4
   WHEN DIRECTED BY LS, G + AG MEASURE SITE TO CREST
138             6.0 12.0 37.0           4
   RETURNS PANTEL TO COLLIMATOR
140  022  024 40.0 70.0220.0            4
   G BORE SIGHTS AND RETURNS PANTEL TO COLLIMATOR
200             2.0  2.5  3.5           3
   OPENS RIGHT CAB DOOR
202             1.0  1.5  2.5           3
   MOVES TO DEPRESS RIGHT PEDAL LATCH, RETURNS TO STATION
204  112        5.0  7.7 12.0           1
   ELEVATES TUBE TO LOADING ELEVATION
206  018       30.0 60.0180.0           4
   WHEN DIRECTED BY CS, G + AG MEASURE SITE TO CREST
208             3.0  8.0 20.0           4
   RETURNS TUBE TO LOADING ELEVATION
210  022        4.0  7.0 12.0           4
   DEPRESSES TUBE FOR ATTACHMENT OF M-140 DEVICE
212       024 30.0 60.0210.0            4
   AG BORE SIGHTS + CHECKS DIRECT FIRE TELESCOPE
214  718        5.0  7.0 12.0           1
   AG RETURNS TUBE TO LOADING ELEVATION
300             3.5  5.0  6.5           3
   PREPARES LEFT SPADE FOR EMPLACEMENT
302             6.0  7.8 12.0           3
   CHECKS FUNCTION OF FIRING MECHANISMS
304            21.0 32.0 41.0           3
   INSPECTS, CLEANS, OPERATES BREECH BLOCK + POWER RAMMER
306            22.0 32.3 42.5           1
   PROCURES + SECURES WATER BUCKET AND SPONGE
306             5.0  8.0 10.0           4
```

```
   PROCURES PRIMERS. PLACES THEM IN A CONVENIENT + SAFE LOCATION
400             2.0  3.0  4.0          1
   OPENS REAR HULL DOOR WHILE DISMOUNTING
402             5.5  7.0  8.0          3
   PREPARES RIGHT SPADE FOR EMPLACEMENT
404             8.0 12.0 20.0          4
   GATHERS FUZE SETTERS IN HOWITZER
406  502        9.5 16.5 25.0          4
   ARRANGES FUZE SETTERS AND WRENCHES IN SV
408             5.0  8.0 15.0          4
   OPENS AND ARRANGES FUZE BOXES
500         900  3.5 14.1 25.5         4
   DIRECTS SD INTO POSITION
502  900        3.0  5.0  6.0          4
   OPENS REAR DOOR OF SECTION VEHICLE
504         408  5.0  6.0 15.0         4
   HELPS MAN OPEN + ARRANGE FUZE BOXES
600            11.0 16.5 20.0          1
   OBTAINS + ASSEMBLES AIMING POSTS
602         104  6.0  8.0 11.0         4
   RECEIVES COLLIMATOR
604             3.0  4.0  6.0          1
   MOVES TO SET COLLIMATOR
606            35.0 45.0 80.0          2
   REMOVES COVER. FOCUSES COLLIMATOR ON G:S SCOPE
608         128 10.5 45.1110.0         1
   ALIGNS COLLIMATOR
610             4.0  6.0 10.0          1
   RETURNS TO SECTION VEHICLE FROM COLLIMATOR
700  800       22.0 49.7 64.0          2
   INSTALLS BATTERY COMMUNICATION SYSTEM
702  110        5.0  8.0 15.0          4
   REMOVES MUZZLE COVER
704             2.0  2.5  4.0          4
   STORES MUZZLE COVER
706  300        1.0  2.0  3.0          4
   OBTAINS AIMING POSTS
708  118        2.0  3.0  6.0          4
   G + GUN GUIDE DECIDE LOCATIONS FOR AIMING POSTS
710         132 65.5112.8177.0         1
   EMPLACES AND ADJUSTS AIMING POSTS
712             8.0 13.8 19.0          1
   AIMING POST SETTER RETURNS TO WEAPON
714             2.0  3.0  5.0          4
   OBTAINS M-140 DEVICE
716  210       15.0 20.0 30.0          4
   ATTACHES M-140 DEVICE TO TUBE
718  024       10.0 15.0 25.0          4
   REMOVES M-140 DEVICE
720             5.0  7.0 10.0          4
   STORES M-140 DEVICE
800         002  2.0  2.8  3.0         1
   MD BACKS HOWITZER ONTO SPADES
802  006        4.0  6.0  8.0          2
   MD SETS BRAKES AND TURNS OFF VEHICLE
804             4.0  5.0  6.0          2
   MD EXITS HATCH
806         108  4.5  8.0 14.0         2
```

```
   DIRECTS G TO RAISE TUBE, DISENGAGES + STOWS TRAVEL LOCK
608             3.5  4.0  6.0           1
   OPENS + UNLOCKS DIRECT FIRE TELESCOPE COVER
810             1.5  2.0  3.0           3
   MOVES TO BALLISTIC COVER, SIGNALS G
812  114        9.0 10.5 14.0           3
   LIFTS + LOCKS BALLISTIC COVER
814             4.0  7.0 10.0           4
   MD STOWS INSTRUMENT PANEL
816             3.5  4.0  4.6           4
   MD SECURES HATCH
900        500  3.5 14.1 25.5           4
   SD MOVES SV INTO POSITION
902             4.0  6.0  8.0           4
   SD TURNS 548 OFF, LOCKS BRAKES
```

FIRE MISSION LIBRARY

```
002              3.0   4.0   7.0            1
  RECEIVES + ANNOUNCES FIRE MISSION
004              3.0   4.0   7.0            1
  ANNOUNCES PROJECTILE
006              3.0   4.0   7.0            1
  ANNOUNCES CHARGE
008              3.0   4.0   7.0            1
  ANNOUNCES FUZE
010              3.0   4.0   7.0            1
  IF FUZE IS TIME, STATES TIME
012              3.0   4.0   7.0            1
  ANNOUNCES DEFLECTION
014              3.0   4.0   7.0            1
  ANNOUNCES QUADRANT
020  104         2.0   2.5   3.0            4
  VERIFIES ADJUSTMENT OF FIRE CONTROL INSTRUMENTS
022

024              2.0   2.5   3.0            4
  INSURES WEAPON IS SAFE TO FIRE, GIVES COMMAND TO FIRE
026              4.0   5.0   8.0            4
  REPORTS PIECE READY, RECEIVES + GIVES COMMAND TO FIRE
100  012         2.5   5.5  10.5            1
  SETS DEFLECTION
102              4.0   9.0  13.0            1
  TRAVERSES TUBE
104  202         2.0   3.0   4.0            1
  AFTER AG CALLS SET, ENSURES BUBBLES ARE LEVEL + CALLS READY
200  014         2.0   4.5  10.5            1
  SETS QUADRANT
202              3.0   8.0  19.5            1
  ELEVATES TUBE TO FIRING POSITION, CALLS SET
300  502         3.0   7.1  15.0            1
  RECEIVES PROJECTILE + MOVES TO LOAD POSITION
302              6.0   9.0  11.0            1
  LOADS PROJECTILE + SETS RAMMER
304  700         1.0   1.5   2.0            1
  RECEIVES CHARGE AND MOVES TO LOAD POSITION
306              2.0   4.7   7.0            1
  LOADS PROPELLANT CHARGE + SETS FIRING MECHANISM
308              3.0   6.0  10.5            1
  INSERTS PRIMER + CLOSES BREECH BLOCK
310              2.0   4.5  11.0            1
  ATTACHES LANYARD TO FIRING MECHANISM
312  024         2.0   5.0   9.0            1
  FIRES WEAPON AND CALLS QUADRANT + ROUND, IF NECESSARY
314              5.5   9.2  15.0            1
  SWABS AND CLEANS POWDER CHAMBER
316              3.0   5.0   8.0            1
  INSPECTS BORE + ANNOUNCES BORE CLEAR
318              3.5   3.8   4.1            1
  UNHOOKS LANYARD
400  004        18.0  40.0  95.0            1
```

```
   SELECTS + PREPARES PROJECTILE
402  008        3.0  6.3 18.0         1
   SELECTS PROPER FUZE
404             5.5 20.0 42.0         1
   AFFIXES + SETS FUZE
500       404   5.5 20.0 42.0         1
   HOLDS PROJECTILE WHILE ANOTHER AFFIXES + SETS FUZE
502  404        3.0  6.3 10.0         1
   CARRIES PROJECTILE TO HOWITZER
504             3.0  3.9  4.5         1
   RETURNS TO REAR OF SECTION VEHICLE [PROJO]
600  006       10.0 13.0 16.0         1
   SELECTS + UNPACKS CHARGE
602             3.0 15.0 25.0         4
   CUTS PROPER CHARGE
604             2.5  3.0  4.0         4
   HANDS CHARGE TO MOTOR DRIVER
606             6.0  7.5 10.0         4
   CARRIES EXCESS POWDER TO POWDER DUMP
608  312        6.0  7.5 10.0         4
   RETURNS FROM POWDER DUMP TO SECTION VEHICLE
700  604        3.0  4.3  7.5         1
   RECEIVES CHARGE, MOVES TO HOWITZER, PASSES CHARGE IN
702             3.0  3.9  4.5         1
   RETURNS TO REAR OF SECTION VEHICLE [CHARGE]
```

MARCH ORDER LIBRARY

```
002             2.0  3.0  5.0          4
   RECEIVES MARCH ORDER, GIVES COMMAND TO MARCH ORDER
004        716  5.0 10.0 19.0          1
   DIRECTS MD TO START HOWITZER AND MOVE BACKWARDS
006  718        2.0  3.5  4.5          1
   DIRECTS MD TO PULL FORWARD AND STOP
008             2.0  3.0  5.0          4
   DIRECTS SD TO START SECTION VEHICLE
010             2.0  4.0  8.0          4
   CHECKS SPADES FOR SECURITY
012  410       10.0 15.0 25.0          4
   DIRECTS CREW TO MOUNT UP, MAKES CHECKS, SIGNALS XO
014             7.0  8.8 11.0          1
   UNLOCKS CUPOLA + ENTERS
100  002        4.0  7.0 12.0          4
   PREPARES TELESCOPE MOUNT FOR TRAVEL
102            13.0 16.0 22.0          5
   STORES PANORAMIC TELESCOPE FOR TRAVEL
104             1.0  1.5  2.0          4
   RETURNS ELEVATION CONTROL TO GUNNER
106  502        3.0  6.0  9.0          1
   ELEVATES TUBE TO PREPARE FOR TRAVEL
108        702 15.0 25.0 35.0          4
   TRAVERSES GUN AS DIRECTED BY MD
110        704  1.5  3.3  6.0          1
   LOWERS TUBE AS DIRECTED BY MD
112             3.0  4.5  7.0          3
   CAB POWER TO OFF,LOCKS CAB TRAVERSE,SPADES CAN BE STORED
114  716  206  1.5  2.0  4.0          4
   DEPRESSES LEFT PEDAL AND ADVISES MD SPADE IS UNLOCKED
116  504        7.0  9.0 12.0          4
   RECEIVES COLLIMATOR AND STORES IT
118             2.0  3.5  6.0          3
   CLOSES LEFT CAB DOOR
200  002        2.5  4.8  7.0          1
   LOWERS TUBE TO MINIMUM ELEVATION
202             3.0  5.0 10.0          4
   PREPARES ELEVATION QUADRANT FOR TRAVEL
204  408        2.0  3.5  6.0          3
   CLOSES RIGHT CAB DOOR
206  716  114  1.5  2.0  4.0          4
   DEPRESSES RIGHT PEDAL AND ADVISES MD SPADE IS UNLOCKED
300  002        3.0  4.0  7.0          4
   CLOSES BREECH BLOCK
302             8.0 10.0 14.0          4
   SECURES THE POWER RAMMER
304            12.0 18.0 26.0          4
   SECURES SPONGE, BURLAP, + CLEANING MATERIALS
306             4.0  6.0 10.0          4
   PLACES UNUSED PRIMERS IN TRAVEL COMPARTMENTS
308  720  410  3.0  9.0 15.0          1
   LIFTS + LOCKS LEFT SPADE
310  012        3.0  4.5  7.0          2
```

```
   ENTERS HOWITZER, SECURES REAR DOOR IN POSITION
400  002        6.0 10.0 16.0          4
   GATHERS FUZE SETTERS
402            12.0 16.0 22.0          4
   STOWS FUZE SETTERS IN HOWITZER
404             6.0  8.0 11.0          4
   STOWS UNUSED FUZES IN CONTAINERS
406             4.0  6.0 10.0          4
   STORES FUZE CONTAINERS IN HOWITZER
408             1.5  2.0  3.0          4
   PUSHES RIGHT CAB DOOR SHUT FOR AG
410  720  308  3.0  9.0 15.0           1
   LIFTS AND LOCKS RIGHT SPADE
500  002        2.5  3.5  6.0          4
   OBTAINS MUZZLE COVER
502  200       13.0 20.0 30.0          2
   INSTALLS MUZZLE COVER
504            46.0 58.6 70.0          1
   MOVES TO COLLIMATOR, PUTS COVER ON IT, TAKES IT TO G
600  002       49.0 56.2 65.0          1
   MOVES TO GET AIMING POSTS, STORES THEM IN HOWITZER
602             8.0 12.0 20.0          4
   DISCONNECTS COMMO LINES FROM TERMINALS, STORES PHONE
700             1.5  2.3  3.0          1
   LIFTS GUN TRAVEL LOCK
702  106   108 15.0 25.0 35.0          4
   MD DIRECTS G TO TRAVERSE GUN
704        110  1.5  3.3  6.0          1
   MD GIVES INSTRUCTIONS FOR GUN TO BE LOWERED
706             3.5  5.0  8.0          4
   LOCKS TUBE IN TRAVEL LOCK POSITION
708  102        7.0  8.5 12.0          4
   MOVES TO BALLISTICS SHIELD, LOWER + LOCKS IT
710             3.5  4.0  6.0          1
   MOVES TO AND CLOSES DIRECT FIRE TELESCOPE
712             3.0  5.0  8.0          4
   MD OPENS DRIVER:S HATCH, ENTERS, POSITIONS HIMSELF
714             4.0  7.0 10.0          4
   MD INSTALLS INSTRUMENT PANEL OUTSIDE OF HATCH
716        004  5.0 10.0 19.0          1
   AS DIRECTED BY CS, STARTS HOWITZER + MOVES BACKWARD
718  114        2.0  4.0  9.0          4
   MD ADVISES CS THAT SPADES ARE UNLOCKED
720  006        2.0  3.5  4.5          1
   AS DIRECTED BY CS, MD DRIVES FORWARD + STOPS
800  002       10.0 15.0 20.0          1
   MOVES TO DRIVER STATION OF SECTION VEHICLE
802  008        6.0  8.0 12.0          4
   SD STARTS SECTION VEHICLE + UNLOCKS BRAKES
```

LOCOMOTION LIBRARY

```
1000  102        2.5  3.5  5.0
   EXITS BACK OF HOWITZER (AFTER REAR DOOR IS OPENED)
1002             2.5  3.5  5.0
   EXITS BACK OF HOWITZER (REAR HULL DOOR IS OPEN)
1004             1.5  2.0  3.5
   EXITS SV FROM OUTSIDE FRONT SEAT
1006             2.5  3.5  5.0
   EXITS SV FROM 50 CAL POSITION
1008             2.0  3.0  4.5
   EXITS BACK OF SV
1010  910        3.5  4.5  6.0
   ENTERS BACK OF HOWITZER. MOVES TO POSITION
1012             2.5  3.5  5.0
   ENTERS BACK OF SV
1014             3.5  4.5  7.0
   ENTERS FRONT OF SV. MANS 50 CAL
1016  910        2.0  2.5  4.0
   ENTERS SV TO OUTSIDE FRONT SEAT
1018             2.0  3.5  6.0
   ASSUMES TRAVEL POSITION IN HOWITZER
1020             3.0  4.3  7.5
   MOVES DISTANCE BETWEEN BACK OF HOWITZER & BACK OF SV
1022             3.5  4.5  8.0
   MOVES DISTANCE BETWEEN BACK OF HOW & A SIDE CAB WINDOW
1024             5.2  6.5 13.0
   MOVES DISTANCE BETWEEN BACK & FRONT OF HOWITZER
1026             7.6  9.5 19.0
   MOVES DISTANCE BETWEEN BACK OF HOWITZER & FRONT OF TUBE
1028             5.2  6.5 13.0
   MOVES DIST BETWEEN BACK OF SV & A SIDE CAB WINDOW OF HOW
1030             7.1  9.0 18.0
   MOVES DISTANCE BETWEEN BACK OF SV & FRONT OF HOWITZER
1032             9.8 12.3 24.5
   MOVES DISTANCE BETWEEN BACK OF SV & FRONT OF TUBE
1034             8.0 10.0 20.0
   MOVES DIST BETWEEN FRONT OF SV & A SIDE CAB WINDOW OF HOW
1035             6.0  8.0 10.5       4
   MOVES DISTANCE BETWEEN REAR OF HOW & FRONT OF SV
1036            10.0 12.5 25.0
   MOVES DISTANCE BETWEEN FRONT OF SV & FRONT OF HOWITZER
1038            12.6 15.8 31.5
   MOVES DISTANCE BETWEEN FRONT OF SV & FRONT OF TUBE
1040             3.2  4.0  8.0
   MOVES DISTANCE BETWEEN BACK & FRONT OF SV
1041             6.9  8.6 17.3
   MOVES DISTANCE BETWEEN BACK OF HOWITZER AND FRONT OF SV
1042
   MOVES DISTANCE BETWEEN FRONT & BACK OF HOWITZER (INSIDE)
1043             1.5  2.5  4.0
   MOVES SHORT DISTANCE
1044             2.5  3.0  5.0
   MOUNTS FRONT OF HOWITZER. MOVES TO TRAVELING LOCK
1046             2.5  3.0  5.0
   MOUNTS FRONT OF HOWITZER. MOVES TO RECUPERATOR GUIDE PINS
1048             7.0 10.0 13.0
   MOUNTS FRONT OF HOWITZER. MOVES TO COMMAND CUPOLA
```

Note: For ease of presentation to the reader, the general locomotion tasks have been presented as a separate library. In actual use, however, the tasks contained in this library would be appended to each of the other libraries as certain general locomotion tasks are required when emplacing, firing, or march ordering a howitzer.

APPENDIX B Software for the Main Program of the ARI Crew Performance Model

```
C      ***************************************************************************
C      *                          MODEL WRITTEN FOR                              *
C      *                          DR. LLOYD CRUMLEY                              *
C      *                         FORT SILL FIELD UNIT                            *
C      *                       ARMY RESEARCH INSTITUTE                           *
C      *                     BY SID SACHS, MARCH 1979                            *
C      ***************************************************************************
C      READ IN MAIN CONTROL CARD AND SET UP STORAGE FOR MODEL
       COMMON STOR (4000)
       MAX = 4000
       MACHIN = 0
       MACHIN = 1
C      MACHIN =  1 FOR UNIVAC, 0 FOR OTHERS
       DO 9 I = 1, MAX
 9     STOR(I) = 0.0
       READ (5,1) NO CREW, MAX TSK, INTER, JUMP
 1     FORMAT(I2,I4,I3, I2                                                    )
C      SET UP WORKING STORAGE FOR MODEL
       I  CREW N = 1
       I  TASK N = I CREW N + MAX TSK + 1
       I  HOLD C = I TASK N + MAX TSK + 1
       I  HOLD T = I HOLD C + MAX TSK + 1
       I  CONC C = I HOLD T + MAX TSK + 1
       I  CONC T = I CONC C + MAX TSK + 1
       I TIMES   = I CONC T + MAX TSK + 1
       I  MN TSK = I TIMES + 5 * MAX TSK + 5
       I  TIM EN = I MN TSK + NO CREW + 1
       I  WK TM = I TIM EN + NO CREW
       I TSK EN = I WK TM + NO CREW
       I  ORDER = I TSK EN + MAX TSK
       I TEM MN = I ORDER + MAX TSK
       I  ELASP = I TEM MN + NO CREW
       I MAN CR = I ELASP + INTER
       I MAN PC = I MAN CR + NO CREW
       LAST     = I MAN PC + NO CREW
       IF ( MAX .LT. LAST ) GO TO 2
       CALL MODEL(STOR(ICREWN), STOR( ITASKN),STOR(IHOLDC), STOR(IHOLDT),
     1            STOR(ICONCC), STOR( ICONCT),STOR(ITIMES), STOR(IMNTSK),
     2            STOR(ITIMEN), STOR( IWKTM ),STOR(ITSKEN), STOR(IORDER),
     3            STOR(ITEMMN), STOR(IELASP), STOR(IMANCR), STOR(IMANPC),
     9 NO CREW, MAX TSK, INTER, JUMP, MACHIN                                 )
       S T O P
 2     CONTINUE
       WRITE ( 6,3) LAST
 3     FORMAT (40H COMMON STATEMENT NEED TO BE AT LEAST                ,I5)
       STOP
       END
```


PRECEDING PAGE BLANK-NOT FILMED

```
      SUBROUTINE MODEL
     1 (CREW NO, TASK NO, HOLD   , HOLD TK  CONC CR, CONC TK, TIMES,
     2  MN TASK,   TIM END, WORK TM,  TSK END, ORDER T, TEM MAN,
     3  ELAPSE, MANCR, MANPC,
     9  NO  MAN , MAX TSK, NO ITER, JUMP, MACHIN                          )
      REAL ELAPSE(3)
      REAL TIM  END(1),  WORK TM(1), TSK END(2)
C     READ IN CONTROL CARDS FOR TASKS
      IF ( JUMP .EQ. 0 )
     .NO TASK = INPUT ( CREW NO, TASK NO, HOLD CR, HOLD TK, CONC CR,
     .  CONC TK, TIMES, MN TASK, ELAPSE)
      IF ( JUMP .GE. 1 )
     .NO TASK = INPUTL( CREW NO, TASK NO, HOLD CR, HOLD TK, CONC CR,
     .  CONC TK, TIMES, MN TASK, ELAPSE, ORDER T, JUMP, MACHIN        )
      IF ( NO TASK .GT. MAX TSK ) GO TO 8
C     CHANGE TASK NO. TO A LOCATION COUNTER
      CALL CH TASK ( MN TASK, CREW NO, TASK NO, NO TASK)
      CALL CH TASK ( MN TASK, HOLD CR, HOLD TK, NO TASK)
      CALL CH TASK ( MN TASK, CONC CR, CONC TK, NO TASK)
C     ORDER TASK BY A TIME SEQUENAL
      CALL ORDER ( NO MAN, TEM MAN , MN TASK, HOLD CR, HOLD TK, CONC CR,
     . CONC TK, ORDER T )
C     DO ANY INTIALIZE FOR SUMMARY RESULTS
      CALL START  ( NO MAN, MAN CR, MANPC)
      DO 1 I=1, NO ITER
C     OBTAIN TIME FOR ONE  ITERATION
         ELAPSE(I) = TOT TIM(NO MAN  , NO TASK, TIM END, WORK TM,
     .  ORDER T, CREW NO, HOLD TK, CONC TK, TIMES  , TSK END        )
C        ELAPSE(I) IS THE TOTAL TIME FOR JOB TO BE FINISHED
C        TIM END IS AN ARRAY OF FINISHING TIME FOR EACH CREW MEMBER
C        WORK TM IS AN ARRAY OF TOTAL WORKING TIME FOR EACH CREW MEMBER
C        TSK END IS AN ARRAY OF FINISHING TIME FOR EACH TASK
C     ADD TIME TO SUMMARY TABLES
      CALL ADD( ELAPSE(I), NO MAN, NO TASK, TIM END, WORK TM, TSK END,
     . MAN CR, MAN PC )
    1 CONTINUE
C     GET SUMMARY
      CALL SUMMAR ( ELAPSE, NO ITER, MAN CR, MAN PC, NO MAN, MACHIN     )
      RETURN
    8 CONTINUE
      WRITE ( 6,9) NO TASK
    9 FORMAT(50H INCREASE NUMBER OF TASKS IN CONTROL CARD TO        ,I4)
      STOP
      END
```

```
      FUNCTION INPUT L
     . (CREW NO,TASK NO, HOLD CR,HOLD TK,CONC CR, CONC TK,TIMES,MN TASK,
     . TEM, TASK NR, JUMP, MACHIN                                       )
      REAL TIMES(5,2), TEM(11)  , TIME(6)
      INTEGER  ERROR, CREW NO(2), TASK NO(2), HOLD CR(2), HOLD TK(2),
     .   CONC CR(2), CONC TK(2), MN TASK(1) , TASK NR(2)
      INTEGER TASKS (19)
      INTEGER C HOLD
      I = 0
      MAN NO = 0
      JOB NO = 0
      ERROR = 0
      GO TO 10
    1 CONTINUE
C     PRINT OUT MAN AND TASKS NUMBER FROM LIST
      WRITE (6,4) NOCREW, (TASKS(K), K=1,J)
    4 FORMAT(5HOMAN ,I2,10H HAS TASKS, 19I5)
   10 CONTINUE
C     READ  ARD
      READ  5,2) NO CREW, TASKS
    2 FORMAT(20I4)
        = 0
C     CHECK FOR NEW MAN NUMBER
      IF (  NO CREW    .EQ. MAN NO ) GO TO 6
C     NEW MAN
         MN TASK ( MAN NO + 1 ) = I    + 1
         IF (    NO CREW   .EQ. MANNO + 1 ) GO TO 5
C     LAST MAN
            IF (   NO CREW    .NE. 0 ) GO TO 7
         IF( ERROR .EQ. 1 )    S T O P
      WRITE (6,33)
C     READ IN TASK DECK
   33 FORMAT(21H0  TASK   CREW    JOB   /)
   20 CONTINUE
      READ (JUMP,21) NTASK,NHOLD,CHOLD,TIME,TEM
   21 FORMAT (3I5,3F5.1,F3.0,F4.3,I3/5X,11A6)
      IF ( NTASK .EQ. 0) GO TO 30
C     CHECK FOR TASKS USED
      DO 24 J=1,I
         IF( TASK NR(J) .NE. NTASK)  GO TO 23
            HOLD TK (J) = NHOLD
            CONC TK (J) = CHOLD
            TIMES(1,J) = TIME (1)
            TIMES(2,J) = TIME (2)
            TIMES(3,J) = TIME (3)
            TIMES(4,J) = TIME (4)
            TIMES(5,J) = TIME (5)
            WRITE (6,22) NTASK,CREW NO(J),TASK NO(J),NHOLD,CHOLD,TIME,
     1             TEM
   22 FORMAT (5I7,3F6.1,F4.0,F6.3,I3/5X,11A6)
            TASK NR(J) = - TASK NR(J)
   23 CONTINUE
      GO TO 20
   30 CONTINUE
C     CHECK FOR HOLD, CONCURRENT TASK, AND IF ALL TASK WERE ON LIST
      DO 29    J = 1, I
         IF( TASK NR(J) . LE. 0 ) GO TO 400
```

```
      ERROR = 40
      WRITE (6,40) CREWNO(J), TASKNO(J),TASK NR(J)
      IF ( MACHIN .EQ. 1)
     .  PRINT  40, CREWNO(J), TASKNO(J),TASK NR(J)
40    FORMAT(4H MAN,I3,12H, JOB NUMBER,I4,16H HAS TASK NUMBER,I5,
     .   28H WHICH IS NOT IN TASK FILE        )
400      IF ( HOLD TK(J) .LE. 0) GO TO 26
            N HOLD = - HOLD TK(J)
            DO  31 K = 1, I
               IF( NHOLD .EQ. TASK NR(K)) GO TO 24
31          CONTINUE
      ERROR = 41
      WRITE (6,41) CREWNO(J), TASKNO(J), HOLD TK(J)
      IF ( MACHIN .EQ. 1)
     .   PRINT 41, CREWNO(J), TASKNO(J), HOLD TK(J)
41    FORMAT(4H MAN,I3,12H, JOB NUMBER,I4,
     . 28H IS WAITING FOR TASK NUMBER ,I4,22H WHICH IS NOT ASSIGNED  )
      GO TO 26
24          HOLD CR(J) = CREW NO(K)
            HOLD TK(J) = TASK NO(K)
26       CONTINUE
         IF(CONCTK(J) .LE. 0) GO TO 29
            C HOLD = - CONC TK(J)
            DO 27 K= 1,I
               IF ( CHOLD .EQ. TASK NR(K)) GO TO 28
27          CONTINUE
      ERROR = 42
      NR TASK = TASK NR(J)
      WRITE (6,42) CREWNO(J), TASKNO(J),  NR TASK,  CONC TK(J)
      IF ( MACHIN .EQ. 1)
     .   PRINT 42, CREWNO(J), TASKNO(J),  NR TASK,  CONC TK(J)
42    FORMAT(4H MAN,I3,12H, JOB NUMBER,I4,13H, TASK NUMBER,I5,
     . 31H DOES NOT HAVE CONCURRENT TASK  ,I5,9H ASSIGNED )
      GO TO 29
28          CONCCR(J)= CREW NO(K)
            CONCTK(J)= TASK NO(K)
29    CONTINUE
      INPUT L = I
      IF (ERROR .NE. 0 ) S T O P
      R E T U R N
5     CONTINUE
      MAN NO = MAN NO + 1
      JOB NO = 0
6     CONTINUE
      IF (TASKS(J+1) .EQ. 0) GO TO 1
      J = J + 1
      JOB NO = JOB NO + 1
      I = I + 1
      CREW NO(I) =     NO CREW
      TASK NO (I) = JOB NO
      TASK NR(I) = TASKS(J)
      IF (J .EQ. 19) GO TO 1
      GO TO 6
7     CONTINUE
      ERROR = 1
      WRITE (6,8) CREW NO(I), TASK NO(I)
      IF ( MACHIN .EQ. 1)
     .  PRINT  8, CREW NO(I), TASK NO(I)
8     FORMAT(22H ERROR IN INPUT - CREW ,I4, 7H, TASK  ,I4)
      GO TO 1
      END
```

```
      SUBROUTINE SUMMAR
     . ( ELAPSE, NO ITEM, MAN CR, MAN PC, NO MAN, MACHIN                    )
      REAL ELAPSE(3), MAN PC(1)
      INTEGER MANCR(1)
      CALL SORT( NO ITEM, ELAPSE)
      NO IT 10 = NO ITEM/10
      IF( NO IT 10 .LT. 1 ) NO IT 10 = 1
      WRITE (6,5)
5     FORMAT(1H0,5X,61HCOMPLETION TIMES, FASTEST TO SLOWEST, EVERY 10TH
     .PERCENTILE  )
      WRITE (6,1) ELAPSE(1), (ELAPSE(I), I= NOIT10,NOITEM, NO IT 10)
      IF ( MACHIN .EQ. 1)
     .PRINT     1, ELAPSE(1), (ELAPSE(I), I= NOIT10,NOITEM, NO IT 10)
1     FORMAT(11F10.4)
      WRITE (6,2) ( I, MANCR(I), I=1,NO MAN)
      IF ( MACHIN .EQ. 1)
     .PRINT     2, ( I, MANCR(I), I=1,NO MAN)
2     FORMAT(13H0CRITICAL MAN,I3,I4,9(I6,I4)/13X,10(I6,I4))
      X = NO ITEM
      X = X/100.
      DO 3 I=1, NO MAN
         MANPC(I) = 100. - MANPC(I) / X
3     CONTINUE
      WRITE (6,4) (I, MANPC(I), I=1, NO MAN )
      IF ( MACHIN .EQ. 1)
     .PRINT     4, (I, MANPC(I), I=1, NO MAN )
4     FORMAT(13H0IDLE TIME    ,10(I3,F5.1,2H> )/13X,10(I3,F5.1,2H> ))
      RETURN
      END
```

```
      FUNCTION INPUT
     .(CREW NO.TASK NO. HOLD CR.HOLD TK.CONC CR. CONC TK.TIMES.MN TASK.
     . TEM                                                              )
      REAL TIMES(5.2). TEM(7)
      INTEGER  ERROR. CREW NO(2). TASK NO(2). HOLD CR(2). HOLD TK(2).
     .   CONC CR(2). CONC TK(2). MN TASK(1)
      I = 0
      MAN NO = 0
      JOB NO = 0
      ERROR = 0
      GO TO 10
 1    CONTINUE
C     PRINT OUT LAST TASK
      WRITE(6.9) CREW NO(I). TASK NO(I). ( TIMES(J.I). J=1.4). TEM
 9    FORMAT(5H CREW.I3.5H TASK.I3.     35X. 6H, TIME,4F7.1,3X,6A6,A4 )
      IF ( HOLD CR(I) .NE. 0) WRITE (6,11) HOLD CR(I). HOLDTK(I)
 11   FORMAT(1H+.15X.6H. HOLD.2I3)
      IF ( CONC CR(I) .NE. 0) WRITE (6.12) CONC CR(I). CONCTK(I)
 12   FORMAT(1H+.27X.6H. CONC.2I3)
      IF ( TIMES(5.I) .NE. 0.0 ) WRITE (6.14) TIMES(5.I)
 14   FORMAT(1H+.39X. 5H ONLY. F6.3)
 10   CONTINUE
      I = I + 1
C     READ CARD
      READ (5.2) CREW NO(I). TASK NO(I). HOLD CR(I). HOLD TK(I).
     .   CONC CR(I). CONC TK(I). ( TIMES(J.I). J=1.5). TEM
 2    FORMAT( 3(I2. I3). 3F4.1. F2.0. F3.3. 8X.6A6. A4)
C     CHECK FOR NEW MAN NUMBER
      IF ( CREW NO (I) .EQ. MAN NO ) GO TO 6
C     NEW MAN
      WRITE (6.13)
 13   FORMAT(1X)
         IF ( CREW NO(I) .EQ. MANNO + 1 ) GO TO 5
C     LAST MAN
            IF ( CREW NO(I) .NE. 0 ) GO TO 7
         MN TASK ( MAN NO + 1 ) = I
         IF( ERROR .EQ. 1 )    S T O P
         INPUT = I - 1
         R E T U R N
 5    CONTINUE
      MAN NO = MAN NO + 1
      MN TASK(MAN NO ) = I
      JOB NO = 0
 6    CONTINUE
      JOB NO = JOB NO + 1
      IF ( JOB NO .EQ. TASK NO(I) )     GO TO 1
 7    CONTINUE
      ERROR = 1
      WRITE (6.8) CREW NO(I). TASK NO(I)
 8    FORMAT(22H ERROR IN INPUT - CREW .I4. 7H. TASK  .I4)
      GO TO 1
      END
```

```
      SUBROUTINE CH TASK ( MN TASK, CREW NO, TASK NO, NO TASK )
C     CHANGE MAN/TASK NUMBER TO LOCATION TASK NUMBER
      INTEGER MN TASK(1), CREW NO(2), TASK NO(2), CREW
      DO 1 I = 1, NO TASK
         CREW = CREW NO (I)
         IF ( CREW .NE. 0 )
     .   TASK NO (I) = MN TASK( CREW) + TASK NO(I) - 1
 1    CONTINUE
      RETURN
      END
```

```
      SUBROUTINE ORDER ( NO MAN, M TASK, MN TASK, HOLD CR, HOLD TK,
     . CONC CR, CONC TK, ORDER T )
C     PLACE TASK IN ORDER AMONG CREW MEMBERS
      INTEGER M TASK(1), MN TASK(1)
      INTEGER HOLD CR(2), HOLD TK(2), CONC CR(2), CONCTK(2), ORDER T(2)
C     SET FIRST TASK FOR EACH MAN
      DO 1 I=1, NO MAN
         M TASK(I) = MN TASK(I)
 1    CONTINUE
      NEXT = 0
      IF ( MN TASK(1) .LE. 1 ) GO TO 2
         N TASK 1 = MN TASK(1) - 1
         DO 10  NEXT = 1, N TASK 1
            ORDER T ( NEXT ) = NEXT
 10      CONTINUE
 2    CONTINUE
      MOVE = NEXT
         LAST = 1
      DO 7 MAN NO = 1, NO MAN
 3       CONTINUE
C     OBTAIN MAN NEXT TASK
         MAN TSK = M TASK (MAN NO)
C     JUMP IF MAN IS FINISH
         IF ( MAN TSK .EQ. 0 ) GO TO 7
C     SKIP IF THERE IS NO HOLD
         IF ( HOLD CR (MAN TSK) .EQ. 0 ) GO TO 4
C     JUMP IF TASK HOLDING FOR IS NOT ALREADY ON LIST
         MAN HLD = HOLD CR (MAN TSK)
         IF ( HOLD TK(MAN TSK) .LT. M TASK(MAN HLD) )      GO TO 4
            IF ( M TASK( MAN HLD) .NE.0) GO TO 6
 4       CONTINUE
C     JUMP IF NON-CONCURRENT TASK
         IF (CONC CR(MAN TSK) .EQ. 0) GO TO 5
         MAN CON = CONC CR(MAN TSK)
C     JUMP IF CONCURRENT TASK IS NOT READY TO GO ON LIST
         IF ( CONC TK(MAN TSK) .GT. M TASK(MAN CON))   GO TO 6
C     PLACE CONCURRENT TASK ON LIST
         NEXT = I ORDER (NEXT, M TASK(MANCON),  1, MN TASK(MAN CON + 1)
     .      ORDER T )
 5       CONTINUE
C     PLACE THIS TASK ON LIST
         NEXT = I ORDER (NEXT, M TASK(MAN NO),  1, MN TASK(MAN NO + 1),
     .      ORDER T )
C     CHECK FOR MAN NEXT TASK
         GO TO 3
 6       CONTINUE
C     SET SWITCH TO GO THRU LIST FOR THIS MAN AGAIN
         LAST = 0
 7    CONTINUE
C     CHECK TO SEE THAT THERE WAS AS LEAST ONE MOVE LAST TIME THRU LIST
      IF ( MOVE .EQ. NEXT) GO TO 8
C     GO BACK THRU LIST OF CREW MEMBER AGAIN
      IF ( LAST .EQ. 0) GO TO 2
      RETURN
 8    CONTINUE
      IF ( LAST .EQ. 1) RETURN
      WRITE (6,9)
 9    FORMAT( 50H ERROR - LOOPING IN SUBROUTINE ORDER
     .25H WAITING ON MAN TASK                        )
      DO 12  I=1,NOMAN
         IF ( MTASK(I) .EQ. 0) GO TO 12
            MTASK(I) = MTASK(I) - MN TASK(I) + 1
            WRITE ( 6,11) I, MTASK(I)
 11   FORMAT (10X,2I5)
 12   CONTINUE
      STOP
      END
```

```
      FUNCTION IORDER ( NEXT, M TASK, ICON, MX TASK, ORDER T )
C     TO STORE TASK NUMBER IN ORDER, UP THE MAN TASK NUMBER BY ONE OR
C     SET IT TO ZERO IF MAN WILL BE DONE.
      INTEGER  ORDER T (9)
      I = NEXT + 1
      ORDER T(I) = MTASK * ICON
      M TASK = M TASK + 1
      IF(M TASK .GE. MX TASK) MTASK = 0
      I ORDER = I
      RETURN
      END
```

```
      SUBROUTINE TRIANG(IXT,A,B,C,X)
C
C     THIS ROUTINE WILL CALCULATE RANDOM TRIANGULARLY DISTRIBUTED
C     VARIABLES
       IF(C.EQ.A) GO TO 1
       IF(B.EQ.A) AM=0.
       IF(B.EQ.A) GO TO 2
      AM=(B-A)/(C-A)
 2     CONTINUE
C     OBTAIN RANDOM UNIFORM NUMBER BETWEEN 0 AND 1
      CALL RAND( VAL, 4H0001, IXT)
      IF(VAL.LE.AM) XI=SQRT(AM*VAL)
      IF(VAL.GT.AM) XI=1.-SQRT(1.-AM-VAL+AM*VAL)
      X=A+XI*(C-A)
      RETURN
 1     X=A
       RETURN
      END
```

```
      SUBROUTINE START
     . ( NO MAN, MAN CRI, MAN PC
      INTEGER MANCRI(1)
      REAL MAN PC (1)
      DO 1 I= 1, NO MAN
         MAN CRI(I) = 0
         MAN PC (I) = 0.0
    1 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE ADD(LONGST, NOMAN, NOTASK,TIMEND, WORKTM, TSK END,
     . CRI MAN, PER CNT                                            )
C                         LONGST IS THE TOTAL TASK TIME
C                   TIM END IS AN ARRAY OF FINISHING TIME FOR EACH CREW
C                   WORK TM IS AN ARRAY OF ACTUAL WORKING TIME FOR CREW
C                   TSK END IS AN ARRAY OF ENDING TASK TIME
      REAL TIM END(1), WORK TM(1), TSK END(2)
      REAL LONGST, PER CNT(1)
      INTEGER CRI MAN(1)
      TIME = 0.0
      DO 1 I = 1, NO MAN
C        IF ( TIMEND(I) .EQ. LONG ST ) CRI MAN (I) = CRI MAN(I) + 1
         PER CNT (I) = PER CNT(I) + WORK TM(I) / LONG ST
         IF ( WORKTM (I) .LT. TIME ) GO TO 1
            TIME = WORKTM(I)
            J = I
    1 CONTINUE
      CRI MAN(J) = CRIMAN(J) + 1
      RETURN
      END
```

```
      FUNCTION TOT TIM ( NO MAN, NO TASK, TIM END, WORK TM, ORDER T,
     , CREW NR, HOLD TK, CONC TK, VAR TIM, TSK END )
      REAL TIM END(1), WORK TM(1), VAR TIM(5,2), TSK END(2)
      REAL LONGST
      INTEGER ORDER T(2), CREW NR(2), HOLD TK(2), CONC TK(2), TASK NO
      INTEGER TASK NR
C     ZERO OUT TIMING SUM
      DO 1 MAN NO = 1, NO MAN
         TIM END (MAN NO ) = 0.
         WORK TM (MAN NO ) = 0.
 1    CONTINUE
      SWITCH = 0.
      DO 5 N ORDER = 1, NO TASK
         TASK NO = ORDER T (N ORDER)
      MAN NO = CREW NR (TASK NO)
      IF ( MAN NO .NE. 0 ) GO TO 15
         HOLD TK( TASK NO) = 0
         IF ( RANDTM(VAR TIM(1, TASK NO), HOLD TK) .NE. 0.0 )
     .                                  HOLD TK ( TASK NO) = 1
         GO TO 5
 15   CONTINUE
C     GET MAN TIME READY FOR TASK
         TIMES = TIM END (MAN NO)
C     CHECK FOR HOLD
         IF( HOLD TK (TASK NO) .EQ. 0 )          GO TO 2
         N H TASK = HOLD TK( TASK NO)
         TIMES = AMAX1 ( TIMES, TSK END( N H TASK) )
 2       CONTINUE
C     CHECK FOR CONCENT. TASK
         IF ( CONC TK( TASK NO) .EQ. 0 )       GO TO 4
         IF( SWITCH .NE. 0. ) GO TO 3
         SWITCH = TIMES
         TASK NR = TASK NO
         MAN NR = MAN NO
      GO TO 5
 3       CONTINUE
         TIMES = A MAX 1( TIMES, SWITCH )
 4       CONTINUE
C     OBTAIN TIME FOR TASK
         EVENT = RANDTM ( VAR TIM(1, TASK NO) , HOLD TK )
C     ADD TIME TO MAN TIME, MAN WORKING TIME, TASK END TIME
         TSK END( TASK NO) = TIMES + EVENT
         TIM END ( MAN NO) = TSK END ( TASK NO)
         WORK TM ( MAN NO) = WORK TM( MAN NO)+ EVENT
         IF ( SWITCH .EQ.  0.) GO TO 5
            SWITCH = 0.
            TSK END ( TASK NR) = TSK END( TASK NO)
         TIM END ( MAN NR) = TSK END ( TASK NO)
            WORK TM ( MAN NR) = WORK TM( MAN NR) + EVENT
 5    CONTINUE
C     FIND LONGEST TIME OF CREW
      LONGST = TIM END(1)
      DO 6 MAN NO = 2, NO MAN
         IF( LONGST .LT. TIM END (MAN NO) )  LONGST = TIM END( MAN NO)
 6    CONTINUE
      TOT TIM = LONGST
      RETURN
      END
```

```
      FUNCTION RANDTM ( X,N)
      INTEGER N(2)
      DIMENSION X(5)
      IF(IX .LE. 0) IX=1
C     CHECK FOR CONDITIONAL EVENT
      IF ( X(5) .EQ. 0.0 ) GO TO 1
C     CONDITIONAL EVENT
         Y = 0.0
      IF( X(5) .GE. 1.0 ) GO TO 3
         CALL RAND( VAL, 4H0001, IX )
         IF ( VAL .GT. X(5) ) GO TO 2
    1 CONTINUE
      CALL TRIANG(IX,X(1)+X(4), X(2)+X(4), X(3)+X(4), Y)
    2 CONTINUE
      RANDTM = Y
      RETURN
    3 I = X(5)
      IF ( N(I) .EQ. 0) GO TO 2
      GO TO 1
      END
```

```
      SUBROUTINE SORT (N,ARRAY)
      REAL ARRAY (3)
      DO 3 I= 2, N
         T = ARRAY(I)
         J= I - 1
1        CONTINUE
         IF ( ARRAY (J)   .LE.   T ) GO TO 2
            ARRAY (J + 1  ) = ARRAY(J)
            J = J - 1
            IF ( J .GT. 0 ) GO TO 1
2        CONTINUE
         ARRAY ( J + 1 ) = T
3     CONTINUE
      RETURN
      END
```

```
      SUBROUTINE RAND (VAL. N. IX)
      IX = AND(IX * 65539, 134217727 )
      VAL = FLOAT(IX   * .74505806E-08       )
      RETURN
      END
```

DISTRIBUTION

1 US ARMY WESTERN COMMAND ATTN: APPE
1 DEPARTMENT OF THE NAVY TRAINING ANALYSIS AND EVALUATION GROUP
1 HQDA ATTN: DAAG-ED
1 HQ, ICATA ATTN: ATCAT-OP-Q
1 US ARMY MATERIEL SYSTEMS ANALYSIS ACTIVITY ARMY PROCUREMENT RESEARCH OFFICE
2 HQDA RESEARCH AND STUDIES OFC
1 MILITARY OCCUPATIONAL DEVELOPMENT DIV DAPC-MSP-O, RM 852C HOFFMAN BLDG 1
4 OASD (MRA AND L)
1 MARINE CORPS DEVELOPMENT AND EDUCATION COMMAND ATTN: CODE E041
1 HQ TCATA TECHNICAL LIBRARY
1 HQDA ODCSPER
1 HQDA ATTN: DAMI-ISI
1 USA AVIATION SYSTEMS COMD ATTN: DRSAV-ZDR
1 USA CORADCOM ATTN: AMSEL-PA-RH
1 USA ARRADCOM ATTN: ATFE-LO-AC
1 HEADQUARTERS US MARINE CORPS ATTN: CODE MTMT
1 HEADQUARTERS, US MARINE CORPS ATTN: CODE MPI-20
2 US ARMY EUROPE AND SEVENTH ARMY
1 1ST INFANTRY DIVISION AND FT. RILEY ATTN: AFZN-DPT-T
1 USA INTELLIGENCE AND SECURITY COMMAND ATTN: IAOPS-TNG-T
2 HQ TRADOC TECHNICAL LIBRARY
1 NAVAL TRAINING EQUIPMENT CEN ATTN: TECHNICAL LIBRARY
1 MILITARY OCCUPATIONAL DEVELOPMENT DIRECTORATE ATTN: ATZI-NCR-MS-M, RM 3N33 HOFFMAN BLDG II
1 DATA ANALYSIS DIVISION ATTN: ATZI-NCR-MD, HOFFMAN BLDG II
1 USA MILPERCEN ATTN: DAPC-POO-T
1 8TH INFANTRY DIVISION
1 HQDA ARMY FORCE MODERNIZATION COORDINATION OFFICE
1 HQDA ATTN: DASG-PTB
1 NAVAL AIR SYSTEM COMMAND /
1 1230 USARCOM RESERVE CENTER
1 US ARMY SOLDIER SUPPORT CENTER /
1 USA FORCES COMMAND AFLG - DEPUTY CHIEF OF STAFF FOR LOGISTICS
1 DIRECTORATE OF TRAINING ATTN: ATZQ-T
1 DIRECTORATE OF COMBAT DEVELOPMENTS ATTN: ATZQ-D
1 HQDARCOM MARINE CORPS LIAISON OFC
1 DEPARTMENT OF THE ARMY US ARMY INTELLIGENCE + SECURITY COMMAND
1 USA MISSILE COMMAND ATTN: DRSMI-NTN
1 CECOM ATTN: DRSEL-ILSD
1 USA FORCES COMMAND
1 PM TRADE /
1 US MILITARY DISTRICT OF WASHINGTON OFC OF EQUAL OPPORTUNITY
1 ARMY TRAINING SUPPORT CENTER ATTN: ATIC-SMD
22 ARI LIAISON OFFICE
1 7TH ARMY TRAINING COMMAND
1 HQDA, DCSOPS UNIT TRAINING
1 HQDA, DCSOPS TRAINING DIRECTORATE
1 HQDA, DCSLOG MAINTENANCE MANAGEMENT
1 HQDA, OCS STUDY OFFICE
1 U.S. NAVY TRAINING ANALYSIS EVALUATION GROUP
1 USACDEC ATTN: ATEC-EX-E HUMAN FACTORS
1 ATTN: SM-ALC/DPCR
1 OASA (RDA) DEPUTY FOR SCIENCE AND TECHNOLOGY
1 OFC OF NAVAL RESEARCH /
1 AFHRL/LRT
1 AFHRL/LRLG
1 AIR FORCE HUMAN RESOURCES LAB ATTN: AFHRL/TSR
1 AFAMRL/BB
1 NAVY PERSONNEL R AND D CENTER DIRECTOR OF PROGRAMS
1 NAVY PERSONNEL R AND D CENTER /
2 OFC OF NAVAL RESEARCH PERSONNEL AND TRAINING RESEARCH PROGRAMS
1 NAVAL PERSONNEL R + D CENTER /

PRECEDING PAGE BLANK-NOT FILMED

1 OFC OF NAVAL RESEARCH PROJECT OFFICER, ENVIRONMENTAL PHYSIOLOGY
1 OFC OF NAVAL RSCH ORGANIZATIONAL EFFECTIVENESS PRO.
1 NAVAL AEROSPACE MEDICAL RSCH LAB AIRBORNE RANGER RESEARCH
1 NAVAL AEROSPACE MEDICAL RSCH LAB AEROSPACE PSYCHOLOGY DEPARTMENT
1 USA TRADOC SYSTEMS ANALYSIS ACTIVITY ATTN: ATAA-TCA
1 HEADQUARTERS, COAST GUARD CHIEF, PSYCHOLOGICAL RSCH BR
1 USA RESEARCH AND TECHNOLOGY LAB /
1 USA ENGINEER TOPOGRAPHIC LABS ATTN: ETL-GSL
1 USA MOBILITY EQUIPMENT R AND D COMD ATTN: DRDME-TQ (SCHOOL)
1 FT. BELVOIR, VA 22060
1 ATTN: ATTG-ATB-TA
1 USA HUMAN ENGINEERING LAB
1 USA MATERIEL SYSTEMS ANALYSIS ACTIVITY ATTN: DRXSY-C
1 USA ARCTIC TEST CEN ATTN: AMSTE-PL-TS
1 USA COLD REGIONS TEST CEN ATTN: STECR-OP
1 USA CONCEPTS ANALYSIS AGCY ATTN: CSCA-RQP
1 USA CONCEPTS ANALYSIS AGCY ATTN: CSCA-JF
1 USACACDA ATTN: ATZL-CAC-IC
1 USACACDA ATTN: ATZL-CAC-IM
1 USACAC ATTN: ATZL-CAC-IA
1 USACACDA ATTN: ATZL-CAC-A
1 USA RSCH DEVEL + STANDARDIZA GP, U.K.
1 USA RESEARCH AND DEVELOPMENT LABS CHIEF, BEHAV SCIENCES DIV, FOOD SCI LAB
1 TRAJANA ATTN: SAJS-OR
1 NAVAL AIR SYSTEMS COMMAND ATTN: AIR-5313
1 USACQEC TECHNICAL INFORMATION CENTER
1 USAARL LIBRARY
1 USA TRADOC SYSTEMS ANALYSIS ACTIVITY ATTN: ATAA-SL (TECH LIBRARY)
1 UNIFORMED SERVICES UNIT OF THE HEALTH SCI DEPARTMENT OF PSYCHIATRY
1 USA COMPUTER SYSTEMS COMMAND ATTN: COMMAND TECHNICAL LIBRARY H-9
1 CENTER FOR NAVAL ANALYSIS
1 NAVAL HEALTH RSCH CEN LIBRARY
1 NAVAL PERSONNEL R AND D CEN LIBRARY ATTN: CODE P106
1 HONEYWELL INC. SYSTEMS AND RESEARCH CENTER
1 AIR FORCE HUMAN RESOURCES LAB ATTN: AFHRL/OTS
1 HQ. FT. HUACHUCA ATTN: TECH REF DIV
1 USA ACADEMY OF HEALTH SCIENCES STIMSON LIBRARY (DOCUMENTS)
1 SCHOOL OF SYSTEMS AND LOGISTICS /
1 DEPARTMENT OF THE NAVY TRAINING ANALYSIS AND EVALUATION GP
1 USMA DEPT OF BEHAVIORAL SCI AND LEADERSHIP
1 USA COMMAND AND GENERAL STAFF COLLEGE ATTN: LIBRARY
1 USA TRANSPORTATION SCHOOL USA TRANSP TECH INFO AND RSCH CEN
1 USA ADMINCEN TECHNICAL RESEARCH BRANCH LIBRARY
1 USA FIELD ARTY BD /
1 INSTITUTE FOR DEFENSE ANALYSES
1 USA TRAINING SUPPORT CENTER ATTN: ATIC-DST-PA
1 AFHRL TECHNOLOGY OFC (H)
1 USA MOBILITY EQUIPMENT R AND D COMMAND ATTN: DRDME-ZG
1 DA US ARMY RETRAINING BDE RESEARCH + EVALUATION DIVISION
1 US MILITARY ACADEMY DEPT. OF HISTORY, BLDG 601
1 MARINE CORPS INSTITUTE
1 NAVAL SAFETY CENTER /
1 GALLAUDET COLLEGE LEARNING CENTER
1 USAAVNC AND FT. RUCKER ATTN: ATZQ-ES
1 US ARMY AVN TNG LIBRARY ATTN: CHIEF LIBRARIAN
1 USA AIR DEFENSE SCHOOL ATTN: ATSA-DT
1 USAAVNC ATTN: ATZQ-D
1 US MILITARY ACADEMY DIRECTOR OF INSTITUTIONAL RSCH
1 USA AIR DEFENSE SCHOOL ATTN: ATSA-CD-MS
1 USAADS-LIBRARY-DOCUMENTS
1 USA AIR DEFENSE BOARD ATTN: FILES REPOSITORY
1 USA INFANTRY BOARD ATTN: ATZB-IB-AE

1 USA INTELLIGENCE CEN AND SCH ATTN: ATSI-DT-SFL
1 USA ORDNANCE CEN AND SCH ATTN: ATSL-TD-TAC
1 USA ARMOR SCHOOL ATTN: ATZK-TD
1 USA ARMOR CENTER DIRECTORATE OF COMBAT DEVELOPMENTS
1 NAVAL POSTGRADUATE SCH ATTN: DUDLEY KNOX LIBRARY (CODE 1424)
1 USA TRANSPORTATION SCHOOL DEPUTY ASST. COMMANDANT EDUCA. TECHNOLOGY
1 USA SIGNAL SCHOOL AND FT. GORDON ATTN: ATZH-ET
1 USA QUARTERMASTER SCH ATTN: ATSM-TNG-TM-ET
1 USA MILITARY POLICE SCHOOL ATTN: LIBRARY
1 USA ARMOR CENTER + FT. KNOX OFFICE OF ARMOR FORCE MGT + STANDARDIZATION
1 CHIEF OF NAVAL EDUCATION AND TNG /
1 USA SIGNAL SCHOOL + FT. GORDON EDUCATIONAL TECHNOLOGY DIVISION
1 HQ ATC/XPTD TRAINING SYSTEMS DEVELOPMENT
1 USA INSTITUTE FOR MILITARY ASSISTANCE ATTN: ATSU-TD-TA
5 USA INTELLIGENCE CEN AND SCH ATTN: ATSI-ERM
1 US ARMY ARMOR CENTER ATTN: ATZK-TD-PMO
1 USA AIR DEFENSE CENTER, FT. BLISS ATTN: ATZC-DIM
1 USA QUARTERMASTER SCHOOL DIRECTORATE OF TRAINING DEVELOPMENTS
1 US COAST GUARD ACADEMY /
1 USA TRANSPORTATION SCHOOL DIRECTORATE OF TRAINING + DOCTRINE
1 USA INFANTRY SCHOOL LIBRARY /
1 USA INFANTRY SCHOOL ATTN: ATSH-I-V
1 US ARMY INFANTRY SCHOOL ATTN: ATSH-CD
1 USA INFANTRY SCHOOL ATTN: ATSH-DOT-LRD
1 USA INFANTRY SCHOOL ATTN: ATSH-EV
1 USA MP + CHEM SCH/TNG CEN + FT. MCCLELLAN ATTN: ATZN-PTS
1 USA MP + CHEM SCH/TNG CEN + FT. MCCLELLAN DIR, COMBAT DEVELOPMENT
1 USA MP + CHEM SCH/TNG CEN + FT. MCCLELLAN DIR, TRAINING DEVELOPMENT
1 USA MP + CHEM SCH/TNG CEN + FT. MCCLELLAN ATTN: ATZN-MP-ACE
1 USA INSTITUTE OF ADMINISTRATION ATTN: RESIDENT TRAINING MANAGEMENT
1 USA FIELD ARTILLERY SCHOOL MORRIS SWETT LIBRARY
1 USA INSTITUTE OF ADMINISTRATION ACADEMIC LIBRARY
1 USA WAR COLLEGE ATTN: LIBRARY
1 USA ENGINEER SCHOOL LIBRARY AND LEARNING RESOURCES CENTER
1 USA ARMOR SCHOOL (USARMS) ATTN: LIBRARY
1 US COAST GUARD ACADEMY LIBRARY
1 USA TRANSPORTATION SCHOOL TRANSPORTATION SCHOOL LIBRARY
1 ORGANIZATIONAL EFFECTIVENESS CEN + SCH ATTN: LIBRARIAN
1 US ARMY INTELLIGENCE CENTER + SCHOOL ATTN: ATSI-TP
1 US ARMY INTELLIGENCE CENTER + SCHOOL ATTN: ATSI-RM-M
1 US ARMY INTELLIGENCE CENTER + SCHOOL ATTN: ATSI-ES
1 USA FIELD ARTILLERY SCHOOL DIRECTORATE OF COURSE DEV + TRAINING
1 DEPARTMENT OF THE AIR FORCE AIR UNIVERSITY LIBRARY (ATC)
1 HQ TRADOC TRAINING DEVELOPMENT INSTITUTE
2 BRITISH EMBASSY BRITISH DEFENCE STAFF
2 CANADIAN JOINT STAFF
1 COLS (W) LIBRARY
1 FRENCH ARMY ATTACHE
1 AUSTRIAN EMBASSY DEFENSE, MILITARY AND AIR ATTACHE
3 CANADIAN DEFENCE LIAISON STAFF ATTN: COUNSELLOR, DEFENCE R AND D
1 ROYAL NETHERLANDS EMBASSY MILITARY ATTACHE
1 CANADIAN FORCES BASE CORNWALLIS ATTN: PERSONNEL SELECTION
2 CANADIAN FORCES PERSONNEL APPL RSCH UNIT
1 ARMY PERSONNEL RESEARCH ESTABLISHMENT
1 I PSYCHOLOGICAL RESEARCH UNIT ATTN: CP4-6-13 (LTC M. J. ELEY)
6 LIBRARY OF CONGRESS EXCHANGE AND GIFT DIV
1 DEFENSE TECHNICAL INFORMATION CEN ATTN: DTIC-DDA-2
140 LIBRARY OF CONGRESS UNIT DOCUMENTS EXPEDITING PROJECT
1 US GOVERNMENT PRINTING OFC LIBRARY, PUBLIC DOCUMENTS DEPARTMENT
1 US GOVERNMENT PRINTING OFC LIBRARY AND STATUTORY, LIB DIV (SLL)
1 THE ARMY LIBRARY ATTN: ARMY STUDIES SEC
3 / /