AD-A257 052

ARMY RESEARCH INSTITUTE

Research Product 92-07

Crew Requirements Definition System User's Guide

July 1992

Fort Bliss Field Unit
Training Systems Research Division

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

Approved for public release; distribution is unlimited.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. [illegible]

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
1992, July

3. REPORT TYPE AND DATES COVERED
Final Sep 85 - Mar 91

4. TITLE AND SUBTITLE
Crew Requirements Definition System User's Guide

5. FUNDING NUMBERS
MDA903-85-C-0440
63007A
793
1102(112)
C1

6. AUTHOR(S)
Kellner, Arthur J. (New Mexico State University);
Christ, Richard E. (ARI); and Conroy, Joseph A. (SAIC)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Science Applications International Corporation
1700 Goodridge Drive
McLean, VA 22102

8. PERFORMING ORGANIZATION REPORT NUMBER
--

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Research Institute for the Behavioral and Social Sciences
ATTN: PERI-I
5001 Eisenhower Avenue
Alexandria, VA 22333-5600

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
ARI Research Product 92-07

11. SUPPLEMENTARY NOTES
Contracting Officer's Representative, Richard E. Christ.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release;
distribution is unlimited.

12b. DISTRIBUTION CODE
--

13. ABSTRACT *(Maximum 200 words)*

The Crew Requirements Definition System (CRDS) permits analysts and researchers to develop, examine, and modify crew designs in a timely, cost-effective manner. Designs may vary in terms of the number and types of tasks to be performed, the number and types of personnel assigned to perform the tasks, the time-based task network, and the time required to perform each task. Since the CRDS is a fully computer-assisted task performance analysis tool, the effects of these variables can be examined without conducting field studies for each design alternative.

This User's Guide begins with an overview of the CRDS. After providing instructions on how to install the CRDS on a personal computer and information on the user-software interface, the User's Guide describes the underlying rationale, capabilities, and features of the CRDS and gives annotated instructions for its use. To facilitate the user's understanding of the capabilities of the CRDS, the Guide assists the user in developing, examining, and modifying one example problem and then thoroughly describes two additional sample problems.

14. SUBJECT TERMS
Crew design
Unit design
Army organizations
Organizational concepts
Computer-assisted aids

15. NUMBER OF PAGES
103

16. PRICE CODE
--

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

NSN 7540-01-280-5500

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

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

EDGAR M. JOHNSON
Technical Director

MICHAEL D. SHALER
COL, AR
Commanding

Research accomplished under contract
for the Department of the Army

Science Applications International Corp.

Technical review by

Charles O. Nystrom
William R. Sanders

NOTICES

FINAL DISPOSITION: This Research Product may be destroyed when it is no longer needed. Please do not return it to the U.S. Army Research Institute for the Behavioral and Social Sciences.

NOTE: This Research Product is not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

Research Product 92-07

Crew Requirements Definition System User's Guide

Arthur J. Kellner
New Mexico State University

Richard E. Christ
U.S. Army Research Institute

Joseph A. Conroy
Science Applications International Corp.

Field Unit at Fort Bliss, Texas
Michael H. Strub, Chief

Training Systems Research Division
Jack H. Hiller, Director

U.S. Army Research Institute for the Behavioral and Social Sciences
5001 Eisenhower Avenue, Alexandria, Virginia 22333-5600

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

July 1992

Army Project Number
2Q263007A793

Human Factors in Training and
Operational Effectiveness

Approved for public release; distribution is unlimited.

FOREWORD

The U.S. Army Research Institute for the Behavioral and Social Sciences supports the Army with research and development on manpower, personnel, training, and human performance issues as they impact the development, acquisition, and operational performance of Army systems and the combat readiness and effectiveness of Army units. The impact of behavioral and performance issues on the effectiveness of Army systems and units is in part a function of how the personnel and equipment are organized to conduct and support combat operations. The Army has identified a need to develop tools to increase the efficiency and reliability of the process of designing organizational units. The Fort Bliss Field Unit is conducting advanced development research to meet this need.

This report is a comprehensive guide on how to use a computer-assisted tool, the Crew Requirements Definition System (CRDS). The CRDS is a model building aid for small organizational units. It enables analysts and researchers to study alternative organizational solutions to problems in small-unit performance and workload. The study may be directed at the effects of variations in (a) unit composition and size, (b) task start times and sequencing, or (c) task allocation to personnel or equipment items. Since the CRDS is a fully computer-assisted task performance analysis tool, the effects of these variables can be examined without having to conduct separate field studies for each design alternative.

The research and development program that led to the CRDS described in this User's Guide was sponsored by the Force Design Directorate for the Combined Arms Command of the U.S. Army Training and Doctrine Command (TRADOC); both the R&D program and this product have been briefed to successive Deputy Chiefs of Staff for Combat Developments at Headquarters TRADOC. Prototypes of the CRDS were demonstrated at the 28th Army Operations Research Symposium, the 23rd Meeting of the Department of Defense Human Factors Engineering Technical Group, and the 33rd Annual Meeting of the Human Factors Society. This User's Guide is keyed to Version 1.0 of the CRDS software, which is being released in conjunction with the Guide.

Edgar M. Johnson

EDGAR M. JOHNSON
Technical Director

ACKNOWLEDGMENTS

The authors owe a special debt of gratitude to Robert E. Robinson, who worked with a subcontractor and then as a consultant to the prime contractor for this research product, Science Applications International Corp. He was responsible for designing the specifications and writing the source code for the earliest prototype versions of the CRDS software. He was always willing to respond to the authors' questions, suggestions, and concerns, and his responses were always helpful and appreciated. The early prototypes of the CRDS were written for an Apple MacIntosh personal computer system, and the software was subsequently converted by others into its present IBM-compatible format.

This User's Guide is an example of a research product whose development was stimulated by a close and cooperative relationship between defense laboratories and academic centers. In particular, since 1980 the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) and the Consortium of Universities of the Washington Metropolitan Area (CUWMA) have combined their research talents and skills through the Consortium Research Fellows program. The first author was a graduate student in the Department of Psychology at New Mexico State University when he was selected to work with technical and analytical personnel in the ARI Field Unit at Fort Bliss, Texas, as a Research Fellow.

This research product has benefited from the significant contributions of many individuals. First, special thanks are due to those from the Department of Army force development community who took time out of their busy schedules to serve as evaluators of this User's Guide and the CRDS software. The comments and suggestions made by Charles O. Nystrom and William R. Sanders, listed as technical reviewers on the inside front cover, were especially appreciated. They and all the other users of earlier drafts of this research product documented and shared with the authors their suggestions for improving the User's Guide.

CONTENTS

CONTENTS (Continued)

LIST OF TABLES

Page

LIST OF FIGURES

PART ONE: INTRODUCTION

Purpose

The Crew Requirements Definition System (CRDS) is a computer-based tool developed to assist in the creation, evaluation, and modification of small unit or crew designs. For the CRDS, a crew design is described as a scheme or model that specifies the numbers and types of personnel and tasks assigned to the crew and defines the time-based task network and the assignment of personnel to perform each task. After the user has collected and entered the data necessary to describe an initial crew design, the CRDS enables the user to specify and evaluate alternatives to that design. The resulting creation and evaluation of alternative crew designs is both efficient and cost effective, largely because real or potential design problems can be identified without having to conduct separate field studies for each design alternative.

This User's Guide is <u>not</u> a simplified step-by-step outline for how to use the CRDS. Rather, it describes the underlying rationale, capabilities, and features of the CRDS in addition to giving instructions and examples for its use.

Background of the CRDS

The CRDS was originally envisioned to be one component of a larger computer software package called the Systematic Organizational Design (SORD) methodology (see Christ, Conroy, & Briggs, 1990, and Kellner, Conroy, & Christ, 1992). The SORD methodology standardizes the process and structure for creating and documenting initial organizational concepts in the design of Army units up through company size. The technology built into the SORD methodology has been transferred to the U.S. Army Training and Doctrine Command (TRADOC) and will soon become the required, standard technique for designing Army units.

However, since the proponent of the SORD methodology (the U.S. Army Combined Arms Command) is principally responsible for integrating the organizational concepts created by separate functional areas or branches into combined arms forces, there was no need to incorporate a crew design capability into the SORD methodology. The crew designs developed at the functional area or branch level are used by the force designers as building blocks in the design of the higher echelon forces. Consequently, the crew design capability of the CRDS was not incorporated into SORD, but rather was designed as a stand-alone tool.

As it currently exists, the CRDS is useful in any military or civilian situations in which there is a need to develop and evaluate alternative small unit designs. The system is not application specific, but rather can be used whenever the user has some knowledge or educated assumptions about the tasks the small unit is to perform, the types of personnel assigned to perform the tasks, any task network requirements, and the time required to perform each task.

The CRDS is most appropriate for the development of low echelon, specialized organizational units. These types of units, generally called crews or cells, tend to be small in terms of the number and types of personnel and equipment assets assigned to them. Henceforth, this User's Guide refers to these types of low echelon units as crews or cells.

Unless otherwise specified, a crew is the small, specialized, low echelon unit of concern in the CRDS. In the present context, a **crew** refers to the personnel that operate, maintain, or otherwise service a specific crew-served materiel system. For example, combat and materiel developers are concerned with designing cost and operationally effective crews for materiel systems such as a howitzer, tank, helicopter, or missile launcher.

However, the CRDS can also be used effectively to design an organizational cell. A **cell** refers to the personnel **and** equipment assets which jointly perform a set of mission essential tasks. The personnel and equipment assigned into a cell are those necessary to provide functions such as those associated with a fire direction center, mess section, maintenance team, or forward area refueling unit.

Caveat on the Terminology and Routines Used in the CRDS

Because of its genesis, the CRDS retains much of the flavor and terminology that are perhaps more appropriate in the design of larger, more diverse higher echelon organizational units. However, unless new funds are made available to enhance the CRDS software, the current software must be considered the final version. The funds and other means necessary to modify the software, to include the wording and format of input and output video display screens, simply are no longer available to the authors of this manual.

It is important to note that there are some potential problems in the current CRDS software. For example, the CRDS will prompt the user to specify the number and types of **resources** assigned to a crew for performing its mission essential tasks. While most users of the CRDS will consider these resources to be soldiers, with specified military occupational specialties (MOS) and skill levels, the CRDS permits the resources of a crew to be either personnel or equipment items (or, for that matter, software programs). This more general treatment of the resources available to a crew greatly enhances the robustness of the CRDS. However, to improve the intelligibility of this User's Guide for a typical user, the term "resource" that appears in a CRDS display will be translated in the Guide to mean personnel or crew member, unless otherwise specified.

More generally, the User's Guide has been written to take into account any and all potential problems that have been identified in the software. Fortunately, the existence of potentially confusing terminology on a computer monitor or screen is not a great problem. The user can gain great benefit from the aids provided by the CRDS in spite of this nuisance. Likewise, because there is considerable redundancy in the various CRDS outputs, the fact that a given type of output may not be absolutely reliable does not invalidate the information that is available in other, perfectly reliable outputs.

Overview of the User's Guide

The remainder of the CRDS User's Guide is organized into the following parts:

<u>Part Two: Overview of the CRDS Methodology</u>

Part Two contains a description of the objectives, approach, and some possible applications of the CRDS. A quick reference for using the CRDS is also provided.

<u>Part Three: Installing and Understanding the CRDS</u>

Part Three is a description of hardware and software requirements of the CRDS, as well as procedures for installing and activating the CRDS. This part also contains a discussion of the basic features of the user-CRDS interface and procedures for managing CRDS data files.

<u>Part Four: Building a CRDS Data File</u>

Part Four is a description and discussion of the detailed step-by-step procedure for building a CRDS data file. In order to make this procedure as clear as possible, the user is instructed and encouraged to build a prototype data file or template for the crew of a representative weapon system.

Part Five: Viewing and Printing CRDS Output

Part Five contains a discussion of the information available in the tabular and graphic outputs of the CRDS and the procedures for accessing and printing hard copies of this information.

Part Six: Modifying Template Features

An analysis of the organizational design of a crew often suggests that the initial design contains some real or potential problems. Part Six of the User's Guide describes techniques available with the CRDS to quickly and iteratively modify the original design of the crew.

Part Seven: Sample Problems

Part Seven describes and discusses two sample applications of the CRDS, one for the crew of a weapon system and the other for a cell of personnel assigned to a fire direction center. Also included in this part of the Guide are suggestions for handling these and other types of data sets.

Part Two may be treated as a supplemental section of the User's Guide. The CRDS software is sufficiently user friendly that a user could skip the overview of the CRDS in Part Two and proceed directly to subsequent parts of the Guide. However, it is suggested that all prospective users of the CRDS carefully read Parts Three through Seven, preferably while simultaneously interacting with the CRDS as the software is loaded and operated on a personal computer.

User Characteristics

Since this User's Guide is not a primer on the various operations research techniques upon which the CRDS relies, the user should have some knowledge of these techniques to use the system most effectively.

What is most necessary is that the user have an understanding of the mission essential tasks that are to be performed, the personnel and equipment items available to perform the tasks, the performance duration of each task, and any constraints on task sequencing. It is preferable that the user's understanding of the crew requirements be based on personal experience in observing crews actually performing mission essential tasks.

PART TWO: OVERVIEW OF THE CREW REQUIREMENTS DEFINITION SYSTEM (CRDS) METHODOLOGY

Objectives

The CRDS is a task performance-based model building aid for crews. As such, the CRDS can serve as: (a) a generator of graphic aids for the study and analysis of crew design and performance; (b) a source of insights and, hence, a point of departure for alternative crew designs; and (c) an archive of previously designed crews for study and briefing.

In a general sense, the CRDS enables the user to examine alternative **organizational** solutions to problems associated with excessive crew workload. In the CRDS, excessive crew workload is defined in terms of (a) an excessive amount of time or number of crew members required to perform mission essential tasks or (b) an excessive demand on individual crew members to perform multiple tasks simultaneously.

In all these regards, the objectives of the CRDS are to aid the user in accomplishing the following:

1. To minimize mission performance time along the longest duration path of the task performance network.

2. To minimize the number of crew members required for a specified task performance network and mission performance time.

3. To further minimize the number of crew members required at the expense of increased mission performance time.

4. To minimize the occurrence of time intervals during which one type of crew member has two or more tasks to perform simultaneously.

The CRDS enables analysts and researchers to study the performance of alternative crew designs in a timely and cost effective manner. The study may be directed at the effects on mission performance time of variations in (a) crew composition and size, (b) task start times and task sequencing, or (c) task allocation to crew members. Since the CRDS is a fully computer-assisted task performance analysis tool, the effects of these variables can be examined without the need to observe crews actually performing their duties in each of the alternative crew designs.

Approach

The CRDS has three key features which contribute to its ease of use while attaining its objectives. These key features of the CRDS are:

- Pre-formatted crew data files or templates,
- A problem-solving structure based upon critical path analysis, and
- Highly useful graphic and tabular data summaries.

Each of these features is described in succeeding paragraphs.

Crew Data Files or Templates

The development and documentation of detailed descriptions of crews are some of the most tedious aspects of the crew design process. This is especially true if time-based task networks are part of the crew description. The automated features of the CRDS provide the user with an interactive, graphic capability to easily and rapidly develop and document these types of crew models.

In the CRDS, the model which describes the composition, organization, and structure of a crew is a highly preformatted data file or template that can be easily filled, changed, updated, or copied. Five types of data must be entered to establish a template. They are:

- The number and names of different types of crew members (e.g., the number of each type of crew member MOS and skill level),
- The number and names of tasks which must be performed by the crew members,
- Any required sequences of task performance,
- The assignment of different types of crew members to perform each task, and
- The performance time measure for each task.

Some of these data may be derived from the required mission capabilities of the higher echelon unit to which the crew under consideration is assigned. Other data may be obtained from the operational requirements documents and target audience descriptions of the major materiel system to which the crew is assigned. Ideally, performance time data should be derived from field observations.

The CRDS may be used to build a new crew template or to access an existing template that was previously developed and stored. In either case, the CRDS supports template creation and modification by allowing the user to save changes to a crew data file at any time.

Critical Path

The CRDS incorporates a critical path approach to the development and evaluation of crew models. This approach builds on the time-based task network structure of a crew template. The CRDS automatically calculates the critical time path based upon task performance times and task contingencies.

A critical path or critical sequence of tasks is defined as that sequence of task performance which consumes the most time from the initiation to the completion of the mission. Each successive task in the critical task sequence must be completed before performance of the next task in the sequence can begin. By definition, there is no idle time in the critical task sequence; all crew member performance time on the critical path is productive time.

While all tasks assigned to the crew are mission essential tasks, not all tasks are on the critical path. The performance of mission essential tasks which are not on the critical path have start and end times which can vary. Personnel performing tasks which are not in the critical task sequence have idle time either before task performance begins or after task performance is completed.

Consider a very simple example. Assume that the mission of a crew requires the performance of four distinct tasks, called Task A, Task B, Task C, and Task D, respectively. Furthermore, assume that a different crew member is assigned to perform each task and that the time required to perform each task is exactly one minute. Finally, assume that Task D may be performed at any point during the total mission duration, but that Tasks A, B, and C must be performed in series.

In this example, the critical path is defined as the sequence of performing, in order, Tasks A, B, and C, and the time required to perform this sequence of task (i.e., three seconds) is the mission completion time. There is no idle time during the performance of these three tasks; each of the three designated crew members initiate the performance of their assigned tasks as soon as possible. On the other hand, the crew member assigned to Task D has a choice concerning when that task will be performed. Task D may be initiated simultaneously with Task A, in which case there will be two seconds between the completion of Task D and the completion of the total mission. Alternately, the initiation of Task D can delayed up to two seconds after that of Task A, in which case there will be up to two seconds of idle time prior to its initiation.

The duration of the critical path sequence is a key indicator of the efficiency of the crew model. For a less than optimally efficient model, the duration of the critical path sequence can be reduced through changes in the crew design, e.g., changes in task timing or in the allocation of tasks to crew members.

Studying the critical path also enables the user to evaluate the level of workload imposed on crew members. In the context of a time-based task analysis, workload can be related to time stress, and defined as the time required to perform a task or set of tasks (T_R) divided by the time available (T_A), yielding the ratio T_R/T_A. In a scenario with no time stress, T_R is less than T_A. As T_R increases and approaches T_A, increasing amounts of workload are imposed on the crew member performing the tasks and, more generally, on the crew. If T_R exceeds T_A (i.e., if the time required to perform a task or set of tasks exceeds the performance time available), mission performance may suffer.

In summary, knowing which tasks are in the critical task sequence, the task performance times, and which type of crew member is assigned to perform the tasks provides a powerful basis for evaluating the efficiency of the crew design.

Graphic/Visual Aids

Once an initial crew design has been developed, its characteristics should be capable of study, analysis, and modification. The goal is to understand the impact of the crew design data and possible changes in those data on a set of mission or system functions. However, even with a relatively simple initial crew design, there are likely to be very many feasible sets of alternative crew data files. Manually creating graphic and tabular summaries for each of these alternatives represent a huge undertaking, one which substantially lengthen the total crew design process.

The CRDS is designed to overcome these problems. The underlying basis of the CRDS is several automated critical path method calculations and summaries. In addition, the system produces other automated calculations and summaries to aid the user. These computer assisted portrayals of crew data files are completed very quickly.

Furthermore, the examination and manipulation of crew data files are easy, because the CRDS allows the user to **see** the various time-based relationships among tasks, task sequences, personnel, task allocation to personnel, and mission performance time. The CRDS automatically creates timelines and other graphic and tabular representations of the crew data file. These representations of the data permit the user to gain insights into key relationships in the crew design. Furthermore, the methods for presenting the data are such that they aid the user in developing 'insights' to procedures that can be used to improve the design of the crew.

If, after creating an initial crew design, the user wishes to create or develop a variation of that design (e.g., insert a change in required task sequencing), the CRDS provides the capability to create alternate files and maintain a copy of each modification as new variations on the original design are created.

Taken together, these features of the CRDS provide the user with the capability to develop organizational models of crews and to subsequently modify those models in an interactive graphic fashion. In addition, the CRDS provides the user with the capability to translate any of the resulting graphic model specifications directly into a report or briefing format. The user may print permanent records and graphs for archival and briefing purposes.

Conflict Resolution

The CRDS uses the presence of task conflicts as the principal indicator that the crew model can be made more efficient. In the CRDS, a task conflict exists whenever two or more tasks whose performance overlap in time are assigned to one type of crew member. If, for any reason, the simultaneous performance of two or more tasks by one type of crew member is not possible, the tasks are considered in conflict.

The CRDS offers four ways to resolve or eliminate conflicts in task performance.

- Change the timing of the tasks. The user reschedules otherwise conflicting tasks so that their respective performances occur during non-overlapping time intervals in the time-based task network. In practice, this solution typically delays the start times of one or more of the conflicting tasks so that a specified type of crew member can perform each of the tasks during different time intervals.

- Change the assignment of crew members to tasks. After examining the crew model, the user identifies other types of available crew members to whom one or more conflicting tasks may be allocated. These other types of crew members must be idle during the intervals in which the newly assigned tasks are to be performed and they must otherwise have the capability to perform the newly assigned tasks.

- Change the requirement for task sequencing. The user redefines the sequence in which tasks are performed. This solution can only be implemented if the tactics, techniques, and procedures of operation for the crew are sufficiently flexible to permit a change in task sequences. Alternately, this solution requires a change in the acceptable operating characteristics of crew-served materiel systems. Such conditions are likely to exist only very early in the force development or system development cycle.

- Increase the number of crew members capable of performing conflicting tasks. The user assigns to the crew additional crew members of the type whose task performance is in conflict. In this solution, the conflict is eliminated since tasks that would otherwise be in conflict are now performed by different crew members of the same type. For example, more than one soldier with a given MOS and skill level could be allocated to the tasks whose performances overlap in time.

Other solutions to the conflicts identified in the crew model are also possible, but they may not be, strictly speaking, organizational solutions. For example, the recruitment, selection, training and placement of personnel could represent long-term solutions to task performance conflicts in a crew.

Trade-offs in the Development of Crew Designs

The reader of the Guide should recognize that potential solutions to conflicts identified in crew models are in reality sub-optimal solutions. There are trade-offs that must be considered in the efficiency, effectiveness, and cost of each proposed solution.

For example, while the performance start time of one of two conflicting tasks may be delayed to eliminate an instance in which a given crew member is otherwise required to simultaneously perform incompatible tasks, this solution may cause unacceptable increases in the overall mission completion time. Alternately, while a task may be reallocated from a crew member with no idle time to one with idle time, this change in task allocation may also eliminate the desirable 'idle time' or 'rest' in a work-rest cycle that is otherwise used to maintain the performance capability of the crew members. The most desirable resolution of a conflict generally will create a design in which the task network will fall between the two extreme described below.

- <u>Task Networks in which All Tasks are Performed in Parallel</u>. In this case, no task would have a required predecessor task -- the most pristine form of task relationships. With this arrangement, there is no shorter total mission performance time without shortening or deleting long-duration tasks. This arrangement, however, requires that some few personnel do many tasks simultaneously or that there are a maximum number of personnel assigned to the crew, one per task. Practically speaking there are prescribed task sequences, but there is often latitude in this regard early in the system design process, and some tasks may be assigned to either machines or people.

- <u>Task Networks in which All Tasks are Performed in Series</u>. In this case, every task has a unique required predecessor task. The performance of each task can begin only after its predecessor task has been completed. Since no two tasks are performed in parallel,there are no conflicts in task performance. The crew is more economical with respect to the demands on crew members (none is required to perform more that one task at a time). Furthermore, there is a minimum requirement for alternative crew members -- one very capable soldier can perform all mission essential tasks. However, this purely serial arrangement of tasks maximizes overall mission performance time.

Clearly there are many optional crew models for any set of task conditions and crew member capabilities. The CRDS permits a user to quickly create the more feasible models and provides sufficient information about the characteristics of those models to allow a useful trade-off determination.

Quick Reference for Using the CRDS

This section summarizes procedures and techniques for using the CRDS. After actively participating in the instructions given in subsequent parts of this User's Guide and gaining some experience in using the CRDS, the user will find the quick reference helpful.

1. Enter data required to develop a crew template or retrieve a previously developed crew template. (See Part Four)

   Minimum data requirements:

   - Number and names of different types of crew members
   - Number and names of tasks to be performed
   - Names of the different types of crew members assigned to perform each task
   - Task sequence information
   - Performance time of each task

2. Calculate the critical path. (See Part Five)

3. Examine and print hard copies of template characteristics. (See Part Five)

4. Modify the template, as necessary and desirable, to attain the objectives of the particular study. (See Part Six)

   Objectives:

   - Minimize performance times along the longest duration path of the task performance network
   - Minimize the number of crew members required for a given mission time and task sequence

- Further minimize the required number of crew members at the expense of increased mission time
- Minimize the occurrence of time intervals during which one type of crew member has multiple tasks to perform simultaneously

Modification Methods:

- Change task start times
- Change allocation of crew members to tasks
- Change task sequence requirements
- Increase crew size by increasing the number of each 'overloaded' crew member

Aids to Modification:

- Critical task list
- Conflict overlap table
- Conflict adjustment table (task start times delays within or outside the initial mission time)
- GANTT chart
- PERT diagram

The remainder of this User's Guide provides a detailed description of how to install and initiate the CRDS, and a description and explanation of each major CRDS function. The order of discussing the CRDS functions is the same as the order in which the functions are listed in the menus of options, even though the user may not typically progress through them in that order. Finally, in Part Seven of the User's Guide, applications of the CRDS to two sample problems are presented.

PART THREE -- INSTALLING AND UNDERSTANDING THE CRDS

Hardware and Software Requirements

The following hardware and software are necessary to run the CRDS program.

1. IBM personal computer (PC) or 100 percent compatible, with a 5 1/4 inch, 360 Kb floppy disk drive designated as Drive A.

2. PC or MS DOS VERSION 3.0 or higher.

3. Microsoft Mouse or compatible with proper drivers.

4. A locally dedicated IBM Proprinter or Epson-compatible printer.

NOTE: Laser printers are incompatible with the CRDS software and will not print graphic outputs of the CRDS.

IMPORTANT: The Epson-compatible printer must be linked directly to the parallel output port designated as LPT1. If the PC is connected to the printer through a local area network, the user should seek assistance from a systems manager.

5. One of the following graphics adapters:

Graphics Device	Resolution	Colors
AT&T & Compaq III	640 X 400	monochrome
AT&T DEB Graphics	640 X 200	16
AT&T DEB Graphics	640 X 400	16
IBM Color Graphics	640 X 200	2
IBM Color Graphics	320 X 200	4
Sigma Design Color-400	640 X 400	16
Sigma Design Laser View	1664 X 1200	4
IBM EGA	640 X 200	16
IBM EGA	640 X 350	monochrome
IBM EGA	320 X 200	16
IBM EGA	640 X 350	16
IBM MCGA	640 X 480	2
IBM EGA	640 X 350	2
IBM VGA	640 X 480	16
IBM VGA-analog	320 X 200	256
MDS Genius Display	736 X 1008	monochrome
Hercules	720 X 348	monochrome
NEC PC-9800/VM	640 X 400	16

Graphics Device	Resolution	Colors
NEC PC-9800/VM	640 X 400	2
Tseng Labs EVA/480	640 X 480	16
NDI Genesis 1024-digital	640 X 480	16
NDI Genesis 1024-analog	640 X 480	16
NDI Genesis 1024-JVC	1024 X 768	16
NDI Genesis 1024-Mitsubishi	1024 X 768	16
NDI Genesis 1280-JVC	1280 X 1024	16
Number Nine Revolution, 111008	512 X 512	256
Toshiba 3100	640 X 400	monochrome
Tecmar Graphics-Master	720 X 352	monochrome
STB GraphicsPlus-II	640 X 352	monochrome
STB GraphicsPlus-II	320 X 200	16
STB GraphicsPlus-III	640 X 400	monochrome
Tecmar Graphics-Master	720 X 704	monochrome
Tecmar Graphics-Master	640 X 200	16
Tecmar Graphics-Master	640 X 400	16
Tecmar Graphics-Master	320 X 200	16
Video-7 Vega Deluxe	640 X 480	16
Video-7 Vega Deluxe	752 X 410	16
Video-7 VGA	720 X 540	16
Video-7 VGA	800 X 600	16
Paradise Auto EGA/480	640 X 480	16
Genoa SuperEGA HiRes	800 X 600	16
Everex Edge	640 X 200	16
Everex Edge	640 X 400	16
WYSE WY-700 Display	640 X 400	monochrome
WYSE WY-700 Display	1280 X 400	monochrome
WYSE WY-700 Display	1280 X 800	monochrome
IBM 3270 PC	720 X 350	monochrome

Conventions of This User's Guide

CRDS Screens

A complete CRDS screen will always be shown within a box, either a box in the shape of the screen or a smaller one such as the following.

Enter task 01 name with a maximum of 10 characters
> Attend Scn
PRESS RETURN TO CONTINUE

Figure 1. Illustration of a complete CRDS screen.

References to Specific Features of CRDS Screens

References to specific features of CRDS screens, whether menu options or prompts to the user, will be shown in this guide within quotation marks and, as nearly as possible, just as they appear in the CRDS screen (e.g., "BUILD TEMPLATE" and "GANTT Timelines").

User Input

Prompted user input will always be shown in bold type and capital letters and will be enclosed within quotation marks (e.g., "**USER INPUT**"). You should not include the quotation marks.

Important Messages

Important messages appear in bold type without quotation marks and are preceded by an alerting word such as **NOTE** or **IMPORTANT** (see Page 17 for examples).

Software Installation

To install the CRDS software, the following actions need to be taken.

1. Insert Diskette #1 of the CRDS software (labelled CRDS1) into Drive A of the system on which the CRDS is to be resident.

2. Change to the A: disk drive by typing "**A:**" and pressing <**Return**> -- (<**Enter**> on some systems).

3. Run the install program (a batch program) by typing "**INSTLCRD**" and then pressing the <**Return**> key. The install program will prompt the user to remove "CRDS1" and insert "CRDS2". Then, the install program will create a directory called "CRD" on the C: drive and copy the CRD files to that directory. After the installation procedure is complete, the prompt "C:\CRD" will appear. This indicates that the user is in the newly created CRD directory.

Getting Started

If the system on which the CRDS is resident has been rebooted or turned off since the CRDS software was last used, the following actions need to be taken in order to use the CRDS.

1. At the "C:\CRD" prompt of the DOS environment, type **"METAWNDO"** and press **<Return>**. This action causes the graphics program to be run.

2. Type **"PRTSCRN"** and press **<Return>**. This causes the printer driver program to be run.

3. Type **"INST_CRD"** and press **<Return>** to run the graphics adapter program. (Note that this action needs to be taken only once, not every time you boot your system.) The user will be prompted for the desired graphics and print software from the host system and will receive a series of prompts to be answered either by typing a **"Y"** for yes or an **"N"** for no. Normally, the user will type **"Y"** in response to each query.

4. Type **"CRD"** and press **<Return>** to run the CRDS program. This will cause the CRDS "MAIN OPTIONS" menu to appear, as illustrated in Figure 2 below.

```
MAIN OPTIONS

FILES
BUILD TEMPLATE
CALCULATE CRITICAL PATH
DISPLAY PERT/GANTT
PRINT OPTIONS
ESC
```

Figure 2. The CRDS Main Options Menu

The CRDS Main Options Menu

The options in the main menu, when selected, may cause additional menus to appear. Each of the main options is briefly described below.

FILES: The "FILES" option displays a menu allowing the user to read or save a template, or to view the template directory.

BUILD TEMPLATE: The "BUILD TEMPLATE" option displays a menu allowing the user to create a new CRDS database or template.

CALCULATE CRITICAL PATH:	This option causes the critical path to be calculated, allowing the user to access the various output formats offered by the CRDS.
DISPLAY PERT/GANTT:	This option displays a menu containing the various output formats offered by the CRDS.
PRINT OPTIONS:	This option displays options for printing the inputs to a CRDS data file.

Selecting Menu Options in CRDS

To access menu options in the CRDS, perform the following steps:

1. Use the arrow keys to move the reverse video bar (the highlighted portion of the screen) over the option to be selected.

2. Press the <**Return**> key.

The options in a CRDS menu can also be selected by pressing the letter in each option that appears in boldface. For example, the user can access the "BUILD TEMPLATE" option by pressing "**B**".

NOTE: Selecting some options of the main menu will not produce a response unless appropriate inputs have been previously made to other options. For example, the "PRINT OPTION" of the main menu is not activated if a template has not been build or read into the computer memory and if the critical path of that template has not been calculated.

Pressing <**Esc**> causes the system to return to a previous screen or menu. Pressing <**Esc**> when in the main menu or selecting the "ESC" option of the main menu causes the system to exit to the DOS environment.

File Management

Selecting the "FILES" option of the CRDS main menu will cause the "FILES OPTIONS" menu, illustrated in Figure 3, to appear.

```
FILES OPTIONS
  READ TEMPLATE FROM DISK
  SAVE TEMPLATE TO DISK
  VIEW TEMPLATE DIRECTORY
  ESC RETURN TO MAIN
```

Figure 3. The CRDS Files Options Menu.

The items in the "FILES OPTIONS" menu enable users to save files and access them at a later time. Each of the options in this menu, as well as additional file management capabilities provided by the CRDS, will be discussed in the present section.

Reading CRDS Data Files From the CRDS Directory

To access a previously saved file from the CRDS directory, select the "READ TEMPLATE FROM DISK" option. The files directory will appear, as illustrated in Figure 4. File names are selected by moving the reverse video over the desired menu option and pressing **<Return>**.

NOTE: Valid names for CRDS data file or template contain one to eight alphanumeric characters. These names are stored in the CRDS directory and displayed in the files directory as an eight character-space file name (with the CRDS using underbars to fill in the eight character spaces, if necessary) and a CRDS-supplied three character extension name ".SRD."

```
SELECT FILE

FDC_____SRD



        TO SELECT A FILE PRESS RETURN
```

Figure 4. Directory of saved CRDS data files.

IMPORTANT: Accessing a file will erase from memory any data currently being used by the program. Therefore, if you were using the data of another template that was not already saved, as described in the next subsection, then you will lose that data.

To use the data that has been selected, press <**Esc**> to return to the "MAIN OPTIONS" menu. To exit the "READ TEMPLATE FROM DISK" option without selecting a file, press <**Esc**> without pressing <**Return**>.

NOTE: For the purpose of facilitating the current instructions, the user should select the "READ TEMPLATE FROM DISK" option, select the file "FDC_____.SRD", and then press <Esc> before continuing to the next subsection.

Saving CRDS Data Files to the PC Hard Disk

To save a CRDS template, select "SAVE TEMPLATE TO DISK" of the "FILES OPTIONS" menu. The menu for entering a file name, illustrated in Figure 5, will appear. Enter the desired name for the data file and press <**Return**>.

ENTER A FILE NAME MENU
>
PRESS RETURN WHEN FINISHED

Figure 5. Box allowing CRDS data file to be saved.

NOTE: The user need only enter the one to eight alphanumeric character name for the data file. Upon saving a template, the CRDS program will automatically insert underbars to file names with less than eight alphanumeric characters and add the ".SRD" extension name to the file name of all data files.

IMPORTANT: The name assigned to a template file saved to disk must be unique or else the CRDS will write over an existing file.

The "SAVE TEMPLATE OPTION" can be used only if the resources and tasks of a template have been defined. If these two parameters of a template have not been previously entered, a template file will not have been created and hence cannot be saved. In this case, the prompt illustrated in Figure 5 will not be displayed; the user must press <**Esc**> to return to the main menu.

The "SAVE TEMPLATE TO DISK" option allows the user to create duplicates of the CRDS data files. This feature enables the user to edit and introduce changes to one data file and keep the other unaltered.

If, following the instructions of the previous subsection, the user accessed (i.e., read) the data file named "FDC_____.SRD," the user should now save that data file with a new name, say, FDC2. Enter this new data file name, press <**Return**>, and then press <**Esc**> to return to the main menu. By following these procedures, the data file directory will now contain two data files, FDC_____.SRD and FDC2____.SRD, which contain the same information.

NOTE: If a CRDS data file is duplicated, any editing changes will apply only to the copy of the data file currently being edited. In other words, changes to a data file will apply only to that copy.

Viewing the List of CRDS Data Files Stored in the Directory

To view the CRDS directory of template files, select the "VIEW TEMPLATE DIRECTORY" option. A screen like that illustrated in Figure 4 will appear displaying the data files directory. If the user has followed the instructions of the previous two subsections, this directory will show "FDC_____.SRD" and "FDC2____.SRD" as the names of two templates.

Even though the screen contains the message, "TO SELECT A FILE, PRESS RETURN," the user will not be able to read data files from memory. The "VIEW TEMPLATE DIRECTORY" option merely allows the user to view a listing of existing CRDS templates.

CRDS File Management in the DOS Environment

Transferring CRDS data files

The user may transfer a CRDS template file from one system to another. This allows CRDS data files to be examined or modified by subject matter experts at more than one location. Transferring CRDS templates requires copying the desired data file from the "C:\CRD" directory of the system on which the CRDS is resident to another directory, normally on a floppy diskette that has been inserted into a floppy diskette drive of the system. To copy a file, complete the following steps.

1. First exit the CRDS by pressing the <**Esc**> key repeatedly. If the CRDS data file has not recently been saved, a warning message will

appear. Upon exiting the CRDS program, the prompt "C:\CRD" will be displayed, indicating that the user is in the "C:\CRD" subdirectory of the DOS environment.

2. Entering the DOS command **"Dir"** causes all CRDS files to be listed. All files that contain CRDS templates or data files are unique because of their ".SRD" extension names. If the guidance of the previous subsections has been followed, there will be one data file named "FDC_____.SRD" and another named "FDC2____.SRD". Assume that the duplicate file is to be copied.

3. Entering the DOS command **"copy"** followed by the complete name of the CRDS data file and the name of the external drive into which a diskette has been inserted will cause the file to be copied onto that diskette. To copy the file named "FDC2____.SRD", the user would type the following:

   "Copy FDC2____.SRD A:"

   In the above example, "A:" refers to the destination drive (the drive to which the file is to be copied).

Deleting CRDS data files

Deleting data files from the CRDS files directory must be accomplished from the DOS environment. To delete data files, complete the following steps.

1. First exit the CRDS by pressing the <**Esc**> key repeatedly. If the CRDS data file has not recently been saved, a warning message will appear. Upon exiting the CRDS program, the prompt "C:\CRD" will be displayed, indicating that the user is in the "C:\CRD" directory of the DOS environment.

2. Entering the DOS command **"Dir"** causes all CRDS files to be listed. All files that contain CRDS templates or data files are unique because of their ".SRD" extension names. If the guidance of the previous subsections has been followed, there will be one data file named "FDC_____.SRD" and another named "FDC2____.SRD". Assume that the duplicate file is to be deleted.

3. Entering the DOS command **"del"** or **"erase"** followed by the complete file name of the data file and pressing <**Return**> will cause that data file to be eliminated. Using the above example, to delete the file "FDC2____.SRD", the user would type **"Del"** followed by a space and then the complete file name, as shown below.

   "Del FDC2____.SRD"

   Pressing <**Return**> causes the named file to be deleted from the file directory.

PART FOUR -- BUILDING A CRDS DATA FILE

Overview

Part Four of the User's Guide addresses procedures to be followed for building a CRDS data file, also called a crew template. As described in Part Two of this guide, a crew template is comprised of the information required to describe precisely the composition and structure of a crew. The CRDS assists the user in building the template through the presentation of highly formatted data input screens. After an overview of the types of data input required and of constraints on the order of entering the data, this part of the User's Guide will provide detailed descriptions on how to build a template.

To facilitate the user's understanding of these instructions, the user will be asked to enter the data required to define an example of a template for the crew of a prototype weapon system. Instructions that specifically address the building of this template will be presented separately from the more general descriptions on how to build a template. These specific instructions are indented and, as mentioned previously, the prompted input appears in bold type.

Required Data Input

As introduced in Part Three of this guide, the user builds a model of a crew by entering data into the preformatted files of the "BUILD TEMPLATE OPTIONS" menu. This menu, illustrated in Figure 6, is accessed from the CRDS "MAIN OPTIONS" menu.

```
BUILD TEMPLATE OPTIONS
ENTER RESOURCES/ITEMS
ENTER TASKS
ASSIGN RESOURCES TO TASKS
ASSIGN TASK RELATIONS
ENTER PERFORMANCE MEASURES
SELECT ACTIVE TASK MEASURE
ESC
```

Figure 6. The CRDS Build Template Options Menu.

As may be seen in Figure 6, there are six options in the "BUILD TEMPLATE OPTIONS" menu that address the input of six different types of data and one option for escaping from the "BUILD TEMPLATE OPTIONS" menu to return to the CRDS "MAIN OPTIONS" menu. To build a complete template, each of the six data input options of the "BUILD TEMPLATES OPTIONS" menu must be selected and completed. After each menu option has been selected for data input, an arrow will appear next to that menu option.

By way of preview, the data input required for each of the menu items is described in succeeding paragraphs.

- Resources/items: Enter the number and names of the different types of crew members that are available and assigned to perform the tasks required by the mission of the crew.

- Tasks: Enter the number and names of the different tasks that must be performed if the crew is to accomplish its mission.

- Assign Resources to Tasks: Enter the numbers and the names of types of crew members assigned to perform each unique task.

- Assign Task Relations: Enter the names of all tasks whose performance must be completed before performance on a currently identified task can begin.

- Performance Measures: Enter the time required for each crew member to perform each task to which they have been assigned.

- Select Active Task Performance Time Measure: If two sets of performance time measures have been entered, the user must specify which one is to be used during a particular run of the CRDS.

Required Order for Data Entry

The user must first enter the numbers and names of the different types of crew members and the different tasks that need to be performed, though the order of entering these two template parameters is not relevant. The number of different types of crew members and the number of tasks which must be performed are necessary and sufficient to create and to save a CRDS data file. Secondly, the user can enter information necessary to assign task relations and to assign types of crew members to tasks, but there is no prescribed or preferred order for entering these two template parameters. Finally, the user would enter task performance time data.

Succeeding sections of this part of the User's Guide will provide detailed instructions for responding to each of the options in the *"BUILD TEMPLATE OPTIONS"* menu, in the order in which they occur and are illustrated in Figure 6. In the process of working though these sections, the user will build a template for the crew of a prototype gun system.

Enter Resources/Item Information

The "ENTER RESOURCES/ITEMS" option of the "BUILD TEMPLATE OPTIONS" menu prompts the user to specify the number of different types of crew members required to perform mission essential tasks and then to provide the names for each type of crew member.

When defining this parameter of a template, it is most common to refer to either the title of the duty position or to the military occupational specialty (MOS) and the associated grade or skill level of each type of crew member.

To enter crew member information, the following actions need to be taken.

1. Select "ENTER RESOURCES/ITEMS" from the "BUILD TEMPLATE OPTIONS" menu. The screen displayed in Figure 7 will appear prompting the user to enter the number of different types of crew members.

```
ENTER NUMBER OF RESOURCES IN THIS TEMPLATE
> 3
PRESS RETURN TO CONTINUE
```

Figure 7. Screen allowing desired number of resources to be entered.

To build the template for the prototype gun, the user should enter "3" and press <**Return**>.

2. After entering the required number of different types of crew member and pressing <**Return**>, the box illustrated in Figure 8 will be displayed to prompt the user to enter the name of the first type of crew member. (The maximum length of the name of a crew member is 10 alphanumeric characters.)

```
ENTER NAME OF RESOURCE NUMBER 01
> SQUAD LDR
PRESS RETURN TO CONTINUE
```

Figure 8. Screen prompting resource name.

3. After entering a name for each type of crew member and pressing <**Return**>, the screen shown in Figure 8 will be redisplayed to prompt the user to enter the name for the next (successively higher numbered) type of crew member.

4. After entering the name of the final type of crew member, the next press of the <**Return**> key will redisplay the "BUILD TEMPLATE OPTIONS" menu illustrated in Figure 6. There will be an arrow next to the "ENTER RESOURCES/ITEMS" option, indicating that input to that option has been provided.

To build the template for the prototype gun, the user should enter the following names for the types of crew members as their numbers are prompted.

Prompted Resource (Crew Member) Number	Resource (Crew Member) Name Input
"1"	**"Squad Ldr"**
"2"	**"Gunner"**
"3"	**"Loader"**

IMPORTANT: At the present stage of development, CRDS does not allow the user to edit input to the "ENTER RESOURCES/ITEMS" option after it has been entered. If this option is reentered for the purpose of editing,

the prompt for the number of resources in the template will not reappear and changes made to resource or crew member names will not be reflected in any of the subsequent screens or printouts. If an incorrect entry is made, the user must exit the system and reinitiate the procedure for building template.

NOTE: Normally, each different type of crew member will be given its own unique name. However, there may be occasions in which more than one instance of a particular type of crew member may be needed to accomplish a mission in a timely manner. For example, several indistinguishable lower ranking soldiers may be necessary to provide general support to the fire mission of a howitzer crew. Once the precise roles of these multiple instances of a type of crew member have been clearly differentiated and defined, they should be given unique identities in the crew template, e.g., Crewmember 1 and Crewmember 2.

Enter Tasks

The procedure for defining the mission essential tasks of the crew is similar to that for defining types of crew members. To enter information on the tasks the crew is required to perform, the following actions need to be taken.

1. Select the "ENTER TASKS" option of the "BUILD TEMPLATE OPTIONS" menu. Figure 9 will appear prompting the user to enter the number of tasks.

ENTER NUMBER OF TASKS IN THIS TEMPLATE
> 8
PRESS RETURN TO CONTINUE

Figure 9. Screen prompting desired number of tasks.

To build the template for the weapon called gun, the user should enter "8" and press **<Return>** to indicate that the mission of the crew requires the performance of eight tasks.

Important: The number of required tasks cannot be edited once the value has been entered and the <Return>

key pressed. If an incorrect entry is made, the user must exit CRDS, without saving the data file, and start the data file building procedure again.

2. After defining the number of tasks, pressing <**Return**> causes the box shown in Figure 10 to be displayed. This screen prompts the user for the name of the first task (10 character spaces maximum).

   To continue building the template for the prototype gun, the user should enter "**Attend Scn**" (for attend to the scanner) as the name for the first mission task.

Enter task 01 name with a maximum of 10 characters
> Attend Scn
PRESS RETURN TO CONTINUE

Figure 10. Box prompting short task name.

3. After entering the name of the first task, pressing <**Return**> causes the box shown in Figure 11 to be displayed. This screen prompts the user to enter a longer version of the task name or a comment on the short name just entered.

Enter long name for task
PRESS RETURN TO CONTINUE

Figure 11. Screen prompting long task name.

NOTE: Due to an error in the present version of CRDS, while the long names or comments for tasks can be entered, they cannot be later retrieved, either on the screen or in printouts. Therefore, there is no need for inserting any information in these "long name" screens. Instead, press <Return> each time the prompt for long task names appears.

To continue building the template for the gun, the user should enter the following task names as each task number is prompted.

Prompted Task Number	Task Name Input
"2"	**"Ann Tgt"**
"3"	**"Fire Ord"**
"4"	**"Aim Gun"**
"5"	**"Fire Gun"**
"6"	**"Load Gun"**
"7"	**"Check Chbr"**
"8"	**"Unload Gun"**

4. When the last of the predesignated tasks have been named, pressing the <**Return**> key will return the user to the "BUILD TEMPLATE OPTIONS" menu. There will be an arrow next to the "ENTER TASKS" option, indicating that input has been provided to this option.

NOTE: Each different task should be given its own unique name. This is particularly important because a task network must be developed and a type of crew member assigned to perform each task. In some cases, the mission of the crew may be to perform a specific task repeatedly. For example, launch (or load) multiple but identical missiles from (or on to) a missile launcher. In these cases, the user should use unique task names to differentiate among instances of the otherwise identical tasks, e.g., Fire1, Fire2, etc.

Editing Task Name Entries

The CRDS allows task names to be edited. To edit these entries, reselect "ENTER TASKS" from the "BUILD TEMPLATE OPTIONS" menu and press the <**Return**> key. Pressing <**Return**> will make the short task names appear in the order in which they were entered. Continue pressing the <**Return**> key until the task name to be edited appears. Press the space bar to delete that task name, and enter the new task name. Pressing <**Return**> only allows the user to move forward through the task list. If the user accidentally moves past the task name that is to be changed, it will be necessary to move the end of the task list and start again.

Saving Your Work

The user can save the template that has been thus far developed. To do so, access the "FILES" option of the "MAIN OPTIONS" menu. Then access the "SAVE TEMPLATE TO DISK" option and enter the desired data file name. The user should consider saving the template or partially built template after any significant amount of data input. By doing so, the user can avoid losing the entire file should there be an accidental exit from the system.

To save the partially built template for the prototype gun, the user should access the "SAVE TEMPLATE TO DISK" option and enter the name "**Example**" for the filename when prompted to do so.

Assign Resources to Tasks

Having specified both the required tasks of the crew and the types of resources or crew members, the user can designate which type of crew member will perform each task. To do so the user should select the "ASSIGN RESOURCES TO TASKS" option of the "BUILD TEMPLATE OPTIONS" menu. A screen similar to that shown in Figure 12 will be displayed.

This screen permits the user to specify information needed to allocate crew members to tasks. These items of information are features of the sentence which is displayed within the rectangle shown near the bottom of the screen:

"There are ___a___ number of Resource ___b___ assigned to Task ___c___."

Using this screen, the user specifies: (a) how many of (b) each particular type of crew member will be assigned to perform (c) each required crew task.

By entering the values assigned to various combinations of these three items of information, the user specifies the allocation of crew members to tasks. The steps which cause these allocations are described in succeeding paragraphs.

1. To specify the name of the task, which will appear in the top and bottom lines of the screen as well as at the right end of the rectangle, the user presses the <**Ctrl-Arrow**> keys (i.e., the <**Ctrl**> and <**Left- or Right-Arrow**> keys pressed simultaneously).

```
RESOURCES AVAILABLE TO BE ASSIGNED TO TASK  Check Chbr
SQUAD LDR   GUNNER   LOADER


There are 01 number of Resource LOADER assigned to Task      Check Chbr
RESOURCES ASSIGNED TO TASK   Check Chbr
```

Figure 12. Screen allowing assignment of resources to tasks.

2. To assign a particular type of crew member to perform the designated task, the user presses the arrow keys (i.e., the < **Right-Arrow**> or <**Left-Arrow**>) to highlight the name of that type of crew member in the list which is displayed near the top of the screen and to display that name in the center of the rectangle.

3. To increase or decrease the value of the number shown at the left-end of the rectangle to indicate how many of the identified type of crew member are required to perform the designated task, the user presses the plus (<+>) or minus (<->) keys, respectively.

NOTE: More than one instance of a particular type of crew member may be assigned to perform a given task, e.g., two identically classified mechanics may be assigned to perform the task of removing a heavy item of equipment from the engine compartment of a vehicle. Likewise, more than one type of crew member may be assigned to perform a given task, e.g., a military police service member and a military intelligence service member may both be assigned to the task of interrogating an enemy prisoner of war. An illustration of both of the examples given above would be one gunner and two loaders assigned to the task of rearming a weapon platform.

4. The user repeats each of Steps 1, 2, and 3 until all assignments are completed.

5. When all assignments are completed, the user presses the <**Esc**> key to quit the "ASSIGN RESOURCES TO TASKS" option and return to the "BUILD TEMPLATE OPTIONS" menu. This menu will show an arrow to the left of the "ASSIGN RESOURCES TO TASKS" option to indicate that this option has been addressed by the user.

To continue building the template of the prototype gun, the user should make the follow assignment of types of crew members to tasks:

Number of	Type of Crew Member	Assigned to Task
"1"	**"Squad Ldr"**	**"Attend Scn"**
"1"	**"Squad Ldr"**	**"Ann Tgt"**
"1"	**"Squad Ldr"**	**"Fire Ord"**
"1"	**"Gunner"**	**"Aim Gun"**
"1"	**"Gunner"**	**"Fire Gun"**
"1"	**"Loader"**	**"Load Gun"**
"1"	**"Loader"**	**"Check Chbr"**
"1"	**"Loader"**	**"Unload Gun"**

Editing Allocation of Resources to Tasks

The user should re-access the "ASSIGN RESOURCES TO TASKS" option and repeatedly press the <**Ctrl-Arrow**> and the <**Arrow**> keys to examine the entries that have been made, checking them for their accuracies. If a change is desired in any previous assignment it can be made by following the instructions given in Steps 1 through 3 above for that particular data input.

Saving Your Work

The user can save the template that has been thus far developed. To do so, access the "FILES" option of the "MAIN OPTIONS" menu. Then access the "SAVE TEMPLATE TO DISK" option and enter the desired data file name.

To save the partially built template for the gun, the user should access the "SAVE TEMPLATE TO DISK" option and enter the name "**Example**" for the filename when prompted to do so.

Assign Task Relations

The "ASSIGN TASK RELATIONS" option of the "BUILD TEMPLATE OPTIONS" menu is used to specify any required order in which mission essential tasks must be performed. The only prerequisite for providing this information is that the tasks themselves must first be specified in the "ASSIGN TASKS" option.

Selecting "ASSIGN TASK RELATIONS" will display the screen displayed in Figure 13. This screen shows at the top of the screen a list of all the previously specified tasks. Inside the rectangular box near the bottom of the screen is shown the name of a task whose predecessor is currently under consideration and a number designating its serial position in the order in

```
CANDIDATES TO PRECEDE TASK
Attend Scn    Ann. Tgt   Fire Ord    Fire Gun     Load gun
Check Chbr    Unload Gun

 Current Task Name  Check Chbr  and Number  07

TASKS TO PRECEDE CURRENT TASK
Fire Gun
```

Figure 13. Screen allowing task relations to be established.

which the task names were entered. The user designates which of the previously specified tasks are "predecessor" tasks whose performance must be completed before the performance of the "current" task can be initiated. To designate tasks as predecessors, the following steps need to be taken.

1. Press the <**Ctrl-Arrow**> keys as necessary to change the task appearing in the rectangle.

2. Tasks which are predecessors to the task shown in the rectangle are designated by pressing the <**Arrow**> keys. Pressing the <**Arrow**> keys moves the reverse video bar over the list of candidate predecessor tasks.

3. When a desired predecessor task has been highlighted (covered by the reverse video), press <**Return**> to establish that task as a predecessor for the task shown in the rectangle. The selected predecessor task will be displayed below the rectangular box.

NOTE: The "ASSIGN TASK RELATIONS" procedure will not allow assignments that will create cycles. A cycle occurs when two tasks either are defined as directly or indirectly preceding each other, thus creating a circular path. The CRDS will not display an error message if the user attempts to assign a circular path. Instead, the task will simply not appear below the rectangular box.

4. Repeat Steps 1 through 3 until all required task relationships have been established.

5. After all required predecessor tasks been entered, press <**Esc**> to return to the "BUILD TEMPLATE OPTION" menu. An arrow next to "ASSIGN TASK RELATIONS" option indicates that information has been entered for this option.

NOTE: This set of data will be determined by a large number of factors, to include equipment constraints (e.g., a gun must be loaded before it can be fired) and operational constraints (e.g., a target must be positively identified as a threat before it can be engaged). The performance of a given task may have to await the completion of more than one predecessor task and the performance of more than one task may be initiated simultaneously after the performance of a given predecessor task is completed.

To continue building the template for the gun, the user should select "ASSIGN TASK RELATIONS", and enter the following input:

<u>Current Task</u> (in rectangle)	<u>Predecessor Task</u> (highlight)
"Attend Scn"	[None]
"Ann Tgt"	[None]
"Fire Ord"	**"Ann Tgt"**
"Aim Gun"	**"Fire Ord"**
"Fire Gun"	**"Load Gun"** and **"Aim Gun"**
"Load Gun"	[None]
"Check Chbr"	**"Fire Gun"**
"Unload Gun"	**"Fire Gun"**

: remainder of this section on assigning task relations may be skipped if the reader is not interested in a rationale for the task relations assigned in the example template.

1. The mission scenario begins with the Squad Leader viewing a scanner. Therefore, "Attend Scn" has no necessary predecessor.

2. Viewing the scanner and announcing a target are tasks which may be performed concurrently. However, the Squad Leader may identify a target without viewing the scanner. Therefore, "Attend Scn" is not listed as a necessary predecessor for "Ann Tgt".

3. "Fire Ord" has "Ann Tgt" as a necessary predecessor because a target must be announced before the Squad Leader can order the Gunner to engage it.

4. It is assumed that the Gunner will not aim the gun at a target unless and until the Squad Leader issues a fire order. (Note that this set of task relationships will allow the Gunner to aim an unloaded gun.)

5. In order for the gun to be fired, it must have been loaded and aimed. Therefore, "Fire gun" has both "Aim Gun" and "Load Gun" as required predecessors.

6. For this example mission, "Load Gun" has no necessary predecessors. In a combat mission, weapons would generally be loaded prior to beginning an operation.

7. The example template presumes that the firing chamber is checked whenever the gun has been fired. The "Check Chbr" task therefore has "Fire Gun" as a necessary predecessor.

8. For this example template, the gun must be fired before an empty shell casing can be removed. Therefore, "Fire Gun" is listed as a necessary predecessor for "Unload Gun".

In order to determine the critical path, the CRDS requires only that the predecessors immediately preceding the task currently under consideration be entered. For example, in the template of the gun crew, even though the performance of a number of tasks may be required before the task of "Unload Gun" may be performed, the task "Fire Gun" is the **last** required predecessor. Therefore, it is sufficient to only enter

"Fire Gun" to establish all the tasks which must precede the performance of "Unload Gun". In fact, as defined, "Unload Gun" must be preceded by "Fire Gun", which must be preceded by "Aim Gun" and "Load Gun". In turn, "Aim Gun" must be preceded by the task sequence of "Attend Scn", "Ann Tgt", and "Fire Ord". The only one of the eight tasks which is not a required predecessor to "Unload Gun" is "Check Chbr", and it might be presumed that the latter task is performed concurrently with unloading the empty shell casing.

Editing Task Sequence Information

Task sequence can be edited at any time. Simply reenter the "ASSIGN TASK RELATIONS" option of the "BUILD TEMPLATE OPTIONS" menu. The screen illustrated in Figure 13 will be redisplayed.

To delete (or un-assign) a task as a necessary predecessor, press the <**PgDn**> key. This moves the reverse video bar to the bottom of the screen thereby allowing a previously selected task to be highlighted. Press the <**Arrow**> keys to highlight one of the previously selected predecessor tasks and then press <**Return**> to delete that task. The deleted task will no longer be listed as a necessary predecessor of the task appearing in the rectangle.

Pressing the <**PgUp**> key will return the video bar to the list of candidate predecessor tasks at the top of the screen. Pressing <**Esc**> will return the display to the "BUILD TEMPLATES OPTIONS" menu.

Saving Your Work

As previously described, the user can and generally should access the "FILES" option to save the template that has been thus far developed.

Enter Performance Measures

The "ENTER PERFORMANCE MEASURES" option allows the user to specify the time required to perform each task defined for the template. Before using this option the user must have completed all of the options which precede it in the "BUILD TEMPLATE OPTIONS" menu, i.e., "ENTER RESOURCES/ITEMS", "ENTER TASKS", "ASSIGN RESOURCES TO TASKS", and "ASSIGN TASK RELATIONS."

The procedure for entering individual task durations is outlined below.

1. Select the "ENTER PERFORMANCE MEASURES" option of the "BUILD TEMPLATE OPTIONS" menu.

The box illustrated in Figure 14 will be displayed, prompting the user to input for the number of alternative sets of performance measures that are to be entered. The CRDS allows the user to enter either one or two sets of task performance time estimates for a single data file. For example, this option enables the user to enter task durations for two sets of mission conditions (e.g., rested and fatigued crews) or for two alternative equipment configurations.

NOTE: Due to an error in the present version of the CRDS, while two sets of task performance time data may be entered, only the first set entered can be reliably retrieved for inclusion into a template. Therefore, the user is encouraged to enter only one set of performance time data for each data file. Alternate sets of performance time data may be entered into copies of the original template.

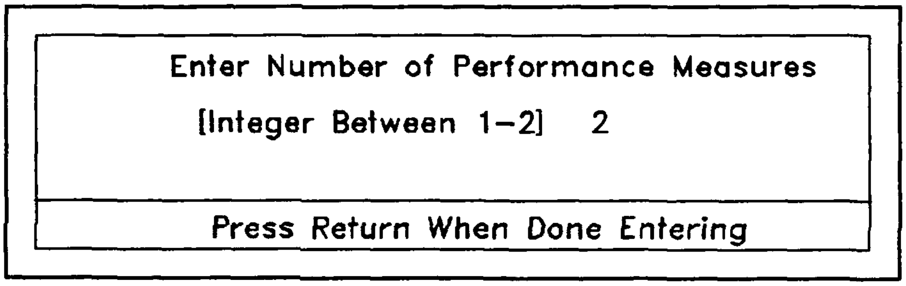

Figure 14. Screen allowing desired number of performance measures to be entered.

2. Enter the desired number of performance measures into the screen illustrated in Figure 14 and press <**Return**>. Another screen, illustrated in Figure 15, will appear prompting the user for the name of the (first) performance measure.

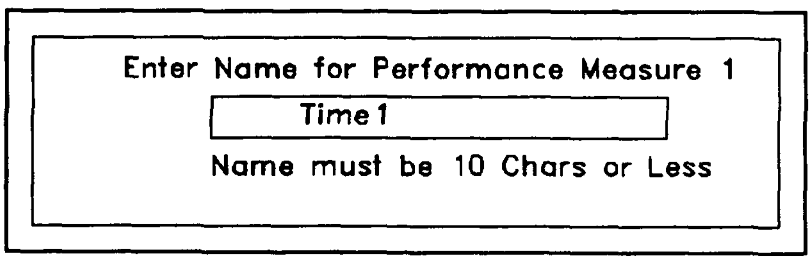

Figure 15. Box prompting the name of the first set of estimates.

3. Enter the name of the performance measure into the space provided and press **<Return>**. Another display will be added to that illustrated in Figure 15, prompting the user to define the unit of measure for the named measure. This new display is illustrated in Figure 16.

4. Enter the time unit of the defined task performance measure. The user could enter

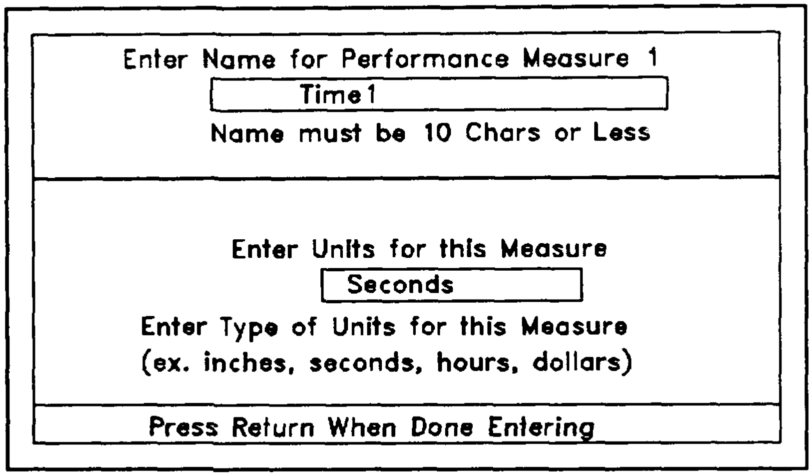

Figure 16. Screen allowing time unit to be entered.

minutes, seconds, or fractions of time units as appropriate. For example, 1/2-second or two-second intervals could be used.

IMPORTANT: Even though non-temporal performance measures are listed as options, at this stage of its development, the CRDS is equipped to process only temporal measures of performance.

5. If the user has indicated in Step 2 that two measures of performance were to be entered, the next two presses of the **<Return>** key will redisplay the prompts illustrated in Figures 15 and 16, prompting for the name of the second set of time measures and the name of the second set of time units, respectively.

NOTE: The CRDS provides no editing capability for the above inputs to the "ENTER PERFORMANCE MEASURES" option. However, as the above inputs consists of <u>labels</u> for the performance time measures, the consequences of making an incorrect entry are not very serious. The task durations themselves <u>can</u> be edited, as described below.

6. After the information called for in Steps 1 through 5 has been entered, pressing <**Return**> will display a screen similar to that illustrated in Figure 17. This screen prompts the user to enter the performance duration for each task, beginning with the first task entered in the "ENTER TASK" option of the "BUILD TEMPLATE OPTIONS" menu. Each time a task duration is entered, pressing the <**Return**> key will cause the screen to reappear, prompting the estimated duration of the next task in the sequence. Figure 17 is

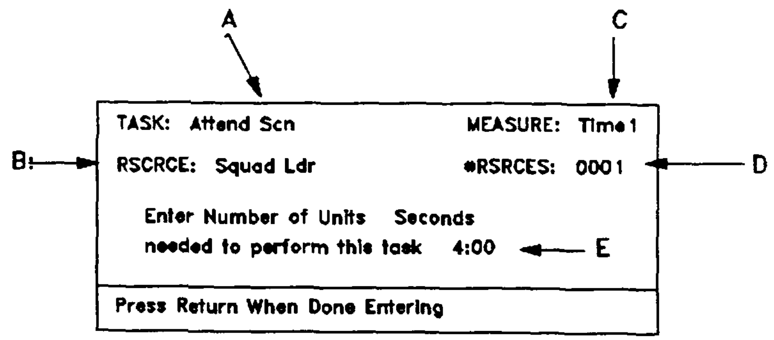

Figure 17. Screen prompting estimated task duration.

labelled to show the locations on the screen of the following information:

A. Name of the task to be assigned a performance measure.

B. Name of the type of crew member assigned to perform the task.

C. Name of the performance time measure (see NOTE on page 45).

D. Required number of the indicated type of crew member.

E. The performance time of the indicated type of crew member (in the time units previously specified).

The CRDS provides information for locations labelled A through D in Figure 17; the user must provide the actual performance time measure in the space labelled E.

7. Once all the performance time measures have been entered, press <**Return**> to return to the "BUILD TEMPLATE" options menu.

To continue building the example template, the user should enter the following performance time measures. (The measure, named Time1, is in units of "**seconds**").

Prompted Task Name	Input To Time1
Attend Scn	"6.0"
Ann Tgt	"2.0"
Fire Ord	"1.0"
Aim Gun	"3.0"
Fire Gun	"1.0"
Load Gun	"4.0"
Check Chbr	"3.0"
Unload Gun	"4.0"

Editing Performance Measures

To edit performance measures, re-select the "ENTER PERFORMANCE MEASURES" option of the "BUILD TEMPLATE OPTIONS" menu. The screen illustrated in Figure 17 will be presented for the first task defined. If necessary, the user can enter any corrections to the performance time measure for this task. Repeatedly pressing the <**Return**> key causes the CRDS to display the data screen appropriate for each task in succession. Pressing the <**Esc**> key will abort the editing at any time and return the user to the "BUILD TEMPLATE OPTIONS" menu.

Select Active Task Measure

If two sets of task performance time measures have been entered, the user must specify which one is to be used for a subsequent analysis of the template created. The default and normally only active task measure is the first set of measures entered (see NOTE on Page 41).

To select the active task measure, perform the following steps.

1. Select the "SELECT ACTIVE TASK MEASURE" option of the "BUILD TEMPLATE OPTIONS" menu.

2. Enter the number of the task performance time measure that is to be used in the subsequent analysis and press <**Return**> to return to the "BUILD TEMPLATE OPTIONS" menu.

PART FIVE -- VIEWING AND PRINTING CRDS OUTPUT

Introduction

After the data required to build a CRDS template have been entered, the user can examine and analyze that template using any of the various tabular and graphic representations provided by the CRDS of those data. The user can also obtain printouts of CRDS information. These include both the input to the CRDS - the information entered through the BUILD TEMPLATE OPTIONS - and the CRDS output - the graphic and tabular summaries of the template data files. However, before this information becomes available, either on the monitor screen or in print, the user must first calculate the critical path.

<u>Calculating the Critical Path</u>

The CRDS automatically calculates the critical path based upon the performance times of tasks and the contingencies among tasks. To calculate the critical path, select the "CALCULATE CRITICAL PATH" option from the "MAIN OPTIONS" menu. Once an arrow is displayed to the left of this option, as illustrated in Figure 18, the critical path has been calculated. The user can now access the various representations of the template data, either on the monitor screen or in hard copy.

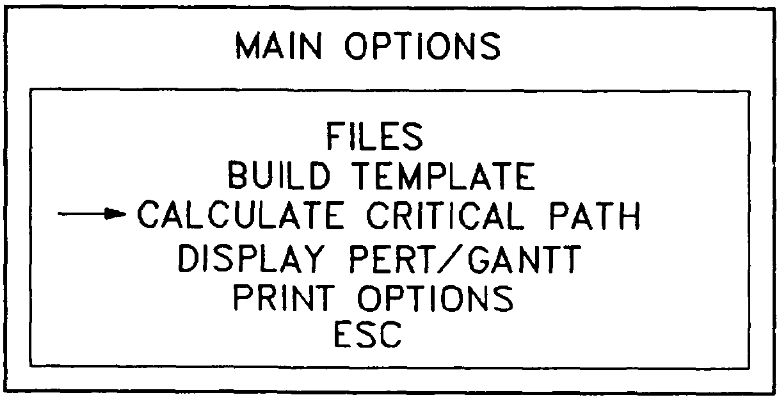

Figure 18. CRDS Main Menu with critical path calculated.

The CRDS Print Capability

As mentioned previously, calculating the critical path enables the user to print CRDS data. These data consist of both the input provided by the user when building the template, and also the various representations and summaries of the crew data file provided by the CRDS. The procedure for printing summaries of the CRDS input will be discussed first.

IMPORTANT NOTE: To successfully obtain printouts of information associated with a CRDS data file, the current version of the CRDS software requires that the resident personal computer be directly connected through its parallel output port to a dedicated Epson-compatible printer. Laser printers are not compatible with the CRDS software and will not print graphic and tabular outputs of the CRDS.

Printing CRDS Input

In order to obtain printouts of the information entered through the "BUILD TEMPLATE OPTIONS" menu, the user must select "PRINT OPTIONS" from the CRDS "MAIN OPTIONS" menu. A PRINT MENU, illustrated in Figure 19,

```
TASK LABELS
REQUIRED NUMBER PER TASK
DUTY PSN OR ITEM LABEL
REQUIRED PREDECESSOR EVENTS
DUTY POSITION OR ITEM PERFORMABILITY
PRINT ALL
ESC
```

Figure 19. CRDS Files Options Menu

will be displayed. If selected, the options of this menu will cause the following information to be printed.

"TASK LABELS" - The (short) names of mission essential tasks.

"REQUIRED NUMBER PER TASK" - The number and names of each type of crew member assigned to perform each task.

"DUTY PSN OR ITEM LABEL" - The names of the types of crew members assigned to the crew.

"REQUIRED PREDECESSOR EVENTS" - The names of all predecessor tasks for each required task.

"REQUIRED SUCCESSOR EVENTS" - The names of all successor tasks for each required task.

"DUTY POSITION OR ITEM PERFORMABILITY" - The performance time data for each required task, listed separately for each type of crew member.

"PRINT ALL" - Each of the six input data sets described above.

Printing CRDS Output

Calculating the critical path also allows the user to print copies of the tabular and graphic output provided by the CRDS. Two different procedures are available to print most types of CRDS output. To print any CRDS output, display that output on the monitor screen (the procedures for displaying the various output are discussed in the next section) and press the <**Print Screen**> key (the <**Prt Sc**> key on some systems). This key press will cause only that part of the output displayed on the monitor screen to be printed.

Some CRDS output may be printed by displaying the output of interest on the monitor screen and pressing the **"P"** key. When this method is applicable, a prompt or instruction to enter "P" to obtain a printout is displayed beneath the output on the monitor screen. When this procedure is available and selected, all of the designated CRDS output data will be printed, even if it is not all displayed on the monitor screen.

Accessing CRDS Output

Calculating the critical path is necessary in order for the user to view the various types of CRDS outputs. These outputs can be used to examine and analyze the template and, if judged desirable, to search for and create alternative crew designs. The creation of an alternative crew design is accomplished by modifying the data which define the crew template. Procedures for modifying a crew template are described in Part Six of this User's Guide. The remainder of this part of the guide will describe how to access each of the output formats and the types of information available when each one is selected for viewing.

To view the different representations of CRDS output, select the "DISPLAY PERT/GANTT" option of the "MAIN OPTIONS" menu. This action will display the menu illustrated in Figure 20. This menu is not labelled when displayed on the screen. However, because it is accessed by selecting the "DISPLAY PERT/GANTT" option of the "MAIN OPTIONS" menu, it will be referred to in this User's Guide as the "PERT/GANTT options" menu.

Resource Loading
See critical Task
Conflict Adjustment
GANTT Timelines
Deconfliction Analysis
Conflict Overlap
→ Calculate Critical Path
PERT Diagram
ESC

Figure 20. PERT/GANTT Options Menu.

The descriptions of the CRDS outputs that follow will use the data file created when the template named "Example" was built following the instructions given in Part Four of this User's Guide. Consequently, if the user has exited the CRDS since building and saving this template built for the crew of a prototype gun system, the user should read this file from the CRDS directory before continuing.

Since the GANTT chart presents the template timeline information in an especially useful graphical format, it will be discussed first.

GANTT Timelines

Instructions for Accessing the "GANTT Timelines" Option

To access the GANTT chart, the following actions need to be performed.

1. Select the "GANTT Timelines" option from the PERT/GANTT options menu. Doing so causes the menu illustrated in Figure 21 to be displayed. This latter menu lists the two GANTT display options offered by the CRDS: (a) a display of the task timeline for all types of crew members together in one GANTT chart, and (b) a display of the timeline attributable to one specified type of crew member. The GANTT chart presenting the timeline for all types of crew members will be described first.

2. Select "Display GANTT" from the menu illustrated in Figure 21 to display the GANTT chart for the template named "Example." This

GANTT chart is illustrated in Figure 22. The various features of the GANTT chart will be described in the next subsection.

Display GANTT
Select Resource
ESC

Figure 21. GANTT Chart Options Menu.

Features of the GANTT Timeline Chart

- The GANTT timeline is a graphic representation of the schedule of start and stop times for each task performed during a crew's mission. If the mission duration is less than 20 seconds, the task timeline is divided into single-second intervals. If mission duration is 20 seconds or longer, the total mission duration will be divided into ten equal timeline intervals.
- Each task timeline is represented by a task name and by a line segment proportional in length to the duration of that task.

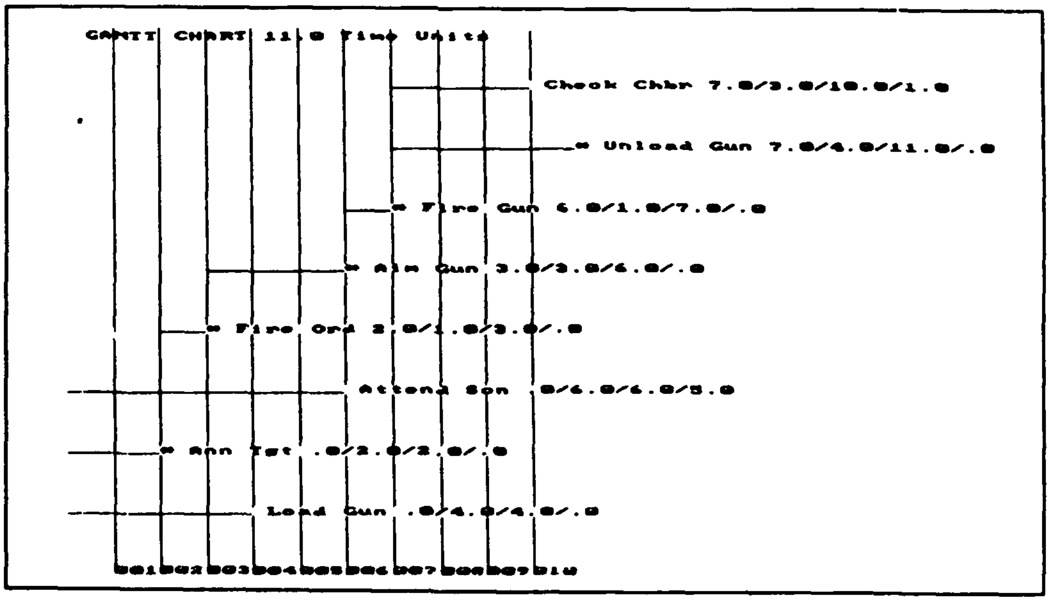

Figure 22. GANTT timeline chart for all types of crew members in the template named "Example."

- Repeated presses of the "+" (plus) key makes the GANTT chart smaller. Conversely, repeated presses of the "-" (minus or hyphen) key makes the GANTT chart larger. If the GANTT chart is too large to fit on the monitor screen, pressing the arrow keys displays different portions of the GANTT chart.

NOTE: It is worth repeating that the print capability for a GANTT chart (the <Print Screen> key) will print only that portion of the chart which is displayed.

- Each task on the critical path is presented with an asterisk preceding the task name.

- The sequence of numbers following each task name refers, in order, to the start, duration, stop, and slack time of the task. For critical tasks, the last value will always be zero.

- The number at the top of a GANTT chart which displays the tasks performed by <u>all</u> types of crew members refers to the stop time of the last task to be completed. This number is also the total duration of the mission.

The GANTT chart can be used to observe and identify tasks whose performance overlap in time. When two or more tasks performed by the same type of crew member overlap on the GANTT timeline, they may represent a conflict which the user will want to resolve through some modification in the parameters of the template.

The information in the GANTT chart for each type of crew member is also available, in a less cluttered and perhaps more useful form, in separate GANTT charts for each individual type of crew member. To view GANTT charts for a specific type of crew member, Press <**Esc**> to return to the menu for the GANTT chart (shown in Figure 21). Select the "Select Resource" option to display a listing of the names of types of crew members. Selecting one of the names and pressing <**Return**> will display the GANTT chart displaying only the timelines for tasks performed by that type of crew member.

> To continue using the template named "Example," select **"Squad Ldr"** to display the GANTT chart for squad leaders, illustrated in Figure 23.

It may be seen that three of the tasks assigned to the crew member named Squad Ldr, i.e., the tasks named "Ann Tgt," "Attend Scn," and "Fire Ord," are performed in overlapping time intervals.

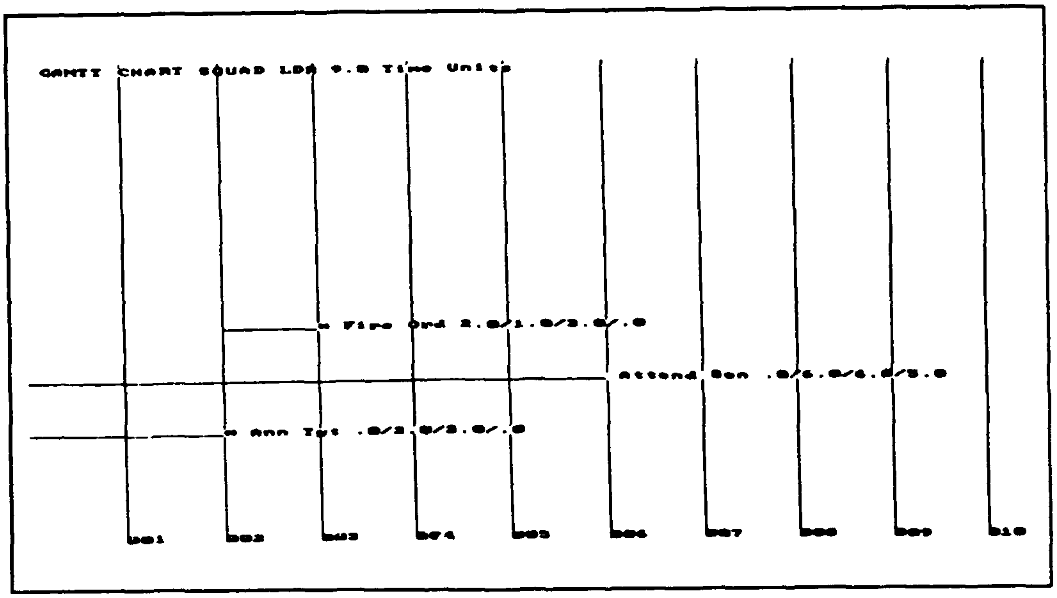

Figure 23. GANTT timeline for tasks performed by the crew member type named "Squad Ldr."

The requirement to perform multiple tasks concurrently could overload this type of crew member. To illustrate, the tasks shown as being performed simultaneously could demand concurrent and incompatible responses of this type of crew member (e.g., that the squad leader look in opposite directions at the same time), or they could demand that different tasks be performed concurrently at different physical locations with respect to the weapon system (e.g., perform one task while the squad leader is to the left and another while the squad leader is to the right of the gun barrel). This overload in task demands on one squad leader could cause the performance of one or more tasks, and hence the performance of the total mission, to deteriorate. We will return to this discussion in Part Six to illustrate how to modify templates.

It should also be noted that the number displayed at\the top of a GANTT chart showing only the tasks performed by a selected type of crew member refers to the total sum of all task performance times for the designated crew member. In Figure 23, this total performance time is shown to be nine seconds, even though, because of the overlap in task performance, all three tasks are completed in only six seconds. Using these numbers, the user can determine the distribution of workload over the different types of crew members. For the template "Example," it can be shown that during a mission whose total duration is 11 seconds, the squad leader, gunner, and loader are assigned tasks whose performances requires nine, four, and eleven seconds, respectively.

As mentioned previously, the GANTT chart provides a timeline representation of the crew's mission. This representation also labels critical tasks and indicates which required tasks overlap with other tasks and thus represent possible conflicts. Consequently, the GANTT chart contains all of the information presented by the other options in the PERT/GANTT options menu. The other options, however, convey this information in a number of useful formats, each of which will be discussed in subsequent sections of this part of the User's Guide.

Resource Loading

IMPORTANT NOTE: Due to an error in the present version of the CRDS, the "Resource Loading" option is not working properly and therefore does not produce reliable results. <u>It is recommended that this option not be used</u>. Since the information that was to be summarized in the resource loading spreadsheet is also available in several alternate formats, not using the "Resource Loading" option will not adversely affect the user's ability to analyze and create alternative crew templates.

See Critical Task

Selecting the "See Critical Task" option of the PERT/GANTT options menu causes the screen illustrated in Figure 24 to be displayed. This screen lists the

Critical Task Sequence

Task		Start	Stop	Duration
2	ANN TGT	0.0	2.0	2.0
3	FIRE ORD	2.0	3.0	1.0
4	AIM GUN	3.0	6.0	3.0
5	FIRE GUN	6.0	7.0	1.0
8	UNLOAD GUN	7.0	11.0	4.0

Figure 24. Screen showing critical task path.

number and name of each task that is on the critical path, in the order in which it is performed. In three columns following the number and name of each critical task is its start time, completion or stop time, and duration, respectively. The list of critical tasks is useful both in determining what types of modifications can be made to the crew template and in assessing the consequences of these changes.

Conflict Adjustment

Selecting the "Conflict Adjustment" option of the PERT/GANTT options menu will display the table illustrated in Figure 25. This table lists the name of each task whose performance overlaps in time that of other tasks performed by the same type of crew member. Assuming that the overlap in task performances represents a conflict, the table also provides information on how the conflict can be resolved by delaying the start time of the designated task.

DECONFLICTION FREQUENCIES

TASK	WITHIN MSN TIME	ADDS MSN TIME	ADD ALL WITHIN	ADD PART WITHIN	ADD PART TO MSM
Attend Scn	2	0	2.0	0.0	0.0
Ann Tgt	0	1	0.0	0.0	6.0
Check Chbr	0	1	0.0	1.0	3.0
Unload Gun	0	1	0.0	0.0	3.0

Figure 25. Table depicting task overlap.

The table illustrated in Figure 25 is labelled "DECONFLICTION FREQUENCIES," and has six columns.

- Column 1, labelled "TASK," lists the names of the tasks in conflict with other tasks performed by the same type of crew member.
- Column 2, labeled "WITHIN MSN TIME," identifies the number of times the designated task is in conflict with other tasks <u>and</u> a delay in the designated task can resolve the conflict <u>without adding</u> to total mission time. It should be apparent to the user that only non-critical tasks will have a non-zero entry in this column.
- Column 3, labelled "ADDS MSN TIME," identifies the number of times the designated task is in conflict with other tasks <u>and</u> a delay in the designated task can resolve the conflict but <u>only</u>

by adding to total mission time. The tasks which have non-zero entries in this column are critical tasks, i.e., tasks on the critical path.

- Column 4, labelled "ADD ALL WITHIN" shows the minimum delay in the start time required to remove at least one of the conflicts identified in Column 2 for a designated non-critical task.

- Columns 5 and 6, taken together, identify the minimum delay in the start time required to remove at least one of the conflicts identified in Column 3 for a designated critical tasks. Column 5, labelled "ADD PART WITHIN," shows the portion of the required delay in start time that would not affect total mission time. Column 6, labelled "ADD PART TO MSN," shows the portion of the required delay that would add to mission time.

The data contained in the table illustrated in Figure 25 provide much information of general value to the user who wishes to understand detailed features of the template under study. However, this information is of possibly greatest value when the user is searching for ways to remove conflicts in the performance of tasks assigned to a particular type of crew member. Consequently, a further description of this information is contained in the next part of this User's Guide.

Deconfliction Analysis

The "Deconfliction Analysis" option of the PERT/GANTT options menu is the one the user may select in order to make modifications to a template data file. The modifications would be introduced to resolve or eliminate a conflict in task performance. A description of the information and the additional options it provides to the user is the basis for the material presented in Part Six of this User's Guide.

Conflict Overlap

If the user selects the "Conflict Overlap" option of the PERT/GANTT options menu, the CRDS presents a table of detailed information on each pair of tasks whose performance times overlap for each type of crew member. That table, labelled "Simultaneous Resource Request," is illustrated in Figure 26. For the template named "Example," the table provides data on the two pairs of tasks whose performance overlap for the crew member "SQUAD LDR," and the one pair of tasks whose performance overlaps for the crew member "LOADER."

Simultaneous Resource Request

SQUAD LDR	1	ATTEND SCN	0.0	to	8.0 -	SLACK = 5.0	
Overlaps by 2.0	2	ANN TGT	0.0	to	2.0 -	CRITICAL -	SLACK IS 0.0
SQUAD LDR	1	ATTEND SCN	0.0	to	8.0 -	SLACK = 5.0	
Overlaps by 1.0	3	FIRE ORD	2.0	to	3.0 -	CRITICAL -	SLACK IS 0.0
LOADER	7	CHECK CHBR	7.0	to	10.0 -	SLACK = 1.0	
Overlaps by 3.0	8	UNLOAD GUN	7.0	to	11.0 -	CRITICAL -	SLACK IS 0.0

If you would like to send this input to the printer press p.

Figure 26. Screen representing simultaneous task requirements.

In all three cases, the table identifies the type of crew member that is required to simultaneously perform two tasks, the numbers and names of the two tasks, their respective start, stop, and slack time (if any), and the amount of overlap in the performance times of the two tasks. As can be seen in Figure 26, tasks on the critical path, i.e., tasks with zero slack time, are labelled "CRITICAL" in the table.

The information contained in the table accessed though the "Conflict Overlap" option is particularly useful for deciding which tasks are candidates for delayed starting times or for reassignment to alternate types of crew members.

Calculate Critical Path

This option of the PERT/GANTT options menu is provided to permit the user to recalculate the critical path after a modification to the template data file. It would be used in conjunction with the "Deconfliction Analysis" option and, hence, is relevant to the discussion of that option given in Part Seven of this User's Guide.

PERT Diagram

A PERT diagram is a network representation of a crew template. It graphically shows the sequencing of tasks and highlights the sequence of tasks which is the critical path sequence.

NOTE: One of the chief strengths of the PERT diagram is its modifiability. As will become evident, there are many ways to represent template data in a PERT

diagram. The CRDS facilitates the creation of these alternative portrayals but the user must be prepared to invest time in generating the PERT diagram that is most useful for the problem at hand. Fortunately, the CRDS file saving capability allows the user to save these modifications, essentially creating a library of alternate versions of the PERT diagram.

To access the CRDS routine which aids the user in designing a PERT diagram and to subsequently display and print the diagram that is developed, the user selects the "PERT Diagram" option of the PERT/GANTT options menu. Doing so causes the menu illustrated in Figure 27 to be displayed. This menu lists the two PERT diagram display options offered by the CRDS: (a) display all the tasks performed by all types of crew members together in one PERT diagram, and (b) display only the tasks performed by one specified type of crew member.

Display Pert
Select Resource
Esc

Figure 27. Menu of PERT options.

The user should initially select the first option, "Display PERT", in order to design a PERT diagram that portrays the task network in a meaningful manner. Doing so for the template named "Example" causes the CRDS to draw the initial PERT diagram for that template. This initial, CRDS-generated PERT diagram is illustrated in Figure 28. The features of this PERT diagram are described in the next subsection.

Features of the Initial CRDS-Generated PERT Diagram

- As mentioned previously, the PERT diagram is a network representation of the crew mission. In this representation, tasks are represented as lines; the start and finish points of these tasks are represented as nodes at the beginning and end of the task lines. Task lines are labelled with their respective task names.

- Tasks are connected to other tasks by "dummy tasks," lines labeled with a "d" or "t" in Figure 28. Dummy tasks connect the finish points of each mission essential task with the start points of required successor tasks in the task network. If a task is followed by more than one required successor task, its finish point will have a dummy task line connecting it to the start of each of those required successor tasks. If a task does not have a required successor task, a dummy task line connects the finish point of that task with the node representing the end or completion of the mission.

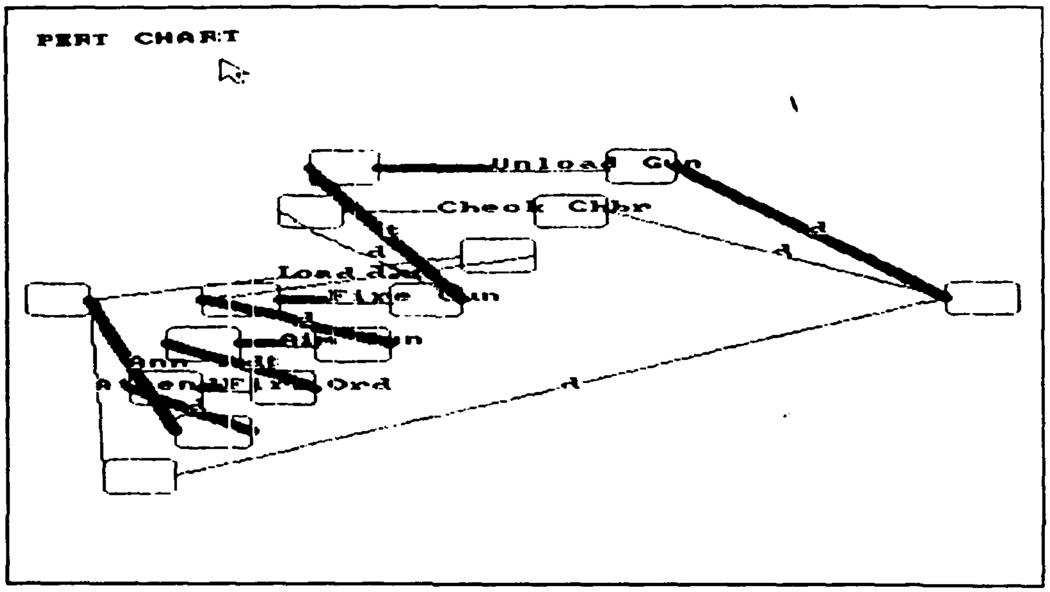

Figure 28. The initial PERT diagram generated by the CRDS.

- The lines representing critical tasks, i.e., tasks in the critical path, are drawn in the PERT diagram with a bolder and thicker line.

- If a PERT diagram is too large to fit on the monitor screen, repeated presses of the "+" (plus) key will make the diagram smaller. Conversely, repeated presses of the "-" (minus or hyphen) key will cause the diagram to be larger in size. If the diagram is too large to fit on the monitor screen, pressing the arrow keys will cause different portions of the diagram to be displayed. The user should note that employing the CRDS print option that uses the <**Print Screen**> key will produce a hard copy of only that portion of a PERT diagram which is displayed on the monitor screen.

The user will generally wish to 're-draw' the initial CRDS-generated PERT diagram. Even the relatively simple diagram illustrated in Figure 28 for the template named "Example" is visually cluttered and hence not as informative as it could be. Procedures for changing the visual appearance of the PERT diagram are described below.

Using the Mouse to Modify a PERT Diagram

As already mentioned, a major strength of the CRDS PERT diagram is its modifiability. The CRDS offers the user a procedure for editing a PERT diagram, both initially and again as the user progressively modifies and updates the data file of a template.

This redrawing capability is accomplished using the mouse, which, if properly installed in the computer system, is enabled whenever the "PERT Diagram" option is selected.

The mouse allows the user to make the task network represented by the PERT diagram appear any way the user desires. If the user wishes to change the location of a node in the diagram, the (normally) arrow-shaped cursor associated with the left button on the mouse is placed over the location of that node. Then, pressing and holding down the left button allows the user to move the node anywhere on the screen. Figure 29 illustrates how the diagram shown in Figure 28 can be redrawn by moving the location of just one node, the node which represents the end of the task named "Ann Tgt." Figure 30 presents the results of our attempt to draw an uncluttered and more readable and useful PERT diagram for the template named "Example."

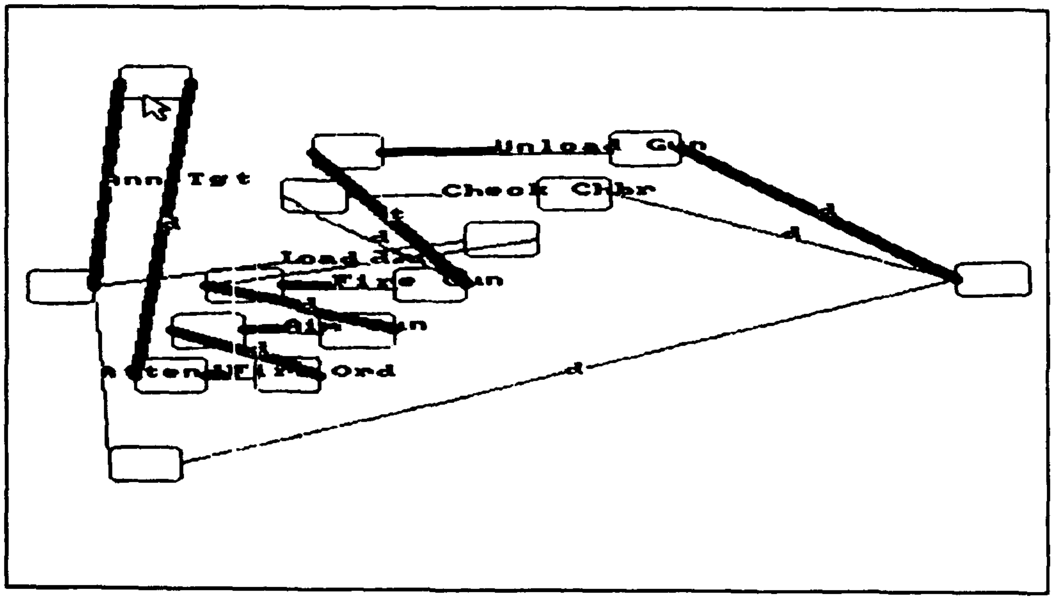

Figure 29. PERT diagram with a single node altered.

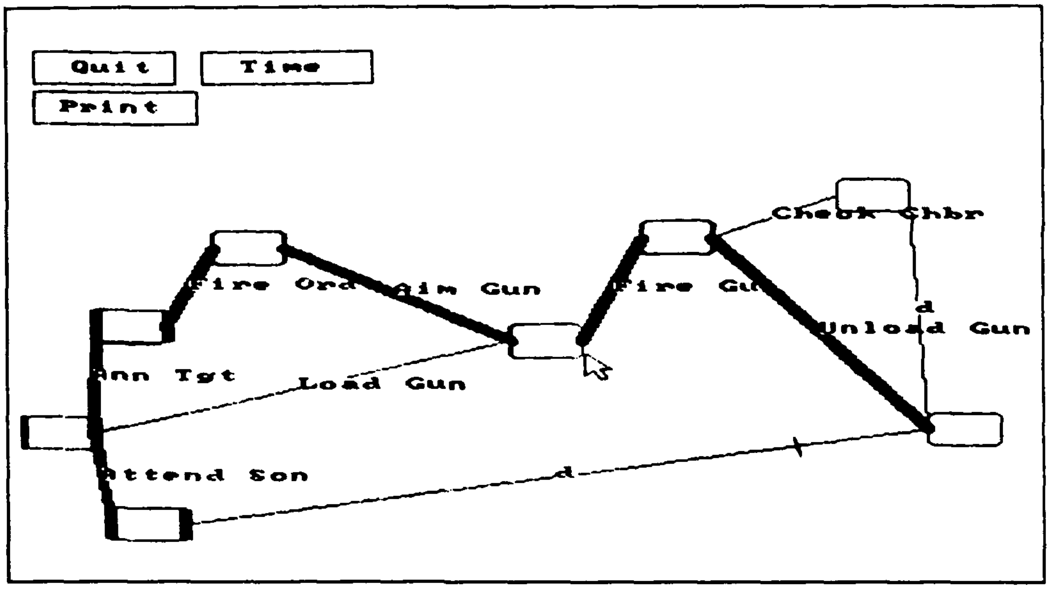

Figure 30. PERT diagram modified to increase its readability and usability.

NOTE: In Figure 30 some of the dummy lines have hidden 'hidden' by making the node representing the finish point of one task congruent with the node representing the start point of a successor task. We have retained the dummy task lines only for those cases in which a task did not have a required successor task.

It must be emphasized that the PERT diagrams illustrated in Figures 28 through 30 are useful only for showing the sequential relationships among tasks during the performance of some specified mission; they illustrate the presence and absence of any necessary predecessor or successor tasks. These diagrams do not automatically display any functions that relate to the performance times of individual tasks or the total mission. Both the vertical and horizontal placement or location of nodes and the lines connecting nodes, as well as the physical lengths of the lines, are arbitrary with respect to task and mission performance timelines.

Viewing PERT Diagrams for Selected Types of Crew Members

Once the user has edited the PERT diagram so it is relatively uncluttered, the diagram may be redrawn to display only the event nodes and tasks performed by one specified type of crew member. To select the PERT diagram for a specific type of crew member, press <**Esc**> to return to the PERT options menu, previously illustrated in Figure 27. Then select the "Select Resource" option. A listing of the names of the types of crew members will be displayed. Selecting one of these names will display the PERT diagram for only that type of crew member.

At any point while developing or viewing PERT diagrams, repeated pressing of the <**Esc**> key will return the user to the PERT/GANTT options menu. The most recent shape or form of the PERT diagram is automatically saved by the CRDS whenever the user escapes from the PERT diagram screen. Hence, the user can return to this screen to examine or modify the PERT diagram at any time during an analysis of the template under study.

The Mouse-Driven Options Menu of a PERT Diagram

Pressing the right button of the mouse while a PERT diagram is displayed on the monitor screen will cause a new menu to be displayed in the upper left corner of the display. There are three options in this menu, any one of which can be selected by placing the arrow cursor on the desired option and pressing the right button of the mouse. The consequences of selecting two of these options are easily described, but the third requires a more detailed discussion which will be given in the next section. Brief descriptions of the three options follow:

- "Quit" - Selecting this option causes the PERT diagram to disappear and the menu of PERT options illustrated in Figure 27 to be displayed. Pressing the <**Esc**> key has the same effect.

- "Print" - Selecting this option is an alternative method for causing a hard copy of the PERT diagram to be printed. Pressing the <**Print Screen**> key has the same effect.

- "Time" - Selecting this option causes an alternative CRDS-generated PERT diagram to be displayed. In this diagram, the horizontal axis is a task and mission performance timeline.

Time-dependent PERT Diagram

If selected, the mouse-driven option labelled 'Time' will causes horizontal distances in the PERT diagram to represent task performance time. The left edge of all nodes are located at the earliest times that the task represented by the line following the node may begin. Vertical distance still has no meaning in terms of measurement but may be used to spread out the nodes and declutter the PERT diagram. As was true for the PERT diagrams shown in Figures 28 through 30, the user can modify the visual appearance of the timeline-based PERT diagram and would most likely want to redraw the CRDS-generated diagram that is initially displayed.

The modification of a timeline-based PERT diagram is accomplished using the same procedures that were described earlier for redrawing the PERT diagrams that are independent of task and mission performance time. However, since the horizontal locations of each node in the timeline-based PERT diagram is constant, the location of nodes can only be varied in the vertical dimension. Also, since each node represents the earliest possible start time for the task which follows its location in the diagram, there is no task line for tasks which do not have a required successor task. Hence, there is no task line representing the last task in the critical path sequence (i.e., the task whose completion marks the end of the prescribed mission). There is also no dummy task lines connecting the nodes representing the completion of noncritical tasks and the completion of the last task in the critical path. A sample problem which uses timeline-based PERT diagrams is given in Part Seven of this User's Guide.

IMPORTANT: Unlike the PERT diagrams that are independent of task performance time, modifications the user makes to redraw an initial CRDS-generated timeline-based PERT diagram are <u>not</u> saved for later examination. Hence, a hard copy of the user redrawn timeline-based PERT diagram should be printed using the <Print Screen> key before the user uses the <Esc> key to exit this option of the mouse-driven options menu or this CRDS run. Also, unlike the non-timeline-based PERT diagram, timeline-based PERT diagrams cannot be generated for only selected types of crew members.

NOTE: It should be stressed again that while the PERT diagram option of the CRDS allows the user to portray the task network of the crew in a very graphic and meaningful manner, it does not contain a great deal of quantitative information. Also, even though the CRDS permits it to be drawn in a semiautomatic manner, it may require a great deal of the user's time and energy to redraw it to the user's satisfaction. Users who wish to utilize the PERT diagram option of the CRDS are encouraged to explore the feature at their convenience.

Escape <Esc>

Selecting this option of the PERT/GANT options menu transfers the user to the CRDS main options menu.

PART SIX – MODIFYING TEMPLATE FEATURES

Introduction

As was previously discussed, a general goal of the CRDS is to enable the user to examine alternative organizational solutions to crew workload problems. In this regard, an examination and analysis of the various graphic and tabular representations of the crew template (as described in Part Five) may show that the initial structure and organization of the crew has some real or potential workload problems.

An <u>overload</u> in work requirements occurs if there is too much demand on available types of crew members. This would be the case if there were a requirement for one type of crew member to simultaneously perform two or more incompatible tasks. If this situation were allowed to exist, one of two consequences is likely to occur: (a) if possible, a crew member might attempt to simultaneously perform two or more tasks (increasing the possibility that performance quality will decline), or (b) a crew member's performance of one or more tasks will be delayed until the incompatible task has been completed (increasing the likelihood that the mission completion time will be too long).

Equally undesirable is the situation in which there is an <u>underload</u> in work requirements, i.e., a situation in which there is too little demand on a crew member. This would occur if there were long periods of time during which a particular type of crew member had no task performance requirements. In this case, there is an excessive amount of unproductive or idle time.

The most obvious solution to a situation in which crew members are overloaded is to increase the number of personnel assigned to perform required tasks. However, adding crew members will increase the costs associated with the crew and may be incompatible with size and mobility constraints of the crew. Similarly, simply shifting tasks from an overloaded to an underloaded crew member may also be inappropriate. Clearly, not all crew members may are capable of adequately performing all required tasks.

To aid the user in addressing problems associated with either overloading or underloading different types of crew members, the CRDS permits the user to quickly develop alternative crew designs for study and analysis. Three different but complementary techniques are available in the CRDS to aid in this process.

- Delay task start time. In a sense, delaying the performance start times of selected tasks can be the simplest solution to either an overload or underload problem. Changing the time interval during which a task is performed may remove the simultaneous task demands placed on a crew member. Since the same crew member performs the task regardless of its start time, the user needs to consider the performance capabilities of only a single type of crew member.

- Alternate assignment of tasks to types of crew members. A more judicious allocation of tasks to different types of crew members may permit the workload to be shifted from an overloaded crew member to an underloaded crew member. However, using this approach to address workload problems associated with an initial crew design means that the user must also consider the task performance capabilities of alternative types of crew members. The performance capabilities of some types of crew members may have to be changed to meet the performance requirements of newly assigned tasks. This may, in turn, require a change in personnel selection or training procedures or a redesign of some features of an equipment item.

- Reassign task sequences. Redefining the sequence in which required tasks are performed is another approach made available in the CRDS for addressing workload problems. However, it is generally the most difficult approach to implement of the three techniques described in this User's Guide. This is especially true late in the development of materiel and personnel assets and of tactics, techniques, and procedures. Once crew assets and operational procedures have been fully developed, they may drive the required sequence of task performance. For example, standard operational procedures typically dictate that a potential target must be positively identified as hostile before it can be engaged.

By employing any one of the three techniques just outlined for addressing workload problems in a crew template, the user may introduce other important changes to the template. Changes in task performance start times, in the allocation of tasks to types of crew members, or in the temporal relationship among tasks may change the critical path through the task network. A change in the critical path will not only affect which tasks are defined as critical (i.e., tasks with no slack time for their performance) but also may increase or decrease the total mission performance time.

Successive sections of this part of the User's Guide will describe in detail how each of the three techniques are accessed and used with the CRDS. The first two (delaying tasks and reassigning tasks to crew members) are accessed through the "Deconfliction Analysis" option of the PERT/GANTT options menu. The third (reassigning task sequences) is accessed through the "ASSIGN TASK RELATIONS" option of the "BUILD TEMPLATES OPTIONS" menu.

To implement each of the approaches described below, the user should first ensure that the template of interest, i.e., the template named "Example," is in the system memory.

NOTE: There may well be other solutions to problems associated with the over and under utilization of different types of crew members, but they often involve more than changes in organizational composition and structure. Judicious use of the capabilities of the CRDS may suggest some of these non-organizational solutions to the problem. (See, for example, the second sample problem given in Part Seven of this User's Guide.) The user is encouraged to explore fully the alternative capabilities of the CRDS to address crew workload and performance problems.

Delay Task

To access and use the delay task approach for addressing crew workload problems, the following actions need to be taken:

1. After calculation of the critical path, access the PERT/GANTT options menu and select the "DECONFLICTION ANALYSIS" option. The "Deconfliction Frequencies" table, illustrated in Figure 31, will appear. (This table was previously described in conjunction with Figure 25.)

   The data shown in this table can be used to illustrate the value of the task delay option. Consider the task named "Attend Scn" shown in the first column of the table. The "2" shown in the second column for "Attend Scn" indicates that it overlaps and, hence, is in conflict with two other tasks. The "2.0" shown in the fourth column indicates that a two-second delay in the start time of the task would resolve its conflict (i.e., would "deconflict" its relationship) with at least one of those two tasks. The placement of the indicated two-second delay in Column 4 of the table shows that this delay in start time would not affect overall mission completion time. (Clearly, the "Attend Scn" task is not on the critical path and it has a slack time of at least two seconds.)

DECONFLICTION FREQUENCIES

TASK	WITHIN MSN TIME	ADDS MSN TIME	ADD ALL WITHIN	ADD PART WITHIN	ADD PART TO MSM
Attend Scn	2	0	2.0	0.0	0.0
Ann Tgt	0	1	0.0	0.0	6.0
Check Chbr	0	1	0.0	1.0	3.0
Unload Gun	0	1	0.0	0.0	3.0

Figure 31. CRDS table depicting task overlap.

Now consider the third task shown in the first column of the table, the task named "Check Chbr." The "1" listed in the third column for this task indicates that it overlaps with one other task. As shown in the table, a four-second delay in the start of the "Check Chbr" task will resolve its conflict with the other task. One second of that delay would fall within the initial total mission time but the remaining three seconds would add to the total mission duration.

Assume that the user decides to eliminate the conflict associated with the task of checking the gun chamber by delaying the start of its performance by four seconds.

2. Press any key and a display listing the crew tasks will appear. This display prompts the user to select a task whose conflict with at least one other task is to be resolved (or whose relationship with another task is to be deconflicted).

3. Move the reverse video over the task to be delay‹ ˀ and press <**Return**>. For this example temp˙ , select task **"Check Chbr"** and press <**Return**>. A menu of actions the user can use for deconflicting the selected task will be added to the display. The format of the total display at this point is illustrated in Figure 32.

4. Select "Delay Task" from the "Deconfliction Features" menu and press <**Return**>. This action will cause the screen illustrated in

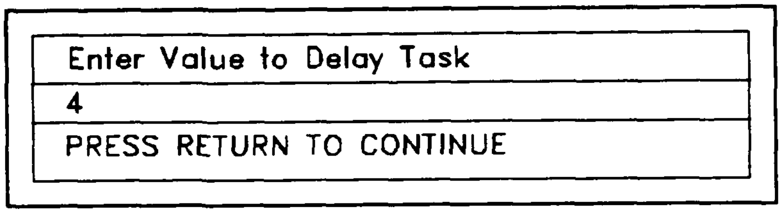

Figure 32. Box allowing the user to specify the desired delay period.

Figure 32 to be presented. That screen prompts the user to enter the number of time units that the selected task is to be delayed.

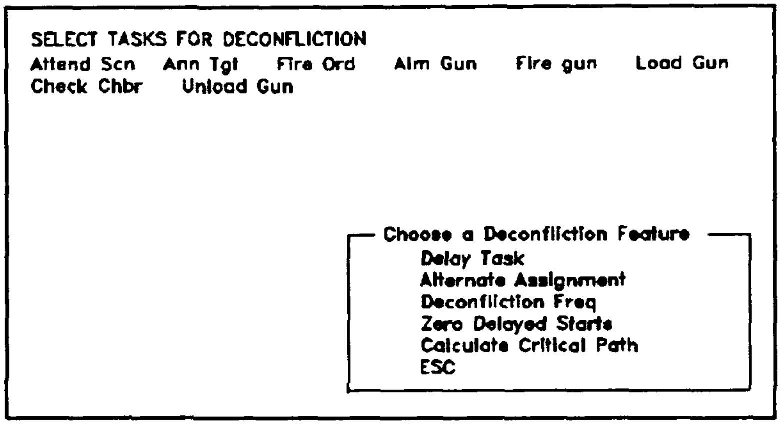

Figure 33. The CRDS "Deconfliction Features" menu and unit task list.

5. Based of the data shown is Figure 31, the user should enter **"4"** and then press <**Return**> to indicate that the start of the designated task "Check Chbr" is to be delayed by four seconds. This action redisplays the "Deconfliction Features" menu illustrated in Figure 33.

6. The user should now select the "Calculate Critical Path" option of the Deconfliction Features" menu. This step is necessary whenever changes are made to a template.

7. Once the critical path is recalculated, it is possible to examine the effects of the delay that has been entered. To do this, select the "Deconfliction Freq" option. A deconfliction frequencies table such as that shown in Figure 31 will again appear. If the user has followed the preceding instructions

for the template named "Example,", the task "Check Chbr" will no longer be listed as conflicting with other tasks.

Verification of this result can be obtained by examining the features of this template in the conflict overlap table or the Gantt Chart. The Gantt Chart, illustrated in Figure 34, also shows that the total mission performance time has been increased from 11.0 seconds to 14.0 seconds.

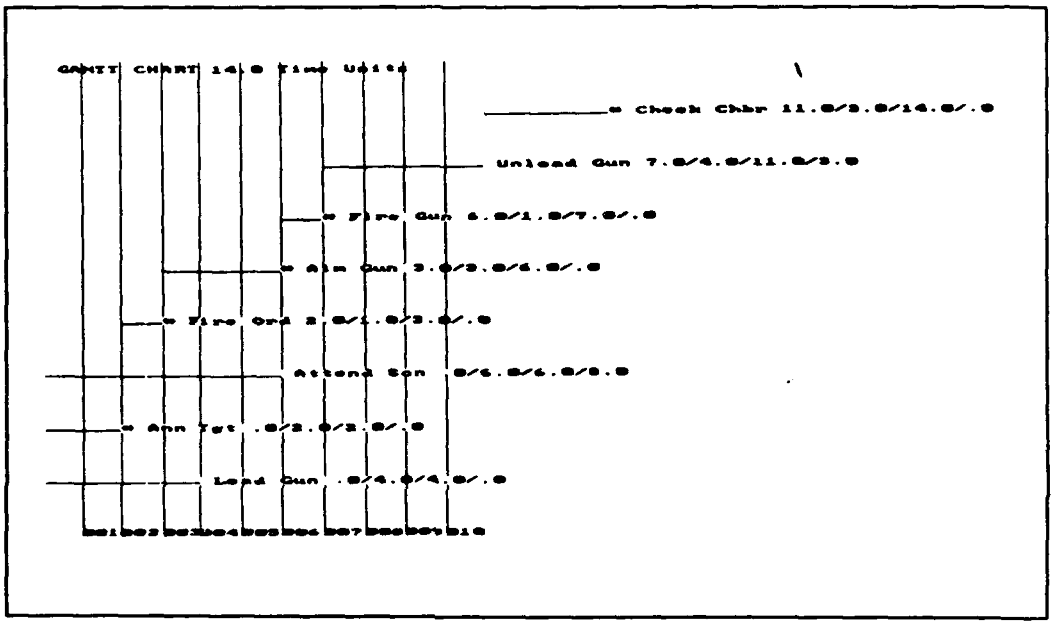

Figure 34. GANTT chart with the task "Check Chbr" delayed by four seconds.

NOTE: While the deconfliction frequencies table shows with how many other tasks a designated task is in conflict, it does not specify what those other tasks are or which type of crew member is assigned to perform the conflicting tasks. For the example template, with only eight tasks and three types of crew members, this may not be a problem; the user can easily remember all the details of the template data file. However, for more structurally complex crew designs the user may need to refer to the screens which show the GANTT timelines charts or to the conflict overlap table. These alternate sources of template information are described in Part Six of this manual. Better still, the user may wish to obtain a printout of those screen displays, and use the hard copy of the screens to assist in remembering the task network and task allocation to types of crew members.

Assume for the sake of this demonstration that the additional three seconds to complete the mission is unacceptable. Instead of delaying the start of the "Check Chbr" task, we can eliminate its conflict with other tasks by reassigning it to a different type of crew member. The procedure for the reassignment of tasks to types of crew members is described in a later section. First, however, it will be necessary to erase the task delay that was just instituted. This is the subject of the next section.

Zero Delayed Starts

If the implemented task delay is determined to be inappropriate as a template modification strategy, the user can erase all task delays and return to the original set of task start times by using the "ZERO DELAYED STARTS" option. To access "ZERO DELAYED STARTS", complete the following steps:

1. Once in the PERT/GANTT menu, select the "Deconfliction Analysis" option. The "Deconfliction Frequencies" table will be displayed. Press <**Return**> twice to make the "Deconfliction Features" menu appear.

2. Move the reverse video block over "Zero Delayed Starts" and press <**Return**>. The "Zero Delayed Starts" option shown on the screen will blink once as an indication that it has been selected. It may be necessary to press <**Return**> more than once to get this feedback.

3. As with any change to the crew template, recalculate the critical path.

4. Move the reverse video over "Deconfliction Freq" and press <**Return**>. The "Check Chbr" task will again be shown as being in conflict with another task. Alternatively, Press <**Return**> repeatedly until the PERT/GANTT options menu is displayed. Then, select the "Conflict Overlap" option. The "Check Chbr" task will be shown in conflict with the "Unload Gun" task for crew member "Loader."

Alternate Assignment

The user can address the workload problem of crew member "Loader" by reassigning one or more of the loader's conflicting tasks to another type of crew member. To reassign tasks to alternative crew members, the user needs to take the following actions:

1. While in the "Choose a Deconfliction Feature" menu, select the "Alternate Assignment" option.

2. The screen illustrated in Figure 35 will be displayed. This is the same screen that was displayed when the "ASSIGN RESOURCES TO TASKS" option of the "BUILD TEMPLATES OPTIONS" menu was selected (see Figure 12).

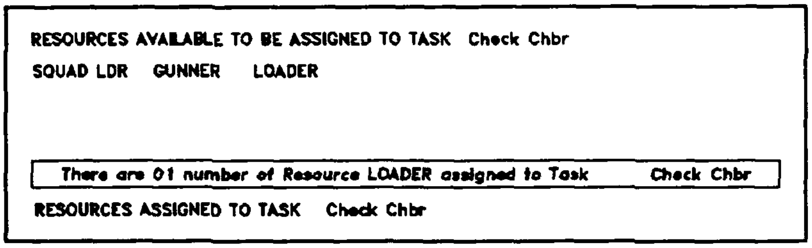

Figure 35. Screen allowing assignment of resources to tasks.

A quick review of the procedure for assigning types of crew members to tasks is provided in the next three paragraphs.

- Press the <**Ctrl-Arrow**> keys to change the task names appearing at the right end of the rectangle.

- Press the arrow keys to move the reverse video over the list of types of crew members available to perform the designated task and change the crew member name that is shown at the center of the rectangle.

- Press the '+' or '-' key to increase or decrease the value of the number shown at the left end of the rectangle. The number shown represents how many of the specified type of crew member is assigned to perform the designated task.

To continue the description of how to make alternative assignments to eliminate conflicts, the user should enter the following "new" assignments:

	Number	Crew member	Task
Change	**"1"**	**"Loader"**	**"Check Chbr"**
To	**"0"**	**"Loader"**	**"Check Chbr"**
and,			
Change	**"0"**	**"Squad Ldr"**	**"Check Chbr"**
To	**"1"**	**"Squad Ldr"**	**"Check Chbr"**

In other words, reassign the task of checking the gun chamber from the crew member named loader to the crew member named squad leader.

3. To cause the alternate assignments just entered to be implemented the critical path must be recalculated. The user should press the <**Esc**> key to return to the "Deconfliction Features" menu, and select the "Calculate Critical Path" option. (For the convenience of the user this option is available from various CRDS menus.)

Important: It has been our experience that reassigning a task from one type of crew member to another may cause the performance time entered for the task in the "BUILD TEMPLATE" options menu to be assigned a value of zero. This makes sense if different types of crew members have different capabilities for performing the designated task. Therefore, it will be necessary for the user to go to the "ENTER PERFORMANCE MEASURES" option of the "BUILD TEMPLATE" menu to check that the appropriate performance time is entered for the (re)assigned task. If a new value is entered, the user must remember to recalculate the critical path.

4. Once the critical path is recalculated, it is possible to examine the effects of the alternate assignments. If the "Conflict Adjustment" or the "Deconfliction Analysis" options are selected from the PERT/GANTT menu, the user will see that "Check Chbr" and "Unload Gun" are no longer on the list of conflicting tasks. Alternately, while the GANTT chart will show these two tasks as overlapping in time, they are assigned to *different* types of crew members and hence are not in conflict. This point is also evident since these two tasks are no longer listed in the table of conflicting tasks shown when the "Conflict Overlap" option is selected from the PERT/GANTT options menu.

Reassignment of Task Sequence

The third approach described in this User's Guide for addressing workload issues in a crew design is to redefine the sequence in which tasks must be performed. As is true for the other options, changing the temporal relationship among required tasks may affect total mission time. Hence, any benefit this option brings through eliminating conflict may be offset by total mission considerations. Alternately, a change in task sequencing may benefit the total mission by eliminating unnecessarily long delays for starting the performance of some required tasks. The instructions which follow are designed to show how features of the CRDS may be used in an attempt to reduce total mission time. (These actions are the same as those previously described in Part Four for assigning and editing task relationships when first building a template.)

1. Press <**Esc**> until the "MAIN OPTIONS" menu appears.

2. Once in the "MAIN OPTIONS" menu, select the "BUILD TEMPLATE" option.

3. Select the "ASSIGN TASK RELATIONS" option of the "BUILD TEMPLATE OPTIONS" menu. A screen, such as the one illustrated in Figure 36 will be displayed.

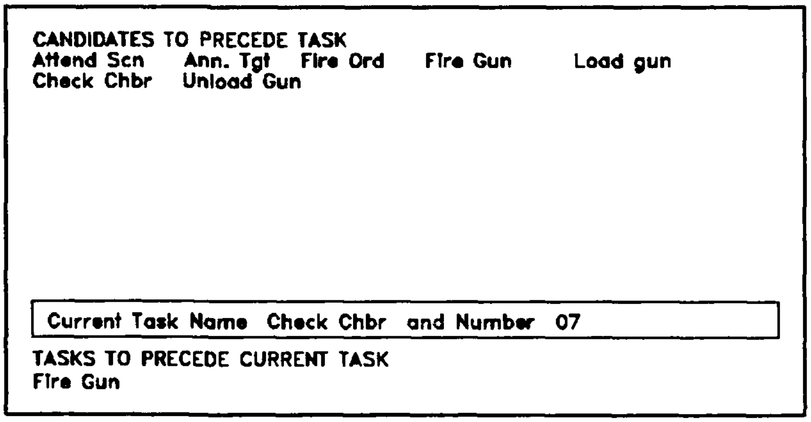

Figure 36. CRDS screen allowing task sequence to be modified.

4. Press the <**CTRL-Arrow**> keys to change the current task name appearing in the rectangle. As the current task name changes, the necessary predecessor tasks initially assigned for each selected task will appear at the bottom of the screen. The user should

press the <**CTRL-Arrow**> keys until "Aim Gun" appears in the rectangle. The necessary predecessor to "Aim Gun" is shown to be "Fire Ord."

For the sake of argument, let us assume that it is not necessary for a fire order to be given **before** the gun is aimed. Instead, the gunner could start aiming the gun as soon as the squad leader announced the target; the gunner would then fire the gun upon receiving the fire order. By deleting "Fire Ord" as a required predecessor to "Aim Gun", we can test the effects of this proposed change.

5. To add a "new" predecessor task, press the <**Arrow**> keys to highlight the desired predecessor task and then press <**Return**>. To delete a task as a required predecessor, press the <**PgDn**> key. This action moves the reverse video bar to the bottom of the screen. Pressing the <**Arrow**> keys highlights, in turn, each previously designated predecessor task. Pressing <**Return**> when a predecessor task is highlighted deletes that task as a predecessor.

   The user should follow these instructions to delete "Fire Ord" as a necessary predecessor task for the "Aim Gun" task.

6. Press <**Esc**> twice to return to the "BUILD TEMPLATE OPTIONS" menu, and again to return to the "MAIN OPTIONS" menu.

7. After recalculating the critical path, the user can access the GANTT chart to examine the impact of the new task relationships. From the GANTT chart, it can be seen that one effect of removing "Fire Ord" as a required predecessor to "Aim Gun" is a change in the tasks in the critical path. The new critical path is comprised of only three tasks: Load Gun, Fire Gun, and Unload Gun. This change in the critical path caused a decrease in the total mission time from 11 seconds to 9 seconds. Hence, a change in operational procedures that changes the required relationship among tasks can affect overall mission completion time.

Conclusion

Part Six of the User's Manual describes three different techniques for addressing workload problems. These techniques required the user to (a) delay the start times of specified tasks, (b) make alternate assignments of designated tasks to specified types of crew members, and (c) redefine the constraints in task sequencing. Each of these approaches to addressing workload issues in a crew design was illustrated using the template built by the user and named "Example." The next part of the User's Guide will continue the discussion of how to use the CRDS by describing applications of the system to two other sample templates.

PART SEVEN: SAMPLE PROBLEMS

To further illustrate how to use the CRDS and interpret its output, two sample applications are presented in this part of the User's Guide. Both sample problems will use real data to develop CRDS templates. The first sample application is derived from data that were obtained for the crew of a weapon system. The second data set is for a cell of personnel assigned to a field artillery fire direction center (FDC).

Most of the information needed to build the templates was obtained through an analysis of appropriate Army documents and with the assistance, and ultimately the concurrence, of appropriate subject matter experts. This information defined the types of personnel assigned to the crew or cell, the tasks which were to be performed to accomplish a designated mission, the assignment of types of personnel to perform the tasks, and any constraints on the sequence in which tasks were to be performed. For both sample problems, task performance time data were obtained from several crews or cells who participated in field studies.

Sample Application 1 -- Weapon System Crew

In order to establish a crew template which incorporated some serious conflicts, several adjustments were made to the required sequencing of tasks which had to be performed by the crew of the weapon system. Consequently, the weapon system, its personnel crew, and the tasks which the crew members had to perform are not identified. Instead, the data and the template will apply to a hypothetical crew.

The mission of the hypothetical crew requires that 19 tasks be performed by three different types of crew members. For this sample application of the CRDS, it is stipulated that each type of crew member is qualified to perform only those tasks to which it is assigned. Consequently, the assignment of types of crew members to tasks cannot be altered.

The time required for each type of crew member to perform the tasks to which it is assigned has been determined empirically and is unalterable. These task performance times are given in Table 1 as a function of the task and type of crew member. Note, that with the exception of Tasks 4, 9, and 13, each task is uniquely assigned to only one of the crew member types. Tasks 4 and 9 are performed jointly by Crew Member Types A and B; Task 13 is performed jointly by Crew Member Types B and C.

Note, that if the 19 tasks were performed serially in the order shown in Table 1, the total time required to perform all 19 tasks, i.e., the total mission time, would be 124.4 seconds. However, in this sample application it is stipulated that at least some tasks may be performed in parallel. It is furthermore stipulated that the order in which the 19 tasks are to be performed is not necessarily dependent upon the exact time at which they are initiated or terminated, but only upon certain specified and required task

TABLE 1

TASK PERFORMANCE TIME (SECONDS)
FOR EACH TASK AND CREW MEMBER
DURING A PRECISELY DESIGNATED MISSION

Task	Crew Member Type		
	A	B	C
1	5.2	--	--
2	--	6.0	--
3	--	9.9	--
4	2.3	2.3	--
5	2.0	--	--
6	--	19.1	--
7	7.6	--	--
[illegible]	--	4.0	--
9	1.1	1.1	--
10	1.7	--	--
11	--	18.0	--
12	2.3	--	--
13	--	15.2	15.2
14	--	--	3.0
15	--	--	7.5
16	--	--	2.2
17	--	--	7.9
18	--	--	3.3
19	--	--	6.1

relationships. As shown in Table 2, certain specified tasks cannot be initiated unless and until other required <u>predecessor</u> tasks have been completed. An alternative, complementary way of considering this same set of task relationships is also shown in Table 2. In this latter case, some specified tasks must be completed before other <u>successor</u> tasks may begin. It will be assumed that the task relationships illustrated in Table 2 cannot be altered.

TABLE 2

REQUIRED TASK RELATIONSHIPS
DURING A PRECISELY DESIGNATED MISSION

Task	Predecessor Task	Successor Task
1	none	2,4,5,9
2	1	3
3	2	6
4	1	none
5	1	none
6	3	7
7	6	8,10
8	7	none
9	1	none
10	7	11
11	10	12
12	11	13
13	12	14,16
14	13	15
15	14	18,19
16	13	17
17	16	18,19
18	15	none
19	15	none

Building and Investigating the Characteristics of the Crew Template

The CRDS assists the user in investigating the consequences of the crew data set defined above. After using these data to build (and save) a template for this sample application, the user would begin the investigation of the initial crew design by selecting the option of the CRDS main menu which calculates the critical path. Table 3 shows the sequence of tasks in the critical path and their respective start, stop, and duration times. The stop or completion time of the last task in the critical task sequence, i.e., Task 19, represents the minimum time required to complete all tasks in the overall mission. In this case, the mission performance time is 101.6 seconds, 22.8 seconds less than the time required if all tasks were performed in serial order.

TABLE 3

TASKS IN THE CRITICAL PATH FOR THE WEAPON SYSTEM CREW SAMPLE PROBLEM

Task	Time		
	Start	Stop	Duration
1	0.0	5.2	5.2
2	5.2	11.2	6.0
3	11.2	21.1	9.9
6	21.1	40.2	19.1
7	40.2	47.8	7.6
10	47.8	49.5	1.7
11	49.5	67.5	18.0
12	67.5	69.8	2.3
13	69.8	85.0	15.2
14	85.0	88.0	3.0
15	88.0	95.5	7.5
19	95.5	101.6	6.1

Figure 37 shows one result produced from redrawing or editing the initial CRDS-generated PERT diagram of the relationship among all 19 tasks. Each line in the figure is labeled to show the task that it represents. The ovals or "nodes" shown in the figure represent the beginning and end of each task. The thicker lines represent the critical time path. Tasks on this path are critical in the sense that they must be performed on schedule and can tolerate no delay without adding to the total mission time. Some of the lighter lines are labelled with the letter "d." These lines identify dummy tasks used to coordinate the performance of tasks whose lines would otherwise overlap and not be separately identifiable in the graphic presentation. The dummy tasks are also used to connect the completion of non-critical tasks to the node that represents the end of the mission.

It should be noted that while the PERT diagram shown in Figure 37 is useful for illustrating the relationship among tasks, the relationship shown is not necessarily dependent on actual task or mission performance times. The vertical distances in the PERT representation are arbitrary; vertical space is used only to spread out the task lines for user study. Likewise, while the user may use horizontal distances in a PERT representation to indicate an approximate task performance time dimension, there is no fixed relationship between the horizontal placement of nodes and the start or completion times of tasks. The user may move any node shown in a PERT diagram any distance in any direction while editing the graphic portrayal of the task network.

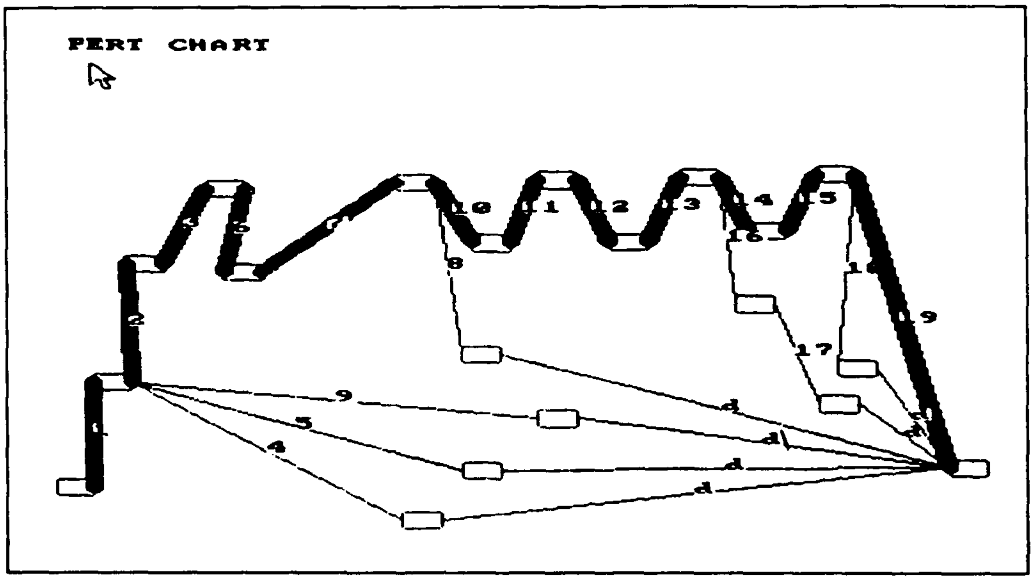

Figure 37. The PERT diagram for the mission essential tasks of the weapon system crew sample problem.

Figure 38 shows a graphic portrayal of the task network which combines the features of the initial PERT representation with a timeline placement. In this representation, horizontal distances represent performance time; the left edge of each oval node is located at the earliest possible start time for the task which follows the node. The user may edit this time dependent PERT representation only by moving nodes in the vertical dimension. Vertical distances have no

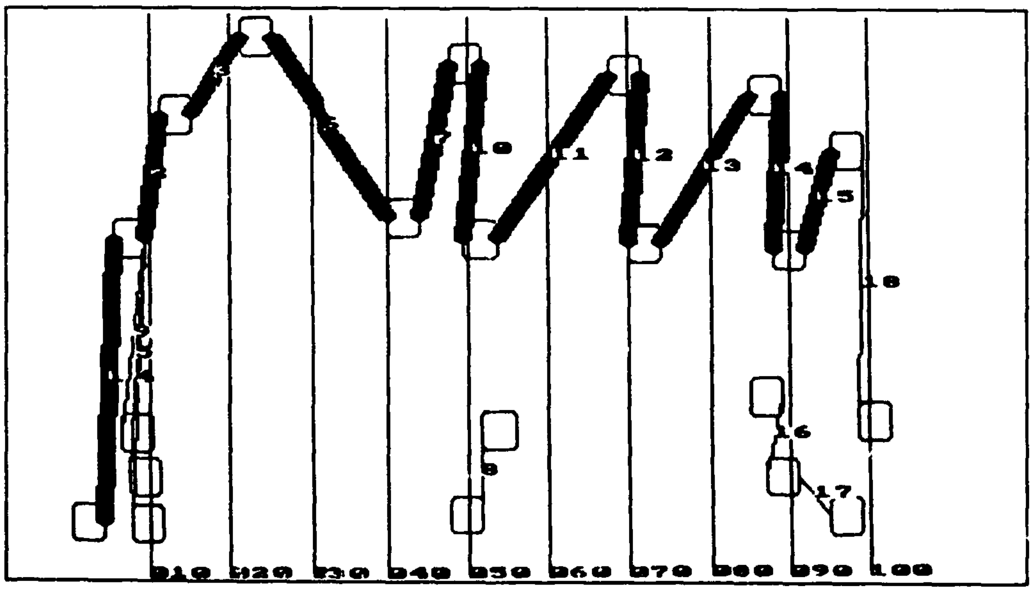

Figure 38. The timeline-based PERT diagram for the mission essential tasks of the weapon system crew.

meaning but are used to create a more comprehensible diagram. It may be seen in Figure 38 that there are several instances in which multiple tasks are performed during the same or in overlapping time intervals. If any of these overlapping tasks are assigned to the same type of crew member there may be an instance of conflict.

NOTE: The timeline-based PERT diagrams generated by the CRDS are missing two features which are found in the PERT diagrams that are independent of performance time. First, the last task in the mission, also the last task in the critical path, is <u>not</u> present in the timeline-based PERT. Second, the lines used to represent dummy tasks are <u>not</u> present in the timeline-based PERT.

As currently programmed, the name of the type of crew member assigned to perform each task is not shown in a PERT diagram. Also, as was described in Part Five of this User's Guide, the purely manual editing that is necessary to create perceptually meaningful and useful PERT diagrams may, in turn, require considerable amounts of the user's time (and patience). Both of these shortcomings of a PERT graphic representations suggest that the user should initially use other, more fully informative and automatically generated outputs of the CRDS to investigate the viability of a crew database.

Figure 39 shows an alternative method for graphically displaying the relationship among all 19 tasks. This graphic representation of the task network, the GANTT chart, is generated automatically and displays all the relevant time characteristics associated with each task. This graphic representation shows also that there are instances in which multiple tasks are performed during the same or in overlapping time intervals. To determine if any of these overlapping tasks are assigned to the same type of crew member the user merely needs to request that GANTT charts be created, in succession, for each type.

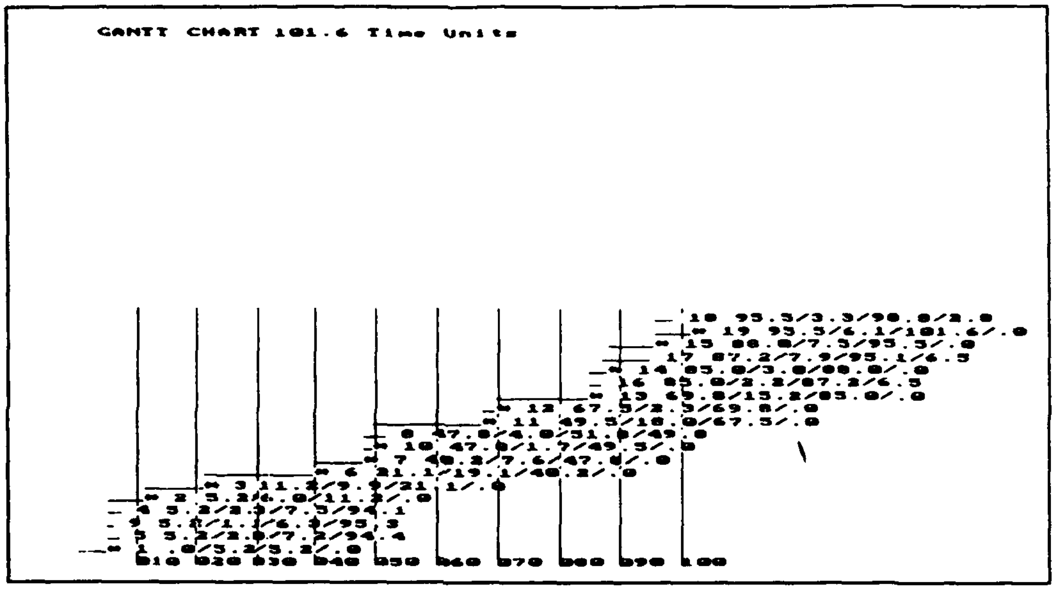

Figure 39. The GANTT chart for the mission essential tasks of the weapon system crew sample problem.

Figure 40 shows the GANTT chart for only those tasks performed by Crew Member Type A. This figure clearly shows that within the first 10 seconds of the mission, Crew Member Type A is required to perform three tasks (Tasks 4, 5, and 9) during the same time interval. If, for any reason, these three tasks cannot be performed simultaneously by this type of crew member, there is conflict. To resolve this particular conflict without making any changes in the template, there must be three Type A crew members assigned to the crew, one to perform each of the three tasks.

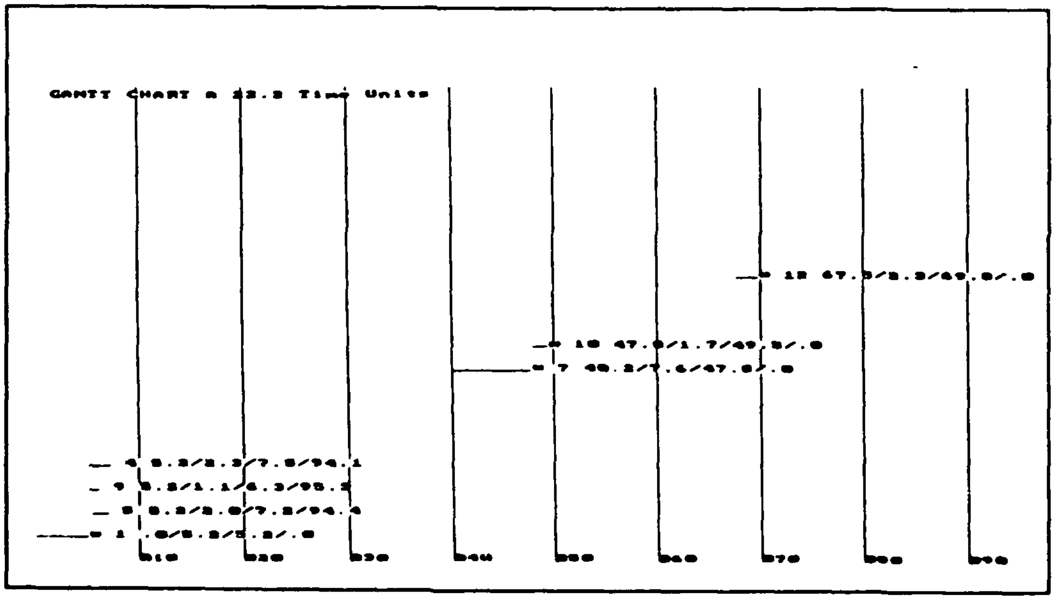

Figure 40. The GANTT chart for the mission essential tasks of only Crew Member Type A.

Similarly, by separately examining the GANTT chart for each of the other two types of crew members, it can be determined that there are requirements for two Type B crew members and two Type C crew members. The specific tasks which are in conflict for each type of crew member may be determined from either the GANTT chart or from the conflict overlap table.

In summary, if the initially created crew template represents the final design of the weapon system crew, there would be a requirement for seven crew members to perform the 19 mission essential tasks. For this sample problem, let it be assumed that there is a need to make modifications in these crew data so that we can meet the dual objectives of minimizing both the size of the crew and the total time required to perform all required tasks. Given the constraints imposed above for modifying these data (i.e., there can be no reassignment of tasks to types of crew members and no change in the assignment of required predecessor tasks), the only way to achieve the desired objectives is to modify the mission timeline by delaying the start times of one or more tasks.

Modifying the Crew Template Without Adding to Mission Time

The CRDS provides the user with the capability to reschedule the start times of user-designated tasks. The tasks most likely to be modified first are those not on the critical path. These tasks may be delayed up to their allowable slack times without adding to the total mission time.

The tasks to be delayed were determined from an examination of the information given in the conflict frequencies table. This information indicates which tasks have conflicts which can be resolved without adding to the mission time and the amounts of delay required to resolve those conflicts. Of course, removing one set of conflicts often creates others, so a series of adjustments generally have to be made. Furthermore, depending upon the particular task conflict which is resolved, the CRDS may not always identify the next conflict to be resolved. For these reasons, the user should alternately check and use the information presented in the GANTT charts and overlap tables as well as that given in the conflict frequency tables.

The authors of the User's Guide made all possible and necessary delays in tasks not on the critical path over a series of 10 successive modifications to the template. In this example this was accomplished by progressively delaying the start times of just three tasks (i.e., Tasks 4, 8, and 9).

IMPORTANT: The user should take note of the fact that the CRDS does not cumulate delays in the start time of a specific task over successive delays. The user must manually record and add each successive delay for each task to the previously cumulated total delay for that task. The calculation of the critical path for a crew template that has been modified by delays in the start times of tasks is based upon task start times that are the sum of the original task start times and the *cumulated delays to those start times.*

Figure 41 shows the GANTT chart which graphically displays the relationship among all 19 tasks after all possible and necessary delays were made to the three tasks identified above. This GANTT chart (and those for each selected type of crew member) show that after some tasks assigned to Crew Member Types A and B are delayed by as much as 86.2 seconds, there are no longer any simultaneous demands for conflicting task performance for these two types of crew members. Hence, only one each of these two types of crew members is required to perform the tasks assigned them.

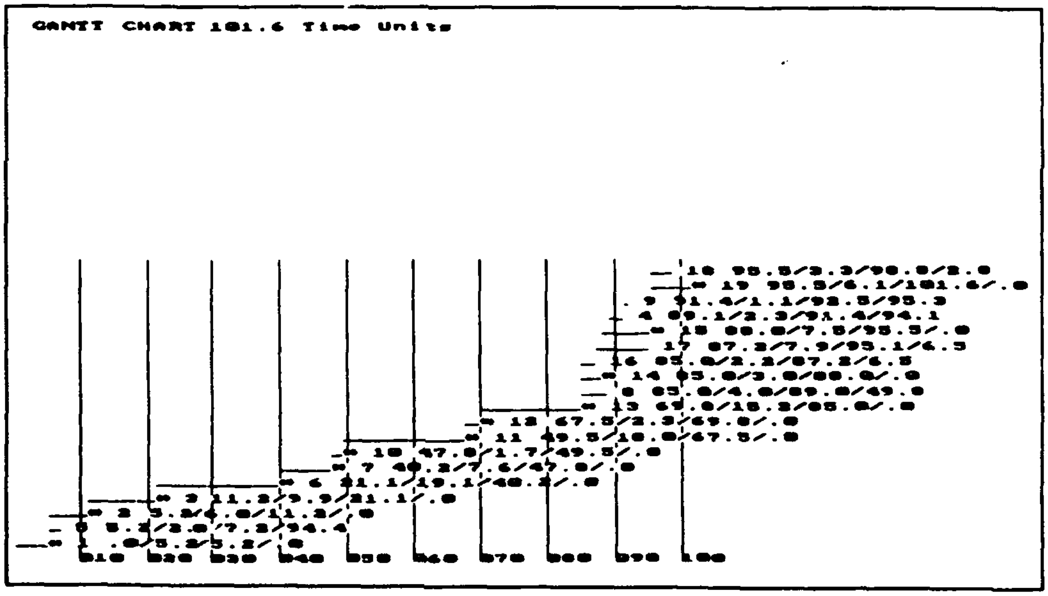

Figure 41. The GANTT chart for the crew sample problem after delaying the start of three non-critical tasks.

NOTE: The user should also note that the slack times for non-critical tasks shown in the GANTT chart are not recomputed by the CRDS after the start times of those tasks are delayed. Hence, while the start, duration, and stop times shown in Figure 41 are changed to reflect the modifications made to the start times of Tasks 4, 8, and 9, the slacks times for those tasks are not similarly adjusted. The slack times shown in the conflict overlap tables are also not adjusted. This failure to adjust slack times for changes made to the initial template database is a fault of the software.

Figure 41 also indicates that the adjustments made thus far did not change which tasks are in the critical path (tasks timelines shown with asterisks) or the total mission time (shown both at the top of the figure and as the stop time of Task 19). The figure does show, however, that the six tasks assigned solely to Crew Member Type C, i.e., Tasks 14 through 19, are still in conflict with one another.

Modifying the Crew Template to Further Reduce Manning at the Expense of Increasing Mission Time

A careful examination of the GANTT chart for only Crew Member Type C indicates that the tasks that are still in conflict are performed after the first 80 seconds of the mission duration. As a result, all slack time for tasks not in the critical path that could be used to eliminate these conflicts have been "used up." Consequently, any further attempts to reduce the required number of crew members will involve delaying the start times of tasks on the critical path. This, of course, will cause an increase in total mission time and introduces the need to consider the trade off between manning level and mission duration.

After verifying the advice available in the GANTT chart drawn for only Crew Member Type C with that given in the overlap and conflict frequency tables, two additional modifications were made to the crew template for this sample application. First, the start time for Task 14 was delayed by 10.1 seconds. Because of the task relationships required for this sample problem, delaying Task 14 also causes similar delays for Tasks 15, 18, and 19. Second, the start time for Task 19 is further delayed by an additional 3.3 seconds.

The results of these latter two modifications are evident in Figure 42. This figure shows the new GANTT chart for Crew Member Type C of this sample problem. Close examination of the start and stop times for tasks assigned to Crew Member Type C reveals no remaining conflicts in task performancc. Hence, only one of this type of crew member is required to perform the seven tasks assigned to it. The new critical path, however, reflects an increase in total mission performance time from 101.6 to 115.0 seconds (see the stop time of the last task performed, Task 19, in Figure 42).

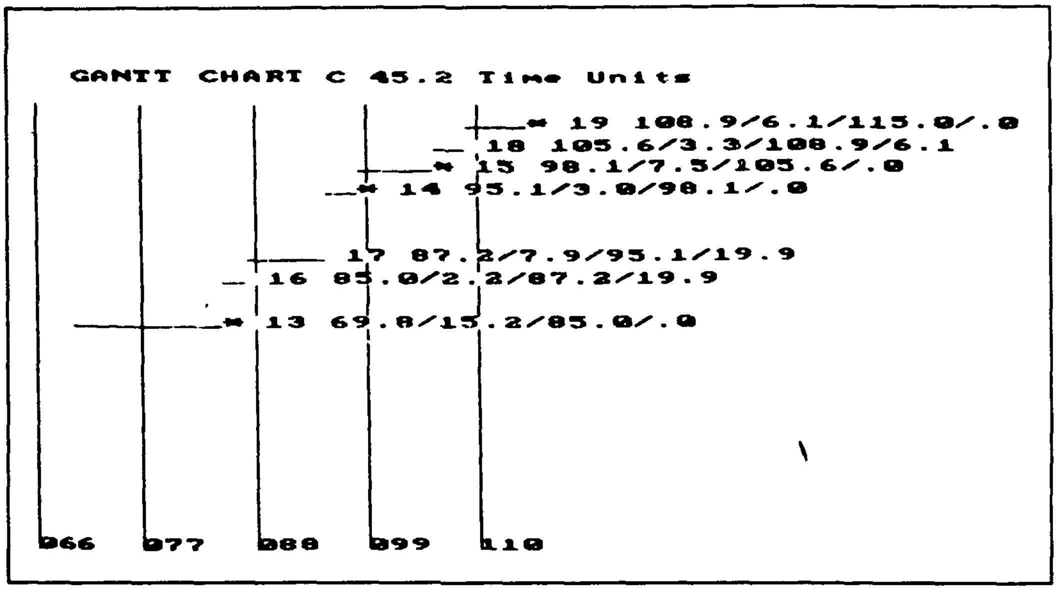

Figure 42. The GANTT chart for only the tasks assigned to Crew Member Type C of the crew after delaying the start of four tasks on the critical path.

Summary

This sample problem shows that the CRDS can be used as an aid in resolving conflicts caused by demands that a given type of crew member simultaneously perform multiple tasks. In the process of resolving these conflicts, it also is shown that the CRDS can be an aid for reducing the total number of crew members required. This application of the CRDS developed two alternative definitions of the crew requirements. In one, the size of the crew was reduced from seven crew members to four, without any change in the mission performance time of 101.6 seconds. In the second, the size of the crew was further reduced to three crew members but only by increasing the mission performance time by 13.4 seconds.

What, if any, are the implications of delaying the start time of tasks not on the critical path? Will the decrease in manning requirements from seven to four offset these other possible outcomes of delaying the performance of these tasks? Is an increase in mission performance time justifiable in order to reduce manning requirements by one? The implications of these potential tradeoffs, and, indeed, the impact of any alternative templates developed using the CRDS require further investigation, especially in an operational context.

Sample Application 2 -- Fire Direction Center Cell

This sample application of the CRDS is for a cell of personnel that are assigned to a field artillery fire direction center (FDC). The data required to build a template for this sample application have already been entered into the CRDS by the authors to develop the file named FDC_____.SRD. The user can access this cell template through the files directory menu.

The application of the CRDS to organizational building blocks other than only the personnel assigned to a crew-served weapon system is an important extension of the tool. Building and studying a template for the team or cell which constitutes a FDC represents a departure from the typical crew in at least two ways.

- The cell is not servicing materiel to generate combat power.

- The cell is comprised of personnel that are widely dispersed in battle deployment; they must communicate by radio.

The objective for describing this particular sample application is not, as was the case with the first sample application, to show how the CRDS can be used to define a cell with a smaller manning requirement. As will be seen below, the template for this cell is such that only one of each type of personnel is required. Rather, the objective of this sample problem, other than to merely demonstrate the building and examination of a cell template, is to show how the CRDS can be used to identify which tasks or personnel would benefit most from enhancements in hardware or software, from a change in how the tasks might be performed, and in assignment of tasks to personnel.

The mission for the <u>manual</u> FDC used in this sample application was to place on-call suppressive fire against a target whose location was an offset from a pre-calculated index or registration point. The mission began with the initial receipt of target information from a forward observer and ended with successful transmission of the shift mission to the battery of 155-mm Howitzers. The cell consists of five types of personnel: a fire direction officer (FDO), a computer (CMPTR), a chart operator(CHRTO), a forward observer (OBSVR), and a set of guns located at a battery location (BTRY).

NOTE: In this particular sample application, the "computer" is a human being, but a purely hardware- and software-based computer could also be envisioned as a resource assigned to this cell, perhaps with a human assigned to operate the computer. Assigning non-human resources to the cell would constitute a third way that the template of a cell could differ from that of a typical crew.

Table 4 identifies the 23 tasks which must be performed by the FDC to accomplish its mission. Table 5 shows the performance times for each task as a function of the type of personnel assigned to perform the task. These performance time data were obtained during tests conducted in a field environment. The constraints on the order in which tasks could be performed are in Table 6, which identifies required predecessor and successor tasks for each mission essential task. Taken together, the data in these three tables are sufficient to build a template for this cell performing the prescribed mission. (See the data file named FDC_____.SRD in the CRDS files directory.

TABLE 4

MISSION ESSENTIAL TASKS OF THE FDC CELL

Task		Description
1	ISSUE CALL	Issues call for fire
2	RDBK CALL	Receives & reads back call for fire
3	IDENT RP	Identifies registration point
4	RDBK RP	Receives & reads back registr point
5	TGT COORD	Announces target coordinates
6	RDBK COORD	Receives & reads back coordinates
7	DESC TGT	Describes target
8	RDBK DESC	Receives & reads back tgt descrip
9	FIORD FDC	Issues fire order
10	MSG TO OBS	Determines & transmits the MTO
11	FM GUN	Transmits fire mission alert to btry
12	RDBK FM	Receives & reads back fire msn alrt
13	FIORD GUN	Transmits fire order to the battery
14	RDBK FIORD	Receives & reads back fiord to cmptr
15	PLOT RG	Plots target & announces chart range
16	RDBK RG	Receives & reads back target range
17	CHT DEFL	Announces chart deflection
18	RDBK DEFL	Receives & reads back chart defl
19	FD/CD/DEFL	Cmpt data-change to cmd-defl to btry
20	RDBK DEFL	Receives & reads back deflection
21	SITE	Computes site & announces to cmptr
22	QUADRANT	Computes & transmits quad to btry
23	RDBK QUAD	Receives & reads back quadrant

TABLE 5

TASK PERFORMANCE TIME (SECONDS)
FOR EACH TASK AND TYPE OF PERSONNEL
DURING THE FDC MISSION

Task	Type of Personnel				
	OBSVR	FDO	CMPTR	BTRY	CHRTO
1	2.45	--	--	--	--
2	--	2.22	--	--	--
3	3.27	--	--	--	--
4	--	2.39	--	--	--
5	6.21	--	--	--	--
6	--	6.95	--	--	--
7	4.36	--	--	--	--
8	--	1.99	--	--	--
9	--	2.28	--	--	--
10	--	2.07	--	--	--
11	--	--	2.12	--	--
12	--	--	--	1.42	--
13	--	--	1.52	--	--
14	--	--	--	1.80	
15	--	--	--	--	39.78
16	--	--	2.42	--	--
17	--	--	--	--	6.78
18	--	--	2.67	--	--
19	--	--	18.79	--	--
20	--	--	--	1.65	--
21	--	18.64	--	--	--
22	--	--	8.82	--	--
23	--	--	--	1.25	--

TABLE 6

REQUIRED TASK RELATIONSHIPS
DURING A FDC MISSION

Task		Predecessor Task	Successor Task
1	ISSUE CALL	none	2,11
2	RDBK CALL	1	3
3	IDENT RP	2	4,15
4	RDBK RP	3	5
5	TGT COORD	4	6
6	RDBK COORD	5	7
7	DESC TGT	6	8
8	RDBK DESC	7	9
9	FIORD FDC	8	10,13
10	MSG TO OBS	9	none
11	FM GUN	1	12
12	RDBK FM	11	13
13	FIORD GUN	9,12	14
14	RDBK FIORD	13	none
15	PLOT RG	3	16,21
16	RDBK RG	15	17
17	CHT DEFL	16	18
18	RDBK DEFL	17	19
19	FD/CD/DEF	18	20
20	RDBK DEFL	19	22
21	SITE	15	22
22	QUADRANT	20,21	23
23	RDBK QUAD	22	none

The CRDS permits the user to quickly examine these data in a variety of different formats. The network of tasks and the critical path are shown in the PERT diagram illustrated in Figure 43. Table 7 shows the timing of tasks in the critical path. It may be seen that thirteen of the 23 tasks are on the critical path and that the time required to complete the designated mission is 98.7 seconds.

NOTE: The horizontal dimension of the PERT diagram shown in Figure 43 has been constructed to approximate the task and mission performance timeline. The authors first developed the timeline-based PERT diagram and used the spatial relationships among the nodes in that diagram to draw the diagram shown in Figure 43. The advantage of following these procedures is that it allows the user to draw a task line for the last task in the critical path as well as various dummy task lines.

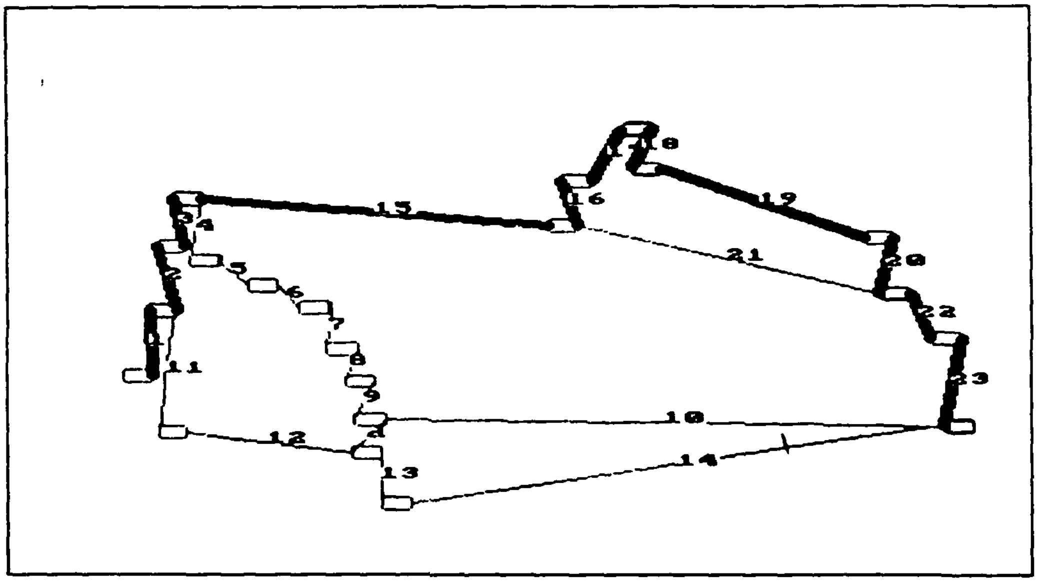

Figure 43. The PERT diagram for the mission essential tasks of the FDC cell sample problem.

Note that six of the tasks on the critical path share the abbreviation "RDBK." This abbreviation indicates that a designated type of personnel receives and then reads back portions of the information flow. Timing for these six tasks total about 12 seconds and is a price intentionally paid for reliability in "manual" fire direction. The CRDS could be used to quantify the effectiveness gained by automating these tasks.

TABLE 7

FDC TASKS ON THE
CRITICAL PATH

TASK		START	STOP	DURATION
1	ISSUE CALL	0.0	2.4	2.4
2	RDBK CALL	2.4	4.7	2.2
3	IDENT RP	4.7	7.9	3.3
4	RDBK RP	7.9	10.3	2.4
5	TGT COORD	10.3	16.5	6.2
15	PLOT RG	16.5	56.3	39.8
16	RDBK RG	56.3	58.7	2.4
17	CHRT DEFL	58.7	65.5	6.8
18	RDBK DEFL	65.5	68.2	2.7
19	FD/CD/DEF	68.2	87.0	18.8
20	RDBK DEFL	87.0	88 6	1.6
22	QUADRANT	88.8	97.4	8.8
23	RDBK QUAD	97.4	98.7	1.2

The relationship among task performance times is displayed in order of earliest start times in the GANTT chart shown in Figure 44. The longest task may be quickly seen to be Task Number 15, plotting of the range to the target; it consumes 39.8 seconds and lies on the critical path. Improving the performance time of that one task could significantly decrease the time required to perform the designated mission. A decrease in mission performance time would increase the number of fire missions that could be managed by a fire direction team within a given time window.

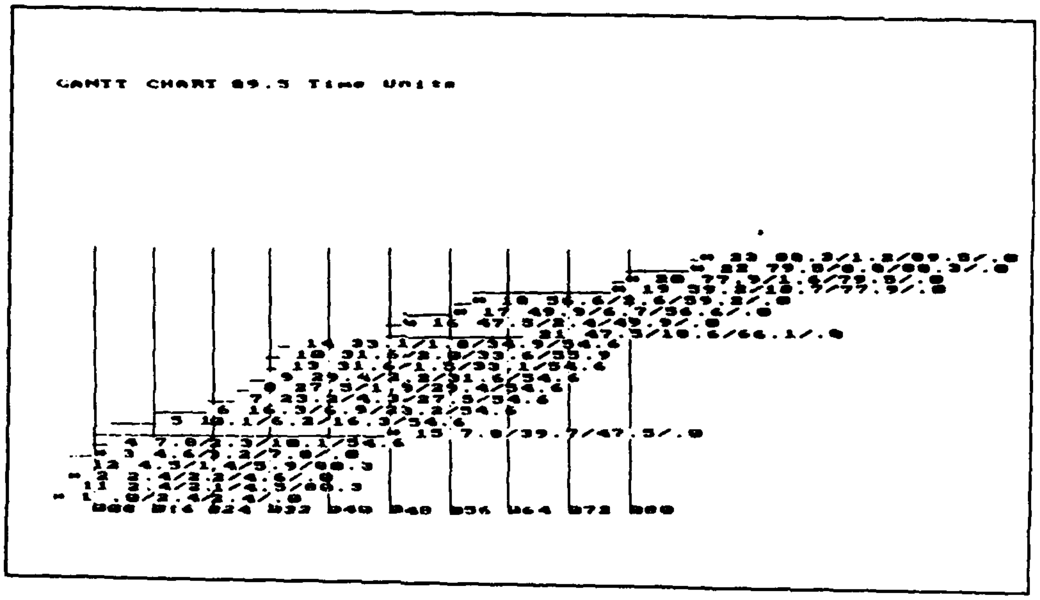

Figure 44. The GANTT chart for the mission essential tasks of the FDC cell.

Summary

This second sample problem shows that the CRDS can be applied to a cell of personnel (and equipment) whose purpose is not merely to service a materiel system, but rather to perform a set of interrelated tasks which must be performed to accomplish some specified function. The functions assigned to a cell are often required to give some other, often higher echelon unit a mission essential capability. This second sample problem also demonstrates that the CRDS can be used as an aid to evaluating various attributes of the unit under study. That evaluation can, in turn, allow the user to project desirable improvements in the capabilities of the types of personnel (and equipment) assigned to the cell as well as operational and organizational procedures for employing those types of resources to improve the overall performance capabilities of the unit.

A Final Suggestion for Future Applications of the CRDS

Both of the sample problems described in this part of the User's Guide, as well as the template named "Example" that was developed and analyzed in earlier parts of the Guide, assume that the unit under study performs a fixed set of tasks repetitively and in a recurring, cyclic manner in the course of performing its mission. This assumption concerning the nature of the conduct of task and mission performance is not necessary if the user wishes to apply the CRDS. Indeed, very many important missions performed by many types of organizational units will not conform to the conditions dictated by this assumption. Some of the more interesting and useful types of crew or cell design must address unit missions comprised of tasks whose performance requirements are probabilistic rather than deterministic.

However, these types of potential applications raise a problem. Namely, how does one define, build, and analyze a unit model or template when the mission of the organizational unit is not comprised of tasks which are performed in a recurring, deterministic sequence or network? It is proposed that there are three approaches that the user can take. Each is briefly described below. While the CRDS may not be directly applicable to the first approach described, it is very appropriate for the other two.

For one approach, the entire modelling process could be converted into a Monte Carlo simulation wherein the population of alternative task sequence combinations and times are sampled over time. This approach would essentially require the small unit designer to use a model building aid other than the CRDS.

While there are such aids available, there is ample reason to believe that using these tools would inevitably create three conditions that could be contrary to the goals of the user: (a) it would require a much more extensive data collection effort and a more detailed level of knowledge about the system and functions under study, (b) it would demand heroic assumptions, and (c) it would devastate the run time required to analyze a unit's organizational structure. Any one or more of these conditions could place unacceptable burdens on any potential user, especially during early stages in the development of new materiel or organizational concepts.

In a second approach, the user could use a mission profile representation of the crew or cell of interest performing at maximum stress levels. If the crew or cell were designed to meet this maximum level of operational demand, it could be assumed that the design would also establish a viable organizational structure for less stressing sets of conditions.

The third approach to designing units whose missions are comprised of probabilistic rather than deterministic task relationships relies on the capability the CRDS provides to the user for modifying an initial crew or cell template. Since it is so quick and simple to create or redo alternative task networks when using the CRDS, the user can replace an action choice (i.e., an action that forms a branch in the task network) with only simple actions. For example, rather than entering into the network an action choice for either engaging or not engaging a potential target, the user can create a database for engaging a target and another database for not engaging a target. Since the user normally has to compare the alternative branches of a task performance network in detail anyway, this third approach has much appeal.

REFERENCES

Christ, R. E., Conroy, J. A., and Briggs, A. L. 1990. Systematic Organizational Design (SORD) Methodology: A Primer (ARI Research Product 90-27). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A230 103)

Kellner, A. J., Conroy, J. A., and Christ, R. E. 1992. User's Manual for the Systematic Organizational Design (SORD) Methodology (ARI Research Product 92-05). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.