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ACARA User's Manual

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ACARA User's Manual

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ACARA (**A**vailability, **C**ost, **A**nd **R**esource **A**llocation) is a computer program which analyzes system availability, lifecycle cost (LCC), and resupply scheduling using Monte Carlo analysis to simulate component failure and replacement. This manual was written to:

(1) Explain how to prepare and enter input data for use in ACARA.

(2) Explain the user interface, menus, input screens, and input tables.

(3) Explain the algorithms used in the program.

(4) Explain each table and chart in the output.

Introduction

ACARA (**A**vailability, **C**ost, **A**nd **R**esource **A**llocation) is a program for analyzing availability, lifecycle cost (LCC), and resource scheduling. It uses a statistical Monte Carlo method to simulate a system's capacity states as well as component failure and repair. Component failures are modelled using a combination of exponential and Weibull probability distributions. ACARA schedules component replacement to achieve optimum system performance. The scheduling will comply with any constraints on component production, resupply vehicle capacity, on-site spares, crew manpower and equipment.

ACARA is capable of many types of analyses and trade studies because of its integrated approach. It characterizes the system performance in terms of both state availability and equivalent availability (a weighted average of state availability). It can determine the probability of exceeding a capacity state to assess reliability and loss of load probability. ACARA can also evaluate the effect of resource constraints on system availability and lifecycle cost.

ACARA interprets the results of a simulation and displays tables and charts for the following:

- Performance, i.e., availability and reliability of capacity states.
- Frequency of failure and repair.
- Lifecycle cost, including hardware, transportation, and maintenance.
- Usage of available resources, including mass, volume, and maintenance man-hours.

ACARA incorporates a user-friendly, menu-driven interface with full screen data entry. It uses a file management system to store and retrieve input and output datasets for system simulation scenarios.

ACARA may be obtained from the Computer Software Management and Information Center (COSMIC) at the University of Georgia. The phone number is (706) 542-3265. The control number for ACARA is #LEW-15713.

Table of Contents

1. Getting Started

1.1 Installing ACARA and Running It from DOS.

ACARA requires an 80386 or 80486 based microcomputer with an 80387 math coprocessor and at least 2 MB of extended memory. The operating system must be DOS 3.3 or higher. **Warning:** ACARA may conflict with RAM resident software and memory managers which reduce DOS memory below 640 K. Such programs may have to be disabled before running ACARA. A dot-matrix printer (e.g., Epson) is required to print any of the graphs in ACARA's results.

ACARA is available as either the executable code or the source code, on either a 3.5 inch or a 5.25 inch high-density diskette.

The executable code will perform all the ACARA tasks, but it does not allow the program to be modified. The package contains the following files:

acara.run	contains the ACARA program
apl2run.exe	executes acara.run
acara.bat	invokes the apl2run sequence from DOS

To run the executable code, enter the appropriate drive and type "ACARA".

The source code is contained in the file acara.atf, which is the APL transfer file format. The code may be modified using an APL editor. The IBM APL2 programming language and also several auxiliary processors are necessary. APL2 for the PC is available from:

IBM Direct
Phone 800-IBM-2468
Part Number 6242936

For more assistance, call the IBM APL Hotline: 408-463-2752.

To run the source code, copy acara.atf into the system APL2 directory. Enter APL2, using the following invocation to run the auxiliary processors:

```
APL232 ap2 ap80 ap100 ap101 ap103 ap120 ap124 ap207 ap210 AT
```

To retrieve ACARA from the transfer file, type the command: "**)IN ACARA**". To execute the program, type: "**ACARA**". The ACARA Main Menu will immediately appear on the screen.

1.2 Using ACARA's Menu System

ACARA's features are accessible through its cursor-driven menu system. This menu appears immediately after you load ACARA from DOS. The cursor is initially at the top left corner of the screen, indicated by the arrowhead symbols surrounding the keyword phrase "ACARA_Info".

The keywords at the top of the screen represent the following primary groups of tasks:

ACARA_Info
Gives general information about ACARA. The cursor is located here at the beginning of the ACARA session. To read this information, press the [Enter] key.

Input
Contains tasks involving ACARA's input, such as:

- **Enter data**
  Interfaces for input data.
- **System Files**
  Manages files of input data.
- **Clear Input**
  Clears input data.

Run
Simulates the current system data (**Individual** Mode) or a batch of ACARA system files (**Batch** mode).

Results contains the following:

- **Performance** Results Tables
- **Failure & Repair** Results Tables
- **Lifecycle Costs** Results Tables
- **Resource** Allocations Results Tables
- **Results Files**
  Loads, saves, copies and deletes results of previous ACARA simulations.
- **Text Files**
  Edits, copies and deletes ASCII files of ACARA tables.

Quit
Lets you leave ACARA. If you are using the executable code, you will return to the DOS environment. If you are using the source code, the Main Menu will disappear, but you will remain in the APL environment. To leave the APL environment, type the system command ")OFF".

To move between any of these options, move the cursor to the right or left, using the cursor keys [→] and [←].

Input, **Run**, and **Results** each has its own pull-down menu. As the cursor moves from left to right, each pull-down menu will appear under its keyword. The ">" symbol following a keyword indicates that the option has a pull-down menu of sub-tasks. The arrowhead "►" on the left side of the pulldown menu is the cursor. The option located at the cursor is described by a phrase displayed on the second row on the screen.

For example, move the cursor to the keyword **Input**. The top portion of the screen should look like Figure 1.2.1, below:

ACARA_Info	►**Input**◄	Run	Results	Quit
Enter ACARA Simulation Parameters.				

```
►Enter data    >
 System Files  >
 Clear Input
```

Figure 1.2.1

Input contains three options: **Enter Data**, **System Files**, and **Clear Input**. Use the [↑] and [↓] cursor keys to move between these options and the [Home] and [End] keys to jump to the top or bottom of the menu.

The options **Enter data** and **System Files** each have submenus of tasks. To call the **System Files** submenu, move the cursor to this keyword and press the [Enter] key. The top portion of the screen will look like Figure 1.2.2, below:

ACARA_Info	▶**Input**◀	Run	Results	Quit

Load a previously saved system.

```
Enter data    >
▶System Files >   ▶Load
Clear Input        Save
                   Copy
                   Delete
                   Rename
                   Import    >
                   File path
                   Help
```

Figure 1.2.2

To select any of the **System Files** options (**Load**, **Save**, etc.), use the [↑] and [↓] cursor keys to move up and down and press [Enter] at your selection. To leave the **System Files** submenu, press the [Escape] key. The screen will again resemble Figure 1.2.1 with the cursor at the **System Files** option.

1.3 Using Help Windows

On-Line help is available in ACARA. For information about a pulldown menu, select **Help**. **Help** is always the last option in the menu. If the pulldown menu has several options, you may be prompted to select from a menu of help topics; move the cursor to your choice and press the [Enter] key.

If the text displayed by the Help Window extends beyond the frame, the phrase "More ↓" will appear below the window, so use the [↑], [↓], [Page Down], and [Page Up] keys to move up and down. To leave the Help Window, press [Escape].

To call the Help Window from an input table or input screen, move the cursor to the input field or column in question and press [F1]. For example, if you are currently using the Block Properties Input Table, and you want help regarding the Capacity, move the cursor to the column labeled "Capacity" and press [F1]. Information about Capacity will appear in the Help Window.

2. Preparing the Data

2.1 Defining Block Types and Individual Blocks

ACARA represents the components of a system as individual blocks. Each block is of a certain type--each type must be given a unique name and has characteristics (mass, volume, etc.) which differentiate it from the others. The name of each type is entered into the **Names and Properties Input Table** (page 18) as are its mass, volume, cost, and capacity. The names will appear at the left of each input table where other block characteristics are defined.

Each individual block is assigned a number and is then assigned to one of these block types, using the **Block Numbers Table** (page 23).

Blocks may be installed into the system all at once or installed in stages. In the case of staged installation, the blocks installed during each stage are entered using the **Installation Time Input Table** (page 25).

2.2 Defining Relationships Between Blocks and Subsystems

A reliability block diagram (RBD) must be prepared for ACARA to properly simulate a system's availability. The RBD depicts a system, which in this context is defined as an arrangement of blocks which successfully performs a function. Each block is either available or unavailable, i.e., there are no gradations of partial block performance. The RBD does not necessarily depict physical connections in the actual system, but rather shows the role of each block in contributing to the system's function.

ACARA can model arrangements of series, parallel, or M-of-N parallel blocks:

> A **series** subsystem is available if all the elements it contains are available.
>
> A **parallel** subsystem is available if at least one of its elements is available.
>
> An **M-of-N** parallel subsystem is available if a specific number of two or more parallel blocks is available. For example, a 2-of-3 parallel subsystem contains three blocks--at least two blocks must be available for the system to be available.

A simple subsystem is defined as a series or parallel combination of two or more blocks. Subsystems can be combined further as series or parallel combinations of other subsystems and/or blocks until the entire system is defined as a combination of subsystems and blocks. The arrangements of blocks and subsystems are specified by the **Block Diagram Table** (page 27).

ACARA has no restrictions on the total number of blocks in the RBD or the number of blocks in a series or parallel subsystem. A block may appear in more than one subsystem if this is appropriate.

The RBD should be annotated as follows. Blocks are sequentially numbered as B1, B2, etc. Subsystems are numbered as S1, S2, etc. and are defined from the "inside out". **A subsystem cannot contain a subsystem of a higher number.** For example, Subsystem S3 can contain S1 and S2, but cannot contain S4. Beginning with the innermost set of blocks, each parallel or series set of blocks is partitioned into a subsystem which in turn may be combined with other blocks or subsystems. The entire system is finally described as a subsystem containing all other subsystems and blocks.

The system shown in Figure 2.2 will be used as an example throughout this manual. The system consists of the following components, or "blocks":

Turbine	Blocks 1, 13
Generator	Block 2
Diode	Blocks 3-5
Battery	Blocks 6-11
Outlet	Block 12

The system contains 6 subsystems, as follows:

Subsystems 1 and 2 are both variable M-of-N parallel arrangements of batteries. These subsystems respectively contain Blocks 6 through 8 and Blocks 9 through 11.

Subsystem 3 consists of Subsystems 1 and 2 in parallel.

Subsystem 4 is a binary M-of-N parallel arrangement of diodes, Blocks 3 through 5.

Subsystem 5 is a parallel arrangement of two turbines, blocks 1 and 13.

Subsystem 6 comprises the entire system and is a series arrangement of Subsystems 3 through 5 and Blocks 2 and 12.

For further information on the Block Diagram Table as well as series, parallel, variable M-of-N and binary M-of-N subsystems, refer to the section entitled "Edit Diagram" (page 27).

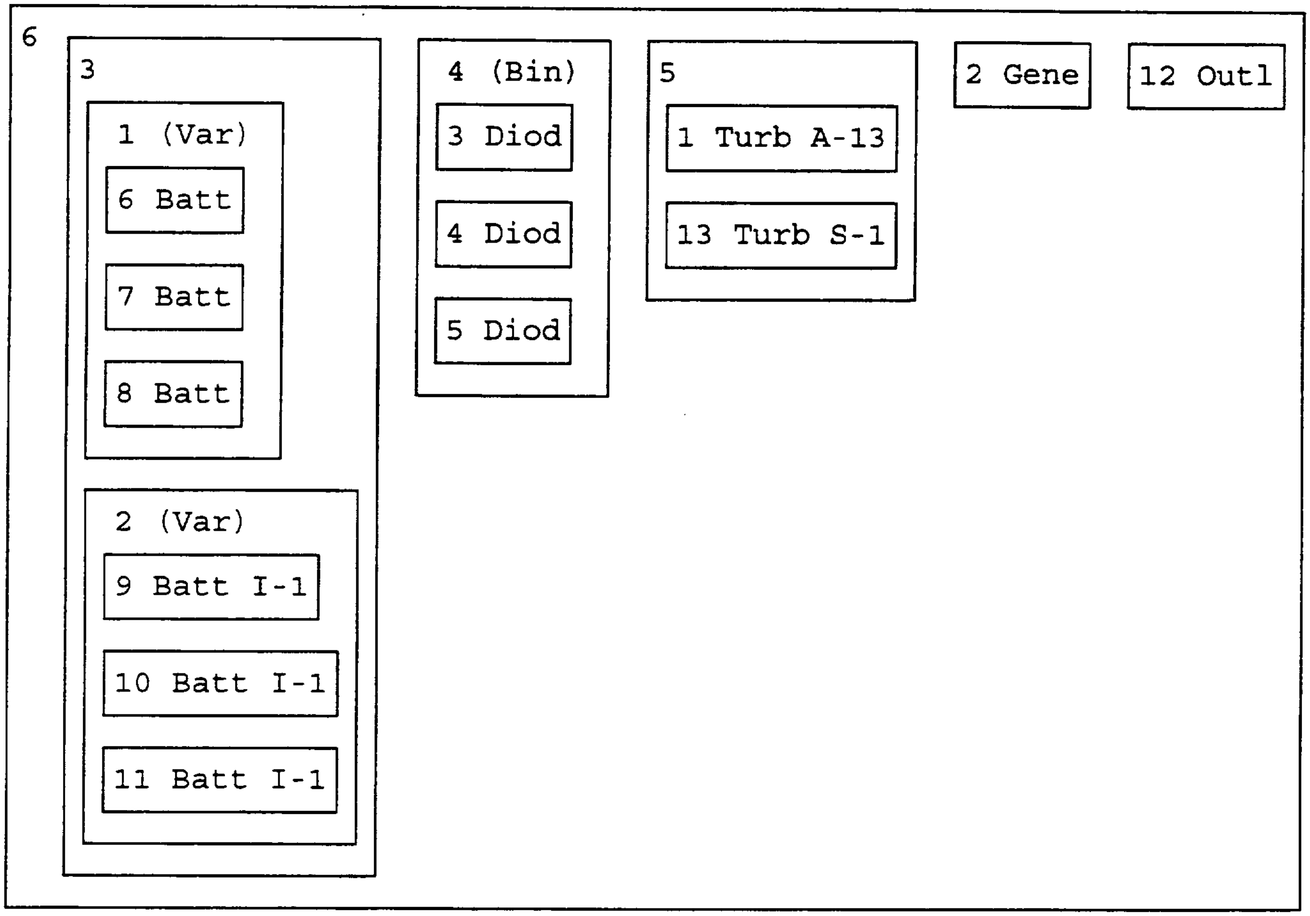

6
3
1 (Var)
6 Batt
7 Batt
8 Batt
2 (Var)
9 Batt I-1
10 Batt I-1
11 Batt I-1
4 (Bin)
3 Diod
4 Diod
5 Diod
5
1 Turb A-13
13 Turb S-1
2 Gene
12 Outl

Figure 2.2

2.3 Modelling Time-to-Failure

ACARA models the time-to-failure for each block using the Weibull distribution function:

$$\text{time-to-failure} = \text{scale} \times (-\ln R)^{1/\text{shape}}$$

The shape and scale factors are adjusted to modify the form of the distribution. Uniform random numbers from 0 to 1 are generated and substituted for the reliability, R. ACARA uses the following models to generate time-to-failure: **early failure** (i.e., infant mortality), **random failure**, and **wearout failure** (i.e., life-limiting failure). These models are adjusted by user-defined parameters to approximate the failure characteristics of each block.

To model early failure, the mean life and shape factor are specified for each block type and the scale factor is calculated from the equation:

$$\text{scale} = \frac{\text{mean life}}{\text{Gamma}(1+1/\text{shape})},$$

where "Gamma" is the Gamma function.

The shape factor for early failure is less than or equal to 1. The chance that a block will suffer an early failure is defined by the **Probability of Early Failure** for its type. The mean life, shape factor, and probability are entered into the **Early Failure Input Table** (page 21).

Random Failure is modelled by the exponential distribution function, a special case of the Weibull, where the shape factor is equal to 1 and the scale is equal to the Mean Time Between Failure (MTBF). The MTBF is entered using the **Random and Wearout Failure Input Table** (page 22).

Wearout Failure is also modelled by the Weibull function. The shape factor must be 1 or more. The wearout mean life and shape factor are entered into the **Random and Wearout Failure Input Table**. If the block is installed having an initial age (i.e., it is not brand new), its initial age is subtracted from its first time-to-failure due to wearout. Likewise, if it undergoes a failure-free period, this period is added to its first time-to-failure. Initial ages and failure-free periods are entered into the **Block Ages Input Table** (page 24).

ACARA generates time-to-failure events using one or a combination of these models and assigns the minimum resulting time for each block as its next failure event. The early failure model is canceled by assigning to the block type an early failure probability of zero; random failure, by an excessively large MTBF, and wearout failure, by an excessively large mean life.

ACARA also simulates redundant pairs of active and standby blocks. A standby block is installed as dormant (i.e, inactive), and its time-to-failure will be initially modelled by random failure, in which the MTBF is multiplied by its characteristic "Dormant MTBF Factor" (page 22). When the corresponding active block fails, the standby is immediately activated and its time-to-failure will be modelled by early, random, and wearout failure until the active block is replaced. Redundant active/standby block pairs are specified in the **Redundancy Table** (Page 30).

2.4 Modelling Down Time

When a block fails, ACARA estimates the time it remains down until it is replaced with a spare.

The down time for a failed block depends in part upon the availability of spares and resources. These spares may be local spares, that is, initially located at the site. If a local spare is available when the block fails, the block is immediately replaced and down time will depend only on the mean-time-to-repair (MTTR). If no local spares are available, ACARA will schedule a replacement according to the scheduled production quantities for that block type, the constraints on mass and volume and the delay associated with manifesting and loading spares to the resupply vehicle (i.e., resupply cutoff). ACARA also checks the constraints on the maintenance agents to determine when the block can be replaced. The production quantities, local spares, resource constraints and resupply cutoff are entered using the **Resources Input Menu** (page 31).

Down time also depends on the resupply interval, since spares are assumed to be delivered only during regular periods. The resupply interval is entered into the **Simulation Parameters Input Screen** (page 15).

Once all the above conditions are met to allow the block to be replaced, ACARA then estimates the time required to replace it. The time-to-repair depends upon the MTTR's for that block type. MTTR's may be specified for up to three separate maintenance agents. Examples of maintenance agents are crew, equipment, and robotics. The MTTR's for each block type are specified in the **Repair Time and Personnel Quantities Input Table** (page 20). ACARA assumes that the maintenance actions occur simultaneously, so that the block's repair time is determined by the maintenance agent having the maximum MTTR. During the simulation, the time-to-repair may either be set equal to the maximum defined MTTR or be determined stochastically.

3. Entering Data Into ACARA

The features under the **Enter Data** option let you enter the input required to run an ACARA simulation. Move the cursor right to **Input** and down to **Enter Data**, then press [Enter]. The menu should resemble Figure 3.

Input is entered into ACARA using Input Windows and Input Tables. Refer to the Appendix for instructions for using these input interfaces, such as how to get a printout or an ASCII (text) file from the table. Whenever invalid data is entered into ACARA, a tone will sound and ACARA will return to the error until it is corrected.

```
| ACARA_Info | ►Input◄ | Run | Results | Quit |
| Enter Simulation Parameters.                 |
             ►Enter Data   > | ►Simulation
              System Files > |  Cost Parameters
              Clear Input    |  Block Data       >
                             |  Block Diagram    >
                             |  Resources        >
                             |  Units & Nomen.
                             |  Print Input
                             |  Help
```

Figure 3.

3.1 Simulation Parameters

The **ACARA Simulation Parameters Input Window** (Figure 3.1) is used to enter the parameters necessary to run a simulation.

```
                    Simulation Parameters

 Number of Runs:      [ 10  ]

 Duration:            [ 15  ]       Period Length:        [  3  ]

 Resupply Interval:   [ 1   ]       Capacity Increment:   [ 10  ]

 Do you want to normalize to available System Capacity?(Y/N)  [Y]

 Do you want a Monte Carlo Simulation of Repair time? (Y/N)   [Y]

 Do you want to track failure types? (Y/N) [Y]
```

Figure 3.1

The simulation parameters are as follows:

Number of Runs
Sets the number of iterations used to characterize the system. More accurate results and more capacity states will be determined if more iterations are specified; however, this is at the expense of increased computation time.

Duration
Sets the number of years of system operation to be simulated. The duration must be divisible by both the period length and the resupply interval.

Period Length
Sets the time interval, in years, used in the simulation for purposes of statistical analysis.

Resupply Interval
Sets the time interval, in years, between deliveries of spares to the system. This period must be greater than the resupply cutoff time to manifest spares (page 34).

Capacity Increment
Sets the increment over which capacities are "binned" to evaluate reliability, expressed as a percentage. A smaller increment results in more detail, but requires more computation time.

Do you want to normalize to available system capacity?
Indicates whether the system capacity should be scaled to the system's current capability. Enter either "Y" or "N" (Yes or No). If the system is installed in stages, it may be preferable to scale the capacity.

Do you want a Monte Carlo Simulation of Repair time?
Indicates whether the Monte Carlo method should be used to determine the elapsed time for each installation and replacement. Enter either "Y" or "N" (Yes or No). If the answer is "No", ACARA will use the MTTR's (mean time to repair) associated with each block type and assign the maximum value to all blocks of that type. The latter method uses less computation time.

Do you want to track failure types?
Indicates whether to distinguish between early, random, and wearout failures. Enter either "Y" or "N" (Yes or No). Answering "No" reduces the memory requirements, but some results tables will not be available (pages 58 and 64).

3.2 Cost Parameters

The **Cost Parameters Input Window** is shown on Figure 3.2. Enter into the field labeled "Transportation" the cost per unit mass used to calculate transportation costs. Enter into the remaining fields the costs per hour associated with the types of maintenance actions (i.e., Crew, Equipment, Robotics, etc.). The units for cost and mass and the maintenance nomenclature are arbitrary and can be changed by the user (page 35).

Cost Parameters		
Transportation:	[3]	($k/lb)
Crew:	[80]	($k/hour)
Equipment:	[20]	($k/hour)
Robotics:	[40]	($k/hour)

Figure 3.2

3.3 Block Data Menu

The Block Data Menu, shown in Figure 3.3, contains the input tables for entering information about each block type.

```
ACARA_Info | ►Input◄ | Run | Results | Quit
Enter Block Properties.

►Enter data   >   Simulation
 System Files>    Cost Parameters
 Clear Input     ►Block Data       >   ►Names & Properties
                  Block Diagram    >    MTTR & Personnel
                  Resources        >    Early Failure
                  Units & Nomen.        Random & Wearout
                  Print Input           Block Numbers
                  Help                  Initial Ages
                                        Installation Times
                                        Nom. Quantities
                                        Help
```

Figure 3.3 Block Data Menu

Names and Properties

The **Names and Properties Input Table** (Figure 3.3.1) is used to enter the names and characteristics of each block type. Each row with a name must have each of the other columns filled by an entry; blank entries will not be accepted.

BLOCK TYPE NAMES & PROPERTIES

Block Type	Mass lbs	Volume ft3	Cost $k	Capacity %
Turbine	129	34.2	82.0	100
Generator	156	22.6	12.3	100
Diode	0.12	0.28	.018	50
Battery	53.1	6.8	11.9	25
Outlet	1.7	0.8	.085	100

Figure 3.3.1

The input columns are as follows:

Name
Each name must be unique and contains up to 20 characters. This is the only input column in ACARA where block names can be entered.

Mass
Mass per unit block. Units for mass, volume, and cost are arbitrary (page 35).

Volume
Volume per unit block.

Cost
Cost per unit block.

Capacity
The percentage of the total system capability that the block either produces, conducts, or supports. The capacity in this column is ignored if the individual blocks belong to an M-of-N parallel arrangement, since the M-of-N subsystem capacity set in the Block Diagram Table will override the individual capacity (page 28). This column cannot be left blank, however, so enter a dummy capacity.

Remember that a block's capacity is by definition a percentage of the total system capability. A "support" block that does not contribute directly to the output, and yet is necessary for the system to be operational, still has a defined capacity. The capacity will depend on the degradation in system capability resulting when the block fails. For example, a structure that supports a battery may be considered to be in series with that battery. It can be assigned a capacity equal to that of the battery, since the battery will fail whenever the structure fails. If it is appropriate, the support block can be assigned a capacity of 100%, so as not to act as a bottleneck to the RBD.

Repair Time and Personnel

The **Repair Time and Personnel Input Table** (Figure 3.3.2) is used to enter the mean time to repair (MTTR) and the number of personnel required for installation or maintenance of each block type. ACARA assumes that installing a block requires as much time and personnel as does repairing a block.

ACARA accounts for three types of maintenance agents. In the example, they are called "Crew", "Equipment", and "Robotics". The nomenclature is arbitrary and may be modified by the user. (page 35)

ACARA determines the time for each maintenance agent and assumes that the maintenance actions occur simultaneously. To account for down time due to repair for any given block, the repair time is estimated either by:

(1) Directly using the maximum MTTR of the three maintenance actions. In the example system, the repair time for the turbine will be 13.5 years, based on the Crew MTTR.

(2) Using a Monte Carlo method, i.e., the result of a Weibull distribution about the maximum MTTR. The shape factor is set at 3.44 to approximate a normal distribution. This model requires more computation time.

To use the Monte Carlo method for all block types, enter 'Yes' in the appropriate field in the Simulation Parameters Input Window (page 15).

REPAIR TIME & PERSONNEL

Block Type	Crew MTTR,Hrs	Crew No.	Equipment MTTR,Hrs	Equipment No.	Robotics MTTR,Hrs	Robotics No.
Turbine	13.5	1	3.8	1	0.3	1
Generator	5.2	1	1.1	1	0.3	1
Diode	0.3	1	0	1	0	1
Battery	1.1	1	0.9	1	0.3	1
Outlet	2.3	1	0	1	0.3	1

Figure 3.3.2

Early Failure

The **Early Failure Input Table** (Figure 3.3.3) is used to enter data related to "infant mortality". The early failure model is based upon the Weibull distribution function (page 12). This distribution is adjusted by the Weibull shape and scale factors. The scale factor is calculated using the mean life and the shape factor.

The input columns are as follows:

Probability
The probability that the given block will suffer an early failure. The probability must be at least 0, but no more than 1.

Mean Life
Defines the mean life, in years, for the early failure distribution.

Shape
Defines the shape for the early failure distribution. The shape factor must be greater than 0, but no greater than 1.

EARLY FAILURE DATA

Block Type	Probability	Mean Life	Shape
Turbine	0	0.5	1
Generator	0	0.5	1
Diode	0.25	0.5	1
Battery	0.25	0.75	1
Outlet	0	0.5	1

Figure 3.3.3

Random and Wearout Failure

The **Random and Wearout Failure Input Table** (Figure 3.3.4) is used to enter the random and wearout failure distribution data by block type. The input columns are as follows:

Random MTBF
The random mean-time-between-failures for active blocks, in years, according to the exponential distribution function. To cancel random failure for a block type, assign to it an MTBF of 99999 years.

Dormant MTBF Factor
The factor by which to multiply the random MTBF to model random failure for a standby block in the dormant state. In the example system shown on page 11, Subsystem 5 is a redundant pair of turbines, Blocks 1 and 13. Block 1 is the active block and is assigned an MTBF of 49.2 years, while its standby, Block 13, is initially dormant, and has an MTBF of 492 years. If Block 1 fails, Block 13 will be activated and its MTBF will be 49.2 years until Block 1 is replaced.

Wearout Mean Life
Defines the mean life, in years, for the wearout failure model using the Weibull distribution function. To cancel the wearout failure model for a block type, assign to it a mean life of 99999 years.

Wearout Shape
Sets the shape factor for the wearout failure distribution. The mean life and shape factor are used to calculate the scale factor, which, along with the shape factor, adjusts the Weibull distribution (page 12). The wearout shape factor must be greater than or equal to 1.

RANDOM & WEAROUT FAILURE DATA

Block Type	Random MTBF Years	Dormant MTBF Factor	WearOut Mean Life Years	WearOut Shape Factor
Turbine	49.2	10	19.8	3.44
Generator	55.8	1	25.6	1
Diode	43.1	1	99999	1
Battery	62.5	1	7.7	10
Outlet	82.8	1	25.8	3.44

Figure 3.3.4

Numbers

The **Block Numbers Input Table** (Figure 3.3.5) assigns the type to each block in the system. The type names, entered in the Names and Properties Input Table, appear to the left. Block numbers corresponding to each name are entered in the right column.

Consecutive block numbers may be signified using a dash: for example, in Figure 3.3.5, for the diodes, ACARA interprets the notation '3-5' as 'Blocks 3, 4, and 5.'

If the space needed exceeds the available column width, press [F2] to call the menu and select **Insert** to insert blank rows (See Appendix, page 120).

BLOCK TYPES & BLOCK NUMBERS

Block Type	Block Identifier Numbers
Turbine	1 13
Generator	2
Diode	3-5
Battery	6-11
Outlet	12

Figure 3.3.5

Age

The **Block Age Table** (Figure 3.3.6) assigns initial ages to individual blocks which are not "brand new" when they are installed. To properly account for the age of such a block, its initial age is subtracted from its time-to-first-failure determined by the wearout failure model. The early failure and random failure models do not account for initial age.

The Initial Age is also used to indicate any blocks which have a "failure-free" period at their installation. In this case, the failure free period is entered as a negative number. During the simulation, the failure free period is added to the time-to-first-failure so to properly account for the initial period during which the block will not experience failure by the wearout model.

Enter the block ages and the corresponding block numbers into the left and right columns. Any block whose number is not entered into this table is assumed to be brand new (i.e., Initial Age = 0 years) when it is installed.

Consecutive block numbers may be indicated using a dash as in the Block Numbers Screen. If more space is needed, use the **Insert** feature (See Appendix, page 120).

BLOCK AGES AT BEGINNING OF SIMULATION

Age, Years	Block Numbers
2	2

Figure 3.3.6

Installation Times

The **Block Installation Time Table** (Figure 3.3.7) assigns installation times to blocks that have not been installed at the beginning of the simulation. This will be the case if the system is constructed in stages. Any such block will be initially assigned a capacity of zero and will not contribute to the capacity of the system until it is installed at the time indicated by this table.

Enter the installation years and the corresponding block numbers into the left and right columns. Any blocks not entered will be assumed to be installed at year zero.

Consecutive block numbers may be indicated using a dash. If more space is needed, use the **Insert** feature (See Appendix, page 120).

BLOCK INSTALLATION TIMES

Installation Time, yrs	Block Numbers
1	9-11

Figure 3.3.7

Nominal Quantities

This table shows the quantities of each block type installed during each year as indicated by the Installation Times input table, assuming no constraints on spares and negligible installation time. Note that this is not an input table.

Block Quantities at Each Installation Time

	Resupply Period	
Block Types	0	1
Turbine	2	0
Generator	1	0
Diode	3	0
Battery	3	3
Outlet	1	0

Figure 3.3.8

3.4 Block Diagram Menu and Redundancy

The **Block Diagram Menu** (Figure 3.4) defines the relationships of blocks and subsystems within the system and defines pairs of redundant blocks.

```
| ACARA_Info | ►Input◄ | Run | Results | Quit |
| Edit Block Diagram Table.                     |

             ►Enter data  > | Simulation
              System Files> | Cost Parameters
              Clear Input   | Block Data       > 
                            | ►Block Diagram   > | ►Edit Diagram
                            | Resources        > |  View Diagram
                            | Units & Nomen.     |  Print Diagram
                            | Print Input        |  Redundancy
                            | Help               |  Help
```

Figure 3.4

Edit Diagram

The Block Diagram Table defines arrangements of individual blocks and subsystems. Refer to Figure 3.4.1. The input columns are as follows:

Subsystem#
Identifier number for each subsystem. The numbers must be unique and in numerical order.

Type
There are four possible subsystem types (Use either upper or lower case:

Series (S)
A series subsystem is available if all the elements it contains are available.

Parallel (P)
A parallel subsystem is available if at least one of its elements is available.

Variable M-of-N Parallel (V)
An M-of-N parallel system is available if a specified number of two or more parallel blocks are available. M-of-N arrangements can only comprise blocks, they cannot contain any subsystems. A variable arrangement will decrease its capacity as each block fails. The capacity is zero when all of the blocks in the subsystem are down.

Binary M-of-N Parallel (B)
A binary arrangement is available at its specified capacity only if a specified minimum number of the blocks it contains are available. The capacity is zero if this minimum is not met.

Elements
Identifier numbers for the blocks or subsystems contained in each subsystem. Block numbers are preceded by the letter "**b**" and subsystems by "**s**". Either upper or lower case are acceptable. A block number may be repeated in two or more different subsystems. Consecutive numbers may be indicated by a dash. If the space needed exceeds the column width, press [F2] to call the menu and select the **Insert** feature (Refer to the Appendix, page 120).

The following two columns, **Minimum #** and **Capacity**, pertain only to Variable and Binary M-of-N subsystems:

Minimum #
Enter the number of blocks that must be available for the entire arrangement to be available.

Capacity

Variable: Enter the possible capacity values for the subsystem. An M-of-N subsystem is available at the first capacity in this set when M or more blocks are available. It is available at the second capacity when (M-1) blocks are available, and so on to the last capacity level, which occurs when only one block is available.

Binary: Enter the percent capacity the subsystem will support when all of its blocks are available. It is at 0% capacity when any block is not available.

BLOCK DIAGRAM TABLE

Sub-sys#	Type	Elements	M-of-N data Min#	Capacity
1	v	b6-8	3	50 40 25
2	v	b9-11	3	50 40 25
3	p	s1 2		
4	b	b3-5	1	100
5	p	b1 13		
6	s	s3 4 5 b2 12		

Figure 3.4.1

View Diagram

The **View Diagram** option displays the Block Diagram. Figure 2.1 displays the example system (page 11).

Note that series arrangements are horizontal, while parallel and M-of-N arrangements are vertical.

The following notation may follow the block type names:

I-XX	Installation is delayed until year XX.
A-XX	Active block whose standby block is #XX.
S-XX	Standby block whose active block is #XX.

Caution: For large systems, creating the diagram may require a lot of CPU time!

To print the diagram, select **Print Diagram** from the menu. Large diagrams may use several sheets which must be joined side by side.

Redundancy

The Redundancy Table specifies pairs of active and standby blocks (See Figure 3.4.3). A standby block is operational when it is installed, but is dormant. Its useful life will be determined only by the exponential distribution (i.e., random failure). Its dormant MTBF will be the product of its random MTBF and its "Dormant MTBF Factor" (page 22). When the active block fails, the standby is immediately activated, and will fail according to the normal rules of early, random and wearout failure. The standby will return to the dormant state when the active block is repaired.

For each redundant pair of blocks, enter the number for the active block into the left column and the number for the corresponding standby block into the right column. An active block can have only **one** standby block and vice versa. In the example below in Figure 3.4.3, Block 13 is a standby for Block 1.

To specify a system that has no redundant block pairs, enter zeroes into the left and right columns.

Redundant Blocks

Active Block#	Standby Block#
1	13

Figure 3.4.3

3.5 Resources Constraints

The Resources Input Menu, shown in Figure 3.5, is used to enter data related to the amounts of available resources for installing and maintaining the system, such as the production quantities of each block type, constraints on spares, and constraints on mass delivery, manpower and other resources.

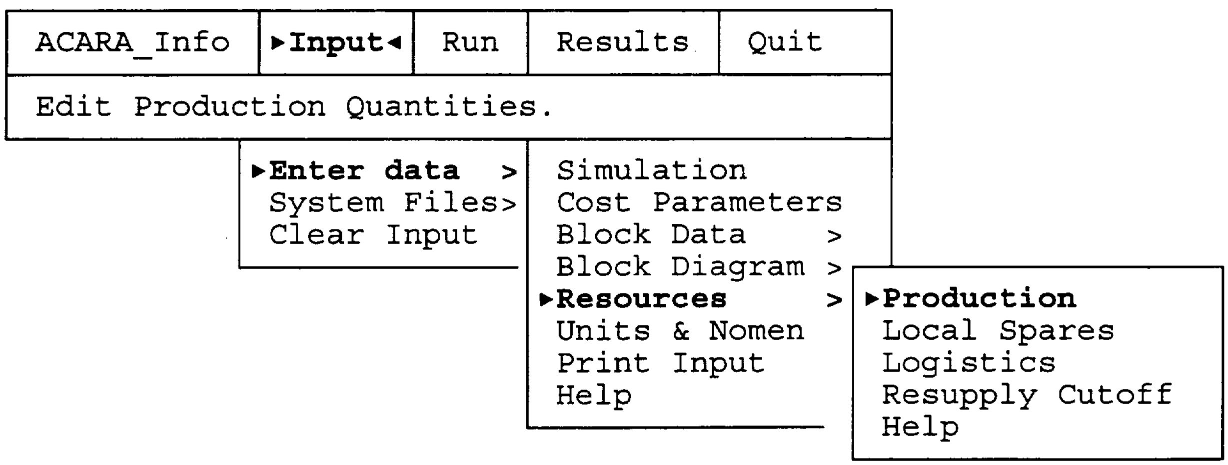


Figure 3.5

Production

The Production Quantities Table (Figure 3.5.1) is used to enter the quantity of each block type fabricated at each period. These blocks are available for installation and for replacement.

This input table may extend beyond the right edge of the screen. To scroll the table to the right or left, press [Ctrl-Right] or [Ctrl-Left], or select the **Go to Column** option from the Input Table Menu.

To copy the values from a column to each column to the right, move the cursor to that column, select **Copy Column** from the Input Table Menu, and press [Enter].

In the example below, the production quantity during period 10 through to the end of the duration is 0 for each block type.

Production Quantities

	Resupply Period									
Block Type	0	1	2	3	4	5	6	7	8	9
Turbine	3	0	0	0	0	0	0	0	0	0
Generator	2	0	0	0	0	0	0	0	0	0
Diode	10	0	0	0	0	0	0	0	0	0
Battery	3	3	0	0	0	0	3	3	0	0
Outlet	3	0	0	0	0	0	0	0	0	0

Figure 3.5.1

Local Spares

The **Local Spares Input Table** (Figure 3.5.2) is used to enter the quantities of available local spares. The input columns are as follows:

Initial Local Spares
The quantity of initial spares for each block type at the system location which are available for immediate replacement.

Local Spares Limit
The maximum number of local spares for each block type which may be stocked at the system location at any time for immediate replacement.

BLOCK SPARES DATA

Block Type Name	Initial Local Spares	Local Spares Limit
Turbine	0	0
Generator	0	0
Diode	1	1
Battery	0	0
Outlet	0	0

Figure 3.5.2

Logistics

The Logistics Constraints Table (Figure 3.5.3) is used to enter the mass and volume constraints for the resupply vehicle and the time constraints for each maintenance agent.

This input table, like that used to for entering the Production Quantities, may extend beyond the right edge of the screen. To scroll to the right or left, press [Ctrl-Right] or [Ctrl-Left], or select the **Go to Column** option from the Input Table Menu.

To copy the values from a column to each column to the right, move the cursor to that column, select **Copy Column** from the Input Table Menu, and press [Enter].

In the example below, the constraints during period 7 through to the end of the duration are equal to those during period 6.

Logistics Constraints

	Resupply Period					
Constraints	1	2	3	4	5	6
Mass (lbs)	600	200	60	60	60	60
Volume (ft3)	120	20	10	10	10	10
Crew (hrs)	40	5	5	5	5	5
Equipment(hrs)	12	2	2	2	2	2
Robotics (hrs)	99999	99999	99999	99999	99999	99999

Figure 3.5.3

Resupply Cutoff

The resupply cutoff is the time (days) necessary to manifest and load spares on the resupply vehicle. This period cannot exceed the resupply interval entered in the Simulation Parameters Input Window (Section 3.1).

For the example used in this report, the resupply cutoff is 60 days.

3.6 Units and Maintenance Action Nomenclature

Since ACARA is intended to be a general-purpose program for simulating a system, the units for mass, volume, and cost and the nomenclature for the maintenance actions are arbitrary. The **Units and Nomenclature Input Window**, shown in Figure 1.6, lets you specify appropriate units and nomenclature. The words entered in this input screen will appear in all ACARA input and output tables, but will not effect the results.

Units		Nomenclature	
Mass :	[**lb**]	Maint. Agent#1:	[**Crew**]
Volume:	[**ft3**]	Maint. Agent#2:	[**Equipment**]
Cost :	[**$k**]	Maint. Agent#3:	[**Robotics**]

Figure 3.6

3.7 Print Input

Use the **Print Input** feature for batch printouts of the current input data. The input window on Figure 3.7 will appear. In each field, enter the number of copies (up to 9) you want of each input table.

Individual tables can also be printed while editing the data. To make a printout, press [F2] and select the **Print** option from the Input Table Menu.

```
                     Input Printouts

 Simulation & Cost Parameters [0]
 Block Properties       [1]     MTTR Data                    [0]
 Early Failure Data     [0]     Random & Wearout Failure [0]
 Block Types & Numbers  [0]     Initial Ages                 [0]
 Installation Times     [0]     Nominal Inst. Times          [0]
 Block Diagram          [0]     Redundancy Table             [0]
 Production Quantities  [0]     Spares Data                  [0]
 Logistics Constraints  [0]
```

Figure 3.7

3.8 System Files

ACARA input data is stored in "system files" for future analysis. You can load, save, copy, delete, and rename these files using the **System Files** menu. The menu is also used to import system files from ETARA (an older simulation program, similar to ACARA).

Load
Retrieves previous ACARA input from a system file. The screen displays each file's descriptive name, size, and creation date. To see the DOS names, press [F3]. Move the cursor to the desired file and press [Enter] to load the file, or [Escape] to return to the Main Menu without loading a file.

Save
Saves the current data into a system file. You will be prompted to enter 50-character phrase to describe the file. Use [Page Up] and [Page Down] to scroll up and down to see each file. Enter the descriptive name and press [Enter]. The DOS name for the system file is an abbreviation of the description, with the extension ".asl". Press [Escape] to return to the Main Menu without saving data.

Copy
Copies a system file. Move the cursor to your selection and press [Enter]. At the prompt, enter a name for the copy and press [Enter] again. To cancel and return to the Main Menu, press [Escape].

Delete
Erases a system file. Move the cursor to a file you want to delete and press the [Enter] key. To return to the Main Menu, press [Escape].

Rename
Changes the descriptive name of a system file. Move the cursor to the file you want to rename, press [Enter], and enter a new name at the prompt. Press [Enter] again. To cancel and return to the Main Menu, press [Escape].

Import
Retrieves data from an ETARA system file. Move the cursor to the ETARA file you want to retrieve and press [Enter]. Only the DOS names will be visible on the screen.

File Path
Changes the file drive for system files. At the prompt, type the appropriate file drive designation letter and press [Enter].

4. Running ACARA Simulations

ACARA simulates systems by either **Immediate Mode** or **Batch Mode**.

Immediate
Simulates the data currently entered into ACARA. ACARA will perform the amount of iterations entered into the Simulation Parameters Input Screen. To stop the simulation early, press [Escape].

Batch
Runs a sequence of ACARA simulations files without user intervention. After **Batch** is selected from the Main Menu, a list of descriptive names for the available system files will appear, as in Figure 4.1. To see any system files beyond the bottom of the screen, press [Page Down] to scroll down. Press [F3] to toggle between the descriptive file name and the DOS name.

Enter the number of iterations for each system you want to run into the column labeled "#Runs". ACARA will ignore the files that have a "0" next to their names. In the example below, ACARA will run "Example I" for 750 iterations and "Example II" for 1000 iterations. When finished, press [F2] to call the pulldown menu. To begin running the batch, select **Run** and press [Enter]. To cancel the batch mode and return to the Main Menu, select **Quit**.

To stop a simulation early, press [Escape]. As each simulation is completed, the results will be saved into a file having the same name as the system file.

To retrieve the results of a simulation, select **Results Files** from the Main Menu, press [Enter], and then select **Load**. The available results files will appear. Move the cursor to the desired file and press [Enter].

Batch Simulation Mode

#Runs	System Files (*.AS1)	Yr/Mo/Day	Hr:Min
750	Example I	92/07/28	15:36
1000	Example II	92/07/19	10:35
0	Test Case A	92/07/19	10:27
0	Test Case B	92/07/16	15:57
0	Test Case C	92/07/16	15:56

Figure 4.1

5. ACARA Results

To see the results of an ACARA simulations, move the cursor to **Results** at the top of the screen. The pulldown menu classifies the results into the following groups of tables:

Performance
Describes the availability of capacity states.

Failure and Repair
Shows the frequency of failures and replacements of blocks in the system as well as downtime and delays.

Lifecycle Cost
Shows the maintenance cost over time.

Resource Allocations
Shows the scheduling of resupply deliveries and usage of maintenance time.

Each of these tables has a menu which lets you control the printer, create text files, or view a graph. Refer to Appendix C for further instructions.

The results examples appearing in this report correspond to the example input shown in each of the figures in Section 3. The input tables for Production Quantities and Logistics Constraints (See pages 32 and 34) are each assumed to have the same values from the time period at the column furthest to the right of the table to the end of the duration.

In addition to the tables, the menu also has the following options:

Computation Time
Displays the time required for ACARA to calculate the results.

Results Files
Loads, saves, copies, renames, and deletes ACARA results files.

Text Files
Edits, copies, renames, and deletes text (ASCII) files.

5.1 Performance

Time at Capacity

Table 5.1.1 displays the capacity states attained by the system during the simulation and the amount of time the system had been operating at each state. The left hand column shows the capacity levels. The top row of the table shows the time periods. The column on the far right side of the bottom section shows the total time at each capacity state. The bottom row (entitled "Sums") shows the total amount of time for each period.

Time at Capacity
(Normalized to Installed Capacity)

			Period			
Capacity	1	2	3	4	5	Overall
100.00	.906	.300	.574	.000	.000	1.780
90.00	.100	.072	.228	.213	.217	.830
88.89	.232	.600	.096	.000	.000	.927
86.67	.000	.000	.000	.000	.000	.000
83.33	.326	.300	.112	.000	.000	.738
80.00	.221	.336	.299	.205	.037	1.098
75.00	.040	.000	.289	.396	.083	.809
72.22	.573	.300	.000	.000	.000	.873
66.67	.000	.000	.000	.000	.000	.000
65.00	.060	.300	.067	.345	.981	1.752
55.56	.131	.000	.000	.000	.000	.131
50.00	.245	.000	.000	.102	.058	.405
40.00	.000	.000	.075	.106	.073	.253
25.00	.000	.000	.000	.079	.045	.125
.00	.166	.792	1.259	1.555	1.506	5.278
Sums	3.000	3.000	3.000	3.000	3.000	15.000

Table 5.1.1

State Availability

Table 5.1.2 displays the capacity states attained by the system and the fraction of time the system had been operating at that state during each period. The column on the far right side of the bottom section shows the fraction of the total duration that the system had attained each capacity state.

Availability of Each Capacity State
(Normalized to Installed Capacity)

	Period					
Capacity	1	2	3	4	5	Overall
100.00	.302	.100	.191	.000	.000	.119
90.00	.033	.024	.076	.071	.072	.055
88.89	.077	.200	.032	.000	.000	.062
86.67	.000	.000	.000	.000	.000	.000
83.33	.109	.100	.037	.000	.000	.049
80.00	.074	.112	.100	.068	.012	.073
75.00	.013	.000	.096	.132	.028	.054
72.22	.191	.100	.000	.000	.000	.058
66.67	.000	.000	.000	.000	.000	.000
65.00	.020	.100	.022	.115	.327	.117
55.56	.044	.000	.000	.000	.000	.009
50.00	.082	.000	.000	.034	.019	.027
40.00	.000	.000	.025	.035	.024	.017
25.00	.000	.000	.000	.026	.015	.008
.00	.055	.264	.420	.518	.502	.352
Sums	1.000	1.000	1.000	1.000	1.000	1.000

Table 5.1.2

Cumulative Availability

Table 5.1.3 displays the fraction of time that the system has attained a capacity state equal to or greater than the capacity on the left-hand column. The column on the far right, labeled "Overall" is the total fraction of the duration that the system has attained a capacity in excess of that capacity state.

Availability of Capacity State or Greater
(Normalized to Installed Capacity)

	Period					
Capacity	1	2	3	4	5	Overall
100.00	.302	.100	.191	.000	.000	.119
90.00	.335	.124	.267	.071	.072	.174
88.89	.413	.324	.299	.071	.072	.236
86.67	.413	.324	.299	.071	.072	.236
83.33	.521	.424	.337	.071	.072	.285
80.00	.595	.536	.436	.139	.084	.358
75.00	.609	.536	.533	.271	.112	.412
72.22	.800	.636	.533	.271	.112	.470
66.67	.800	.636	.533	.271	.112	.470
65.00	.819	.736	.555	.386	.439	.587
55.56	.863	.736	.555	.386	.439	.596
50.00	.945	.736	.555	.420	.459	.623
40.00	.945	.736	.580	.455	.483	.640
25.00	.945	.736	.580	.482	.498	.648
.00	1.000	1.000	1.000	1.000	1.000	1.000

Table 5.1.3

Two graphs are associated with the Cumulative Availability table:

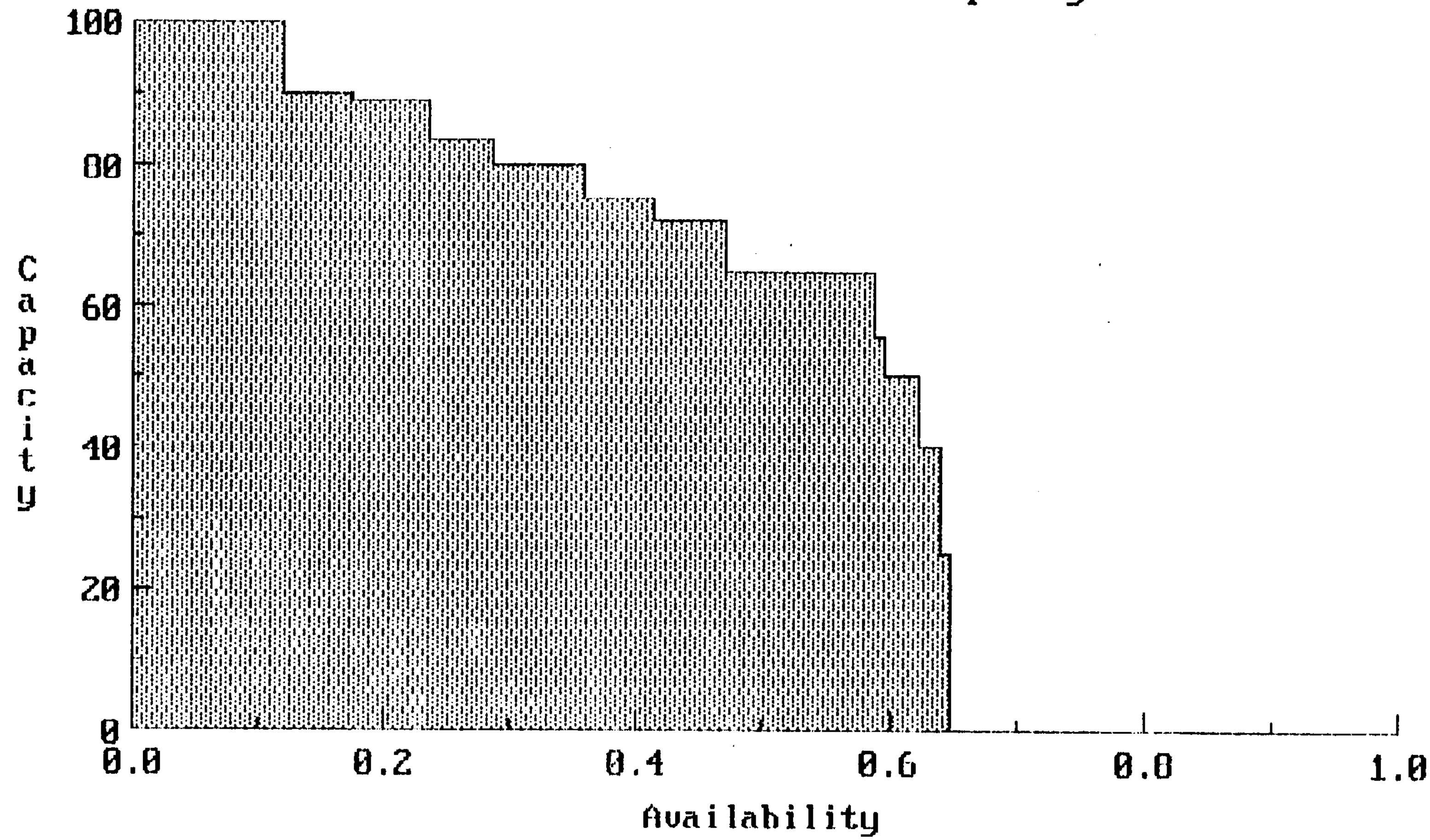
System Availability

Figure 5.1.3a is a graph of overall system capacity versus availability over the entire duration. The axes are normalized with 1.0 corresponding to 100%.

System Availability (for a Specified Period)

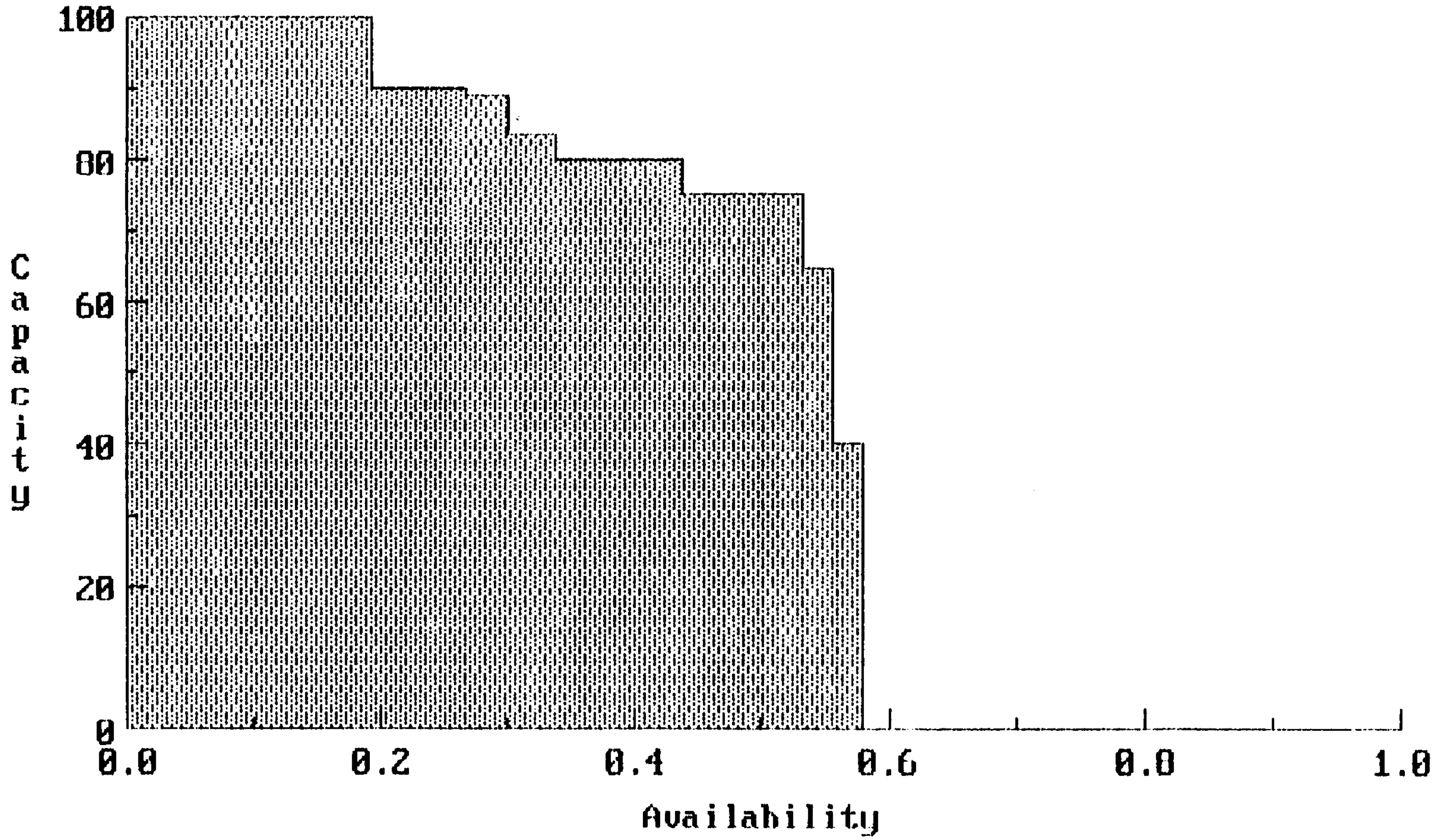
Figure 5.1.3b is a graph of capacity that the system operated at or above versus the availability, during a period specified by the user.

Figure 5.1.3 a
System Availability
(Normalized to Installed Capacity)



ACARA
92 Dec 30, 17:00

Figure 5.1.3 b
System Availability
(Normalized to Installed Capacity)
Period # 3



ACARA
92 Dec 30, 17:00

Equivalent Availability

Equivalent availability results from the product of the capacity state (%) and the state availability divided by 100 (See Table 5.1.4). The equivalent availability for each period is displayed at the bottom row and is the sum of each column. Figure 5.1.4 is a graph of the overall equivalent availability for each period.

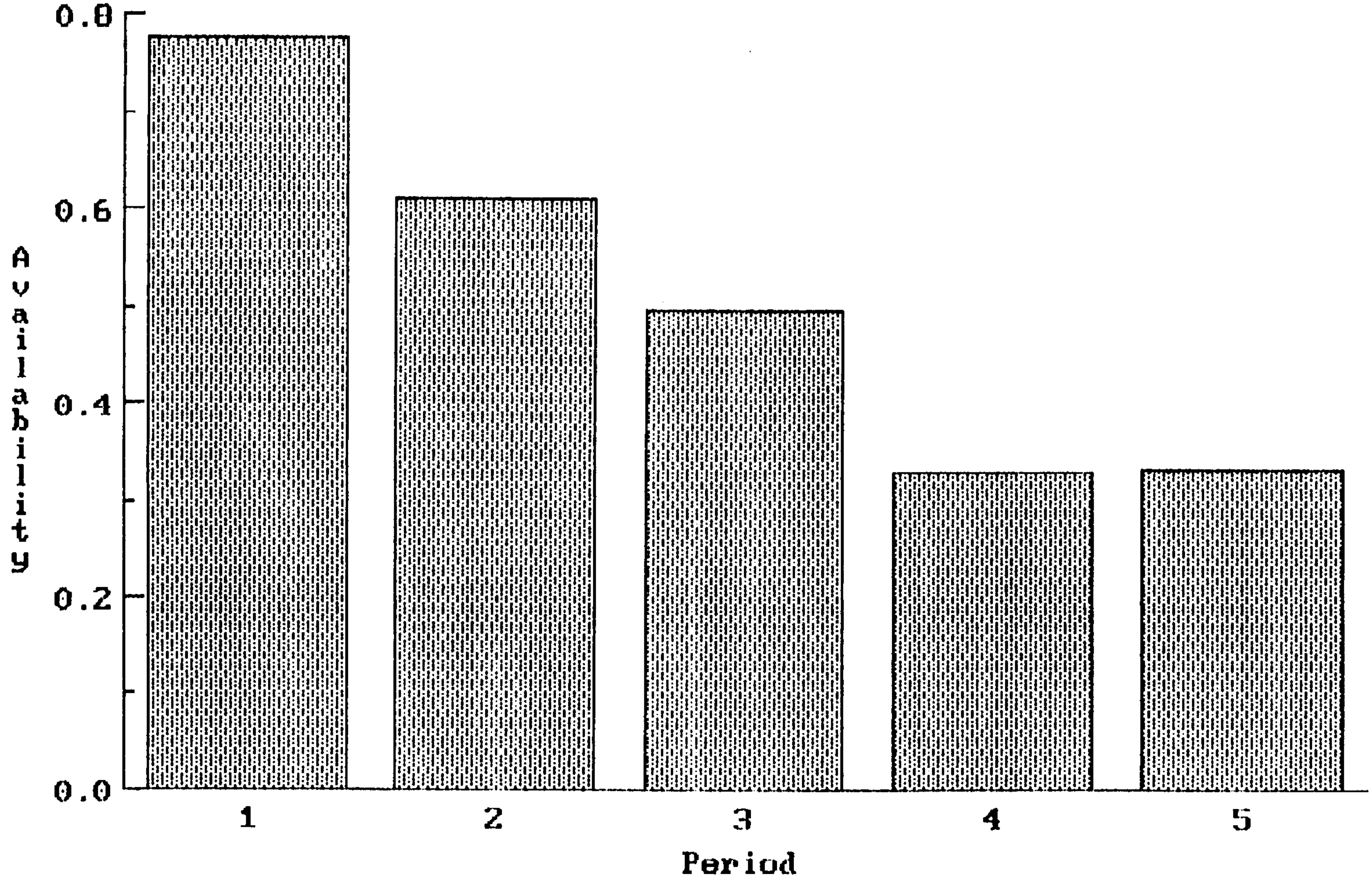
Equivalent availability is a single measure of a system's overall "goodness". It is the ratio of the total actual system production (accounting for degraded output due to one or more failed blocks) to the total ideal production. The area under the graph of state availability versus the system capacity states is equal to the equivalent availability for that time period. It may be thought of as a weighted average system capacity. This may be expressed in other ways. Suppose the example is a power station capable of 100 MW at the 100% state. The equivalent availability of 50.9% may be obtained by the profile in Table 5.1.4, or by operating constantly at 50.9 MW output for 100% of the time or by operating at 100 MW output for 50.9% of the time and at 0 MW during the remaining 49.1%. In each case, the same energy is produced during the time period.

Equivalent Availability
(Normalized to Installed Capacity)

	Period					
Capacity	1	2	3	4	5	Overall
100.00	.302	.100	.191	.000	.000	.119
90.00	.030	.022	.068	.064	.065	.050
88.89	.069	.178	.028	.000	.000	.055
86.67	.000	.000	.000	.000	.000	.000
83.33	.090	.083	.031	.000	.000	.041
80.00	.059	.090	.080	.055	.010	.059
75.00	.010	.000	.072	.099	.021	.040
72.22	.138	.072	.000	.000	.000	.042
66.67	.000	.000	.000	.000	.000	.000
65.00	.013	.065	.015	.075	.212	.076
55.56	.024	.000	.000	.000	.000	.005
50.00	.041	.000	.000	.017	.010	.014
40.00	.000	.000	.010	.014	.010	.007
25.00	.000	.000	.000	.007	.004	.002
.00	.000	.000	.000	.000	.000	.000
Eq. Avail.	.776	.610	.496	.330	.331	.509

Table 5.1.4

Figure 5.1.4
Equivalent Availability
(Normalized to Installed Capacity)



ACARA
92 Dec 30, 17:00

Overall Availability

Table 5.1.5 displays the overall availability results. These are the same values as in the columns on the far right side of each of Tables 5.1.1 through 5.1.4, entitled "Overall".

SYSTEM CAPACITIES AND AVAILABILITIES
(Normalized to Installed Capacity)

System Capacity State	Time @ Capacity State, Yrs.	Avail. of Capacity State	Avail. of Cap. State or Greater	Equivalent Availability
100.00	1.780	.119	.119	.119
90.00	.830	.055	.174	.050
88.89	.927	.062	.236	.055
86.67	.000	.000	.236	.000
83.33	.738	.049	.285	.041
80.00	1.098	.073	.358	.059
75.00	.809	.054	.412	.040
72.22	.873	.058	.470	.042
66.67	.000	.000	.470	.000
65.00	1.752	.117	.587	.076
55.56	.131	.009	.596	.005
50.00	.405	.027	.623	.014
40.00	.253	.017	.640	.007
25.00	.125	.008	.648	.002
.00	5.278	.352	1.000	.000
Totals:	15.000	1.000		.509

Table 5.1.5

Reliability

Table 5.1.6 displays the probability that the system will produce a given capacity level or more continuously during each time interval. The system capacity levels appear vertically along the left and the time periods appear along the top. The probability that the system will exceed a given capacity at a given period of time is found at the intersection of that period and capacity. In the example, at period 3, the probability that the system's capacity will exceed 50% is 0.40. The increment between capacity levels is defined by the "Capacity Increment" in the Simulation Parameters Input Screen (page 15).

Reliability
(Normalized to Installed Capacity)

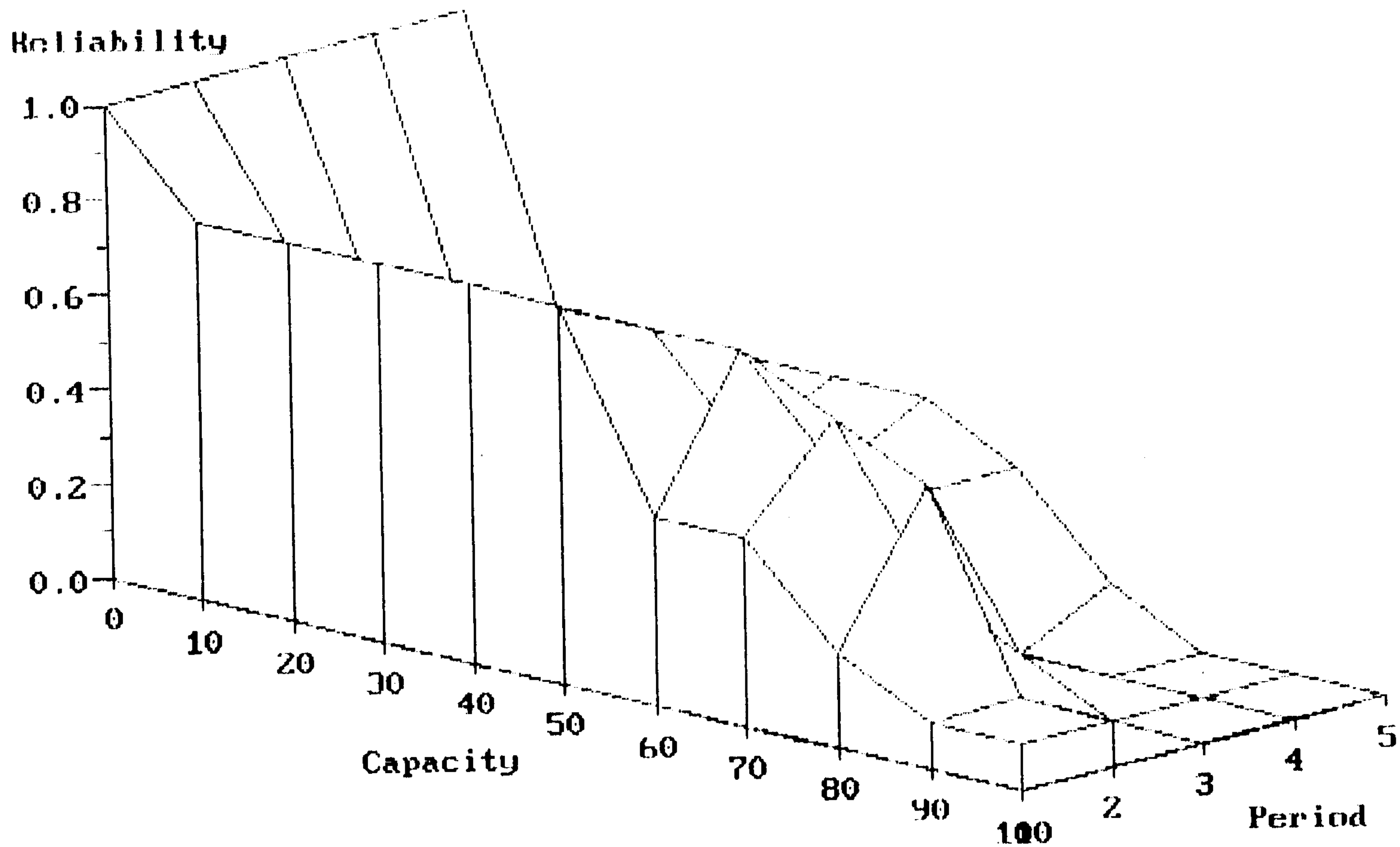
	Period				
Capacity	1	2	3	4	5
100	.100	.100	.000	.000	.000
90	.100	.100	.000	.000	.000
80	.200	.500	.100	.000	.000
70	.400	.600	.200	.000	.100
60	.400	.700	.400	.300	.300
50	.800	.700	.400	.300	.400
40	.800	.700	.500	.300	.400
30	.800	.700	.500	.300	.400
20	.800	.700	.500	.400	.400
10	.800	.700	.500	.400	.400
0	1.000	1.000	1.000	1.000	1.000

Table 5.1.6

Three graphic representations of this table are available:

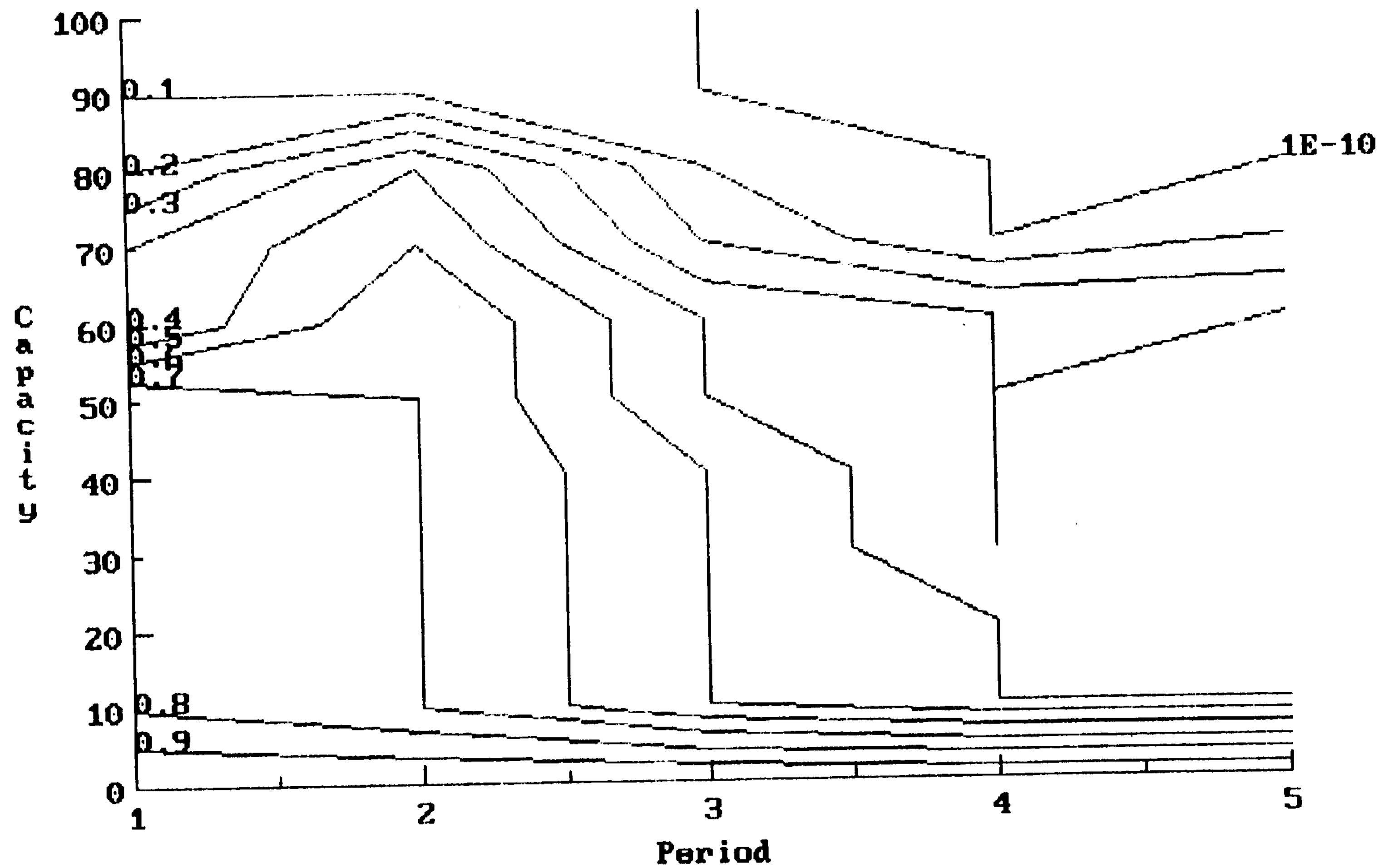
Surface Plot (Figure 5.1.6a)
Contour Plot (Figure 5.1.6b)
Bar Chart (Figure 5.1.6c)

Figure 5.1.6 a
Reliability
(Normalized to Installed Capacity)



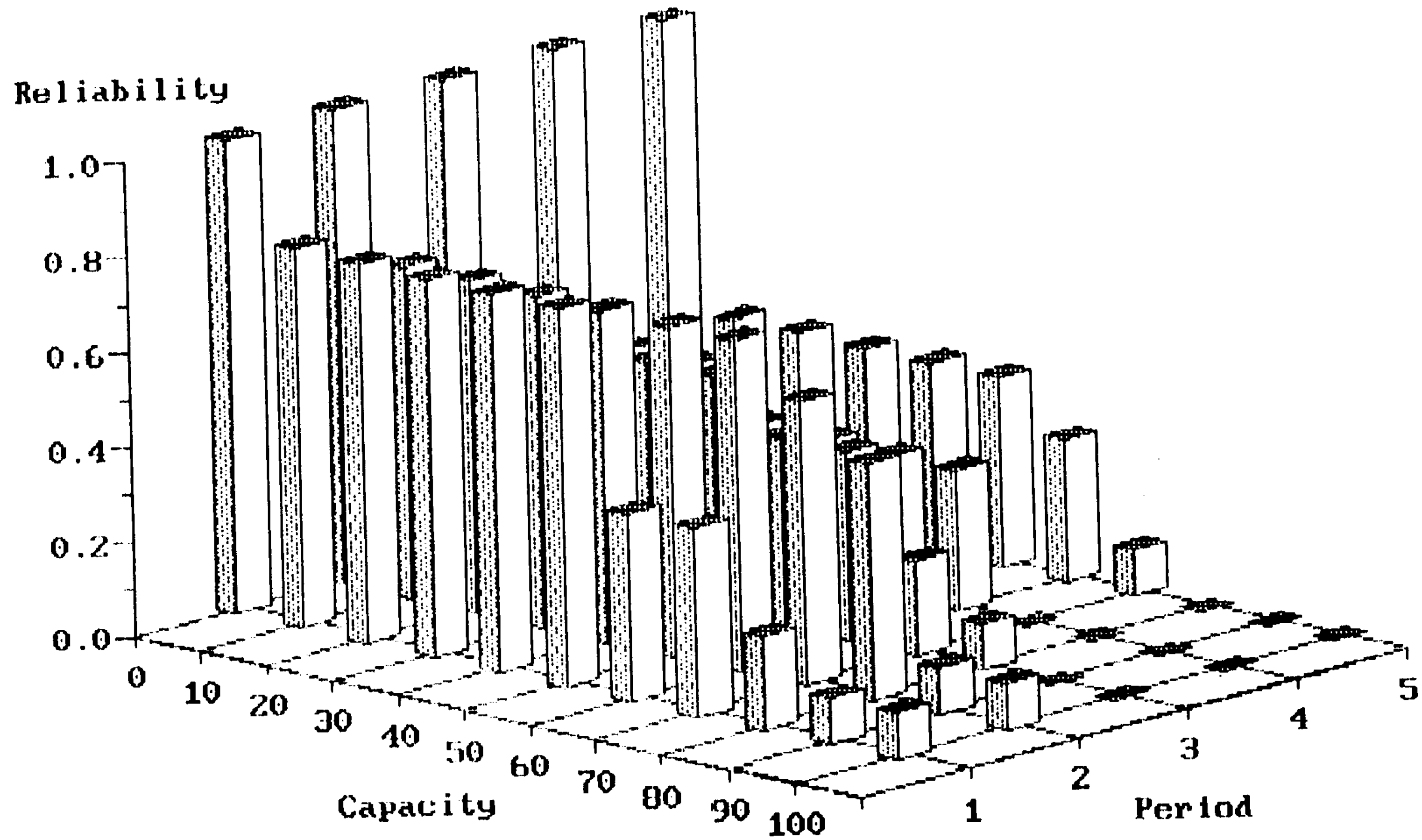
ACARA
1992 Dec 30 17:00

Figure 5.1.6 b
Reliability
(Normalized to Installed Capacity)



ACARA
92 Dec 30, 17:00

Figure 5.1.6 c
Reliability
(Normalized to Installed Capacity)



ACARA
1992 Dec 30 17:00

Continuous State Behavior

Refer to Table 5.1.7. The columns are as follows:

Capacity State
All system capacity states encountered in the simulation.

Time at Each Capacity State
Total time that the system operated at the capacity state. Note that the time periods correspond to those in the column labeled "Overall" in Table 5.1.1, "Time at Capacity".

Fraction of Duration
Fraction of the total duration spent at the capacity state.

Average Continuous State Time
Average continuous time at each capacity state.

Average Number of Occurrences per Duration
Average number of times the capacity state was encountered during the simulation.

CONTINUOUS STATE BEHAVIOR
(Normalized to Installed Capacity)

Capacity State	Time@Each Capacity State, Yrs	Fraction of Duration	Average Continuous State Time	Ave. Number Occurrences per Duration
100.00	1.780	.119	433.113	1.500
90.00	.830	.055	189.327	1.600
88.89	.927	.062	677.027	.500
86.67	.000	.000	.016	.100
83.33	.738	.049	449.077	.600
80.00	1.098	.073	250.459	1.600
75.00	.809	.054	210.895	1.400
72.22	.873	.058	398.318	.800
66.67	.000	.000	.008	.400
65.00	1.752	.117	399.738	1.600
55.56	.131	.009	159.065	.300
50.00	.405	.027	211.308	.700
40.00	.253	.017	231.249	.400
25.00	.125	.008	227.792	.200
.00	5.278	.352	2752.183	.700
Totals:	15.000	1.000		

Table 5.1.7

Print

Use this feature to generate batch printouts of one or more of the Performance Results in Section 5.1. The window on Figure 5.1.8 will appear when **Print** is selected. In each field, enter the number of copies (up to 9) you want of each table.

```
[1] Time at each Capacity.
[1] Capacity State Availability.
[0] Cumulative Availability.
[0] Equivalent Availability.
[0] System Capacity
  & Overall Availability.
[0] Reliability.
[0] Capacity State Behavior.
```

Figure 5.1.8

5.2 Failure and Repair Analysis

Failure PDF (Probability Density Function)

For a specified block type, Table 5.2.1 displays the probability that a given number of failures will occur during a period. The occurrences of failures range from zero to the maximum encountered during the simulation and are displayed vertically along the left side of the table. The time periods are displayed along the top row and correspond to the period length.

Failure Frequency of Occurrence PDF
Block Type: Battery

	Period				
Occurrences	1	2	3	4	5
0	.100	.800	.000	.000	.200
1	.100	.100	.300	.400	.700
2	.500	.100	.000	.000	.000
3	.200	.000	.400	.400	.100
4	.100	.000	.200	.100	.000
5	.000	.000	.100	.100	.000

Table 5.2.1

Two graphs are available with Table 5.2.1:

Failure Frequency of Occurrence for a Single Period

Figure 5.2.1a plots the failure frequency and the cumulative probability as a function of the number of failures during a selected period. The repair frequency uses the left axis and is plotted with vertical bars. The cumulative probability uses the right axis and is plotted with a dashed line.

Failure Frequency of Occurrence over All Periods

Figure 5.2.1b plots the most probable number of failures and the maximum number of failures by period over the duration.

Figure 5.2.1 a
Failure Frequency of Occurrence PDF
Block Type: Battery
Period: 3

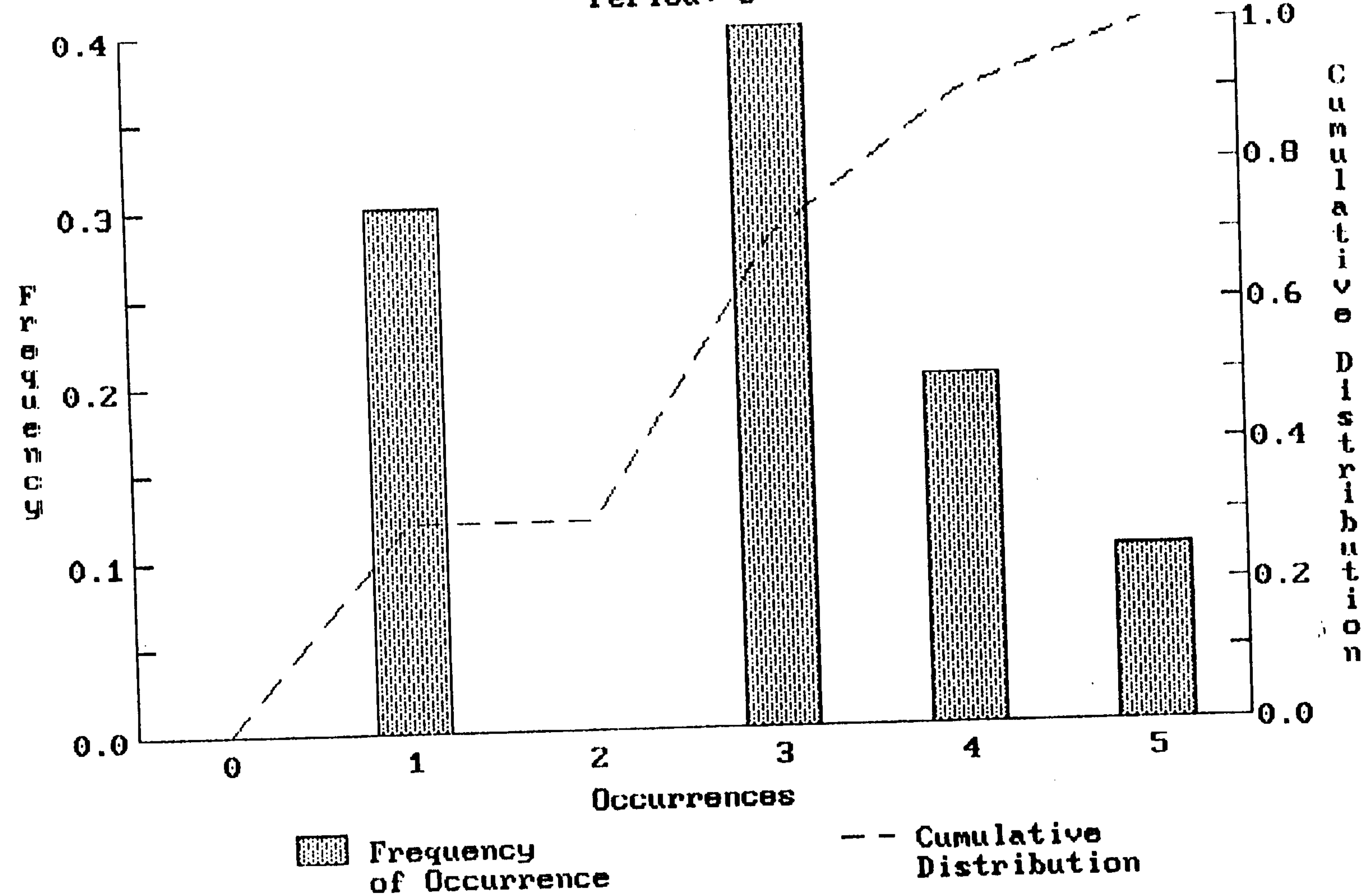


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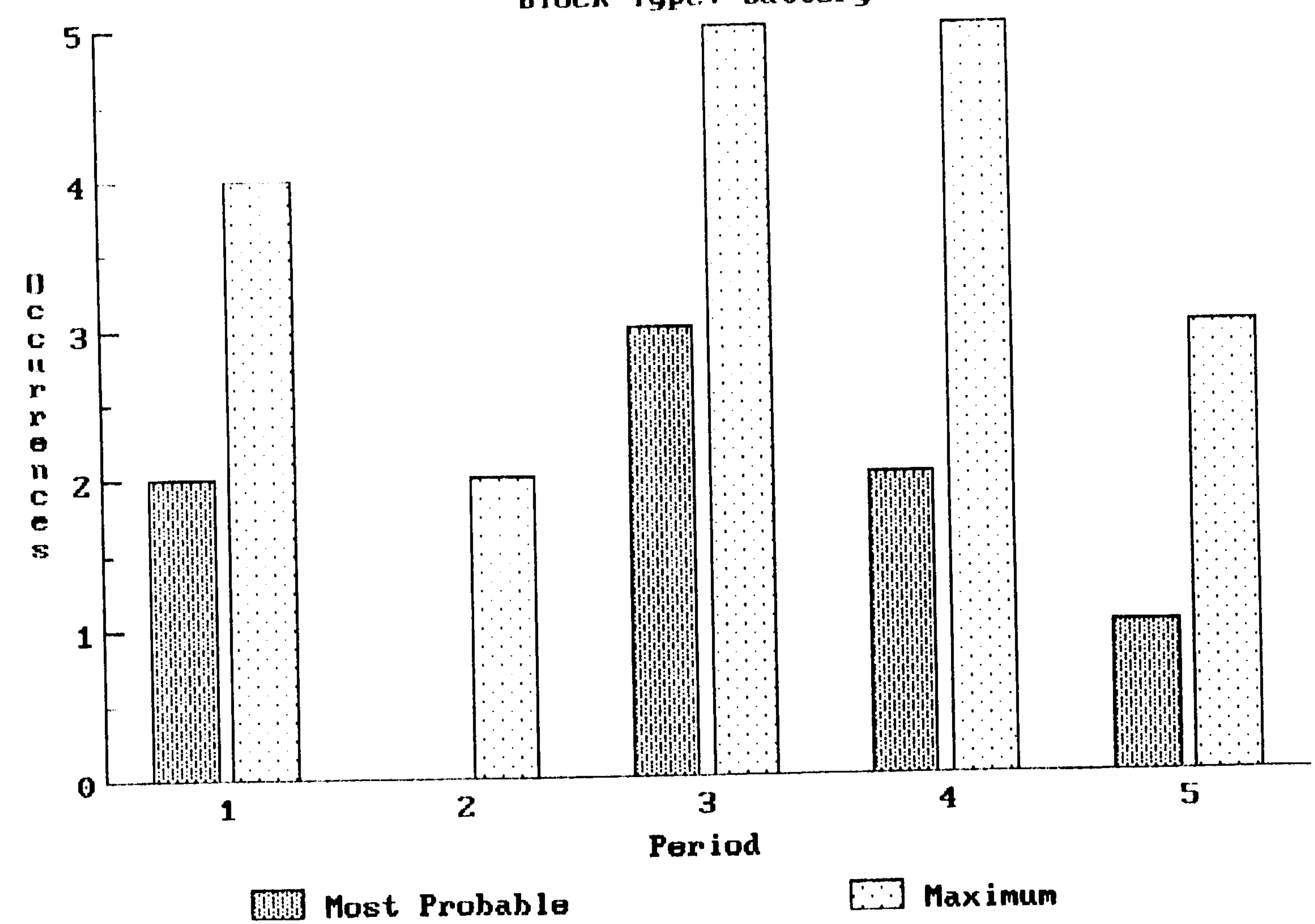
Figure 5.2.1 b
Failure Frequency of Occurrence PDF
Block Type: Battery



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Failure CDF (Cumulative Density Function)

For a specified block type, Table 5.2.2 displays the probability that the number of failures occurring during a given period will be no more than the quantity shown along the left side. In the example, the probability that the battery will experience no more than two failures during Period 4 is 0.40.

Failure Frequency of Occurrence CDF
Block Type: Battery

	Period				
Occurrences	1	2	3	4	5
0	.100	.800	.000	.000	.200
1	.200	.900	.300	.400	.900
2	.700	1.000	.300	.400	.900
3	.900	1.000	.700	.800	1.000
4	1.000	1.000	.900	.900	1.000
5	1.000	1.000	1.000	1.000	1.000

Table 5.2.2

Early, Random, and Wearout Failures by Period

For a selected block type, Table 5.2.3 displays the quantities of early failures, random failures, and wearout failures that occurred during each time period. A bar chart is available for this table and is shown on Figure 5.2.3.

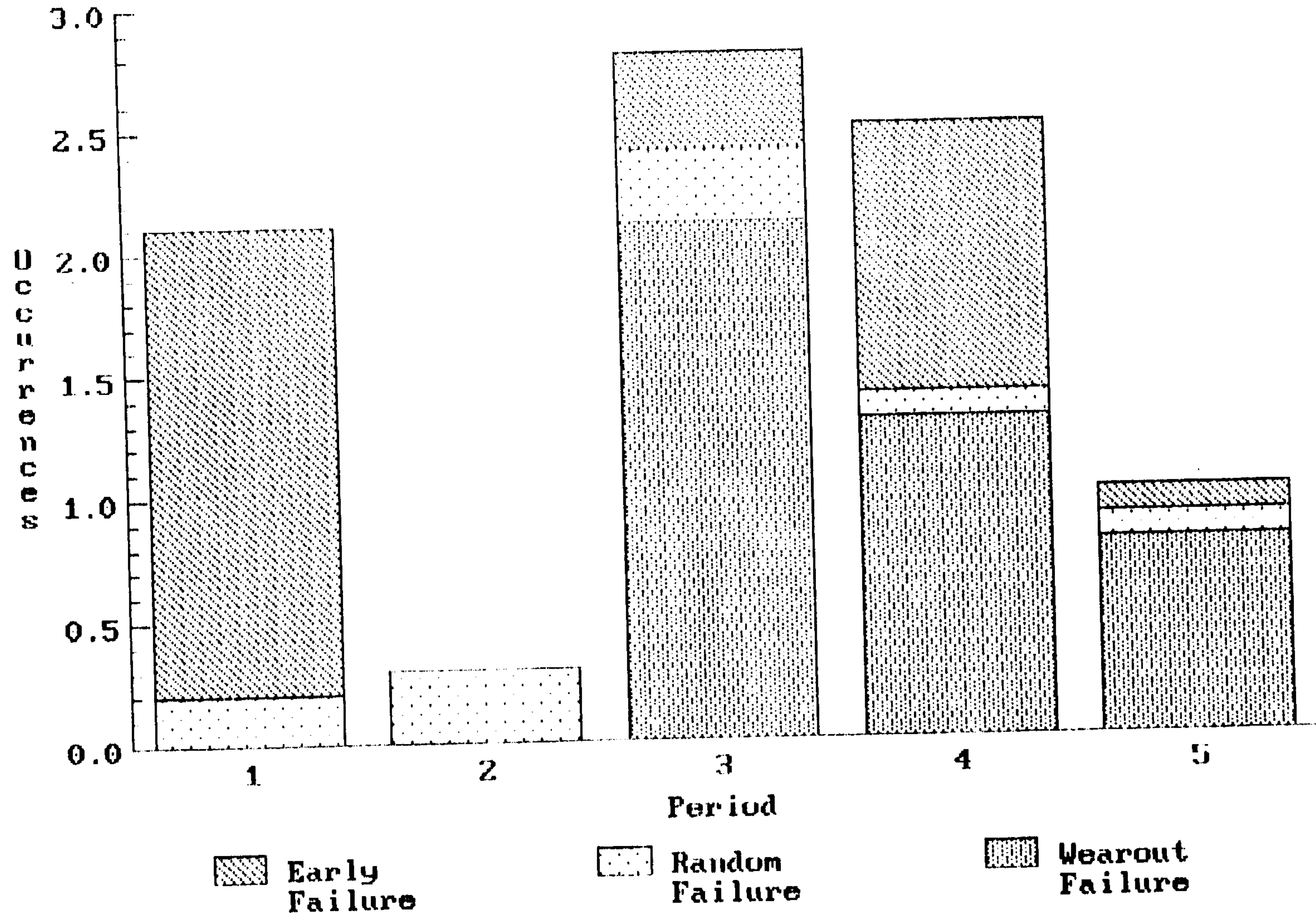
Note that these results will not be available if you have specified that you did not want to track the failure types (page 16).

Early, Random, & Wearout Failures by Period
Block Type: Battery

Failures	Period 1	2	3	4	5	Overall
Early	1.900	.000	.400	1.100	.100	3.500
Random	.200	.300	.300	.100	.100	1.000
Wearout	.000	.000	2.100	1.300	.800	4.200
Total	2.100	.300	2.800	2.500	1.000	8.700

Table 5.2.3

Figure 5.2.3
Early, Random, & Wearout Failures by Period
Block Type: Battery



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Repair PDF (Probability Density Function)

For a selected block type, Table 5.2.4 displays the probability that a given number of repairs during a given period will be no more than the quantity shown along the left side.

Replacement Frequency of Occurrence PDF
Block Type: Battery

	Period				
Occurrences	1	2	3	4	5
0	.500	1.000	.000	.000	.900
1	.500	.000	.100	.000	.000
2	.000	.000	.400	.100	.100
3	.000	.000	.500	.900	.000

Table 5.2.4

Two graphs are available with Table 5.2.4:

Repair Frequency of Occurrence for a Single Period

Figure 5.2.4a plots the repair frequency and the cumulative probability as a function of the number of repairs during the selected period. The repair frequency uses the left axis and is plotted with vertical bars. The cumulative probability uses the right axis and is plotted with a dashed line.

Repair Frequency of Occurrence over All Periods

Figure 5.2.4b plots the most probable number of repairs and the maximum number of repairs by period.

Figure 5.2.4 a
Replacement Frequency of Occurrence PDF
Block Type: Battery
Period: 3

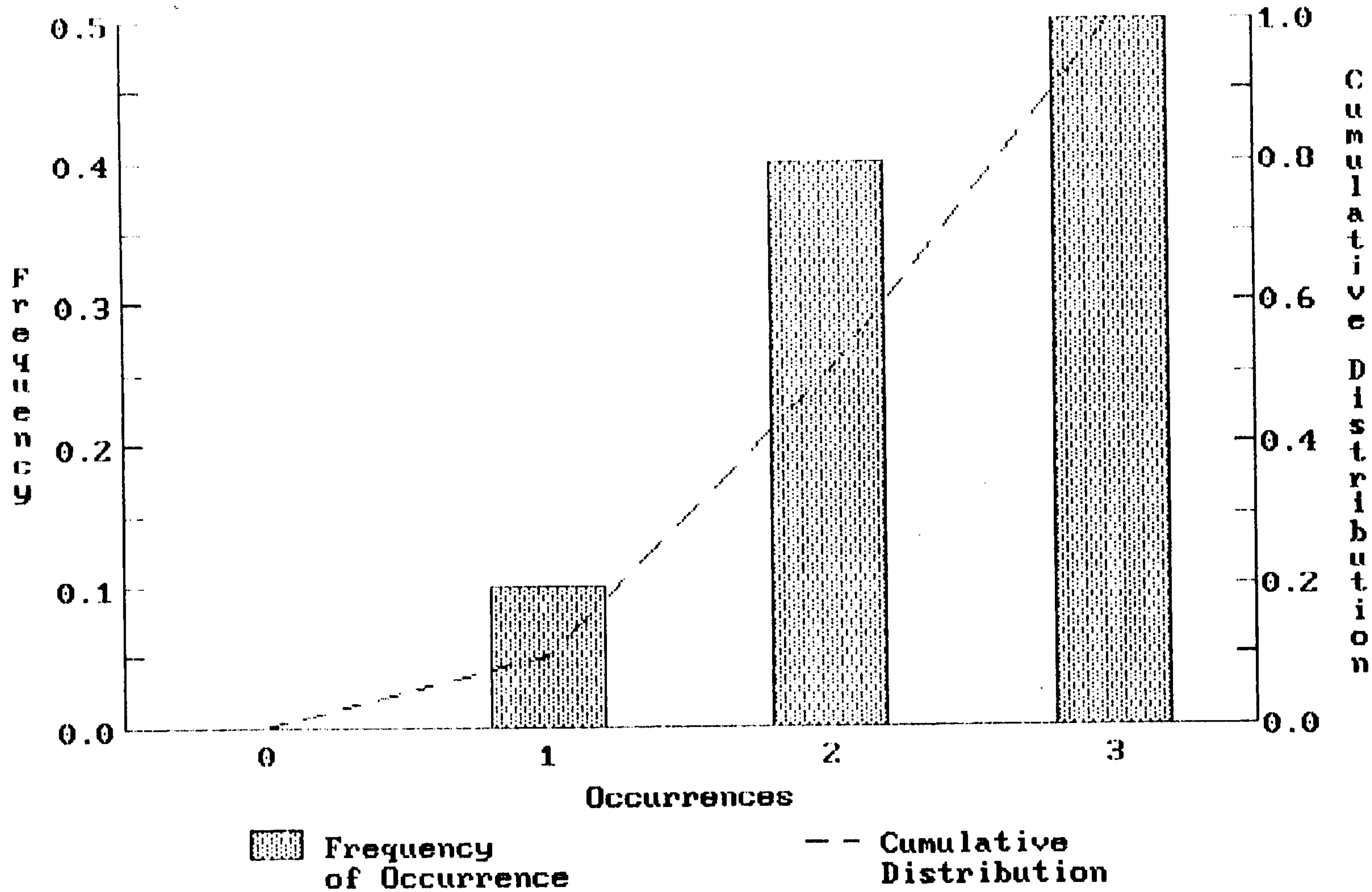

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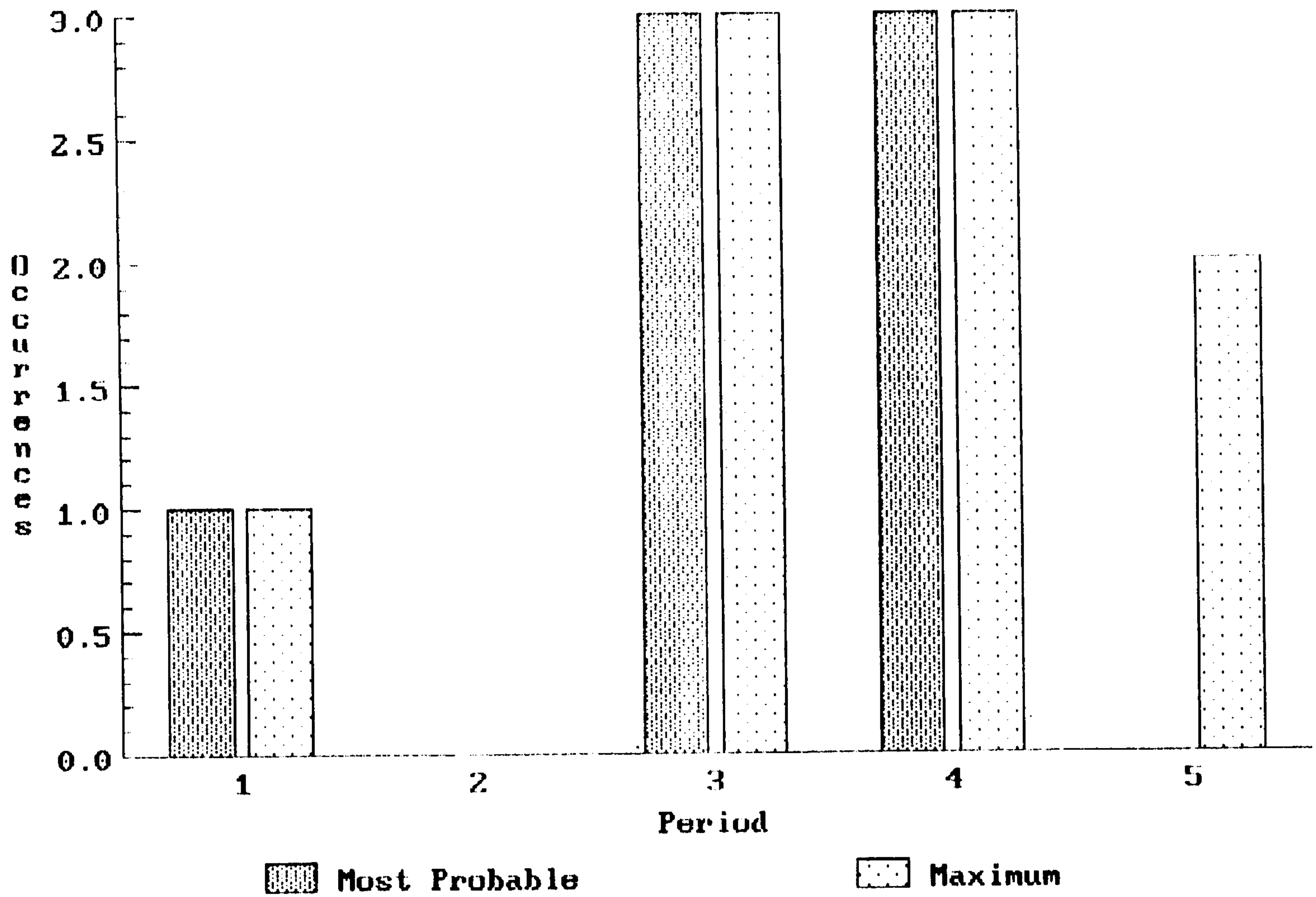
Figure 5.2.4 b
Replacement Frequency of Occurrence PDF
Block Type: Battery



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Criticality

Table 5.2.5 displays the mean reduction of system capacity (%) caused by a failure of each of the block types in the system.

CRITICALITY BY BLOCK TYPE

Block Type Name	Mean Effect of Failure on Capacity
Turbine	4.00
Generator	24.56
Diode	.00
Battery	10.59
Outlet	16.50

Table 5.2.5

Accumulated Early, Random, and Wearout Failures

Table 5.2.6 displays the mean number of occurrences of early, random, and wearout failures for each block type.
Note that these results will not be available if you have specified that you did not want to track the failure types (page 16).

Accumulated Early, Random, and Wearout Failures

Block Type	Early	Random	Wearout	Total
Turbine	.000	.300	.400	.700
Generator	.000	.200	.200	.400
Diode	2.000	1.600	.000	3.600
Battery	3.500	1.000	4.200	8.700
Outlet	.000	.400	.100	.500

Table 5.2.6

Individual Block Failure Results for a Selected Block Type.

Refer to Table 5.2.7. The columns are as follows:

Block Number
Individual block numbers associated with the selected type. These numbers were defined by the Block Numbers Input Table.

Mean Occurrences of Failure
Number of failures for each block. This is the number of failures experienced by each block divided by the number of iterations.

Down Time
Down time for that block, expressed in days.

% of Duration, Down
Percent of the duration that the block was unavailable.

Delay Time
Delay before a spare can be supplied at the next spares replenishment action. Subtracting the Delay Time from the Down time yields the active repair time.

Individual Block Failure Results
Block Name: Battery

Block Number	Mean Occurrences of Failures	Down Time Days	% of Duration Down	Delay Time Days
6	2.00	1853.64	33.86	1853.58
7	1.60	1362.64	24.89	1362.59
8	1.50	1710.17	31.24	1710.12
9	1.20	1455.63	26.59	1455.59
10	1.50	2035.55	37.18	2035.51
11	.90	886.63	16.19	886.60
Total:	8.70	9304.26	169.94	9304.00

Table 5.2.7

Failure and Repair Results by Block Type

Refer to Table 5.2.8. The columns are as follows:

Block Name
Block type names as defined in the Names and Properties Input Table.

Block Quantity
Quantity of blocks of each type.

Failures
Number of total failures divided by the number of simulations.

Failures/Year
Number of failures divided by the duration.

Repair time
Active repair time (days) for each block type.

Repair Time, %Total
Percentage of total repair time associated with each type.

Down time, %Total
Time the blocks of each type were not available divided by the total down time.

Delay time, %Total
Delay time for each type divided by the total delay time.

Failure, Repair, Down Time & Delay Time by Block Type.

Block Type	Quantity	Failures	Failures /Year	Repair Time Days	Repair Time hrs/yr	Repair Time %Total	Down Time %Total	Delay Time %Total
Turbine	2	.70	.05	.00	.00	.00	12.75	12.75
Generator	1	.40	.03	.00	.00	.00	11.74	11.74
Diode	3	3.60	.24	.04	.07	12.05	1.69	1.69
Battery	6	8.70	.58	.26	.42	74.63	73.21	73.21
Outlet	1	.50	.03	.05	.07	13.32	.61	.61
Total:	13	13.90	.93	.35	.56	100.00	100.00	100.00

Table 5.2.8

5.3. Lifecycle Cost (LCC)

This section deals with the costs of hardware production, transportation, and maintenance. The names of the three maintenance operations, i.e., "Crew", "Equipment", and "Robotics" are arbitrary, and can be changed appropriately. (See page 35.)

Hardware Cost

Tables 5.3.1 a and b show the mean hardware cost. In Table 5.3.1a and Figures 5.3.1a and c, the cost of hardware accumulates whenever hardware is fabricated. Since these costs result directly from the production quantities input, they will be unrealistically high if the simulation assumes unconstrained production quantities. In this case it is better to show the hardware cost accumulating when hardware is installed, or when failed hardware is replaced, as in Table 5.3.1b and Figures 5.3.1b and d. You can select either approach from the Lifecycle Cost Results Menu.

Mean Hardware Cost, $k

	Period					
	1	2	3	4	5	Overall
Turbine	246.000	.000	.000	.000	.000	246.000
Generator	24.600	.000	.000	.000	.000	24.600
Diode	.180	.000	.000	.000	.000	.180
Battery	71.400	.000	71.400	.000	.000	142.800
Outlet	.255	.000	.000	.000	.000	.255
Sums	342.435	.000	71.400	.000	.000	413.835

Table 5.3.1a

Mean Hardware Cost, $k

	Period					
	1	2	3	4	5	Overall
Turbine	164.000	.000	.000	.000	.000	164.000
Generator	12.300	.000	.000	.000	.000	12.300
Diode	.085	.009	.005	.009	.011	.119
Battery	71.400	.000	33.320	35.700	2.380	142.800
Outlet	.085	.008	.017	.008	.000	.119
Sums	247.870	.017	33.342	35.717	2.391	319.338

Table 5.3.1b

Figure 5.3.1 a
Mean Hardware Cost
$k

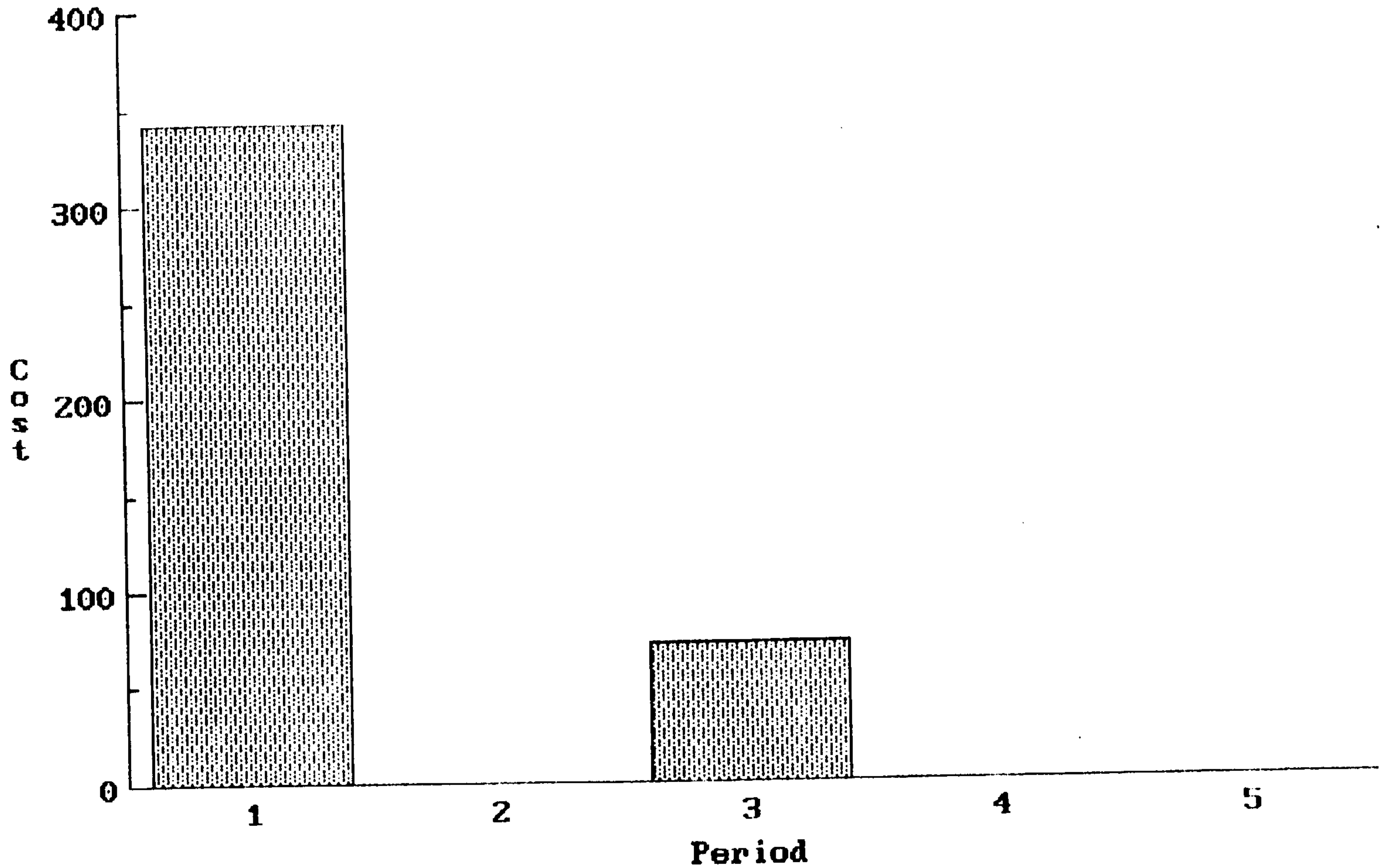

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Figure 5.3.1 b
Mean Hardware Cost ($k)
(Hardware Costs accumulated when spares are used as replacements.)

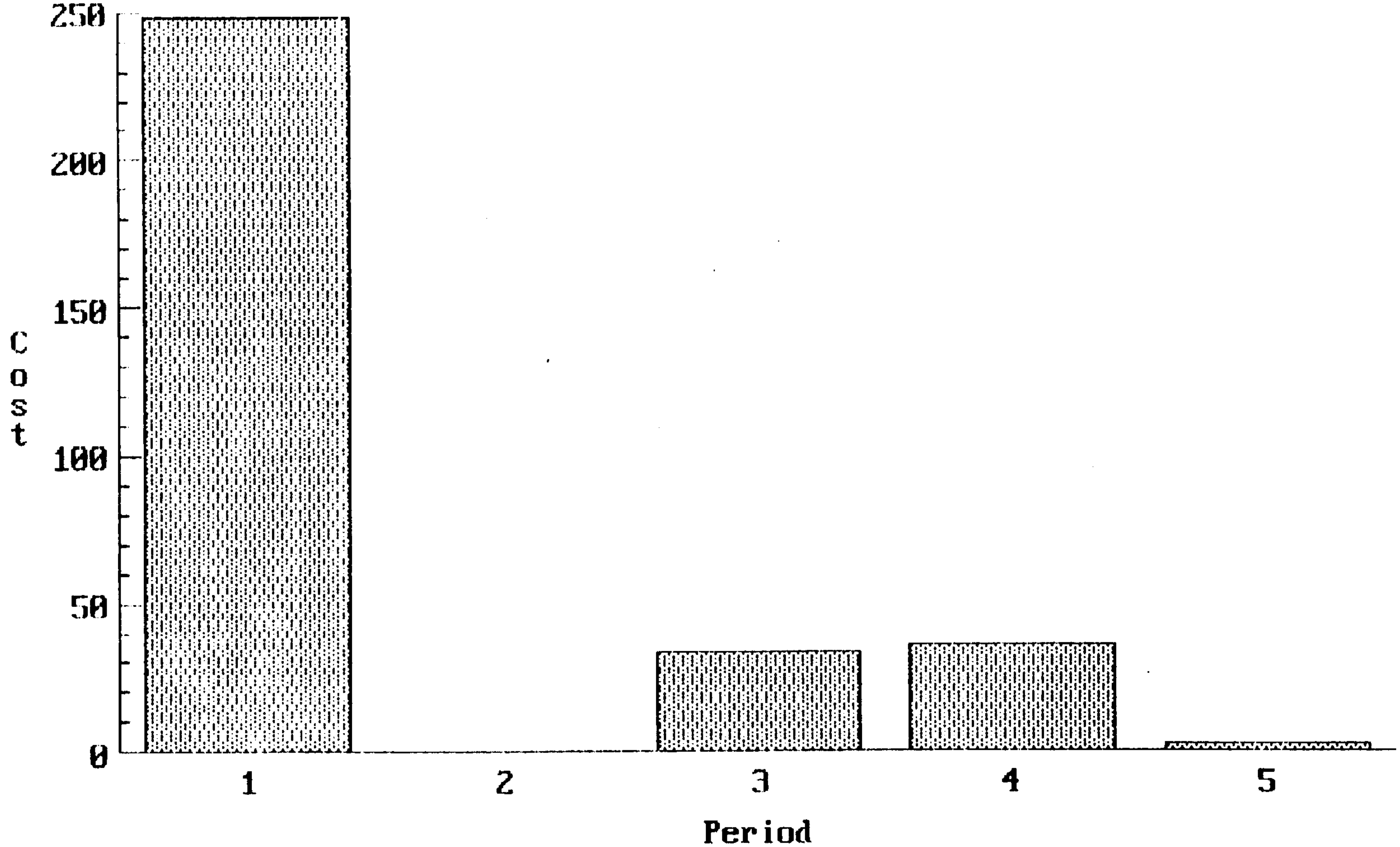

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Figure 5.3.1 c
Mean Hardware Cost ($k)
(Hardware Costs accumulated when spares are placed in depot.)

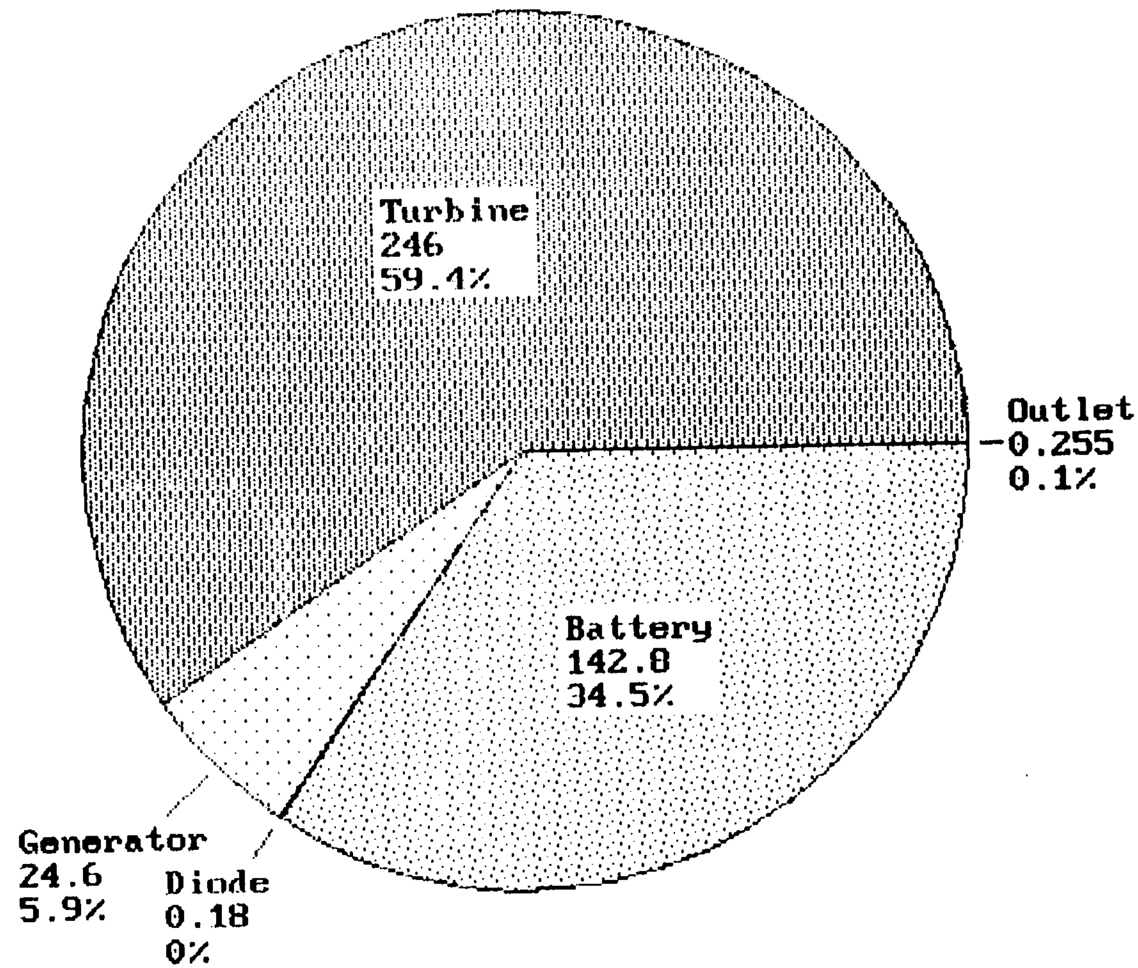

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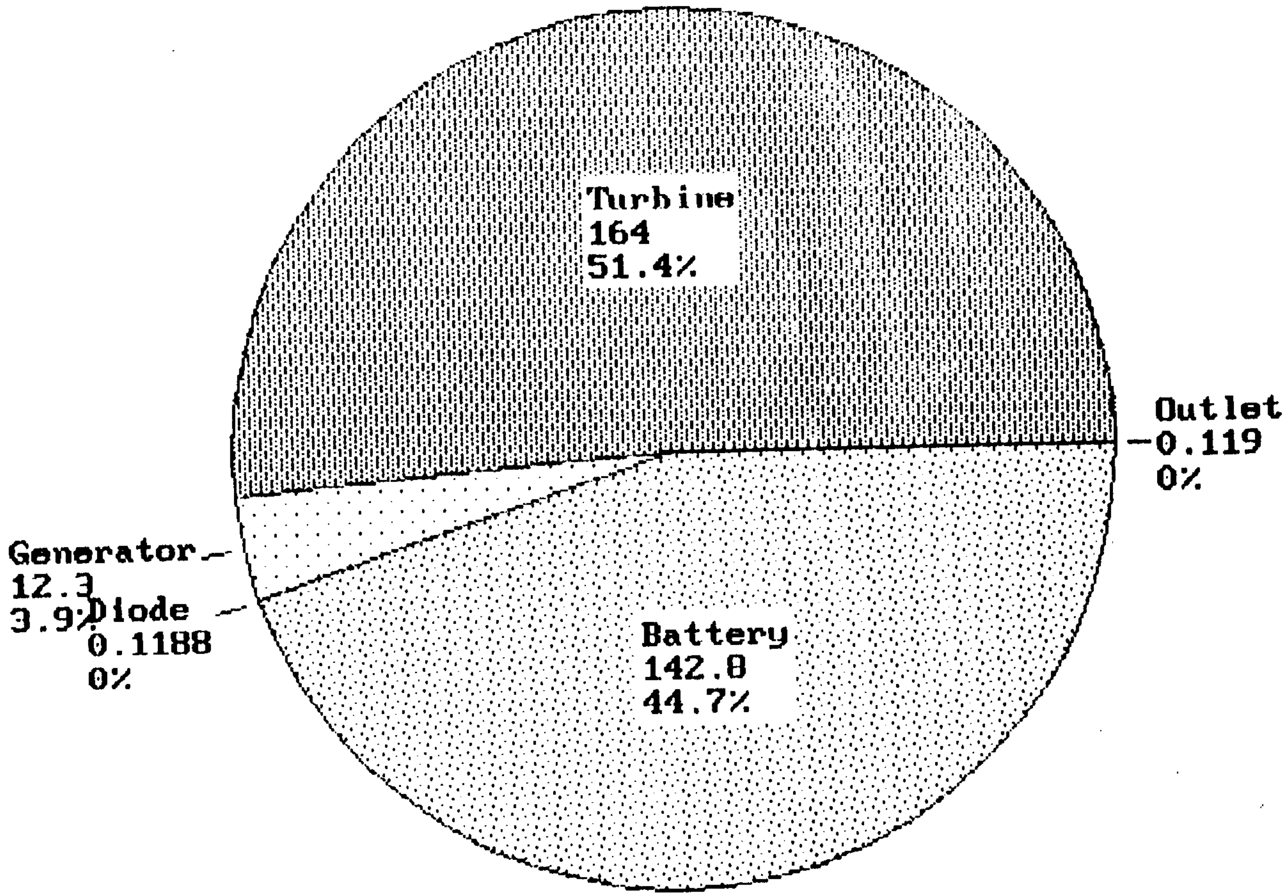
Figure 5.3.1d
Mean Hardware Cost ($k)
(Hardware Costs accumulated when spares are used as replacements.)



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Transportation Costs

Table 5.3.2 displays the mean transportation cost for each block by period. This is the cost to deliver hardware for installation and resupply. It is assumed that the transportation cost for a given block type is directly proportional to the delivered mass. Figures 5.3.2 a and b show these costs in graphical form.

Mean Transportation Cost, $k

	Period 1	2	3	4	5	Overall
Turbine	.774	.000	.000	.000	.000	.774
Generator	.468	.000	.000	.000	.000	.468
Diode	.002	.000	.000	.000	.000	.002
Battery	.956	.000	.446	.478	.032	1.912
Outlet	.005	.001	.001	.001	.000	.007
Sums	2.205	.001	.447	.479	.032	3.163

Table 5.3.2

Figure 5.3.2 a
Mean Transportation Cost ($k x 10*3)

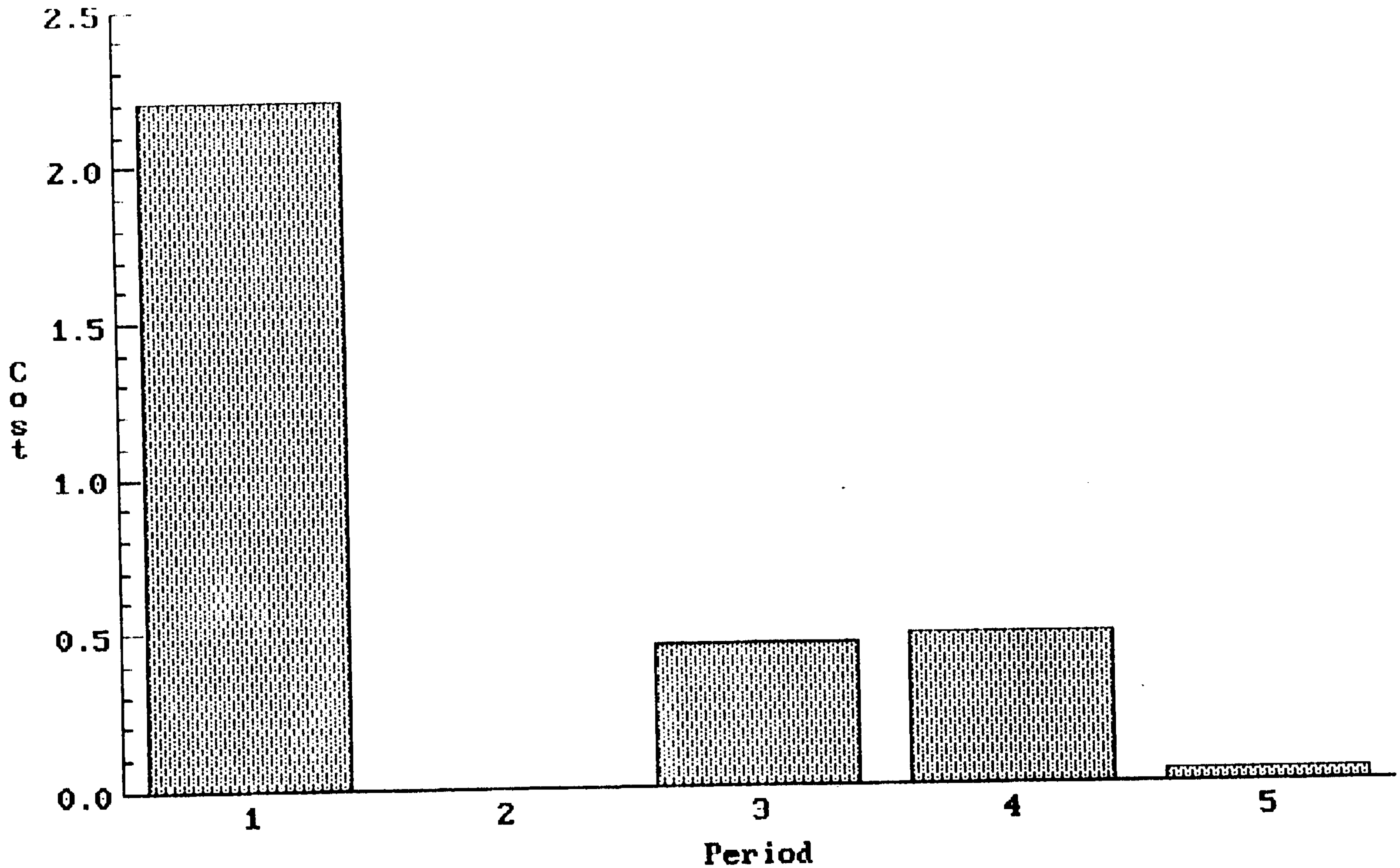

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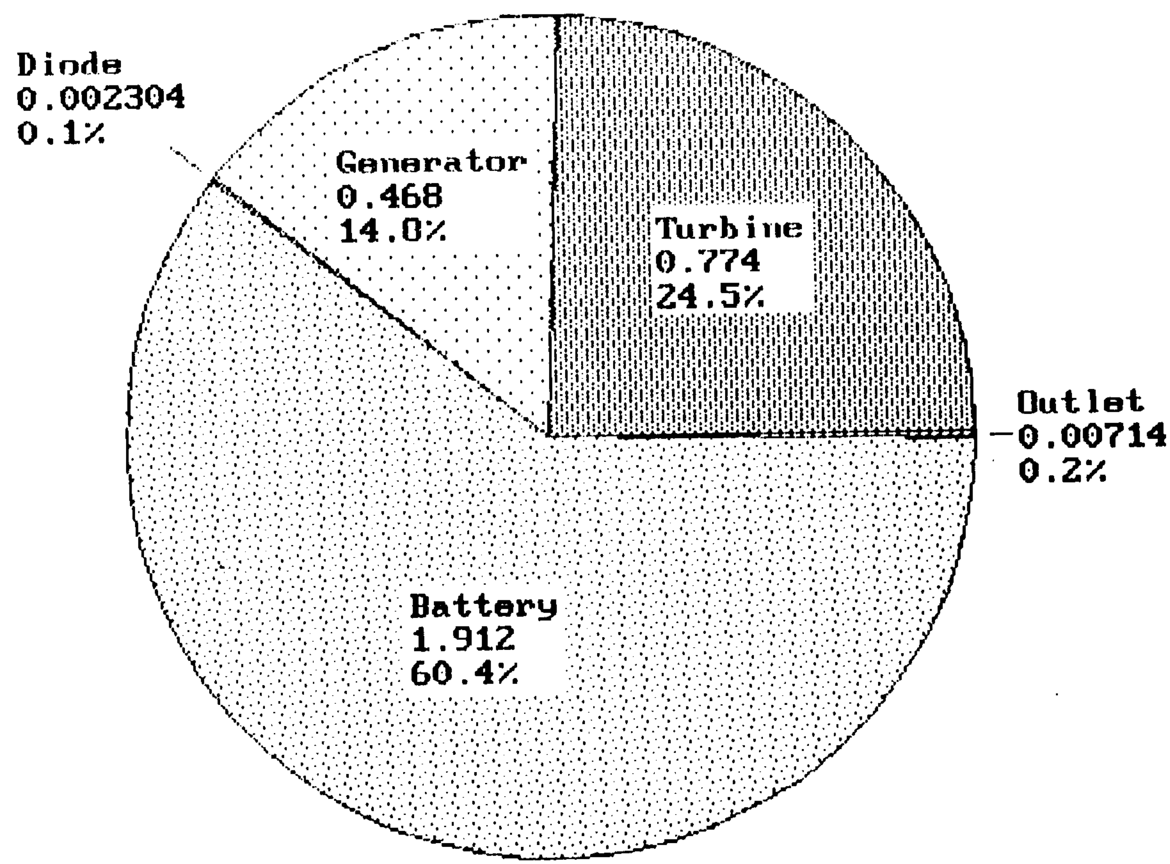
Figure 5.3.2 b
Mean Transportation Cost ($k x 10*3)



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Crew Costs

Table 5.3.3 displays the mean cost for maintenance action #1 (Crew) for each block. This is the cost to replace the failed blocks during each period. Figures 5.3.3 a and b show these costs in graphical form.

Mean Crew Cost ($k x 10*3)

	Period 1	2	3	4	5	Overall
Turbine	2.160	.000	.000	.000	.000	2.160
Generator	.416	.000	.000	.000	.000	.416
Diode	.113	.012	.007	.012	.014	.158
Battery	.528	.000	.246	.264	.018	1.056
Outlet	.184	.018	.037	.018	.000	.258
Sums	3.401	.030	.290	.294	.032	4.048

Table 5.3.3

Figure 5.3.3 a
Mean Crew Cost
$k x 10*3

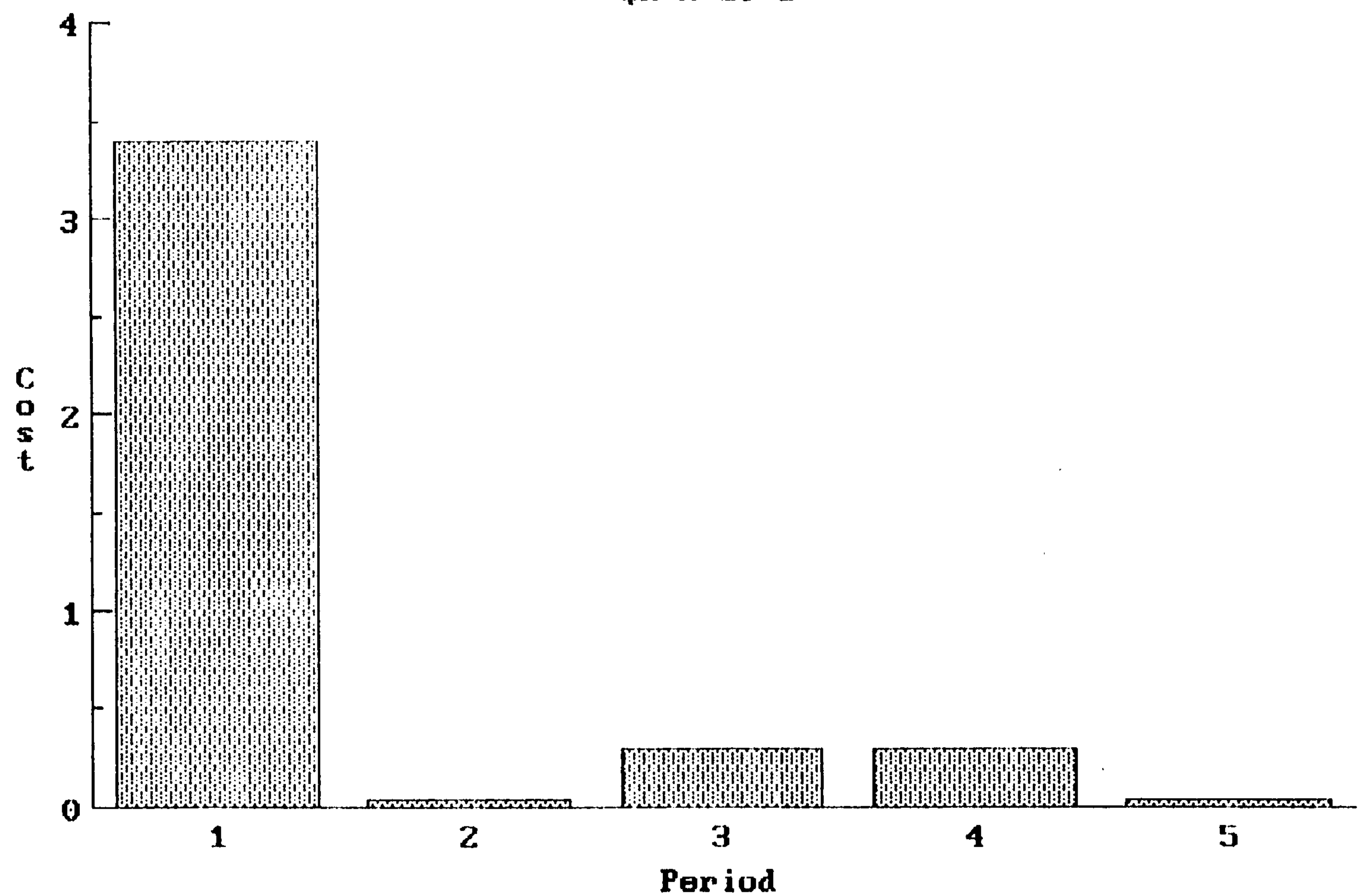

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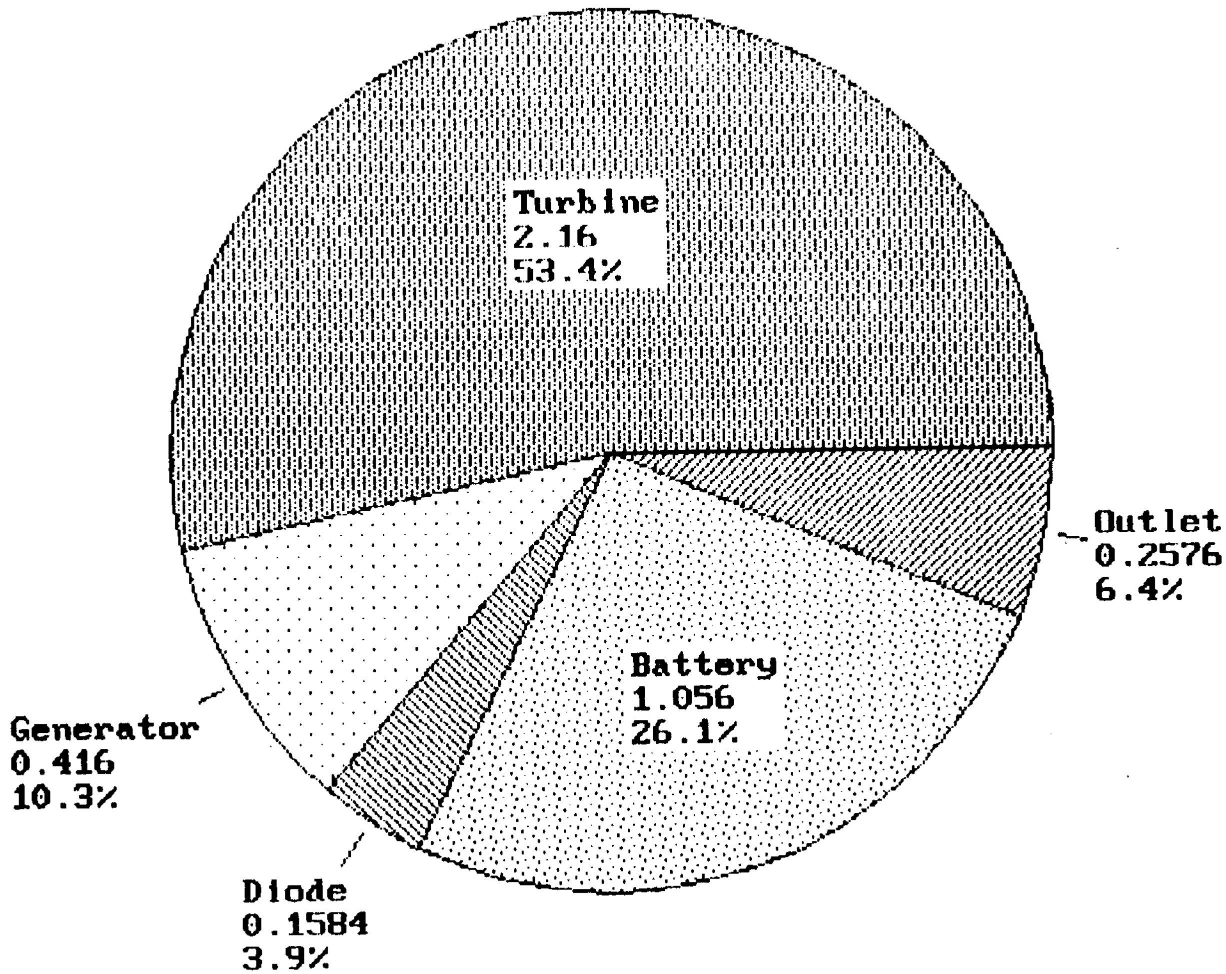
Figure 5.3.3 b
Mean Crew Cost ($k x 10*3)



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Equipment Costs

Table 5.3.4 displays the mean cost for maintenance action #2 (equipment) for each block type. Figures 5.3.4 a and b show these costs in graphical form.

Mean Equipment Cost ($k)

	Period 1	2	3	4	5	Overall
Turbine	152.000	.000	.000	.000	.000	152.000
Generator	22.000	.000	.000	.000	.000	22.000
Diode	.000	.000	.000	.000	.000	.000
Battery	108.000	.000	50.400	54.000	3.600	216.000
Outlet	.000	.000	.000	.000	.000	.000
Sums	282.000	.000	50.400	54.000	3.600	390.000

Table 5.3.4

Figure 5.3.4 a
Mean Equipment Cost
$k

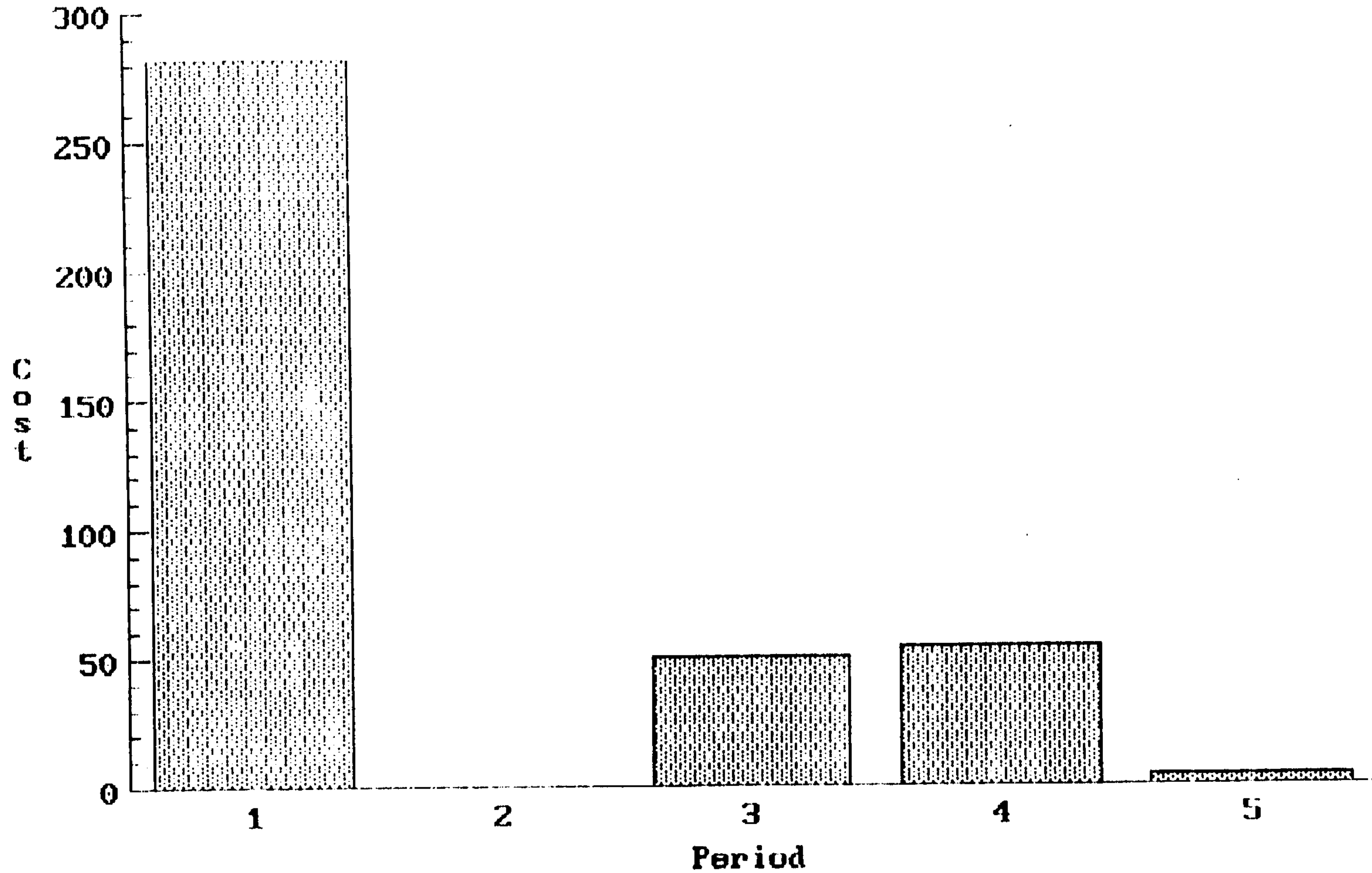

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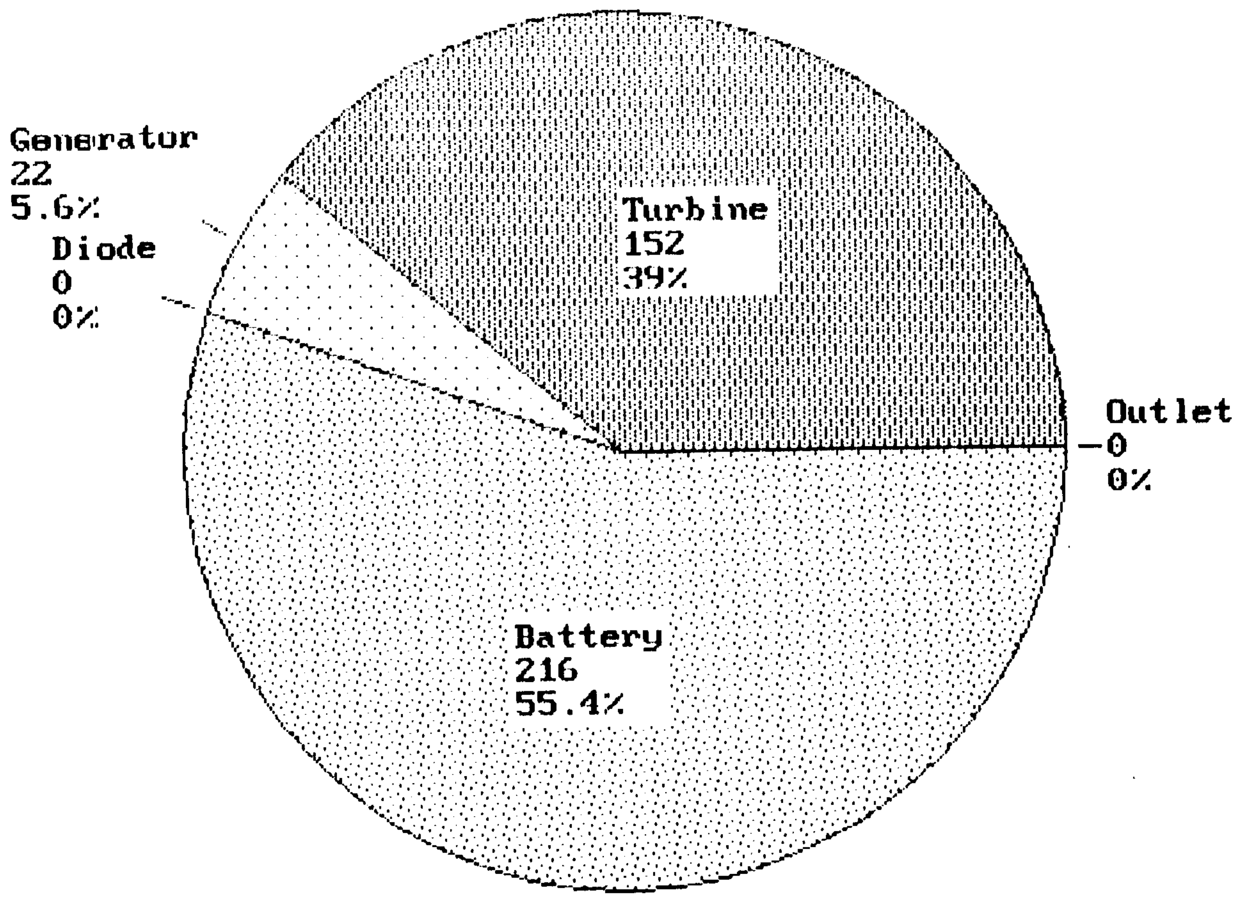
Figure 5.3.4 b
Mean Equipment Cost ($k)



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Robotics Costs

Table 5.3.5 displays the mean cost for maintenance action #3 (robotics) for each block type. Figures 5.3.5 a and b show these costs in graphical form.

Mean Robotics Cost ($k)

	Period					
	1	2	3	4	5	Overall
Turbine	24.000	.000	.000	.000	.000	24.000
Generator	12.000	.000	.000	.000	.000	12.000
Diode	.000	.000	.000	.000	.000	.000
Battery	72.000	.000	33.600	36.000	2.400	144.000
Outlet	12.000	1.200	2.400	1.200	.000	16.800
Sums	120.000	1.200	36.000	37.200	2.400	196.800

Table 5.3.5

Figure 5.3.5 a
Mean Robotics Cost
$k

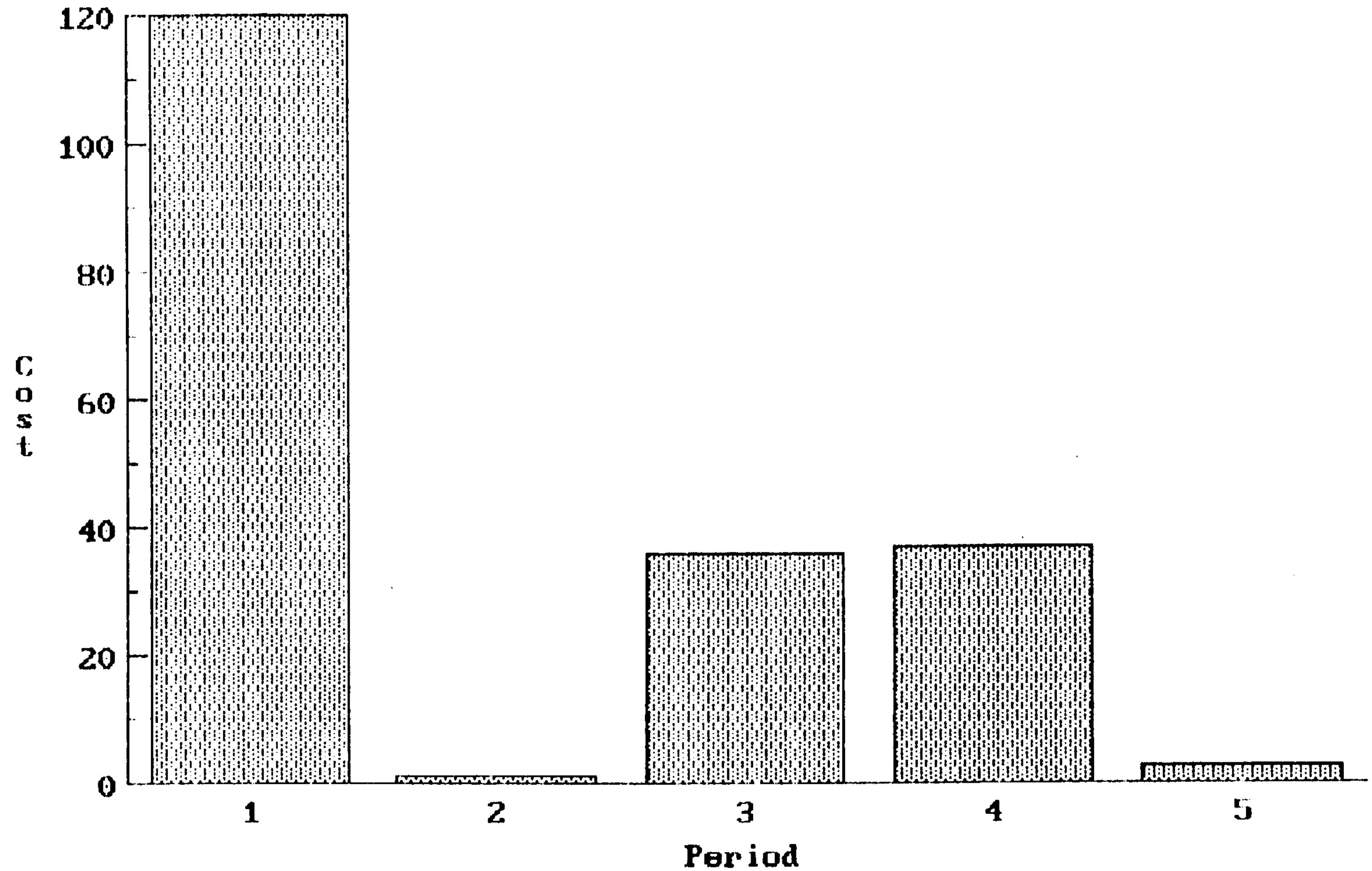

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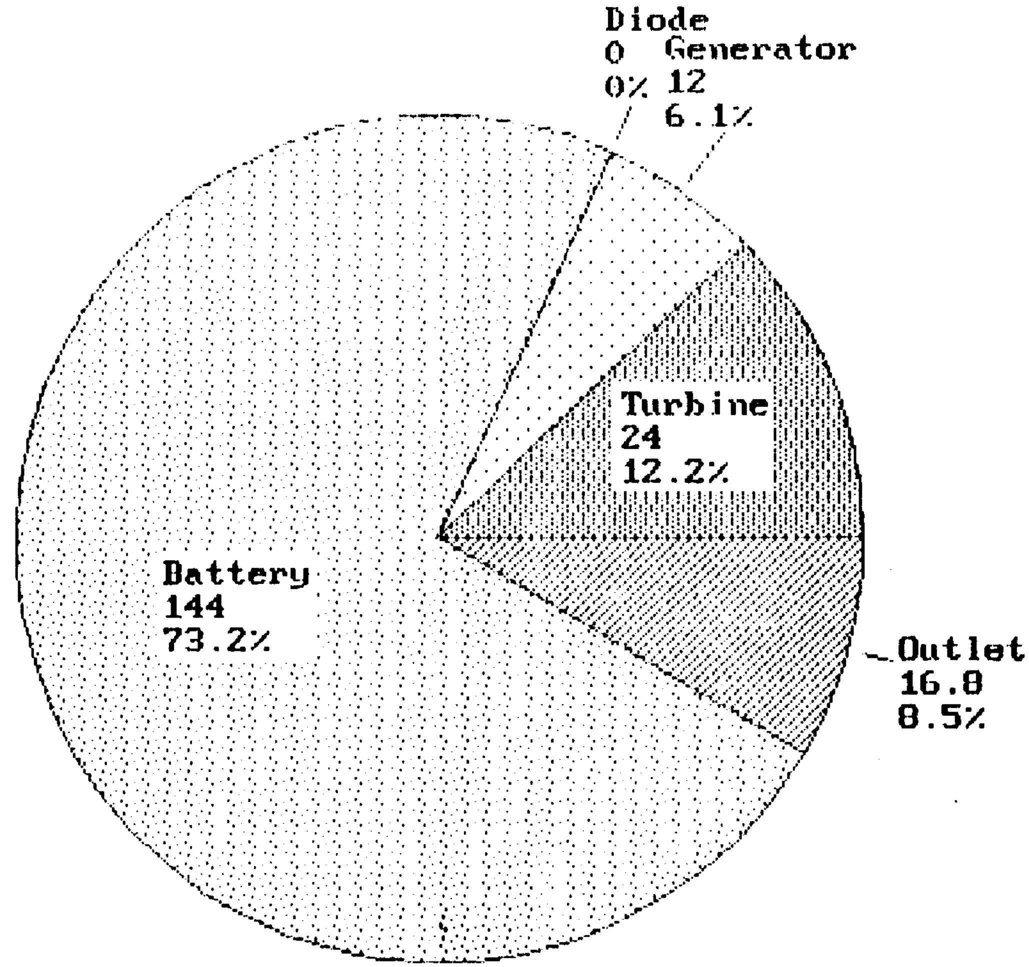
Figure 5.3.5 b
Mean Robotics Cost ($k)



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Total Costs

Table 5.3.6 a,b and Figures 5.3.6 a,b display the total mean cost for each block type by period. This is the sum of the mean hardware cost, transportation cost, and the maintenance costs (crew, equipment, and robotics). For these results, you can select either of two approaches to account for hardware cost (See page 68). Table 5.3.6 a and Figures 5.3.6 a and b display the total costs, assuming that the hardware costs accumulate whenever hardware is fabricated. Table 5.3.6 b assumes that the hardware costs accumulate whenever hardware is installed or replaced at the site.

Mean Total Cost, $k x 10*3

	Period 1	2	3	4	5	Overall
Turbine	3.356	.000	.000	.000	.000	3.356
Generator	.943	.000	.000	.000	.000	.943
Diode	.115	.012	.007	.012	.015	.161
Battery	1.735	.000	.848	.832	.055	3.470
Outlet	.201	.020	.040	.020	.000	.282
Sums	6.350	.032	.895	.864	.070	8.212

Table 5.3.6a

Mean Total Cost, $k x 10*3

	Period 1	2	3	4	5	Overall
Turbine	3.274	.000	.000	.000	.000	3.274
Generator	.930	.000	.000	.000	.000	.930
Diode	.115	.012	.007	.012	.015	.161
Battery	1.735	.000	.810	.868	.058	3.470
Outlet	.201	.020	.040	.020	.000	.282
Sums	6.255	.032	.857	.900	.072	8.117

Table 5.3.6b

Figure 5.3.6 a
Mean Total Cost
$k x 10*3

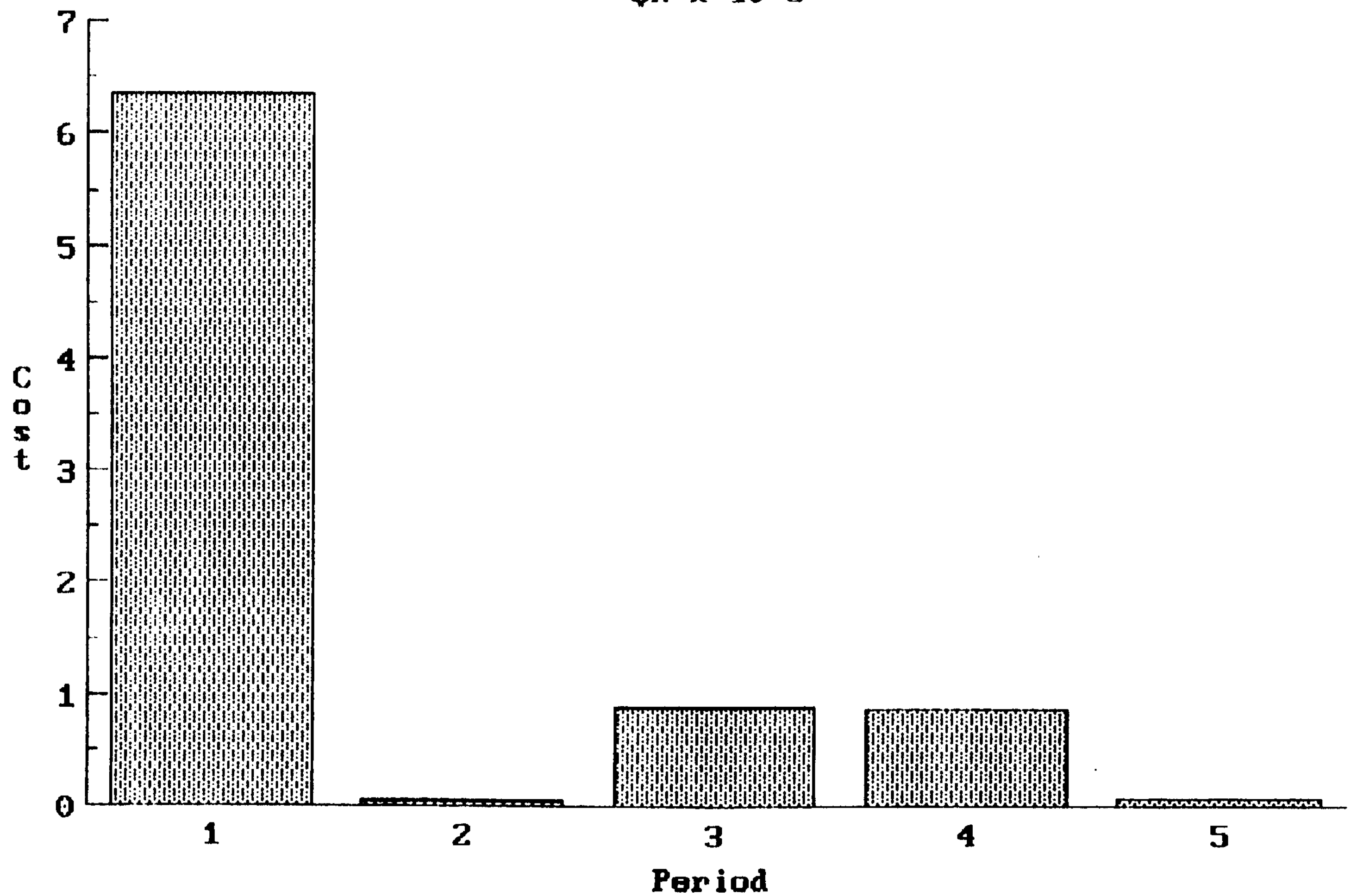

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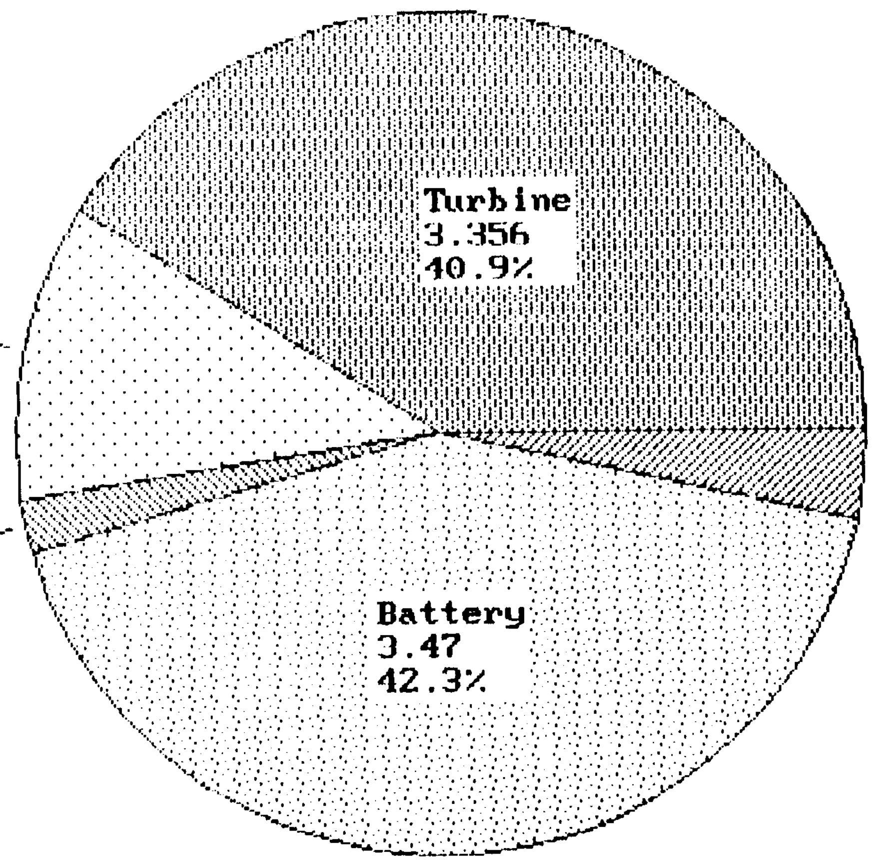
Figure 5.3.6 b
Mean Total Cost ($k x 10*3)
(Hardware Costs accumulated when spares are placed in depot.)



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Overall Costs

Table 5.3.7a and Figures 5.3.7a,b display the overall hardware, transportation, and maintenance costs by period. For these results, you can select either of two approaches to account for hardware cost (See page 68). Table 5.3.7 a and Figures 5.3.7 a and b display these costs, assuming that the hardware costs accumulate whenever hardware is fabricated. Table 5.3.7 b assumes that the hardware costs accumulate whenever hardware is installed or replaced at the site.

Mean Overall Cost, $k x 10*3

	Period 1	2	3	4	5	Overall
Hardware	.342	.000	.071	.000	.000	.414
Transportation	2.205	.001	.447	.479	.032	3.163
Crew	3.401	.030	.290	.294	.032	4.048
Equipment	.282	.000	.050	.054	.004	.390
Robotics	.120	.001	.036	.037	.002	.197
Sums	6.350	.032	.895	.864	.070	8.212

Table 5.3.7a

Mean Overall Cost ($k x 10*3)

	Period 1	2	3	4	5	Overall
Hardware	.248	.000	.033	.036	.002	.319
Transportation	2.205	.001	.447	.479	.032	3.163
Crew	3.401	.030	.290	.294	.032	4.048
Equipment	.282	.000	.050	.054	.004	.390
Robotics	.120	.001	.036	.037	.002	.197
Sums	6.255	.032	.857	.900	.072	8.117

Table 5.3.7b

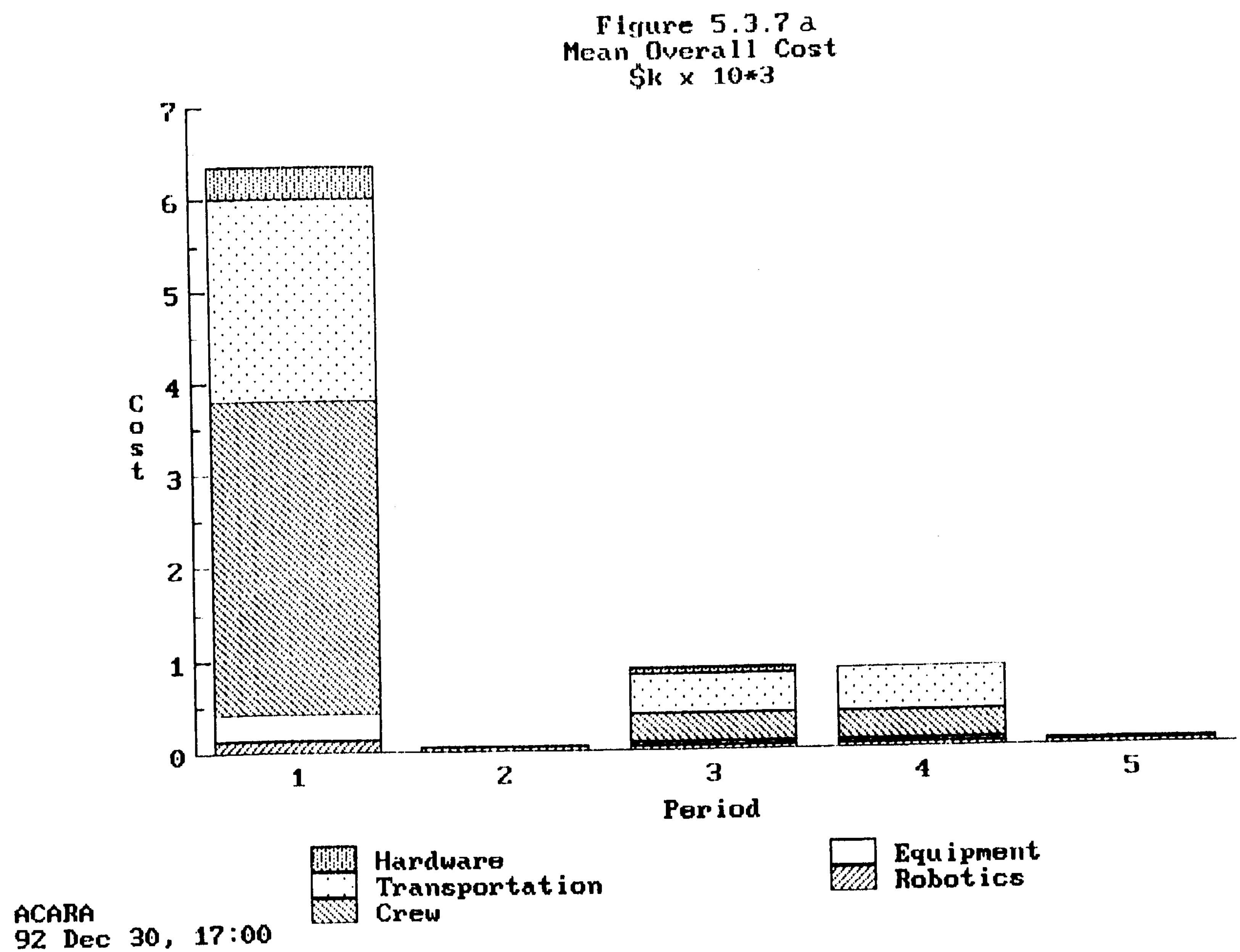
Figure 5.3.7 a
Mean Overall Cost
$k x 10*3
Cost
0
1
2
3
4
5
6
7
1
2
3
4
5
Period
Hardware
Transportation
Crew
Equipment
Robotics
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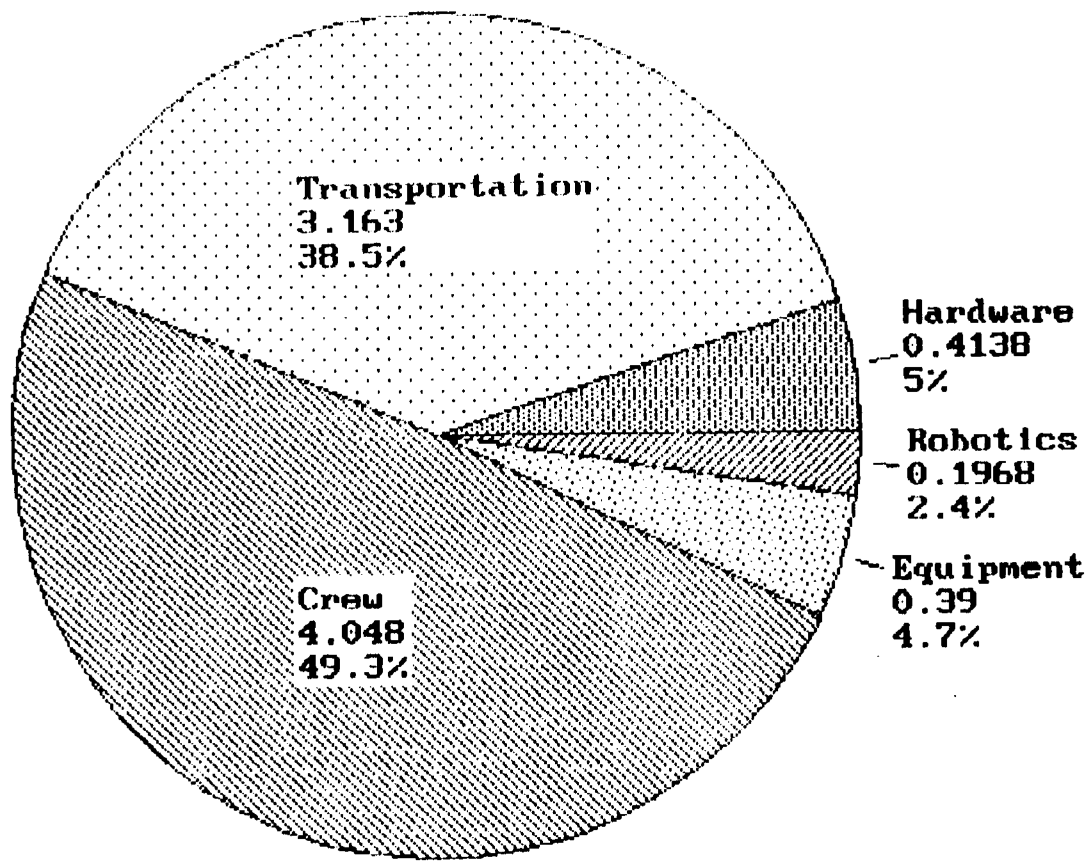
Figure 5.3.7 b
Mean Overall Cost ($k x 10x3)
(Hardware Costs accumulated when spares are placed in depot.)



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Block Costs

Table 5.3.8 a and b display the costs associated with each block type accumulated by the end of the duration. The columns are, respectively, hardware cost, transportation cost, and maintenance costs (crew, equipment and robotics). For these results, you can select either of two approaches to account for hardware cost (See page 68). Table 5.3.8 a and Figure 5.3.8 display these costs, assuming that the hardware costs accumulate whenever hardware is fabricated. Table 5.3.8b assumes that the hardware costs accumulate whenever hardware is installed or replaced at the site.

Mean Block Cost, $k x 10*3

Block	Hardware	Transportation	Crew	Equipment	Robotics	Total
Turbine	.246	.774	2.160	.152	.024	3.356
Generator	.025	.468	.416	.022	.012	.943
Diode	.000	.002	.158	.000	.000	.161
Battery	.143	1.912	1.056	.216	.144	3.470
Outlet	.000	.007	.258	.000	.017	.282
Total:	.414	3.163	4.048	.390	.197	8.212

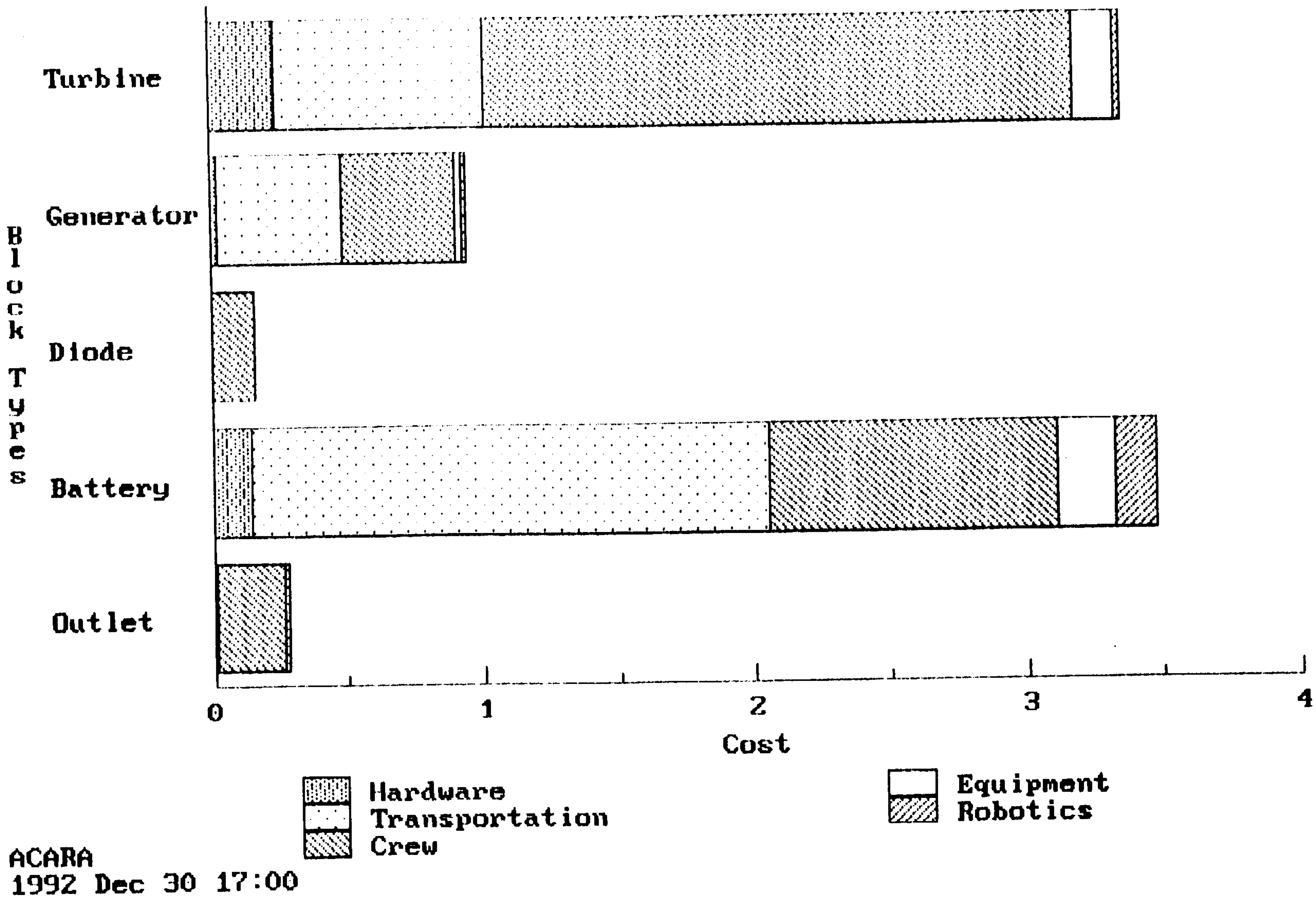
Table 5.3.8 a

Mean Block Cost, $k x 10*3

Block	Hardware	Transportation	Crew	Equipment	Robotics	Total
Turbine	.164	.774	2.160	.152	.024	3.274
Generator	.012	.468	.416	.022	.012	.930
Diode	.000	.002	.158	.000	.000	.161
Battery	.143	1.912	1.056	.216	.144	3.470
Outlet	.000	.007	.258	.000	.017	.282
Total:	.319	3.163	4.048	.390	.197	8.117

Table 5.3.8 b

Figure 5.3.8
Mean Block Cost
$k x 10*3



5.4. Resource Allocations

This section deals with the quantity of depot spares and the usage of hardware mass, volume, and maintenance time over the duration.

Depot Supply

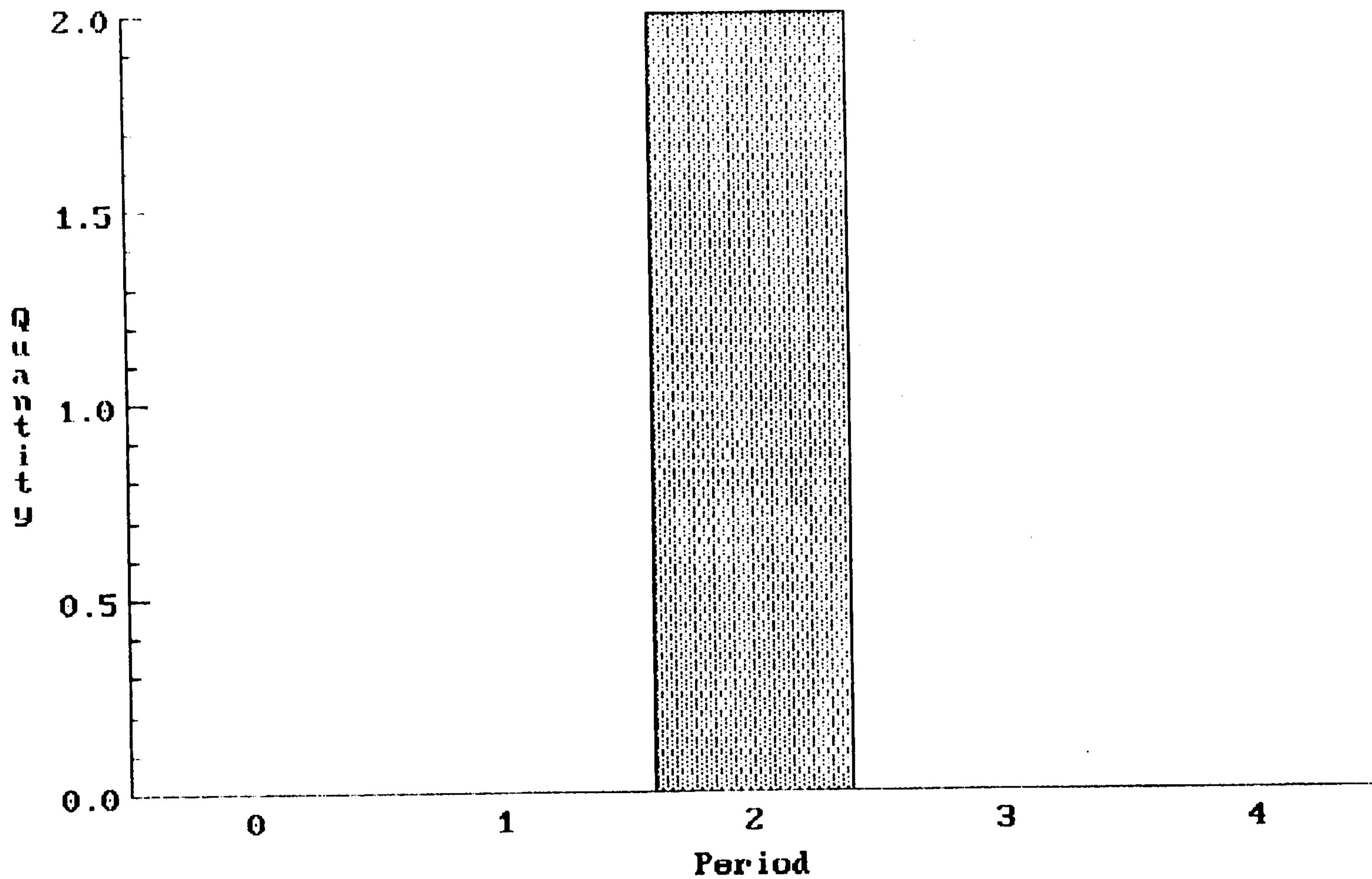
Table 5.4.1 displays the most probable quantity of each block type residing in the supply depot for each block type. A bar chart (Figure 5.4.1) displays the most probable quantity of spares for a selected block type residing in storage.

Most Probable Cumulative Quantity in Supply

	Period				
Block Name	0	1	2	3	4
Turbine	1	1	1	1	1
Generator	2	1	1	1	1
Diode	7	7	7	7	7
Battery	0	0	2	0	0
Outlet	2	2	2	2	2

Table 5.4.1

Figure 5.4.1
Most Probable Cumulative Quantity in Supply
Type Name: Battery



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Hardware Delivered

Tables 5.4.2 a and b show the most probable quantities of each block type delivered to the site by period. Choose either of the following options from the menu:

Resupply	Includes hardware delivered for resupply only. See Table 5.4.2 a and Figure 5.4.2 a.
Total	Includes hardware delivered for both installation and resupply. See Table 5.4.2 b and Figure 5.4.2 b.

These quantities can be displayed as a bar chart for a single block type, selected by the user, as in Figures 5.4.2 a and b.

Most Probable Quantity of Resupply Hardware Delivered

Block Name	Period 0	1	2	3	4	Overall
Turbine	0	0	0	0	0	0
Generator	0	0	0	0	0	0
Diode	0	0	0	0	0	0
Battery	0	0	3	3	0	6
Outlet	0	0	0	0	0	0

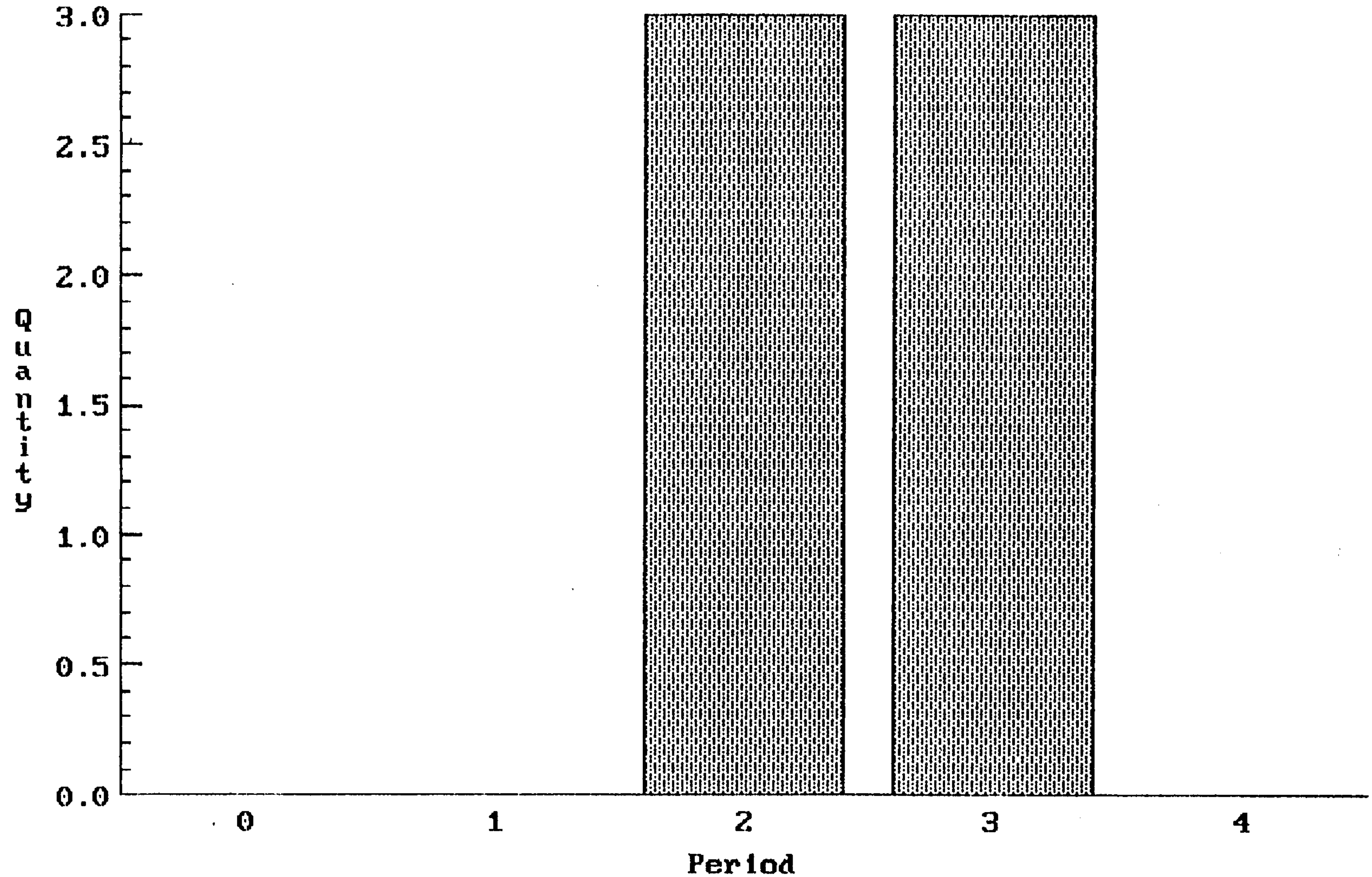
Table 5.4.2 a

Most Probable Quantity of Total Hardware Delivered

Block Name	Period 0	1	2	3	4	Overall
Turbine	2	0	0	0	0	2
Generator	1	0	0	0	0	1
Diode	3	0	0	0	0	3
Battery	6	0	3	3	0	12
Outlet	1	0	0	0	0	1

Table 5.4.2 b

Figure 5.4.2a
Most Probable Quantity of Resupply Hardware Delivered
Type Name: Battery



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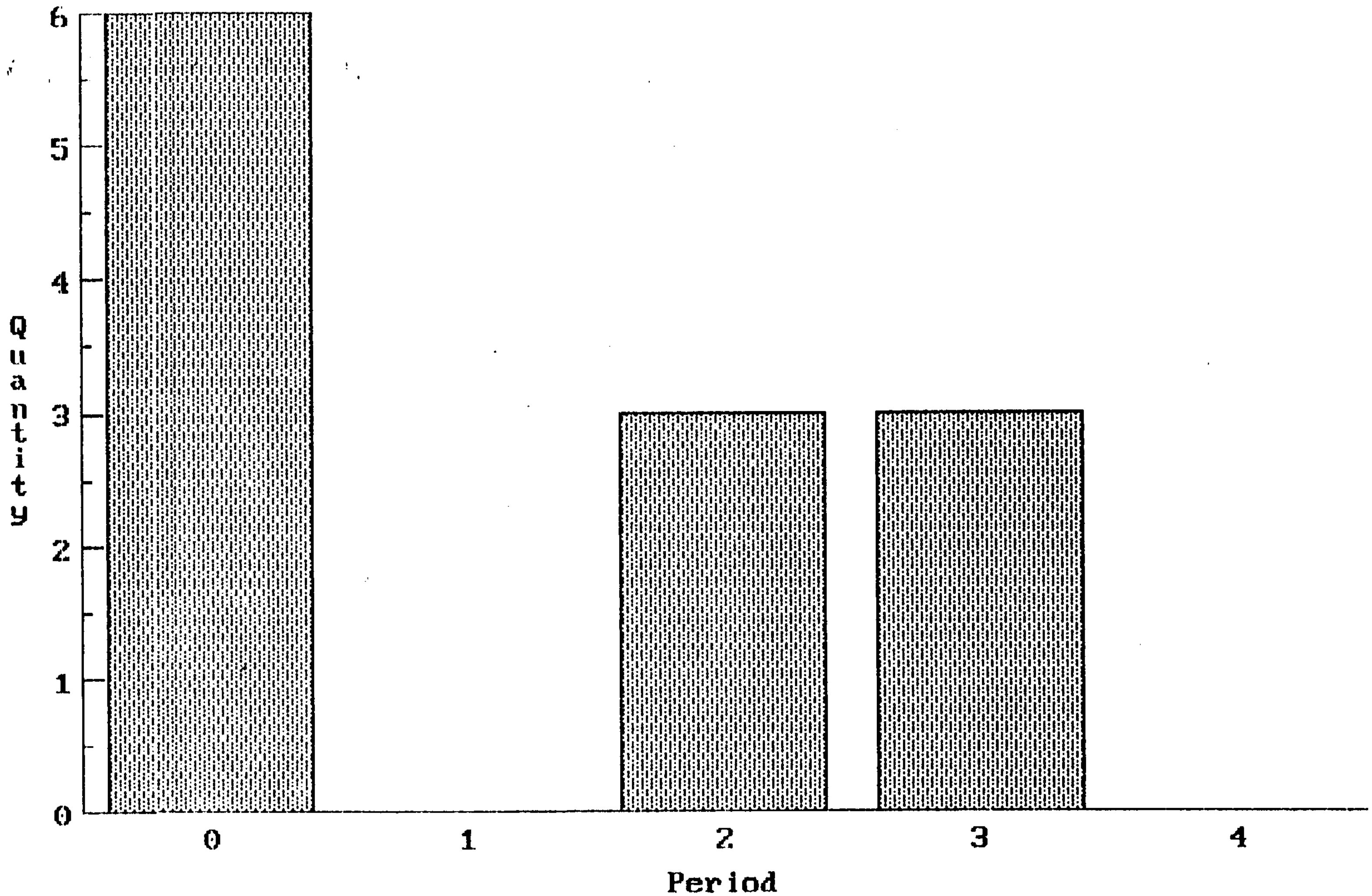
C-2

Figure 5.4.2 b
Most Probable Quantity of Total Hardware Delivered
Type Name: Battery



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Resource Usage

Resource usage (mass, volume, and maintenance hours) may be tabulated with or without installation requirements. Choose either **Resupply** or **Total** from the menu. Tables 5.4.3 through 5.4.7 show the results for the example system used throughout this manual.

Table	5.4.3a, b	Mass	
	5.4.4a, b	Volume	
	5.4.5a, b	Maintenance Action #1	(Crew)
	5.4.6a, b	Maintenance Action #2	(Equipment)
	5.4.7a, b	Maintenance Action #3	(Robotics)

In each case, the row labelled "Sums" shows the total mass at each period. The bottom row, "Constraint", shows the limit imposed on the resource during each period. The constraints for each resource are entered in the Logistics Constraints Table (page 34).

The total amount for each of the above resources is displayed, by period, as a bar chart (Figure 5.4.3 through 5.4.7).

Mean Resupply Mass Usage (lbs x 10*3)

Block Names	Period 1	2	3	4	5	Overall
Turbine	.000	.000	.000	.000	.000	.000
Generator	.000	.000	.000	.000	.000	.000
Diode	.000	.000	.000	.000	.000	.000
Battery	.027	.000	.127	.154	.011	.319
Outlet	.000	.000	.000	.000	.000	.001
Sums	.027	.000	.128	.154	.011	.320
Constraints	.860	.180	.180	.180	.180	

Table 5.4.3a

Mean Total Mass Usage (lbs x 10*3)

Block Names	Period 1	2	3	4	5	Overall
Turbine	.258	.000	.000	.000	.000	.258
Generator	.156	.000	.000	.000	.000	.156
Diode	.001	.000	.000	.000	.000	.001
Battery	.319	.000	.149	.159	.011	.637
Outlet	.002	.000	.000	.000	.000	.002
Sums	.735	.000	.149	.160	.011	1.054
Constraints	.860	.180	.180	.180	.180	

Table 5.4.3b.

Figure 5.4.3 a
Mean Resupply Mass Usage (lbs x 10*3)

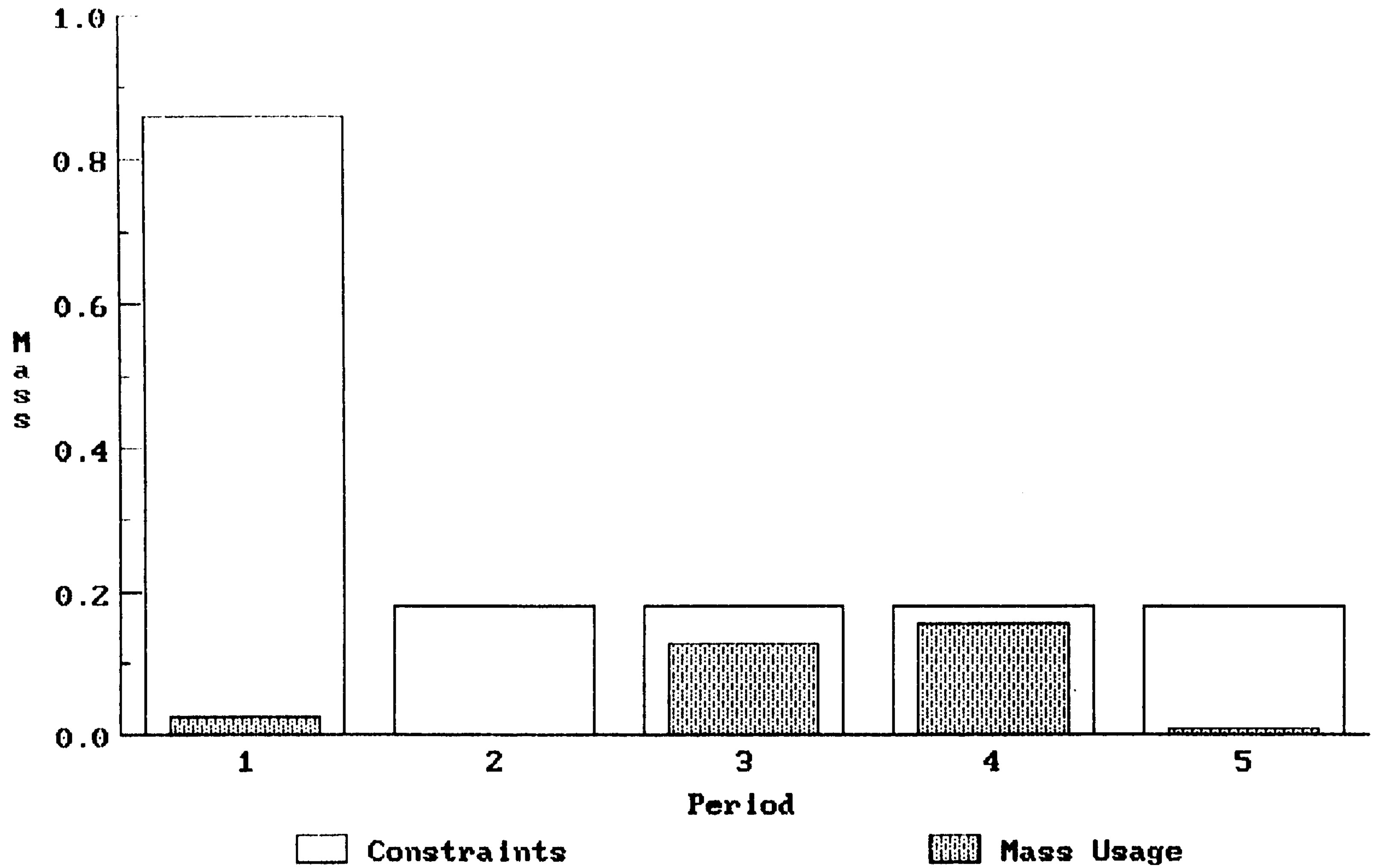

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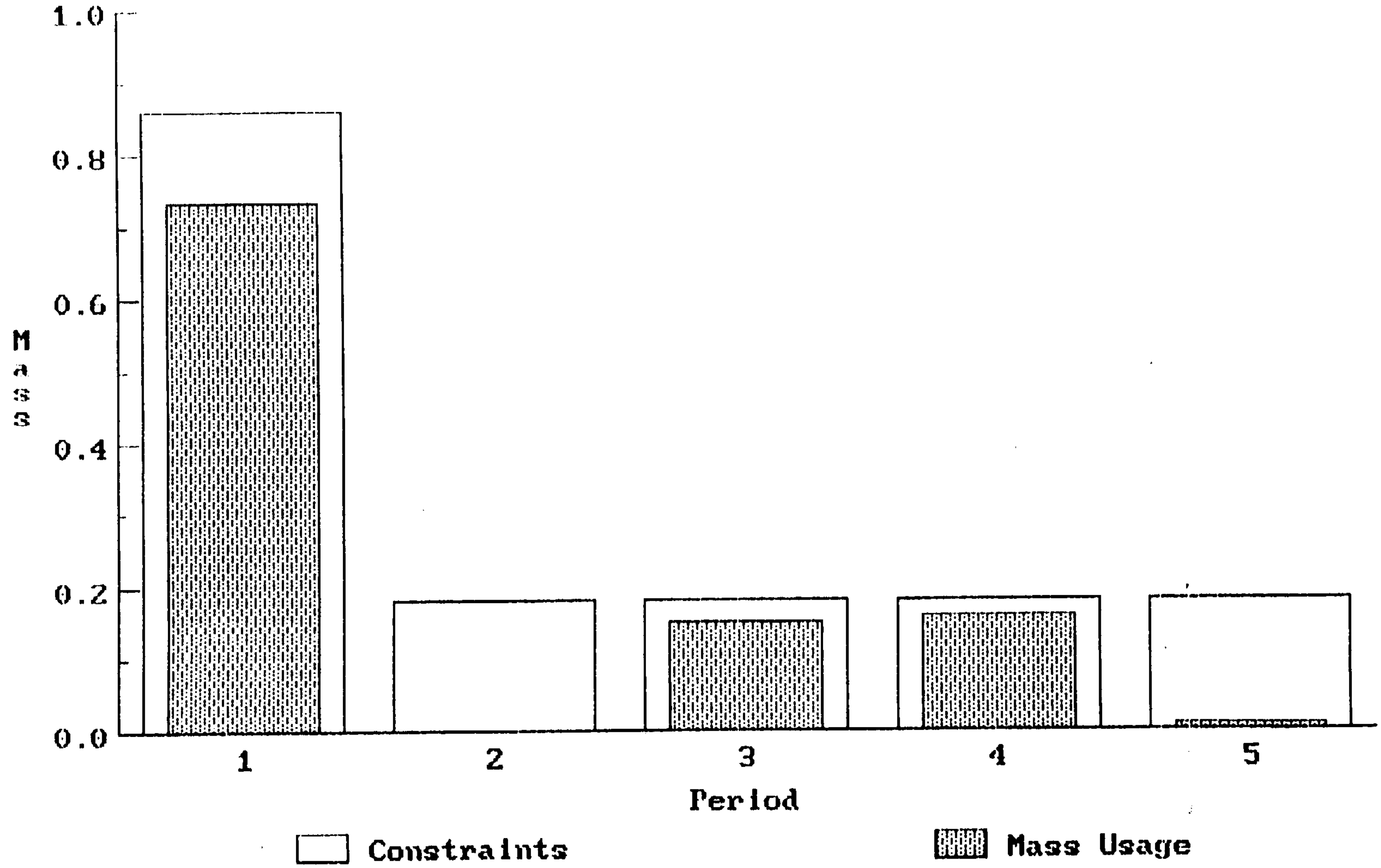
Figure 5.4.3 b
Mean Total Mass Usage (lbs x 10*3)



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Mean Resupply Volume Usage (ft3)

Block Names	Period 1	2	3	4	5	Overall
Turbine	.000	.000	.000	.000	.000	.000
Generator	.000	.000	.000	.000	.000	.000
Diode	.420	.196	.084	.112	.140	.952
Battery	3.400	.000	16.320	19.720	1.360	40.800
Outlet	.000	.080	.160	.080	.000	.320
Sums	3.820	.276	16.564	19.912	1.500	42.072
Constraints	150.000	30.000	30.000	30.000	30.000	

Table 5.4.4a

Mean Total Volume Usage (ft3)

Block Names	Period 1	2	3	4	5	Overall
Turbine	68.400	.000	.000	.000	.000	68.400
Generator	22.600	.000	.000	.000	.000	22.600
Diode	1.260	.196	.084	.112	.140	1.792
Battery	40.800	.000	19.040	20.400	1.360	81.600
Outlet	.800	.080	.160	.080	.000	1.120
Sums	133.860	.276	19.284	20.592	1.500	175.512
Constraints	150.000	30.000	30.000	30.000	30.000	

Table 5.4.4b

Figure 5.4.4 a
Mean Resupply Volume Usage
f1.3

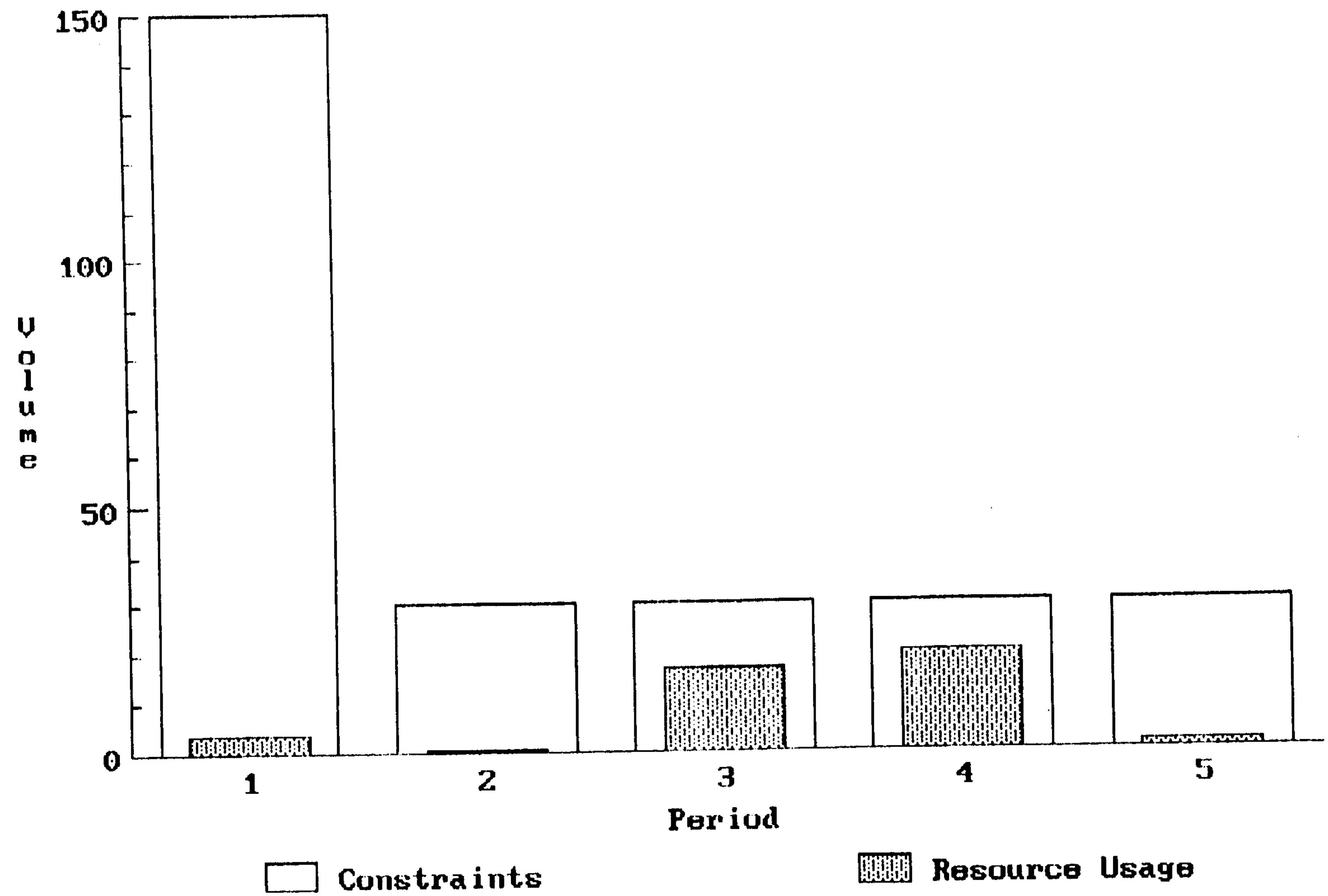

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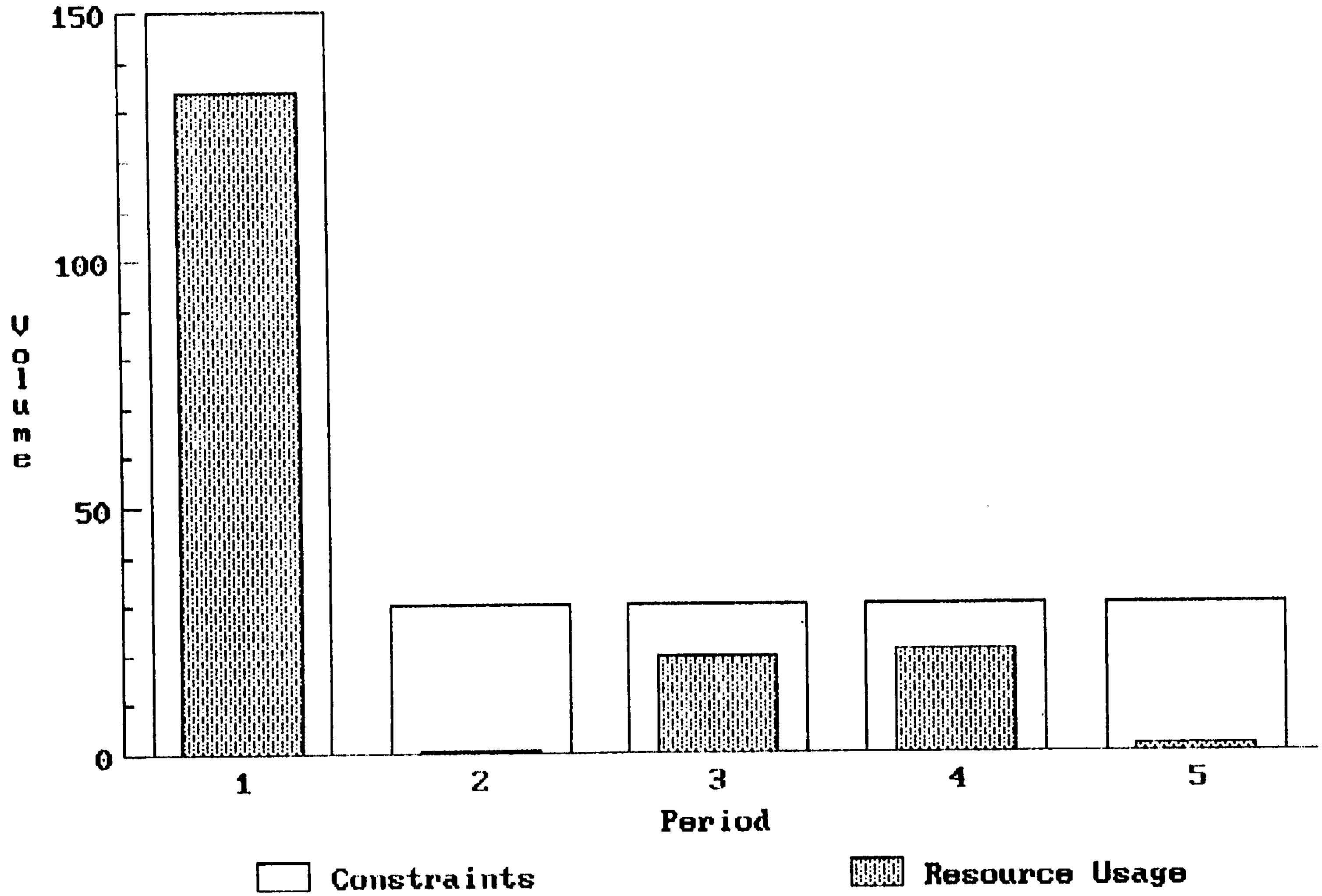
Figure 5.4.4 b
Mean Total Volume Usage
ft3



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Mean Resupply Crew Usage (Hours)

Block Names	Period 1	2	3	4	5	Overall
Turbine	.000	.000	.000	.000	.000	.000
Generator	.000	.000	.000	.000	.000	.000
Diode	.510	.150	.090	.150	.180	1.080
Battery	.550	.000	2.640	3.190	.220	6.600
Outlet	.000	.230	.460	.230	.000	.920
Sums	1.060	.380	3.190	3.570	.400	8.600
Constraints	50.000	15.000	15.000	15.000	15.000	

Table 5.4.5a

Mean Total Crew Usage (Hours)

Block Names	Period 1	2	3	4	5	Overall
Turbine	27.000	.000	.000	.000	.000	27.000
Generator	5.200	.000	.000	.000	.000	5.200
Diode	1.410	.150	.090	.150	.180	1.980
Battery	6.600	.000	3.080	3.300	.220	13.200
Outlet	2.300	.230	.460	.230	.000	3.220
Sums	42.510	.380	3.630	3.680	.400	50.600
Constraints	50.000	15.000	15.000	15.000	15.000	

Table 5.4.5b

Figure 5.4.5 a
Mean Resupply Crew Usage
Hours

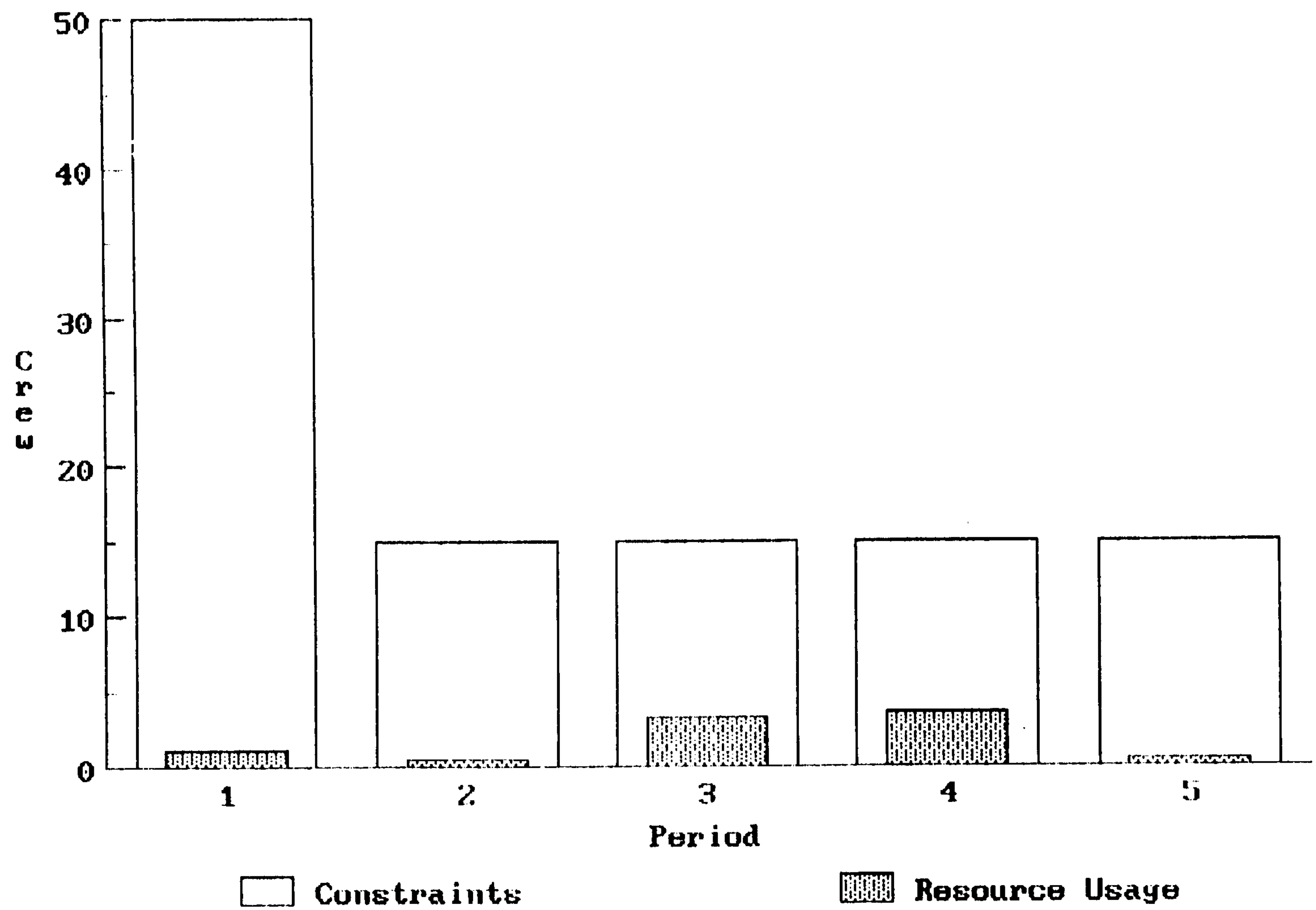

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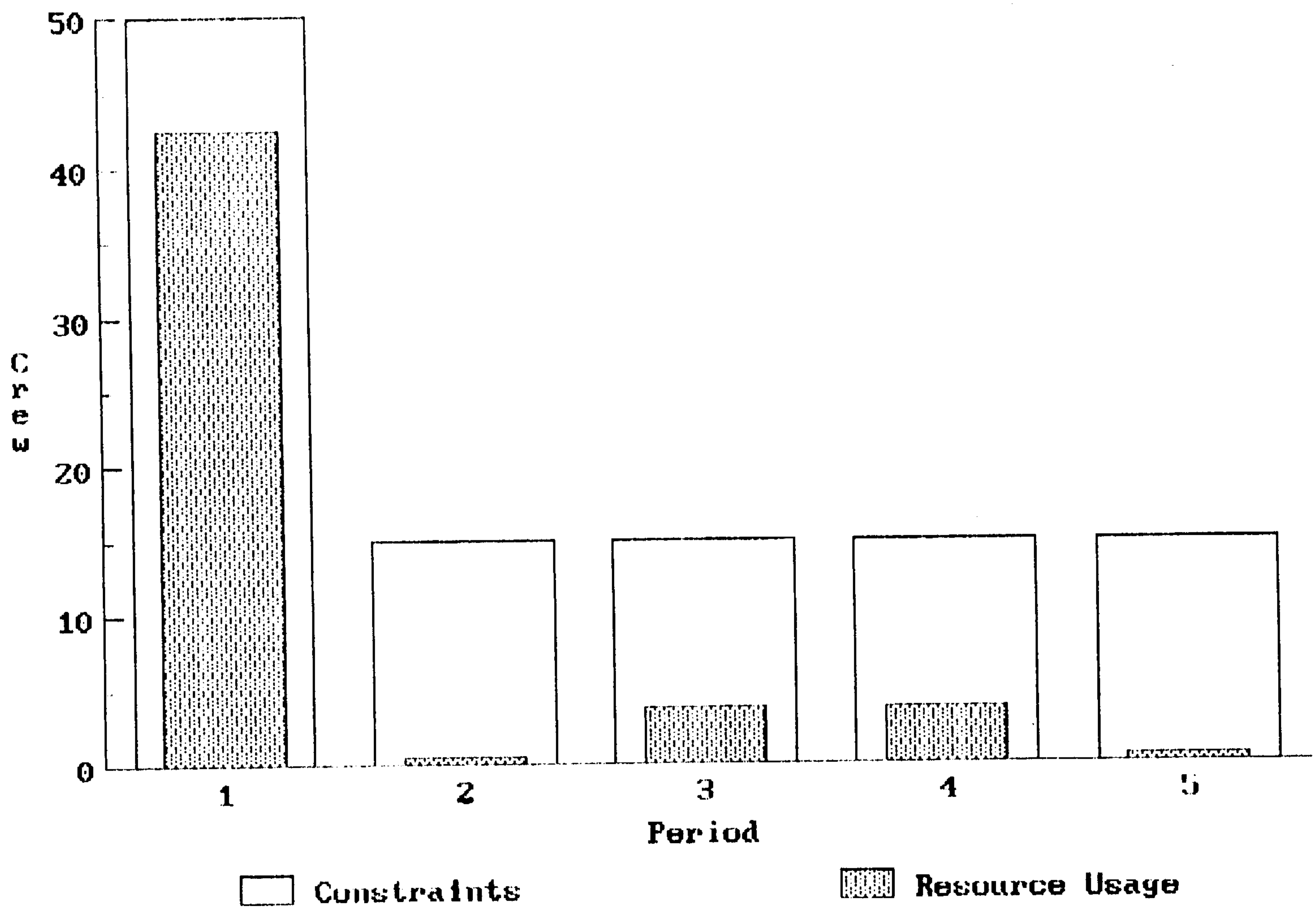
Figure 5.4.5 b
Mean Total Crew Usage
Hours



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Mean Resupply Equipment Usage (Hours)

Block Names	Period 1	2	3	4	5	Overall
Turbine	.000	.000	.000	.000	.000	.000
Generator	.000	.000	.000	.000	.000	.000
Diode	.000	.000	.000	.000	.000	.000
Battery	.450	.000	2.160	2.610	.180	5.400
Outlet	.000	.000	.000	.000	.000	.000
Sums	.450	.000	2.160	2.610	.180	5.400
Constraints	16.000	6.000	6.000	6.000	6.000	

Table 5.4.6a

Mean Total Equipment Usage (Hours)

Block Names	Period 1	2	3	4	5	Overall
Turbine	7.600	.000	.000	.000	.000	7.600
Generator	1.100	.000	.000	.000	.000	1.100
Diode	.000	.000	.000	.000	.000	.000
Battery	5.400	.000	2.520	2.700	.180	10.800
Outlet	.000	.000	.000	.000	.000	.000
Sums	14.100	.000	2.520	2.700	.180	19.500
Constraints	16.000	6.000	6.000	6.000	6.000	

Table 5.4.6b

Figure 5.4.6 a
Mean Resupply Equipment Usage
Hours

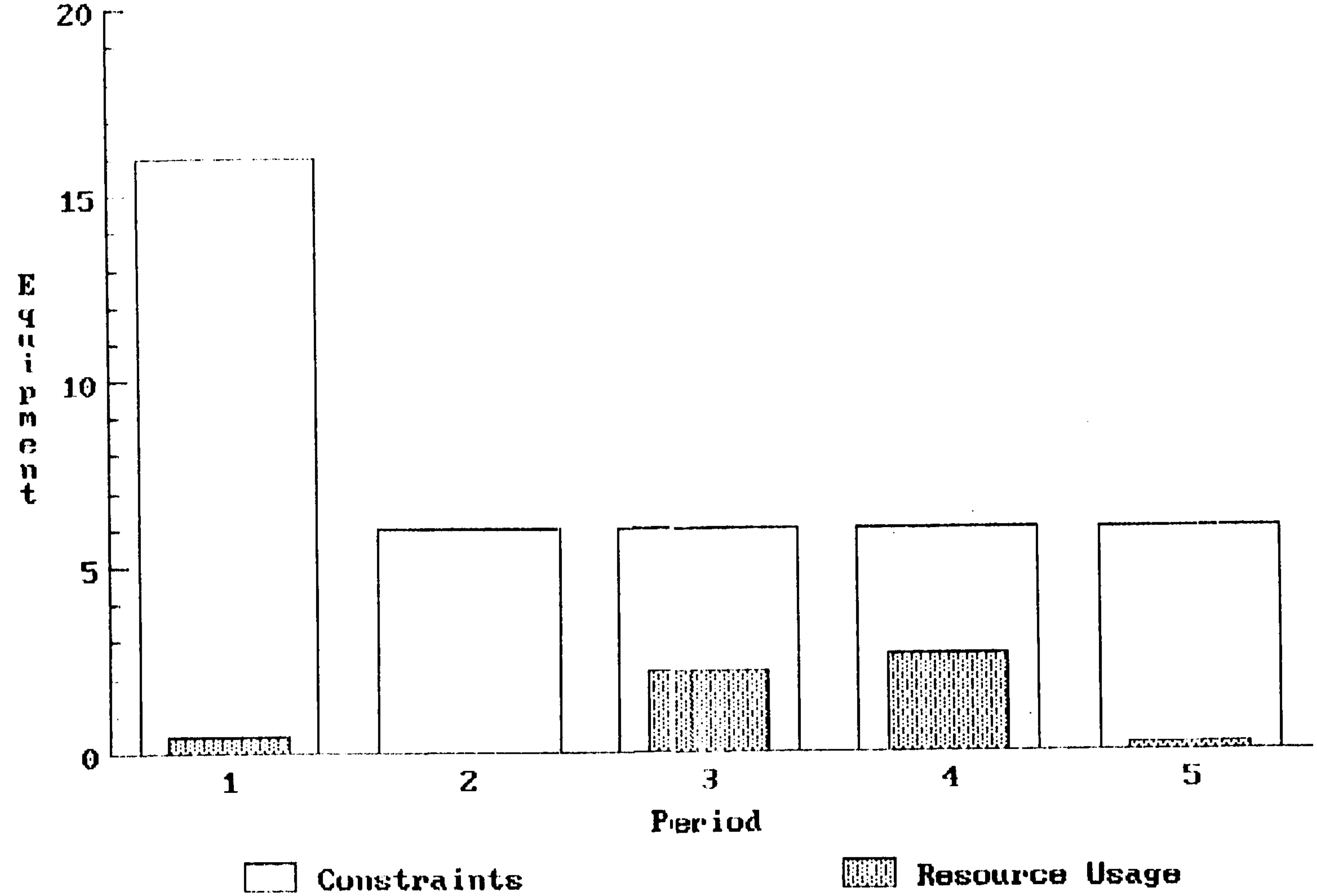

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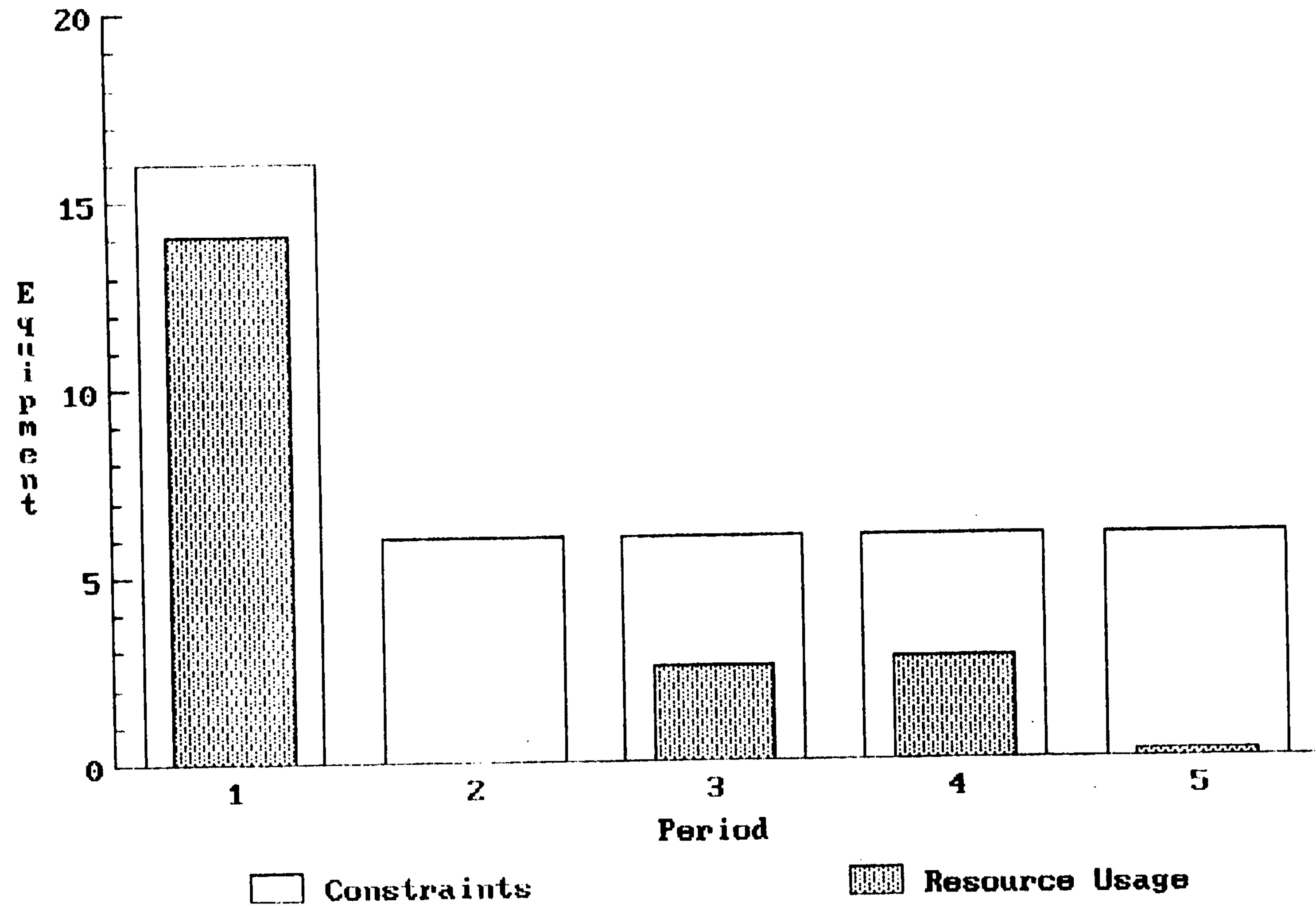
Figure 5.4.6 b
Mean Total Equipment Usage
Hours



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Mean Resupply Robotics Usage (Hours)

Block Names	Period 1	2	3	4	5	Overall
Turbine	.000	.000	.000	.000	.000	.000
Generator	.000	.000	.000	.000	.000	.000
Diode	.000	.000	.000	.000	.000	.000
Battery	.150	.000	.720	.870	.060	1.800
Outlet	.000	.030	.060	.030	.000	.120
Sums	.150	.030	.780	.900	.060	1.920
Constraints	299997	299997	299997	299997	299997	

Table 5.4.7a

Mean Total Robotics Usage (Hours)

Block Names	Period 1	2	3	4	5	Overall
Turbine	.600	.000	.000	.000	.000	.600
Generator	.300	.000	.000	.000	.000	.300
Diode	.000	.000	.000	.000	.000	.000
Battery	1.800	.000	.840	.900	.060	3.600
Outlet	.300	.030	.060	.030	.000	.420
Sums	3.000	.030	.900	.930	.060	4.920
Constraints	299997	299997	299997	299997	299997	

Table 5.4.7b

Figure 5.4.7 a
Mean Resupply Robotics Usage (Hours)

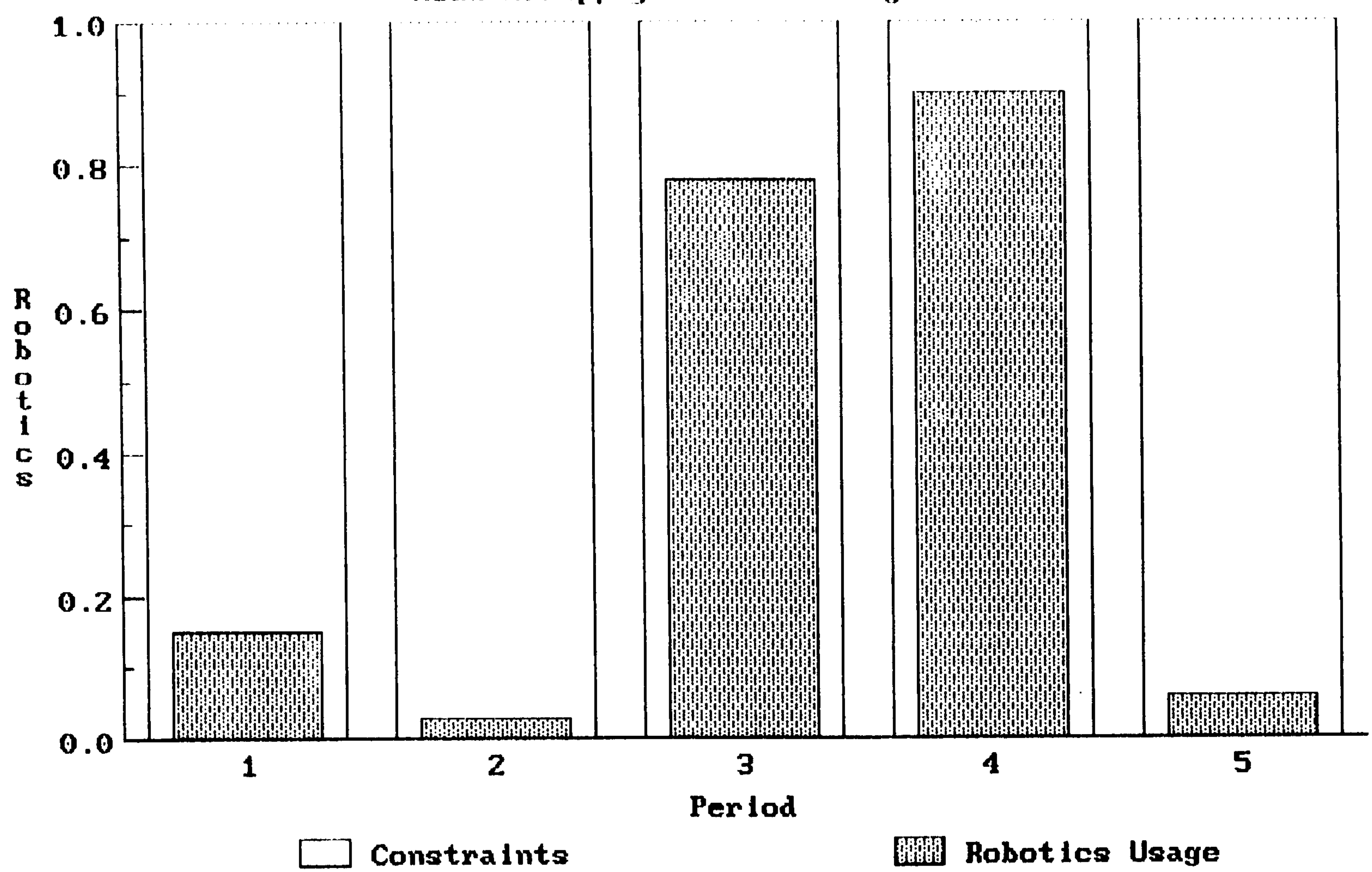

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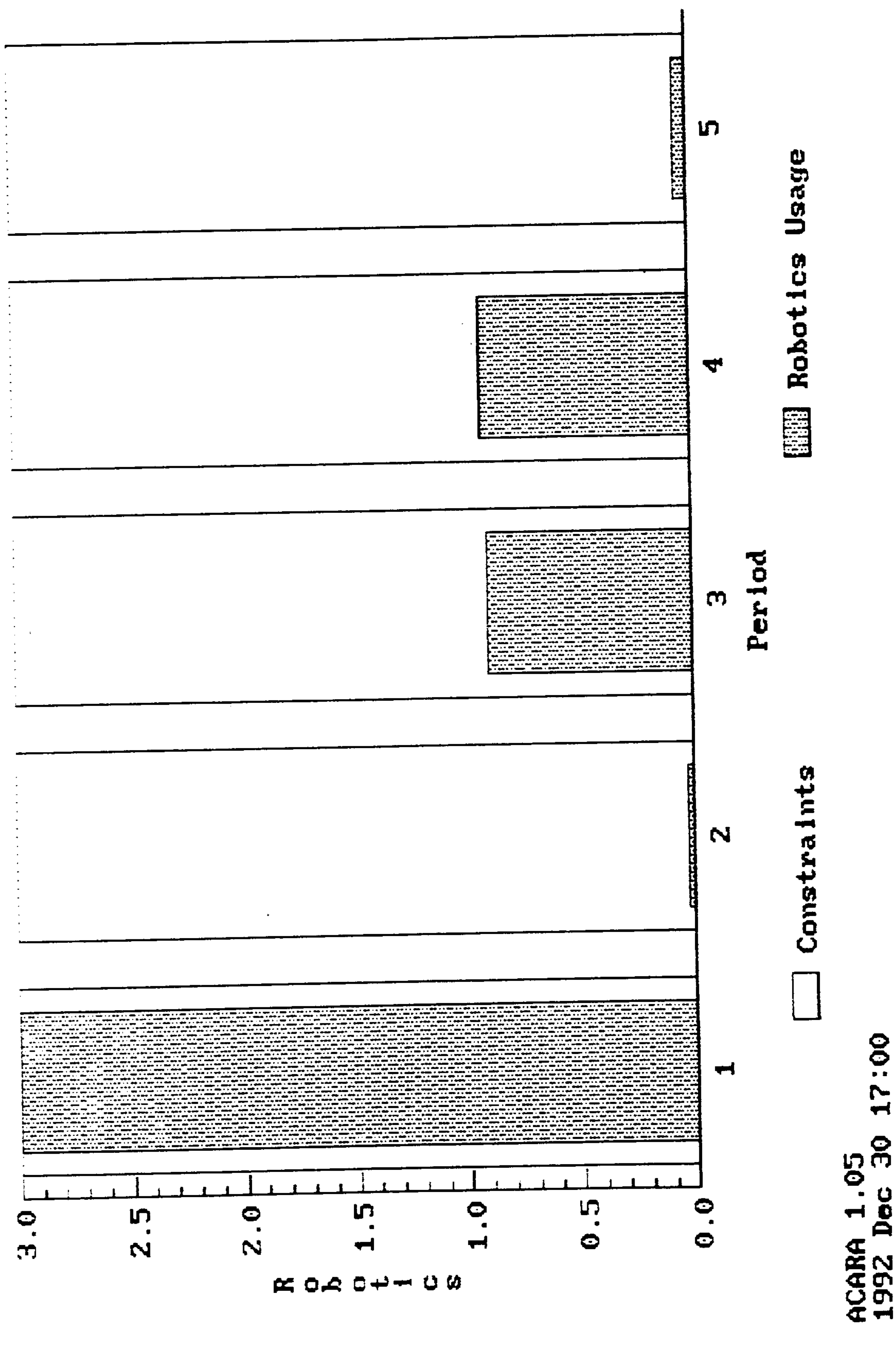
Figure 5.4.7 b
Mean Total Robotics Usage (Hours)



5.5 Results Files

The results of ACARA analyses are stored into "results files" for future use. These files have the extension *.AR1. Each results file contains the output data needed to create each of the tables in the Results Menu as well as the input data needed to repeat the calculation. A Results file is automatically saved after each simulation during **Batch** mode simulation. The **Results Files** menu allows you to load, save, copy, delete, and rename files. The steps are identical to those for system files. Refer Section 3.8, page 37).

When a results file is retrieved, ACARA loads the input as well as the results. You may then change the data and repeat the simulation using **Immediate** mode.

5.6 Text Files

The **Text Files** Menu is used for any ASCII files created from ACARA input or results tables. (See Appendix, page 119). The files have the extension *.txt. The following features are available under this menu:

Edit
Edits file. Select file with cursor and press [Enter]. Edit file and press [F2] when finished. Select **Save** from the menu and type name to save file or select **Quit** to leave without saving.

Printer
Controls the printer. This feature has a pulldown menu with the following options...

Print	Print contents of a text file.
Printer Status	Display line counter and lines per page.
Line Feed	Advance printer one line.
Form Feed	Advance printer one page.
Reset	Reset line counter to zero.
Set Lines/page	Set lines per page.

Copy
Copies file. Select a file with the cursor and press [Enter]. Enter a name for the copy at the prompt and press [Enter] again, or to cancel and return to the Main Menu, press [Escape].

Delete
Erases file. Move cursor to the file you want to delete and press the [Enter] key. To return to the Main Menu, press [Escape].

Rename
Changes text file name. Move the cursor to the file you want to rename, press [Enter] and enter a new name at the prompt. Press [Enter] again, or to cancel, press [Escape].

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Appendix

A. Input Windows

Input windows are used to enter ACARA input parameters. The chart below explains how to use the input windows.

Move cursor right to the next field:	Press [Enter] or [→Tab].
Move cursor left to the previous field:	Press [←Tab].
Leave window and save your entries:	Press [F2] or [Enter] (if cursor is at last field.)
Leave window and cancel all entries:	Press [Escape].
Read help to explain the data to be entered in an input field:	Move cursor to the appropriate input field and press [F1].

B. Input Tables

Input tables are used for entering tabular data. Each input table is controlled by a menu, which is called by pressing [F2]. The menu lets you save the data, use the printer, create files, and use other features. It operates in the same fashion as ACARA's Main Menu.

The chart below explains how to use the input tables.

Move cursor right to next column:	Press [→Tab].
Move cursor left to previous column:	Press [←Tab].
Move cursor down to next row:	Press [Enter].
Move cursor down 5 rows:	Press [Ctrl-Page Up].
Move cursor up 5 rows:	Press [Ctrl-Page Down].
Scroll down: (Move cursor to first row below the bottom.)	Press [Page Down].
Scroll up: (Move cursor to last row above the top.)	Press [Page Up].
Scroll right: (Move cursor to first column right of right edge.)	Press [Ctrl-Right].
Scroll left (Move cursor to last column left of left edge.)	Press [Ctrl-Left].
Leave input table and save entries:	Press [F2] and select [Save] from the menu.
Leave input table and cancel entries:	Press [Escape] or press [F2] and select [Quit] from the menu.
Read help to explain the data to be entered in an input column:	Move cursor to the appropriate column and press [F1].

Printing and Saving Text Files from an Input Table

To print the data, control the printer, or create a file, call the Input Table Menu and move the cursor to **Print/File**. The following features are available:

Print
Prints data. Be sure that the printer is switched **ON** and is "ON LINE".

Printer Status
Displays printer & page depth (lines per page).

Line Feed
Advances printer one line and advances the line counter by one line.

Form Feed
Advances printer one page and resets the line counter to 0.

Reset Printer
Aligns the printer to the top of the page and resets the line counter to 0.

Set Lines/page
Sets page depth. The default page depth is 60.

File
Saves data to a text file. The screen will display every file with the extension ".TXT". Enter an 8-character ASCII name at the prompt. If you do not enter an extension after the name, ".TXT" will be appended to the file name. If you want to send the file to a drive other than the default, select **File Path** from the menu and enter the desired drive.

These files may be edited, copied, renamed, or erased using the **Text File** option from the ACARA Main Menu. They can also be edited using a standard ASCII editor.

File Path
Changes file drive letter designation (A,B,C,etc). If the entry is blank, the default drive is used.

Other Features

The Production Quantities and Logistics Constraints input tables often extend beyond the left and right edges of the screen. They have the following options in the first section of the input table menu to make data entry easier.

Copy Column
Copies the values from the column at the cursor to those columns right of the cursor. Move the cursor to that column, select the **Copy Column** option from the Input Table Menu, and press [Enter].

Move to Column
Moves the cursor directly to a column. Select the **Move to Column** option, move the cursor to the appropriate column heading from the pulldown menu, and press [Enter].

Some input tables have a third menu section entitled **Modify Table**, for inserting, copying, or cutting/pasting rows of data. This menu includes one or more of the following:

Insert
Inserts rows in the table. Move the cursor to the desired location, press [Enter] and move the cursor until the desired number of rows are displayed in reverse video. Press [Enter] again to insert the rows.

Cut
Removes one or more rows. Move cursor to the first line you want to remove, press [Enter] and move cursor to mark the desired number of rows in reverse video. Press [Enter] again to remove these rows.

The rows you most recently cut may be inserted elsewhere in the table using **Paste** (if available in the editor.)

Undo
Undoes most recent change to data done by the **Insert**, **Cut**, **Paste**, or **Copy** options. Select **Undo** from the menu and press [Enter].

Copy
Copies one or more rows. Move cursor to 1st row you want to copy and press [Enter]. Move the cursor down until all of these rows appear in reverse video and press [Enter]. Move the cursor to the desired destination and press [Enter] to copy the rows.

Paste
Inserts most recently 'Cut' rows into data table. First, use **Cut** to remove these rows from the table. Then, using **Paste**, move the cursor to the desired destination in the table and press [Enter] to insert the rows.

The following chart shows the input tables which have one or more of the options in the **Modify Table** section described on the previous page. An "X" indicates that the feature is included. Input tables not listed in this chart have none of these features.

	Insert	Cut	Undo	Copy	Paste
Names & Properties	X	X	X	X	X
Block Numbers	X	X	X		
Initial Ages	X	X	X		
Installation Times	X	X	X		
Block Diagram	X	X	X		
Redundancy	X	X	X		

C. Displaying Output

The following chart explains how to control the display screen for ACARA's output tables under the **Results** menu:

Scroll up or down:	Press [Page Up] or [Page down]. For very large tables that "wrap" across the screen, [Page Up/Down] will scroll from section to section.
Jump to top of table:	Press [Home].
Jump to bottom of table:	Press [End].
Move cursor up or down 5 rows.	Press Ctrl-[Page Up/Down].
Leave the display screen and return to the Main Menu:	Press [Escape].
Print the table:	Press [F2] and select **Print** from the **Print/File** Menu (See Appendix, page 119.)
Save the table as a text file:	Press [F2] and select **File** from the **Print/File** Menu (See Appendix, page 119.)
Display/Print Graph: (if available)	Press [F2] and select the desired graph from the **Graphics** Menu. To print the graph, press [P] while it is still visible. **Important:** A dot-matrix printer (e.g., Epson) is required to print graphs.

D. Abbreviations

ACARA	Availability, Cost, And Resource Allocation
APL	A Programming Language
ap2, ap80, etc.	Auxiliary Processors
CDF	Cumulative Distribution Function
ETARA	Event Time And Reliability Analysis
LCC	LifeCycle Cost
MTBF	Mean Time Between Failures
MTTR	Mean Time To Repair
PDF	Probability Distribution Function
RBD	Reliability Block Diagram
RSM	Resource Scheduling Model

Index

REPORT DOCUMENTATION PAGE

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13. ABSTRACT (*Maximum 200 words*)

ACARA (Availability, Cost, And Resource Allocation) is a computer program which analyzes system availability, lifecycle cost (LCC), and resupply scheduling using Monte Carlo analysis to simulate component failure and replacement. This manual was written to:

(1) Explain how to prepare and enter input data for use in ACARA.

(2) Explain the user interface, menus, input screens, and input tables.

(3) Explain the algorithms used in the program.

(4) Explain each table and chart in the output.

14. SUBJECT TERMS

Availability; Reliability; Monte Carlo simulation

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